# FIELD ENGINEERING.

A HAND-BOOK OF THE

THEORY AND PRACTICE OF RAILWAY SURVEYING, LOCATION, AND CONSTRUCTION,

DESIGNED FOR THE

## CLASS-ROOM, FIELD, AND OFFICE,

AND CONTAINING

*A LARGE NUMBER OF USEFUL TABLES,*

ORIGINAL AND SELECTED.

BY

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# PREFACE.

ALTHOUGH the modern railway system is but about fifty years old, yet its growth has been so rapid, and the progress in the science of railway construction so great, as to render the earlier technical books on this subject inadequate to the needs of the engineer of to-day.

In the course of his practical experience as a railway engineer, the author was strongly impressed with the want of a more complete hand-book for field use, and finally concluded, at the solicitation of his friends, to undertake the preparation of the present volume.

The aim in this work has been:

*First*—To present the general subject of railway field work in a progressive and logical order, for the benefit of beginners.

*Second*—To classify the various problems presented, so that they may be readily referred to.

*Third*—To embrace discussions of all the more important practical questions while avoiding matters non-essential.

*Fourth*—To employ throughout the work a uniform and systematic notation, easily understood and remembered, so that after one perusal the formulæ may be intelligible at a glance wherever referred to.

*Fifth*—To express the resulting formula of every problem in the shape best adapted to convenient numerical computation.

*Sixth*—To furnish a large variety of useful tables, more complete and extended than any heretofore published, especially adapted to the wants of the field engineer.

An elementary knowledge of algebra, geometry and trigonometry on the part of the reader has been taken for granted, as a command of these instrumentalities is deemed essential to the education of the civil engineer. The few references to mechanics, analytical geometry, optics and the calculus may be assumed correct by those not conversant with these branches.

Many of the problems in curves are new, yet there is hardly one that has not presented itself to the author in the course of his practice. The investigation of the valvoid curve is original, and though the mathematical discussion is somewhat difficult, yet the resulting formulæ, taken in connection with Table X, are exceedingly simple and convenient for the solution of a certain class of problems.

The treatment of compound curves is novel and exhaustive. A few general equations are established, which, by slight modifications, solve all the problems that can occur.

No discussion of reversed curves is given, because these are inconsistent with good practice, except in turnouts, under which head they are noticed.

The chapter on levelling includes a discussion of stadia measurements, with practical formulæ. The chapter on earthwork contains a review of several methods for calculating quantities, and states the conditions under which these succeed or fail in giving correct results.

Among the tables, numbers 3, 5, 6, 10, 18, 19, 26 and 29 are original. The adoption of versed sines and external secants throughout the work, wherever these would simplify the formulæ, rendered necessary the preparation of tables of these functions. The table of logarithmic versed sines and external secants has been computed from ten-place logarithmic tables of sines and tangents, so that the last decimal is to be relied on, and no pains have been spared to make the table thoroughly accurate.

Tables numbers 4, 7, 8, 9, 11, 12, 13, 14 and 30 have been recalculated, enlarged, and some of them carried to more decimal places than similar tables heretofore published. The intention has been to give one more decimal than usual, so that in any combination of figures the result of calculation might be reliable to the last figure usually required.

The tables which have been compiled and rearranged are numbers 1, 2, 15, 16, 17, 24, 25 and 31. The tables of log. sines and tangents here given are the only six-place tables which give the differences correctly for seconds. The table of logarithms of numbers is accompanied by a complete table of proportional parts, which greatly facilitates interpolation for the fifth and sixth figures.

In all the tables, whether new or old, scrupulous care has been taken to make the last figure correct, and the greatest diligence has been exercised by various checks and comparisons to eliminate every error. It is, therefore, hoped and believed that a very high degree of accuracy has been obtained, and that these tables will be found to stand second to none in this respect.

The preparation of this work has extended over several years, as time could be spared to it from other engagements. It is, therefore, the expression of deliberate thought, based on experience, and as such is submitted to the judgment of brother engineers. If it shall prove to have even partially met the aim herein announced, and so shall serve to smooth the way of the ambitious student, or to assist the expert in his responsible duties, the labors of the author will not have been in vain.

WM. H. SEARLES, C.E.

NEW YORK, March 1st, 1880.

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# FIELD ENGINEERING.

## CHAPTER I.

### RECONNOISSANCE.

**1.** The engineering operations requisite to and preceding the construction of a railroad are in general:

THE RECONNOISSANCE,
THE PRELIMINARY SURVEY, and
THE LOCATION.

**2.** *The Reconnoissance* is a general and somewhat hasty examination of the country through which the proposed road is to pass, for the purpose of noting its more prominent features, and acquiring a general knowledge of its topography with reference to the selection of a suitable route. The judicious selection of a route may be a very simple or complex problem, depending on the character of the topography, and more especially on the direction of the streams and ridges as compared with the general direction of the proposed road.

**3.** A road running along a water-course is most easily located. In this case the choice is to be made merely between the two banks of the stream, or between keeping one bank continuously and making occasional crossings. When the stream is small it will usually be found best to cross it at intervals, the advantage of direct alignement outweighing the cost of bridging; but when the stream is of considerable size the solution of the problem is not so obvious, requiring patient comparison of results in the two cases to determine whether to cross or not, while in the case of the larger rivers crossing may be out of the question.

When there is a choice of sides, both banks should be traversed by the engineer on reconnoissance, and while examining in detail the one side he should take a general and comprehensive view of the other. Only thus can he gain a complete knowledge of either side. The points to be considered are the relative value of the property on either side, the number and size of tributary streams, and probable cost of crossing them, the cost of graduation as affected by the amount and character of the material to be removed, and the liability to land slides, the amount and degree of curvature required, and the probable revenues which the road can command If, in respect to these points, one bank of the stream gives the more favorable result all the way, the question is decided at once; but in case the greater inducements are found on either bank alternately, as usually happens, the propriety of bridging the stream, with the costs and advantages, must be considered as an additional element in the problem.

**4.** When no water-course offers along which the road may be located, the difficulties of selecting a route are increased, and these usually become greatest when the streams are found to run about at right angles to the direction of the road. Valleys and ridges are to be crossed alternately, involving the necessity of ascending and descending grades, diverting the road from a straight line, and increasing the distance and curvature. The engineer must now seek the lowest points on the ridges, and the highest banks at the stream crossings, in order to reduce as much as possible the total rise and fall, but these points must be so chosen relatively to each other as to admit of their being connected by a grade not exceeding the maximum which may be allowable. The intervening country between summit and stream must usually be carefully examined, even on reconnoissance, to determine where the assumed grade will find sustaining ground at a reasonable expense for graduation and right of way.

In selecting stream crossings, regard should be had not only to the height of the bank, but also to the character of the bottom, its suitability for foundations, and its liability to be washed by the current. The direction and force of the current should be observed, and its behavior during freshets, and the extremes of high and low water ascertained, if possible. An approximate estimate of the cost of bridging may be made.

**5.** The engineer should not only seek the best ground on the route first assumed, but should have an eye to all other possible routes, holding them in consideration pending his accumulation of evidence, and being ready, finally, to adopt that one which promises the greatest ultimate economy. He should be able to read the face of the country like a map, and to carry in his mind a continuous idea or image of any line he is examining, so as to judge with tolerable accuracy of the influence any one portion of the line may have on another as to alignment and grade, even though many miles apart. In the successful prosecution of a reconnoissance he must depend mainly on his own natural tact and a judgment matured by experience.

**6.** The engineer will bring to his aid in the first place the most reliable maps, and those drawn on the largest scale. The sectional maps of United States surveys will be found very useful when they exist. In addition to these it is often desirable to prepare a map on a scale of one or two inches to a mile, on which will be drawn the principal features of the country to be traversed, such as streams, roads, towns, and the principal ridges, if known, but leaving the further details to be filled in by the engineer as he progresses. Such a map furnishes a correct scale for his sketches, and saves much valuable time, as he has only to sketch what the map does not contain, and occasionally to make corrections when he finds the map to be in error. He also notes on the map the *governing points* of the route, such as the best crossings of streams, ridges, or other roads, and any point where the line will evidently be compelled to pass. He may then indicate the route by a dotted line on the map drawn through the governing points. Having traversed the route in one direction he should retrace his steps, verifying or correcting his observations, and making such further notes as seem important. When in a densely wooded country, with but few openings, it may be impossible for him to get a commanding view from any point that will afford him the necessary information as to the general topography. He must then depend largely upon instrumental observations, taking these more frequently, and noting carefully all details likely to prove useful in future surveys.

**7. The instruments** required on an extended reconnoissance are the barometer and thermometer, the hand or Locke level, a pocket or prismatic compass, and a telescope or strong field-glass. To these may be added a telemeter for measuring distances at sight, but when good maps are to be had this instrument is seldom needed. So also some portable astronomical instruments are necessary in a new country, for determining latitude and longitude, but would only be a useless incumbrance in a settled district.

**8.** The mercurial barometer has generally been relied upon for the determination of heights, but owing to its inconvenient dimensions and the danger of breaking, it is now discarded by railroad engineers in favor of the more portable aneroid barometer, except in the case of trans-continental surveys, and when astronomical instruments are to be used also.

**9. The best aneroids** are designed to be self compensating for temperature, so that with a constant atmospheric pressure the reading shall be the same at all temperatures of the instrument. This, however, being a very delicate adjustment, is not always successfully made, so that each instrument is liable to have a small error due to temperature peculiar to itself. This error will be found rarely to exceed one hundredth of an inch, *plus* or *minus*, per change of ten degrees Fah., and is frequently much less than this. Just what the error is in a particular instrument may be determined by careful comparison with a standard mercurial barometer at the extremes of temperature, assuming the error found as proportional to the difference of temperature for all intermediate degrees of heat. The error having been determined for any aneroid, it should be applied, with its proper sign, to every reading to obtain the true reading.

The sizes generally used are 1¾ and 2½ inches in diameter, respectively, and experience seems to prove that there is no advantage in using larger sizes, but rather the contrary.

**10.** The ordinary barometric formulæ and tables have been prepared with reference to the mercurial barometer. In order that they may apply to the aneroid, it is necessary that the latter should be adjusted to read inches of mercury identically with the mercurial column at the sea level at a temperature of 32° Fah. But as the aneroid, unlike the mercurial column, requires no correction for latitude, nor for the variation in the force of gravity due to elevation, that portion of the formula which provides for such corrections, as well as that which provides for a correction due to the temperature of the instrument itself, may be omitted when using an aneroid. Thus the general formula is very much simplified, and becomes

$$z = \log \frac{h_,}{h'} \, 60384.3 \left(1 + \frac{t_, + t' - 64°}{900}\right)$$

in which $h_{,}$ and $h'$ are the readings of the aneroid in inches, and $t_{,}$ and $t'$ the readings of a Fahrenheit thermometer at the lower and upper of any two stations respectively, and $z$ is the difference in elevation in English feet of those stations.

To facilitate the calculation of heights by this formula, we may write

$$\text{Log}\,\frac{h_{,}}{h'}\,60384.3 = [\log h_{,} - \log h']\,60384.3$$

and since only the *difference* of the logs. is required, this will not be affected, if we subtract unity from each. The quantities in Table XV. are prepared, therefore, by the formula

$$(\log h - 1)\,60384.3$$

for every $\frac{2}{100}$ths of an inch from 19 inches to 31 inches.

Table XVI. contains values of $\dfrac{t_{,} + t' - 64^\circ}{900}$ for every degree of $(t_{,} + t')$ from 20° to 200° Fah.

**11.** *To find the difference in elevation of any two stations by the tables:*

Take the difference of the quantities corresponding to $h_{,}$ and $h'$ in Table XV. as an approximation, and for a correction multiply this difference by the coefficient corresponding to $(t_{,} + t)$, in Table XVI., adding or subtracting the product according to the sign of the coefficient.

*Example.—*

| | Lower Sta. in. | Upper Sta. in. |
|---|---|---|
| Aneroid | $h_{,} = 29.92$ | $h' = 23.57$ |
| Thermometer | $t_{,} = 77^\circ.6$ | $t' = 70^\circ.4$ |
| By Table XV. | for 29.92 we have | 28741 |
| | for 23.57 | 22485 |
| | Difference | 6256 |

By Table XVI. for $77.6 + 70.4 = 148$ we have $+ .0933$

Then $6256 \times .0933 = 583.6848$

and $6256 + 584 = 6840$ ft. $= z$.—*Ans.*

**12.** Certain precautions are to be observed in the use of the aneroid. When the index has been adjusted to a correct reading by means of the screw at its back, it should not be meddled with until it can again be compared with a standard mercurial barometer, and even then some engineers prefer to take note of its error, if any, rather than disturb the aneroid.

Again, since the principle of compensation supposes the aneroid to have a uniform temperature throughout its parts, it must be guarded against sudden changes, as otherwise the metallic case will be considerably heated or cooled before the change can affect the inner chamber, thus inducing very erroneous results. The aneroid, therefore, should seldom be taken from its leather case, nor exposed to any radiant heat of sun or fire, nor worn so near the person as to increase its temperature above that of the surrounding atmosphere. If removed to an atmosphere of decidedly different temperature, time must be allowed for the aneroid to be thoroughly permeated by the new degree of heat. The aneroid should be held with the face horizontal while being read; it should be handled carefully, and all concussions avoided, and it should be compared with a standard as often as practicable to make sure that it has suffered no derangement. Observing these precautions, and having a really good aneroid, the engineer should obtain excellent results in the estimation of heights. It has been found that the slight error in compensation, previously alluded to, is subject to a change during the first year or two after the instrument is made, but subsequently it becomes quite permanent.

**13.** For the purpose of obtaining approximate elevations by a simple inspection of the dial, the modern aneroid is provided with a secondary scale reading hundreds of feet, which is placed outside the scale of inches. It is divided according to the following formula prepared by Prof. Airy:

$$z = 55032 \frac{h_, - h'}{h_, + h'} \left(1 + \frac{t_, + t' - 100^\circ}{1000}\right)$$

in which it is evident that no correction for temperature is required when the *average* temperature of the two stations is 50°. When the two scales are engraved on the same plate the zero of the scale of feet is coincident with 31 on the scale of inches; but in some aneroids the scales are on two concentric plates, so that the zero of one may be made to coincide with any division of the other, which is in some respects an advantage.

**14.** The theory of the barometer, as expressed in the above formulæ, assumes the atmosphere to be at rest, and its pressure affected only by temperature, whereas, in fact, the pressure at any point is liable to sudden changes due to variations in the force of the wind, the amount of humidity, etc. The best way to eliminate errors due to these causes is to take readings simultaneously at the points the elevations of which are to be compared. For this purpose an assistant should be stationed at some point of known elevation contiguous to the route to be surveyed, and provided with an aneroid similar to that carried by the engineer. The aneroids, time-pieces, and thermometers having been compared at this point, the assistant should record the readings every ten minutes, with the time, temperature, and state of the weather. The engineer will thus have a standard with which to compare his own observations. If the survey is so extended that the same conditions of atmosphere are not likely to be experienced by the two observers, the assistant should be instructed to move forward to a new station at a designated time; or two assistants may be employed, one at each of two stations between which the engineer intends to make a reconnoissance. Even with these precautions no attempt should be made to obtain the elevation of important points during, or just before, or after a storm of wind or rain.

**15.** When but one aneroid is used the observations at the several stations should be taken as nearly together as possible in point of time, and then repeated in inverse order, taking the mean of the observations at each station, and repeating the whole operation if necessary. Only approximate results can be hoped for, however, with a single instrument, unless the atmospheric conditions are very favorable.

**16. The Locke Level** is an instrument in which the bubble and the observed object may be seen at the same instant, enabling the operator to keep the instrument horizontal, while holding it in the hand, like an ordinary spy-glass. While very portable, it enables the observer to define rapidly all visible points of the same elevation as his own, and to estimate from these the relative heights of other points. It may be made useful in a variety of ways which easily suggest themselves to the engineer in cases where no great precision is required, and where a more elaborate level is not at hand.

**17. The Prismatic Compass** is a portable instrument with folding sights, in using which the bearing to an object may be read at the same instant that the object is observed.

The bearings are read upon a floating card, graduated and numbered from zero to 360°, so that no error can be made in substituting one quadrant for another. The instrument may be held freely in the hand during an observation, though better results are obtained by giving it a firm rest.



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## CHAPTER II.

### Preliminary Survey.

**18.** A preliminary survey consists in an instrumental examination of the country along the proposed route, for the purpose of obtaining such details of distances, elevations, topography, etc., as may be necessary to prepare a map and profile of the route, make an approximate estimate of the cost of constructing the road, and furnish the data from which to definitely locate the line should the route be adopted. The survey is more or less elaborate, according to circumstances. In case the country is new, or the reconnoissance has been incomplete, or if several routes seem to offer almost equal inducements, the survey will partake somewhat of the nature of a reconnoissance, and will be made more hastily than if but one route is to be examined, and that, perhaps, presenting serious engineering difficulties. The survey is made as expeditiously as possible. consistent with general accuracy, but should not usually be delayed for the sake of precision in matters of minor detail.

**19.** For preliminary survey the **Corps of engineers** is organized as follows:

A chief engineer, an assistant engineer, two chainmen, one or two axemen, a stakeman, and a topographer, these forming the compass (or transit) party, to which a flagman is sometimes added; a leveller and one or two rodmen, forming the level party; and to these is sometimes added a cross-level party of two or three assistant rodmen.

**20. The chief engineer** takes command of the corps, and directs the survey. He ascertains or estimates the value of the lands passed over, the owners' names, and the boundary lines crossed by the line of survey. He examines all streams, and estimates the size and character of the culverts and bridges which they will require; he notices existing bridges, and inquires concerning their liability to be carried away by freshet; he selects suitable sites for bridges, examines the character of the foundations, the direction of the current relatively to that of the line, and considers any probable change in the direction of the current during freshets; he inspects the various soils, rocks, and kinds of timber as they are met with, and takes full notes of all these and kindred items in his field book. He not unfrequently assumes in addition the duties of topographer. He should run his line as nearly as may be over the ground likely to be chosen for location, so that the information obtained may be pertinent, and so that the length of the line, the shape of the profile, and the estimate based on the survey may approximate to those of the proposed location. To this end he has due regard to the levels taken, and when they show that the line as run fails to be consistent with allowable grades, he either orders the corps back to some proper point to begin a new line, or makes an offset at once to a better position, or continues the same line with some deflection, simply noting the position and probable elevation of better ground, as in his judgment he thinks best. He should at all times maintain a friendly attitude toward proprietors, and by his polite bearing endeavor to secure their cordial support of the new enterprise. If he is tolerably certain that the location will follow nearly the line of the preliminary survey, he should have with him some blank deeds of right of way, and let these be signed by land-owners while they are favorably disposed. When this cannot be done, a blank form of agreement to allow the surveys and construction of the road to proceed until such time as the terms of right of way may be agreed upon may be made very useful. The chief also selects quarters for his men, and in case of camping out he directs the movements of the camp equipage.

**21. The assistant engineer** takes the bearings of the courses run, and makes a minute of them, with their lengths, or the numbers of the stations where they terminate. He sees that the axemen keep in line while clearing, and the chainmen while measuring; he takes the bearings of the principal roads and streams, and of property lines when met with. In an open country he may save time by selecting some prominent distant object toward which the chainmen measure without his assistance, while he goes forward and prepares to take the bearing of the course beyond. In traversing a forest with not too dense undergrowth, when the line is being run to suit the ground according to a given grade, it is a good plan for the assistant to go ahead of the chainmen as far as he can be seen, select his ground, take his bearing by backsight on the last station, and then have the chainmen measure toward him. In this case both he and the head chainman should be provided with a good sized red and white flag, mounted on a straight pole, to be waved at first to call attention, and afterward held vertically for alignement. Otherwise a flagman must be added to the party, who will select the ground ahead, under the instructions of the chief, and toward whom the survey will proceed in the usual manner.

**22. The head chainman** drags the chain, and carries a flag which is put into line at the end of each chain length by the assistant engineer or the rear chainman. It is his duty to know that his flag is in line and that his chain is straight and horizontal before making any measurement, and to show the stakeman where each stake is to be driven. A stake is usually driven at the end of each measured chain length, called a station, though in an open and level country the stakes at the odd stations may be omitted, in which case marking pins are used to indicate the odd stations temporarily. In case there is much clearing to be done the head chainman plants his flag in line, and ranging past it, indicates to the axemen what is to be cut, going a little in advance through the bushes so that they may work toward him. The head chainman should be a quick, active and strong man, with a good eye and a taste for his work, as very much of the real progress of the survey depends upon him.

**23. The rear chainman** holds his end of the chain firmly at the last stake or pin by his own strength, *not* by means of the stake. He keeps the tally by the pins when they are used, and watches the numbers on the stakes to see that they are correct. The end of a course should always be chosen at the end of a chain, if possible, and if not, then at a brass tag indicating tens of feet, as thus the labor of plotting the map will be much lessened. The numbering of stations is not recommenced with each new course, but is continued from the beginning to the end of the survey, through all its courses, and if one course ends with a portion of a chain the next course begins with the remainder of it. It is the rear chainman's duty to attend to this, holding the proper link at the compass station. Any fraction of a chain measured on the line is called a *plus*, and is counted in feet from the previous station. The length of an offset in the line is never included in the length of the line, but if the line should change its course by a right angle, or more, or less, the numbering would go on as usual.

**24. The axemen** should be accustomed to chopping and clearing, and are, therefore, to be selected in the country rather than the city. They will cut out so much of the underbrush and overhanging branches as may interfere with the sight of the assistant or leveller; but care must be taken not to cut unnecessarily wide, and no tree of considerable size should be felled, except in rare instances. When running by compass, if the assistant goes ahead of the chain, he can always select a position so that no large tree will interfere; or, if the line must be produced and strikes a tree, the compass may be brought up and set close to the tree on the forward side as nearly in line as can be estimated, the slight error in offset being neglected, since the line will be produced parallel to itself by the needle.

**25. The stakeman** prepares and marks the stakes, and drives them at the points indicated by the head chainman. When no clearing is needed, the axemen keep him supplied with stakes, as the rapid progress of the chain will only give him time to drive them. The stakes should be two feet long and pointed evenly so as to drive straight, and are blazed or faced on two opposite sides, one of which is marked in red chalk with the number of the station. The stake must be driven vertically, and with the marked face to the *rear*, so that it may be read by the rodman as he follows the line.

**26. The topographer** makes accurate sketches of all features of the country immediately on the line, and extends the sketches as far each side of the line as he can, in a book prepared for the purpose. He must never sketch in advance of the chain, nor in advance of his own position. His work should be done to scale as nearly as possible, using the same scale for distances on the line and at right angles to it. The scale adopted should never be less than that of the map to be made from the sketches. The ruled lines of a field book are usually one quarter of an inch apart, so that a scale of one line to a station equals about four hundred feet to an inch. This is the smallest scale ever used. The scale of two lines to a station is most convenient for general use. Four lines to a station are needed in special cases to show details, as in passing through villages. The scale may be changed from time to time as found necessary, but no two scales should ever be used on the same page. The numbering of the stations up the page indicates the scale of the sketch.

**27.** When the contours of the surface are required, the topographer may join the level party in order that his estimates of heights and slopes may be corrected by the instrument. He should never draw a mass of contours indiscriminately, but should sketch them as they exist at a uniform vertical interval. This interval may be assumed at five feet in a gently rolling country, and at twenty feet in a mountainous one, but an interval of ten feet will be found most convenient generally. If the topographer accompanies the level he can assume the contours at the even tens of feet in elevation, and mark them so, noting where a contour crosses the surveyed line, and sketching its direction and shape both ways from that point. He will estimate the rate of slope of the ground at right angles to the line as so many feet per hundred, and record it from time to time, noting ascent from the line on either side by "A," and descent by "D." If the slope changes within the limit of the page, the line of change may be sketched and the next slope recorded. When little banks or terraces occur, or bluffs and rocks, which cannot be sufficiently indicated by contours, they should be shown by hatchings, and the height noted. Special care should be taken to sketch roads and houses in their correct positions and dimensions, the latter to be either measured, paced or estimated. The dimensions should also be recorded in numbers. The outline of forests may be shown by a scalloped line, and the kind of timber, and whether dense or scattered, written within the inclosed space. Correct outlines are essential, but no time should be given to shading up a sketch with conventional signs. A single sign, or the name of the thing intended, is all sufficient. Land-owners' and residents' names should be recorded whenever they can be obtained, as well as the names of roads, streams and public buildings.

**28. The leveller** takes charge of the level party and keeps the notes of his work. He reads the rod on benches and at turning points to hundredths of a foot and to tenths at other points. He should direct a bench to be made at least once every half mile, and in a very rough country every quarter of a mile. The benches need not be far from the line, and, if well chosen, may be used as turning points, thus saving time. The elevation of turning points must be computed when taken, so that the elevation of any one of them may be instantly given when called for, and the other elevations will be filled in as far as may be without delaying the survey. As the levels are usually the most essential part of the survey, much care should be taken to have the instrument well adjusted and truly level, and the rod held vertically and correctly read on turning points, but the intermediate work should not be so done as to delay the party unnecessarily. The leveller should use every endeavor to follow closely after the surveying party, so that the chief and topographer may have the advantage of his notes.

**29. The rodman's** first duty is to hold the rod vertically, and he must learn to do this in calm or windy weather, in level field or on side hill. He may carry a small *disk-level*, which applied to the edge of the rod will show when it is vertical. The turning points are to be selected for firmness and definiteness, and so that they will afford a clear view from beyond for a backsight. The rod is held for a reading on the ground at every stake, the number of which is called out to the leveller as soon as the rodman arrives at it; the rod is also to be held at every prominent change of slope on the line, as the crest and foot of every bank, the rodman calling out its distance from the last stake as *plus* so many feet, but all gentle undulations and minor irregularities are to be neglected. The rod will always be read at the surface of a stream or pond, and also at its deepest part on the line, when possible; otherwise the depth of the water may be found by sounding, and so recorded. Should the line run along a stream the surface will be taken occasionally, opposite certain stations, and in case of a canal, the elevation of surface above and below each lock must be noted. The rodman makes inquiry for *high-water marks* or seeks traces of them himself in an uninhabited district, and holds the rod upon them that their elevation may be determined. The rodman carries a small axe or hatchet with which to make benches and to trim out any stray branch that may intercept the leveller's view.

**30. The assistant rodmen** take the slope and elevations of the ground at right angles to the line, using vertical and horizontal rods and a pocket level, or a tape line and clinometer. The cross levels are not taken throughout the whole survey, if at all, but only where the roughness of the country seems to demand it. They may be extended to any distance from the centre line required by the chief—not less, however, than fifty feet as a rule. They may be taken at the stations only, or oftener, if necessary, depending upon the roughness of the surface, the object being to define accurately the contours, and so the shape of the ground. The assistant rodmen will also take soundings when they are needed, either on the line or at right angles to it.

**31.** In defining the duties of the members of the corps, the instruments used have been incidentally noticed.

**32. The compass** is preferable to the transit on preliminary surveys, because it can be operated more rapidly, is lighter, and usually has a better needle. It may have either plain sights or telescope, and be mounted on tripod or jacob staff. The simpler forms are preferred for forest work. Not unfrequently the engineer's transit is employed, but using the needle. A preliminary line should not be run by backsights and deflections, unless local attraction is found to exist to such an extent as to destroy confidence in the needle; or, in special cases, where the natural obstacles to a survey are very great. In the latter case the survey partakes of the nature of a location, and should be conducted with similar care and fidelity.

**33. The chain** is 100 feet long, and composed of 100 links. It should be of steel for lightness, durability, and greater accuracy. Those having rings of hard steel, unbrazed, are least apt to wear. Five marking pins are needed, each having a piece of red flannel attached, for temporary stations, or for keeping points temporarily while measuring by parts of a chain up or down a slope. A pointed plumb bob, with several yards of small cord wound on a carpenter's spool, is useful in chaining over steep declivities or bluffs.

**34. The axes** should be of best quality, with hand-made handles, and not too heavy. The axe of the stakeman should have a fine edge for dressing and a broad head for driving the stakes. When the stakes are not required to be over two feet long, a stout *basket*, having a square, flat bottom, 26x14 inches, should be furnished the stakeman. He will then prepare a basketful of stakes, ready marked, and place them in the basket regularly, in the reverse order of their numbers, so that they will come to hand as wanted. *A small hand-saw* no larger than the basket, with rather coarse teeth, wide set, will be found extremely useful in cutting stakes with square heads and of uniform length, and much more rapidly than can be done with an axe. When not in use, it is to be strapped to the inside of the basket, to prevent its being lost by the way. When the basket is about empty, the stakeman, with the assistance of the axemen, can soon replenish it, and the stakes being all numbered at once, there is less danger of a mistake being made in the tally than when they are marked only as wanted.

**35. The level** should be the regular engineer's level, the same as used on location.

**36. The rod** should be self-reading, *i.e.*, to be read by the leveller, as too much time would be consumed in the constant adjustment of a target by the rodman. It should be as long as can be conveniently handled in order to reduce the number of turning points on hill sides. A very convenient rod may be made of thoroughly seasoned clear white pine, sixteen feet long and two inches wide, with a thickness of one inch at the bottom, increasing to one and a quarter inches at six feet from the bottom, and then gradually diminishing to three eighths of an inch at the top. The rod is shod with a stout strap of steel, extending five inches up the edges, and secured by screws. The top is protected for a few inches by a plate of sheet brass on the back. The face of the rod is a plain surface throughout, and is graduated from the lower edge of the steel shoe as zero. The divisions are fine cuts made with the point of a knife. At the foot and half-foot points the cuts extend across the face. For the tenths and half tenths they extend three quarters of an inch from the right hand edge, terminating in a line scribed parallel to the edge of the rod, thus forming rectangular blocks half a tenth wide, every other one of which is painted black, the body of the rod being white. The feet are indicated by numerals painted red on the blank part of the face, each figure standing exactly on its foot mark, and being exactly one tenth high. For the figure 5 the Roman V. is substituted and for 9 the Roman IX., so that in case a dumpy level is used the 5 may not be mistaken for a 3, nor the 9 for a 6. At the half-foot points a red diamond is painted, so that the graduated line bisects it. No other figures nor graduations are required. With this rod the leveller can read quite accurately to hundredths of a foot, and after some practice can estimate the half hundredths.

**37. The horizontal rod** for cross-levels may be made of white pine, ten feet long and one inch thick by three wide, tipped with brass, painted white, and graduated to feet and tenths. It must be a straight edge, and is levelled by a pocket level placed upon it when needed, or by a small level embedded permanently in one edge. The vertical rod to be used with it is made of pine eight feet long and one and a quarter inches square, and graduated to feet, tenths, and half tenths. All rods when not in use should be laid on a flat surface to prevent their being sprung. Leaning them in a corner soon ruins them for use.

**38. The clinometer** is any small instrument which will measure the slope angle of the surface. The angle is always estimated from the horizon, a vertical being 90°. The rise per 100 feet is found by multiplying the nat. tangent of the slope angle by 100. It may often be found more easily by the leveller reading the rod at a station and then 100 feet left or right of the line. If surface measures are taken in connection with a slope angle they are reduced to horizontal measures by multiplying them by the cosine of the slope angle.

**39. The plane-table** is rarely if ever used on preliminary surveys in the United States. Occasional bearings taken to prominent objects by the assistant engineer, or the use of a prismatic compass by the topographer in connection with his sketches, is found to answer every purpose.

**40. In case a survey is to be made with a transit,** it is necessary to add a back flagman to the party, who will hold his flag or rod on the point last occupied by the transit, so that the assistant may take a backsight upon it. The direction of a new course in each case is determined by the deflection angle to the right or left of the preceding course produced. The bearing of one long course near the beginning of the survey having been carefully ascertained, the bearing of each succeeding course is calculated from the deflections, and entered in a column of the field book headed *Calculated Bearings*, from which the line is afterwards plotted. The magnetic bearing of each course should also be taken from the needle, and recorded as such, but is used only as a check on the transit work. The deflections should be made in degrees, halves, or quarters, if possible, to facilitate the calculation of bearings, and to admit of using a traverse table.

**41.** The attached level and vertical arc of the transit are useful in determining approximately the grade of the line run in advance of the level party, or in seeking for one assumed grade to which it is desired that the line shall conform. For this purpose it is only necessary to set the vertical arc to the angle corresponding to the grade as given in Table XIV., and let the head chainman move about until a point on his rod at the same height from the ground as the telescope is covered by the horizontal cross-hair.

**42.** The point on the ground where a transit is set up is marked by a good-sized plug, flat headed, and driven down flush with the ground, with a tack set in the head to show the exact point or centre. This is called a *transit point.* When a transit point occurs at a regular station, the stake bearing the number of that station is set three feet to the left of the line opposite the plug and facing it. When a transit point occurs between stations the stake is driven three feet to the left of it, marked with the number of the preceding station + the distance from that station in feet.

**43.** As a transit is capable of giving a line with great precision, it is important that the flags used in connection with it should be equally precise in giving points. An excellent flag for this purpose is made of well-seasoned clear white pine ten feet long, two and a half inches wide, and one inch thick. It is tapered for the last four inches to an edge at one end, the edge being formed at the middle of the width. The tapered end is shod with a band of steel covering the edge of the rod, and secured by screws, and the steel is brought to a sharp edge at the point of the rod. The rod is then painted white and tipped with brass at the square or upper end. A centre line on the face is then struck from the point of the steel to the middle of the brass tip by means of a piece of sewing silk and a fine cut made with a knife and steel straight edge. The centre line must *not* be scribed parallel to one edge of the rod, as this is rarely ever straight. The face of the rod is then divided into one-foot spaces, measured from the head of the rod, and these are painted red on either side of the centre line in alternate blocks. On the back of the rod at three and a half feet from the point is placed a small ground-glass bubble-tube, mounted very simply, and attached to the rod by a brass plate and screws, and guarded by two blocks of wood for protection. The centre line of the rod is made vertical by a plumb-line while the level tube is being attached, which ever after secures a vertical rod. If only two feet of this rod can be seen over any obstruction, a point can be set with great precision, provided the level tube is in adjustment. This flag can also be used as a plumb in chaining with much more satisfaction than a cord and weight, especially in windy weather.

**44.** A transit survey usually requires more clearing than one made by compass. When a given course is to be produced in a forest, some large trees will inevitably be encountered, but the labor and delay of felling them may be avoided by the use of *auxiliary lines.* These may be classified as running *parallel* to the main line, at a *small angle* with it, or at a *large angle* with it.

**45. The parallel line** is established by means of two short perpendicular offsets measured with care before reaching the obstacle, and the main line is established beyond the obstacle by means of two more equal offsets. But since short back-sights are to be avoided, these offsets should be at least 100 feet apart, so that it may be difficult to find a parallel line of sufficient length which does not strike some other obstacle, or at least require considerable extra clearing.

**46. The auxiliary lines making a small angle** with the main line are more convenient, not only on this account, but because they require a less number of transit points. By them an isosceles triangle is formed on the ground, having the intercepted portion of the main line as base, and the vertex near the obstacle. The deflections at the points where the lines leave and join the main line are similar and equal, and the deflection at the vertex is double in amount and opposite in direction. No calculation is necessary, for the error in measurement due to the deviation is too small to be noticed. and since the main line is immediately resumed, the calculated bearings of the auxiliary lines are unnecessary. Should the point where the second line joins the main line prove unsuit able for a transit point, the second line may be produced to any convenient point beyond, and so go to form an isosceles triangle on the opposite side of the main line, the triangle being completed by running a third line parallel to the first, and equal to the difference of the first and second. Again, the second line may encounter a serious obstacle before reaching the main line. To avoid this a parallel to the main line may be run from the end of the first line for a convenient distance, and there the second line be put in parallel and equal to its first position, as before described, thus forming a trapezoid.

**47.** The following **general solution** of this problem allows the engineer to make use of any number of auxiliary lines, provided that none of them make an angle of much more than one degree with the main line, with a certainty of resuming the main line in position and direction at the extremity of any course desired, and without necessitating any trigonometrical calculation. It is based on the assumption, practically true for small angles, that the sines are proportional to their angles, and is expressed by the following **rule**:

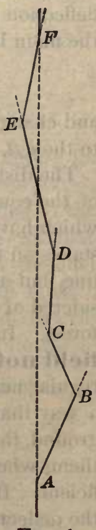

FIG. 1.

Call all deflections to the right *plus*, and all to the left *minus;* multiply the length of each course in feet by the algebraic sum *in minutes* of all the auxiliary deflections made to reach that course; take the algebraic sum of these products, and when the sum equals zero the extremity of the last course will be on the main line. The deflection required at that point to give the *direction* of the main line is equal to the algebraic sum of all the preceding deflections, but taken with the contrary sign.

Thus, if we have left the main line at A, and run by these notes: (Fig. 1.)

we shall have these products:

| Sta. | Defl. | Dist. | Factors. | Products. | |
|---|---|---|---|---|---|
| A | 16′ R | 190 | $+16 \times 190 =$ | $+3040$ | |
| B | 31′ L | 120 | $-15 \times 120 =$ | | $-1800$ |
| C | 18′ R | 175 | $+3 \times 175 =$ | $+525$ | |
| D | 13′ L | 265 | $-10 \times 265 =$ | | $-2650$ |
| E | 15′ R | | $+5 \times$ (?) | | |
| | | | | 3565 | $-4450$ |
| and their algebraic sum is | | | | | $-885$ |

Therefore to render the sum zero we must add 885 as the product of the last course. But 5′ is already given as one factor, so that the other factor must be $\frac{885}{5} = 177$, which is the length of the last course, giving some point $F$ on the main line. The deflection at $F$ from the last course to give the direction of the main line is

$$16 - 31 + 18 - 13 + 15 = 5'$$

and changing the sign we have $-5'$; that is, the deflection is to the *left.*

The distance on the main line from $A$ to $F$ equals the sum of the courses, or 927 feet, but this we have by the stations, which have been kept by stakes in the ordinary way. All the stakes on the auxiliary lines will be more or less off the main line, but as these offsets are usually very small, they are considered of no consequence on a preliminary survey through a forest. In Fig. 1 the offsets are very much magnified. **The field notes** of such auxiliary courses should be kept, not as regular notes, but on the margin or opposite page, and in such a way that, while the line may be retraced by them on the ground, the draughtsman may see that it is not necessary to plot them, when a straight line ruled and measured through is sufficient. It is obvious that in selecting a closing course either the deflection may be assumed and the length calculated, or *vice versa;* but care should be taken to assume such values as do not involve a fraction in either factor, if possible.

**48.** The method of passing an obstacle on the line by **auxiliary lines at a large angle** with the main line will only be resorted to when circumstances are such that the other methods mentioned cannot be employed, as in passing a building, pond, or densely wooded swamp. In such a case we may turn a right angle with the transit, and measure accurately one offset, putting a transit point at its extremity, where another right angle will give a parallel line. If the offset prove too short for an accurate backsight, a temporary point at a sufficient distance may be established for that purpose on the offset line produced before the instrument is removed from the main line. If any other angle than 90° is used it should be selected, when circumstances permit, so that the distances on the intercepted part of the main line may be in some **simple ratio** to the distances measured on the auxiliary line. Thus a deflection of 60° gives a distance on the main line equal to half the length of the auxiliary course, that is,

| | | | | | |
|---|---|---|---|---|---|
| 60° | gives a ratio of | | $\frac{1}{2}$ = | 0.5 | |
| 53° 08′ | " | " | " | 0.6 | nearly |
| 45° 34½′ | " | " | " | 0.7 | " |
| 36° 52″ | " | " | " | 0.8 | " |
| 25° 50½′ | " | " | " | 0.9 | " |

the angles being taken to the nearest half minute.

**49.** If it be desired that the stakes on the auxiliary line should stand on **perpendiculars** through the true stations on the main line, a certain correction must be added to each chain length depending on the angle which the auxiliary makes with the main line. If there is a fraction of the chain at either end of the course, a proportional addition must be made for this. Thus, by referring to the table of external secants, we find that we must add a correction as follows:

| | | | |
|---|---|---|---|
| 2° 33½′ | ...0.1 ft. per chain. | 6° 45½′ | ...0.7 ft. per chain. |
| 3° 37′ | ...0.2 " " | 7° 13½′ | ...0.8 " " |
| 4° 26′ | ...0.3 " " | 7° 39½′ | ...0.9 " " |
| 5° 07′ | ...0.4 " " | 8° 04′ | ...1.0 " " |
| 5° 43′ | ...0.5 " " | 9° 52′ | ...1.5 " " |
| 6° 15½′ | ...0.6 " " | 11° 22′ | ...2.0 " " |

These methods of suiting the angle to an even measure are much superior to assuming an even number of degrees deflection, and then calculating the distance by trigonometry. The last table, which may be extended indefinitely by reference to the table of Ex. secants, is perfectly adapted to **chaining** by surface measure **on regular slopes** when the slope angle is known, the chain being lengthened by the correction corresponding to the slope angle.

**50.** If the chain is lengthened as per above table on auxiliary lines, the numbering of the stakes goes on as usual, but they should have an additional mark as × to show that they are off the main line; and they may stand facing the true stations which they represent, and the length of offset, if known, may also be recorded on them. The leveller will then understand that he is to read the rod not only at the stakes as they stand, but also at the true stations, as nearly as may be. The assistant engineer will always make **a diagram** in his field book, showing exactly the method pursued in reference to auxiliary lines. Having passed the obstacle, it is advisable to return to the main line by a course equal in length to the first auxiliary, and making an equal angle with the main line. If this cannot be done from the end of the first course, a parallel to the main line may be run any convenient distance, and the return line then put in, forming a trapezoid.

**51.** When there is no **obstruction** to sight on the main line, but only **to measurement,** a transit point should be set in line beyond the obstacle before the transit leaves the main line, as a check on the other operations, and the main line should be afterward produced from this point by backsight on the main line, rather than by deflection from an auxiliary line.

**52.** The main line should always be resumed as soon as practicable, making the auxiliary lines the mere exception. When a number of courses at a large angle are likely to be required before the main line can again be reached, it may be better to consider these as regular courses of the survey, and to note them as such. The *simplest* method is always the *best*, because least likely to involve mistakes.

**53.** When the **natural obstacles** are so **numerous** and of such magnitude as to render any continuous line of survey or location extremely difficult, if not impossible, as in the case of a bold rocky shore, all the data necessary to a location should be gathered with precision on the preliminary survey, the measurements and angles being taken with the greatest care, and as many checks as possible should be introduced to verify the work. In meandering such a shore it is probable that a large number of short courses will be used, which may be measured correctly, but there is liability to error in the angles. To verify the latter the more conspicuous transit stations on prominent points of the shore are selected, and these being named by the letters of the alphabet, the deflections between them are taken by careful observations repeated a number of times, as for a triangulation. These points, joined by tie-lines, then form a survey of themselves, much simpler than the full traverse. To obtain the length of these tie-lines, the angles between them and the courses meeting at the same station are measured. Then since each tie-line forms the closing side of a field, in which all the bearings are known, and all the distances, save one, that one may be calculated by latitude and departures. But the angles should first be tested for error in each complete field, and if the error be large the angles must all be remeasured until the error is found and corrected, but if very small it may be distributed among the angles, or among those most probably inaccurate. Before calculating the traverse of any of these fields, it will be advantageous to assume, for an artificial meridian, a line parallel to the average direction of the shore for several miles, and to refer all courses to this meridian for their bearing. This meridian is called the *axis* of the survey, and all bearings referred to it are called *axial bearings*, as distinguished from magnetic bearings. The magnetic bearing of the axis should be some exact number of degrees, so as to facilitate the reduction from one system to the other.

**54.** In plotting the map, the axis is first laid down, and then the lettered stations in their respective positions, after which the meandering surveys can be filled in. The map being drawn on a scale of one hundred feet to an inch, and the contours constructed from the notes of the level and cross-level parties, the engineer may project the location upon it with great certainty and economy of result. But he should calculate the traverse of the location as projected, and compare it with the traverse of the preliminary, to eliminate all errors in drafting, before taking his notes to the field to reproduce the location on the ground. Any point where the location crosses the preliminary should have the same latitude and longitude by the traverse of either line. This system, though laborious, is the only one that will ensure a successful location under the circumstances supposed. Advantage may sometimes be taken of cold weather to cross bays and inlets on the ice, but there is great liability to error in angles taken upon the ice, due both to its motion and to the sinking of the feet of the tripod into the ice as soon as exposed to the rays of the sun.

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## CHAPTER III.

### Theory of Maximum Economy in Grades and Curves.

**55.** Before commencing the field work of location it devolves upon the engineer to decide as to which of the surveyed routes shall be adopted as being most advantageous in all respects, and also to establish the maximum grade in each direction and the minimum radius of curve on that route.

The general considerations which guide the engineer in the selection of one of several routes for location are such as were hinted at in the chapter on reconnoissance, but upon the completion of the preliminary surveys he has at hand a large amount of information which enables him to consider this important question much more in detail. Unless his instructions are explicitly to the contrary, he may assume it to be his duty to find the *best line*, or that one which, for a series of years following the completion of the road, will require the least annual expense, including interest on first cost. The finances of the company may be so limited as not to permit the construction of the best line at once, and it may then be the duty of the engineer to select the *cheapest line*, or that of least first cost, as a temporary expedient, with the expectation of building the road at its best when the improved credit of the company will permit. But generally he will be able to build the cheaper portions of the best line at once, only making deviations and introducing heavier grades at the expensive points to avoid a cost beyond the present means at his command. The selection of the best line may be a question as between different routes or as between different grades and curves on the same route. We will consider the latter case first.

**56.** To solve the **problem of true economy** we must determine the actual expense both of building and operating the line at a given maximum grade, and also what changes will be made in these expenses by a change in that maximum. We have then, on one hand, the annual interest upon the original cost, and, on the other, the annual expense of operating the road. *The best grade is that which will render the sum of these two a minimum.* Both forms of expense consist of two parts: one that is affected by a change in grade, and the other that is not. Clearly the former is the only one we have to consider in either, since when the sum of the variable portions is a minimum, the sum total will be a minimum also. The varying portions then are functions of the grade, though independent of each other. If, therefore, we let $z'$ represent the maximum grade in feet per mile, and let $x$ represent the corresponding value of that portion of the annual expense which varies with the grade, and establish the relation existing between the two, we shall have $x = f(z')$. Similarly if we let $y$ represent the interest on so much of the first cost as is affected by grade, we shall have $y = f'(z')$. The problem then is to find that value of $z'$ which shall render

$$x + y = a \text{ minimum}.$$

Let us now seek the complete expression represented by $x = f(z')$.

The elements that enter into this expression are numerous, and will be considered in succession.

**57. The traction of an engine** is the force with which it pulls a train, and is limited by the reaction of the drivers against the rails. It depends on the weight upon each driver, the number of drivers, and the coefficient of friction. The weight on one driver should not exceed 12,000 lbs., and is usually less than this. If the exact proportions of engine that will be used on the road are not known, the weight per driver may be assumed at 10,000 lbs., with 4 drivers for ordinary grades and traffic, or at 11,000 lbs. with 6 drivers, if the grades are steep and the tonnage large. For extraordinary grades special engines are required, having 8 or 10 drivers. The coefficient of friction, called also the adhesion, varies from .09 to .37, these being the extremes on record. The lowest is due to extremely unfavorable circumstances, as sleet and frost; the highest doubtless to the use of sand, though not so stated in the record. The more common range of values is from .15 to

.25. For our present purpose it will be assumed at .20, so that if a 4-driver engine has 10,000 lbs. on each driver, its traction is $40,000 \times .20 = 8000$ lbs. when hauling its maximum train.

**58. The expense** of running an engine one mile, hauling a train, on the proposed road, can only be estimated from the experience on other roads similarly situated. The expense is composed of the items of fuel, water, oil and waste, repairs (including renewals), wages of conductor, engineer, and fireman, engine-house expenses, and interest on first cost of engine and engine-stall. The range and approximate average of these items is here given:

| Items. | 4-Driver Engine. | | 4-Driver | 6-Driver | 8-Driver |
|---|---|---|---|---|---|
| | Lowest. | Highest. | Average. | Average. | Average. |
| Fuel.... .............. | $0.050 | $0.210 | $0.100 | $0.165 | $0.213 |
| Water................ | .001 | .010 | .004 | .006 | .008 |
| Oil and waste.. ..... | .004 | .030 | .006 | .008 | .010 |
| Repairs and renewals | .050 | .150 | .080 | .104 | .133 |
| Wages............... | 050 | .100 | .075 | .075 | .075 |
| Engine-house ..... | 025 | .060 | .035 | .050 | .060 |
| Interest............. | .025 | .038 | .030 | .038 | .047 |
| Totals... ........ | .205 | .598 | .330 | .446 | 546 |

In a given case the probable value of each item should be estimated separately, and the sum taken afterwards. In the above averages each engine is supposed to haul its maximum train. The relative expense of the several classes of engines has not been established conclusively.

**59. The resistance** offered to the motion of a railway train is occasioned by a variety of causes, concerning which a great deal of uncertainty exists as to their relative effect. An investigation which should seek to determine the exact amount of each partial resistance, and then by a summation derive the total, would be tedious, and, in the present state of our knowledge, unsatisfactory. We shall therefore simply group the resistances under three general heads, namely:

Resistance due to uniform motion on a straight, level track;

Resistance due to grade;

Resistance due to curvature.

**60. The first of these,** considered as an aggregate of the various items of friction in engine and train, of oscillations and impacts, and of resistance of the atmosphere, is found to vary nearly or quite as the square of the velocity. The friction of an engine is greater in proportion to its weight than that of a car, owing to its many moving parts, so that the resistance of a short train is greater in proportion to its total weight than that of a long train. The resistance of the atmosphere is greater also in proportion to the weight of a short train than of a long one. An empty train will offer more resistance in proportion to its weight than a loaded one. A formula which shall express the resistance of a train to uniform motion must include at least the velocity and the weight of the train and engine.

The following empirical formula is based upon a careful investigation of all such records of experiments on the subject, several hundred in number, as have come to the author's notice, and is believed to give results agreeing closely with the *average* experience and practice of the present day. It is designed to give the resistance per ton for all trains, whether freight or passenger, and at any velocity, under ordinary circumstances. Accidental circumstances, such as the state of the weather, and the condition of the road-bed, rails, and rolling stock, may largely modify the resistance, but these, of course, are not taken account of in the formula.

Let $V$ = velocity of train in miles per hour,
" $E$ = weight of engine and tender in tons,
" $W$ = weight of cars in tons,
" $T$ = weight of freight in tons,
" $q$ = resistance to uniform motion in lbs. per ton.

We then have the formula

$$q = 5.4 + \left(.006 + \frac{.0006E^2}{E + W + T}\right) V^2 \qquad (1)$$

**61. The second resistance** considered is that due to gravity in grades. It varies in the exact ratio of the rise to the length of the grade.

Let $G_s$ = rise of grade in feet per station.
" $G_m$ = rise of grade in feet per mile.
" $q'$ = resistance in pounds per ton due to grade.

Then,

$$\left.\begin{aligned} q' &= 2240\,\frac{G_s}{100} = 22.4\,G_s \\ q' &= 2240\,\frac{G_m}{5280} = \frac{14}{33}G_m \end{aligned}\right\} \qquad (2)$$

**62. The third resistance** considered is that due to curvature of the track. This resistance is due to the friction of the wheels upon the top of the rail, and of their flanges upon the side of the rail. The top friction is lateral, due to the oblique position of the wheel on the rail, and longitudinal, due to the greater length of the outer rail, since both wheels are rigidly attached to the axle. The flange friction is due to the reaction of the top friction, which, combined with the parallelism of the axles, throws the truck into an oblique position on the track. A forward flange presses the outer rail, while a rear flange is usually in contact with the inner rail. The centrifugal force of the car will increase the pressure on the outer rail, unless the ties are inclined at an angle sufficient to counterbalance this force. But if the ties are inclined too much, or the velocity is less, the pressure on the inner rail will be increased. An uneven track will cause the truck to pursue a zigzag course, increasing the resistance considerably.

Experiments for determining the amount of curve resistance have been neither numerous nor very satisfactory, but the generally accepted conclusion is that the resistance is a little less than half a pound per ton on a one-degree curve, and that it varies as the degree of curve. On European roads, however, it is estimated at about one pound per ton per degree of curve, owing largely to the form of rolling stock used.

**63.** Let $q''$ = curve resistance in pounds per ton on any curve,
and $D$ = degree of curve.

Then, assuming the resistance per ton on a one-degree curve at 0.560, we have for any other curve

$$q'' = 0.56D \qquad (3)$$

To ascertain what grade upon a straight line will offer the same resistance as a given curve; substitute the value of $q''$ for $q'$ in eq. (2) and solve for $G$; whence

$$\left.\begin{aligned} G_s &= 0.025D \\ G_m &= 1.32D \end{aligned}\right\} \qquad (4)$$

For definition of degree of curve, see Art. 84.

**64.** It is evident that grades and curves, by their resistances, fix a limit to the weight of a train which a given engine can haul over them.

A locomotive is usually built with such a surplus of boiler and cylinder capacity that its power, at ordinary velocities, is limited by the adhesion of the drivers, so that the adhesion is the proper measure of the tractive force.

*To find an expression for the maximum train which a given engine can haul over a given grade and curve:*

Let $P$ = tractive force of engine in pounds,
" $T'$ = weight of paying load in tons per maximum train,
" $W'$ = weight in tons of cars carrying the load $T'$.

Then for uniform motion, at a given velocity,

$$(E + W' + T')(q + q' + q'') = P \tag{5}$$

Let $t$ = average load of one car in tons
" $w$ = average weight of one car and load in tons.

Then $W' + T' = \frac{w}{t}T'$, substituting which in eq. (5) we derive

$$T' = \frac{t}{w}\left(\frac{P}{q + q' + q''} - E\right) \tag{6}$$

In this equation $q$ = the resistance per ton due to uniform motion, $q'$ = the resistance per ton due to the *maximum grade* opposed to the direction of the train, and $q''$ = the resistance per ton due to the *sharpest curve on that grade.*

For accelerated motion the reaction of inertia of the train must be added to the above resistances. This is estimated at $\frac{1}{2}q$, in order that a train starting from rest may acquire the requisite maximum velocity, even on a maximum grade, in a reasonable time, say from 3 to 6 minutes. Therefore, for accelerated motion,

$$T' = \frac{t}{w}\left(\frac{P}{\frac{3}{2}q + q' + q''} - E\right) \tag{7}$$

Now, the values of $T$ and $q$ involve each other, but if we accent $W$ and $T$ in eq. (1) the value of $q$ becomes that used in eq. (7), and we may eliminate $q$ between these equations, and derive the value of $T'$; whence

$$T' = \frac{\frac{t}{w}(P - .0009E^2V^2)}{q' + q'' + 8.1 + .009V^2} - \frac{t}{w}E \qquad (8)$$

Also, for the weight of maximum train and load,

$$W' + T' = \frac{P - .0009E^2V^2}{q' + q'' + 8.1 + .009V^2} - E \qquad (9)$$

which is the expression required.

When there is no curve on the maximum grade, $q''$ is zero; and when there is no grade, $q'$ is zero; hence for a straight level track eq. (7) becomes

$$T'_0 = \frac{t}{w}\left(\frac{2P}{3q} - E\right)$$

and eq. (8)

$$T'_0 = \frac{\frac{t}{w}(P - .0009E^2V^2)}{8.1 + .009V^2} - \frac{t}{w}E \qquad (10)$$

**65. An engine-stage** is a division of the road to which an engine is limited, and over which it regularly hauls a train. Its length varies, on existing roads, from 50 to 200 miles or more, depending on the grades, on the length of the whole line, and on the distance between points favorable for the location of shops, etc. The average engine-stage on American roads is not far from 75 miles. If there are to be several engine-stages on the proposed line, the problem of maximum economy of grade must be solved with reference to each of them separately.

Let $L$ = length of engine-stage in miles,

" $e$ = expense per engine-mile in dollars,

" $A$ = average annual paying freight in tons moving in one direction, and

" $a$ = average annual paying freight in tons, moving in the opposite direction; and if these are not equal, let $A$ be greater than $a$. Now $T'$ eq. (8) is the maximum train-load which, at a velocity $V$, should be hauled up steepest grade $z'$, opposed to the direction of the tonnage $A$; hence $\frac{A}{T'}$ = the number of trains per annum; and since each train must go and return, $\therefore \frac{2LA}{T'}$ = the total train-mileage per annum.

If there were no return tonnage, the annual expense chargeable to $A$ would be $\frac{2ALe}{T'}$, but since some of the cars return loaded with the freight $a$, these are not chargeable to $A$, and must be deducted from the above expression. Hence if we denote the annual expense of engine-mileage by $x$,

$$x = \frac{(2A - a)\,Le}{T'} \qquad (11)$$

in which the value of the maximum grade $z'$ is involved in the value of $T'$.

But we may obtain an expression for $x$ in terms of $z'$; for, at any given velocity, the resistance, $q_0$, on a level is equal to the resistance due to a certain grade $z_0$, the value of which is, by eq. (2), for uniform motion,

$$z_0 = \frac{33}{14} q_0$$

So the resistance, $q$, to motion up a grade $z'$ is equal to the resistance due to some grade $z = \frac{33}{14} q$, the total resistance being that due to the combined grades $z + z'$. Now, since the gross weight of a maximum train, under a constant engine power, is inversely as the resistances, we have, for conditions of accelerated motion:

$$\frac{w}{t} T' + E : \frac{w}{t} T'_0 + E :: \tfrac{3}{2} z_0 : \tfrac{3}{2} z + z'$$

whence

$$T' = \frac{\tfrac{3}{2} T'_0 z_0 - \frac{t}{w} E\left(z' + \tfrac{3}{2}(z - z_0)\right)}{\tfrac{3}{2} z + z'} \qquad (12)$$

in which $T'_0$ = maximum train-load on a level line. Substituting this value of $T'$ in eq. (11) we have

$$x = \frac{\tfrac{3}{2} z + z'}{\tfrac{3}{2} T'_0 z_0 - \frac{t}{w} E\left(z' + \tfrac{3}{2}(z - z_0)\right)} (2A - a)\,Le \qquad (13)$$

which is the complete expression for $x = f(z')$ required.

**66.** Could we also find a complete expression for $y = f'(z')$, we might then proceed to find, by analysis, that value of $z'$ which would render $x + y =$ a minimum. But the value of $y$ cannot be formulated, since it depends on the accidental features of the country through which the line passes; it can only be determined for any given value of $z'$ by an estimate based on the survey. We therefore resort to a graphical solution.

Equation (13) is the equation of a curve in the plane $ZX$, Fig. 2. If we assume several values of $z'$, and calculate the corresponding values of $x$, we may lay these off by scale on the axes of $Z$ and $X$ respectively, and so obtain several points

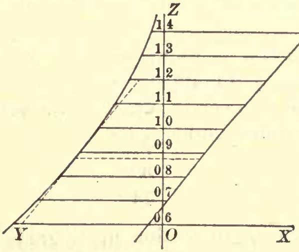


FIG. 2.

through which the curve of annual expense may be drawn. We then make estimates of the cost of constructing the road at the same values of $z'$, and taking the annual interest of each estimate as an ordinate $y$ to $OZ$ in the plane $ZY$, we lay it off to scale at the proper height, thus obtaining a series of points in the plane $ZY$, through which the curve of annual interest on first cost may be drawn. If now we suppose the plane $ZY$ to be revolved to the left about the axis $OZ$ until it coincides with the plane $OX$, as in Fig. 2, we shall see that the two curves are convex to $OZ$ and to each other. The shortest horizontal line intercepted by them indicates the minimum value of $(x + y)$, and the point where this line cuts the axis $OZ$ indicates the corresponding value of $z'$, which is the one required. If tangents be drawn to the curves at the points where the shortest horizontal line intersects them, the tangents will be parallel to each other. Any convenient scales may be used to lay off the values of $z'$ and $x$, provided that the values of $x$ and $y$ be laid off to the *same scale*. It is well to reduce all the values of $x$ by an amount common to them all, and the same with respect to values of $y$, before laying them off to scale. This will bring the two curves nearer together without altering their form.

**67.** To facilitate the calculation of $x$, we give on the next page a table of values of $\frac{1}{T'}$ for several engines, using eq. (8) for this purpose. The value of $x$ is therefore found, eq. (11) or (13), by multiplying $(2A - a)\ Le$ by the proper tabular number, under conditions assumed as follows:

$t$ = 10 tons of freight per car-load;
$w$ = 18 tons per car and load;
$V$ = 12 miles per hour.

For a 4-driver engine, $E = 42$ tons; $P =$ 8100 lbs.
For a 6-driver engine, $E = 49.5$ " $P = 12600$ "
For an 8-driver engine, $E = 59.4$ " $P = 17280$ "

Substituting these values in eq. (8), and making $q'' = 0$, we find the maximum loads of freight which the several engines can haul up the grade whose resistance is $q'$. The reciprocals of these loads are given in the table opposite the grades noted in the first and last columns.

**68.** Since $q''$ is made zero, the grades in the table are assumed to be on straight lines. In locating a road, the *maximum* grade should be reduced on a curve by the amount of the equivalent-grade of the curve, eq. (4), so that the resistance may be no greater on the curve than elsewhere. But grades less than the maximum need not necessarily be reduced for the curves upon them, unless the sum of the grade and the curve-equivalent exceeds the maximum.

**69.** For an example, let us suppose that a certain engine-stage is to be 80 miles long, and that an estimate of the cost of construction has been made, based on a ruling or maximum grade of 52.8 ft. per mile against the heavier traffic, and that the annual interest on the estimate amounts to \$168,000.

Let us further suppose that the average traffic in one direction is estimated at 375 000 tons per annum, and in the other direction at 125 000 tons, that it is decided to use 6-driver engines, and that the expense per engine-mile is estimated at 40 cents; hence $(2A - a)\ Le = 20\ 000\ 000$. We are now required to find the most economical maximum grade.

We first select at least two other maximum grades, and having

$V = 12$. TABLE OF RECIPROCALS OF $T'$. $t = 10$, $w = 18$.

| $G_s$. | $E = 42$, $P = 8100$ | Diff. | $E = 49.5$, $P = 12600$ | Diff. | $E = 59.4$, $P = 17280$ | Diff. | $z'$ ft. per mile. |
|---|---|---|---|---|---|---|---|
| 4.0 | .0479 844 | 22 445 | .0241 385 | 8 954 | .0162 847 | 5 597 | 211.20 |
| 3.9 | .0457 399 | 21 363 | .0232 431 | 8 692 | .0157 250 | 5 464 | 205.92 |
| 3.8 | .0436 036 | 20 357 | .0223 739 | 8 442 | .0151 786 | 5 336 | 200.64 |
| 3.7 | .0415 679 | 19 420 | .0215 297 | 8 203 | .0146 450 | 5 212 | 195.36 |
| 3.6 | .0396 259 | 18 547 | .0207 094 | 7 974 | .0141 238 | 5 092 | 190.08 |
| 3.5 | .0377 712 | 17 732 | .0199 120 | 7 753 | .0136 146 | 4 978 | 184.80 |
| 3.4 | .0359 980 | 16 968 | .0191 367 | 7 543 | .0131 168 | 4 866 | 179.52 |
| 3.3 | .0343 012 | 16 253 | .0183 824 | 7 341 | .0126 302 | 4 757 | 174.24 |
| 3.2 | .0326 759 | 15 583 | .0176 483 | 7 147 | .0121 545 | 4 653 | 168.96 |
| 3.1 | .0311 176 | 14 952 | .0169 336 | 6 960 | .0116 892 | 4 553 | 163.68 |
| 3.0 | .0296 224 | 14 360 | .0162 376 | 6 780 | .0112 339 | 4 455 | 158.40 |
| 2.9 | .0281 864 | 13 803 | .0155 596 | 6 608 | .0107 884 | 4 360 | 153.12 |
| 2.8 | .0268 061 | 13 277 | .0148 988 | 6 442 | .0103 524 | 4 269 | 147.84 |
| 2.7 | .0254 784 | 12 779 | .0142 546 | 6 282 | .0099 255 | 4 180 | 142.56 |
| 2.6 | .0242 005 | 12 310 | .0136 264 | 6 128 | .0095 075 | 4 094 | 137.28 |
| 2.5 | .0229 695 | 11 867 | .0130 136 | 5 979 | .0090 981 | 4 011 | 132.00 |
| 2.4 | .0217 828 | 11 447 | .0124 157 | 5 836 | .0086 970 | 3 930 | 126.72 |
| 2.3 | .0206 381 | 11 048 | .0118 321 | 5 699 | .0083 040 | 3 852 | 121.44 |
| 2.2 | .0195 333 | 10 670 | .0112 622 | 5 566 | .0079 188 | 3 775 | 116.16 |
| 2.1 | .0184 663 | 10 311 | .0107 056 | 5 436 | .0075 413 | 3 701 | 110.88 |
| 2.0 | .0174 352 | 9 970 | .0101 620 | 5 312 | .0071 712 | 3 630 | 105.60 |
| 1.9 | .0164 382 | 9 646 | .0096 308 | 5 193 | .0068 082 | 3 560 | 100.32 |
| 1.8 | .0154 736 | 9 337 | .0091 115 | 5 076 | .0064 522 | 3 493 | 95.04 |
| 1.7 | .0145 399 | 9 043 | .0086 039 | 4 965 | .0061 029 | 3 427 | 89.76 |
| 1.6 | .0136 356 | 8 763 | .0081 074 | 4 856 | .0057 602 | 3 363 | 84.48 |
| 1.5 | .0127 593 | 8 494 | .0076 218 | 4 751 | .0054 239 | 3 301 | 79.20 |
| 1.4 | .0119 099 | 8 239 | .0071 467 | 4 649 | .0050 938 | 3 240 | 73.92 |
| 1.3 | .0110 860 | 7 995 | .0066 818 | 4 551 | .0047 698 | 3 181 | 68.64 |
| 1.2 | .0102 865 | 7 761 | .0062 267 | 4 457 | .0044 517 | 3 124 | 63.36 |
| 1.1 | .0095 104 | 7 538 | .0057 810 | 4 365 | .0041 393 | 3 069 | 58.08 |
| 1.0 | .0087 566 | 7 324 | .0053 445 | 4 274 | .0038 324 | 3 015 | 52.80 |
| .9 | .0080 242 | 7 119 | .0049 171 | 4 187 | .0035 309 | 2 962 | 47.52 |
| .8 | .0073 123 | 6 923 | .0044 984 | 4 104 | .0032 347 | 2 910 | 42.24 |
| .7 | .0066 200 | 6 734 | .0040 880 | 4 022 | .0029 437 | 2 860 | 36.96 |
| .6 | .0059 466 | 6 553 | .0036 858 | 3 943 | .0026 577 | 2 811 | 31.68 |
| .5 | .0052 913 | 6 380 | .0032 915 | 3 865 | .0023 766 | 2 764 | 26.40 |
| .4 | .0046 533 | 6 213 | .0029 050 | 3 791 | .0021 002 | 2 718 | 21.12 |
| .3 | .0040 320 | 6 052 | .0025 259 | 3 719 | .0018 284 | 2 672 | 15.84 |
| .2 | .0034 268 | 5 898 | .0021 540 | 3 648 | .0015 612 | 2 628 | 10.56 |
| .1 | .0028 370 | 5 750 | .0017 892 | 3 580 | .0012 984 | 2 585 | 5.28 |
| 0.0 | .0022 620 | | .0014 312 | | .0010 399 | | 0.00 |

In this table T′ = tons of freight for a maximum train of fully loaded cars hauled up any grade $z'$ at a velocity of 12 miles per hour; the ratio of dead to paying load being assumed at 8 to 10. Hence gross load of train behind engine = $\frac{18}{10}$ T′. The track is assumed straight, hence $q'' = 0$ in eq. (8) for this table.

made an estimate of the cost of constructing the road upon each, take the annual interest of each, as in the first case. Let us suppose the two ruling grades thus selected to be 73.92 ft. and 31.68 ft. per mile, or 1.4 ft. per station and 0.6 ft. per station, and the interest on the estimates to be $145 596 and $204 388 respectively, giving the following statement:

| $G_s$. | $y$. | 1st diff. | 2d diff. |
|---|---|---|---|
| 1.4 | 145 596 | | |
| | | 22 404 | |
| 1.0 | 168 000 | | 13 984 |
| | | 36 388 | |
| 0.6 | 204 388 | | |

Interpolating by second differences, we have the complete statement:

| $G_s$. | $y$. | diff. $y$. | diff. $x$. | $x$. | $x+y$. | $z'$. |
|---|---|---|---|---|---|---|
| 1.4 | 145 596 | 4 290 | 9298 | 142 934 | | 73.92 |
| 1.3 | 149 886 | 5 164 | 9102 | 133 636 | | |
| 1.2 | 155 050 | 6 038 | 8914 | 124 534 | | |
| 1.1 | 161 088 | 6 912 | 8730 | 115 620 | | |
| 1.0 | 168 000 | 7 786 | 8548 | 106 890 | 274 890 | 52.80 |
| 0.9 | 175 786 | 8 660 | 8374 | 98 342 | 274 128 | 47.52 |
| 0.8 | 184 446 | 9 534 | 8208 | 89 968 | 274 414 | 42.24 |
| 0.7 | 193 980 | 10 408 | 8044 | 81 760 | | |
| 0.6 | 204 388 | | | 73 716 | | 31.68 |

The numbers in the fourth and fifth columns are obtained as follows: the values assumed above give us $(2A - a)\ Le =$ $20 000 000, and this multiplied by the tabular differences in the preceding table for a 6-driver engine, gives the numbers in the fourth column. We now observe that the differences of $x$ and of $y$ increase in opposite directions, therefore at some point they will be equal; and a simple inspection shows us that this point is at or near the grade of 0.9, which is therefore the grade required. We now multiply the tabular number for 0.9, and a 6-driver engine by $20 000 000, for the number in the fifth column, and this added to the value of $y$ on the same line gives the sum of $(x + y)$ for the most economical grade. This of course is not the total annual outlay of the road, or engine-stage, because many items of expense which are independent of a maximum grade have not been considered.

If an 8-driver engine were to be used, and the expense per engine-mile estimated at 50 cts., then $(2A - a) Le = \$25\,000\,000$; hence

| $G_s$. | $y$. | diff. $y$. | diff. $x$. | $x$. | $x+y$. | $z'$. |
|---|---|---|---|---|---|---|
| 1.1<br>1.0<br>0.9 | 161 088<br>168 000<br>175 786 | 6 912<br>7 786 | 7 673<br>7 538 | 95 810 | 263 810 | 52.80 |

indicating a saving of $10 318 per annum in the case supposed by using 8-driver engines, although on a steeper ruling grade. On the other hand, should we adopt 4-driver engines, and estimate the expense per engine-mile at 30 cents, we should find the most economical grade to be 0.7 per station and $(x + y) = \$293\,280$, showing a loss in this case of $19 152 per annum, as compared with the results of 6-driver engines.

It should be remembered that the table § 67 is prepared on the assumption that the ratio $\frac{t}{w} = \frac{10}{18}$. If cars are to be used giving for full loads any other ratio, $\frac{t'}{w'}$, a new table may be prepared by multiplying each tabular number by $\frac{10}{18} \times \frac{w'}{t'}$. The velocity adopted of 12 miles per hour is sufficient for ordinary grades. When the maximum grade is very low, it would be better to use 15 or 18 miles an hour in calculating the value of $x$.

**70.** Since $x$, eq. (11), varies directly as $L$, it is important that an engine-stage having heavy grades should be short. Its length, however, must be consistent with the economical length of the adjoining engine-stages, and with the amount of work which an engine ought to perform daily. The most favorable condition for a road would be that in which all the engine-stages were operated at equal expense. But if, to secure this result, the engine-stage of heavy grades must be unreasonably reduced in length, it will be better to adapt the grades to the use of two engines per train.

**71.** The maximum grade $z'$, opposed to the heavier tonnage $A$, having been determined, we have now to consider what is the limit to grades in the opposite direction. The engines are supposed to haul their maximum loads in moving the tonnage $A$, and since the return tonnage, $a$, is less than $A$, the engines, in returning, will not be worked to their full capacity if they encounter no grades steeper than $z'$. We therefore have a margin of power in the returning engines which may be taken advantage of to cheapen the cost of construction, or to shorten the line, by introducing grades, steeper than $z'$, against the lighter traffic.

The weight of a maximum train moving up the grade $z'$ is, eq. (9), $W' + T'$; the weight of the train returning will be

$$W' + \frac{a}{A}T' = \left(\frac{w-t}{t} + \frac{a}{A}\right)T'$$

Substituting this in place of $(W' + T')$, eq. (9), and solving for $q'$, we find the resistance due to a maximum grade opposed to the returning train. Whence, by eq. (2), if we let $Z =$ the maximum return grade, and make $q'' = 0$,

$$Z = \frac{33}{14} \cdot \frac{P - .0009E^2V^2}{E + \left(\frac{w-t}{t} + \frac{a}{A}\right)T'} - \frac{33}{14}(8.1 + .009V^2) \qquad (14)$$

Inasmuch as the value of $Z$ varies with every change made in $z'$, the engineer, when estimating the cost of construction upon the basis of any maximum grade $z'$, should take care that the return grade $Z$ nowhere exceeds its limit as given by the last equation (14). In the example, §69, $z' = 47.52$; hence $T' = 203.37$, eq. (8). Substituting these values, in eq. (14), we find $Z = 81.25$, which is therefore the limit for return grades in this case. With regard to curves on the maximum grade, see §68.

**72.** If in eq. (1) we let $z = \frac{33}{14}q$ be the grade per mile which offers a resistance equal to the resistance to uniform motion on a level, we have

$$z = 12.73 + \left(.01414 + \frac{.001414E^2}{E + W + T}\right)V^2 \qquad (15)$$

When $V = 20$ this becomes

$$z = 18.386 + \frac{.5657E^2}{E + W + T} \qquad (15\tfrac{1}{2})$$

which is the grade down which a train, whose weight is $(E + W + T)$, if started at 20 miles an hour, will continue to move at that speed without steam or brakes. As that speed is not objectionable, so the grade $z$, which induces it is not, provided it does not exceed the values of $z'$ or $Z$ respectively, determined with reference to economy. For the extra work done by the engine in ascending one grade $z$ is utilized in descending the next; and the net result is the same as though the two were replaced by a uniform grade. The engineer therefore is not warranted by economic considerations in reducing undulating grades which do not exceed $z$ to a uniform grade, when to do this would cause any increase in the cost of construction, unless $z$ exceeds the grades $z'$ or $Z$ of maximum economy.

**73.** But when grades exceed $z$, eq. ($15\frac{1}{2}$), the resulting speeds of the maximum train become too great, and the necessary application of the brakes absorbs a portion of the power previously expended in gaining the summit, which is thus worse than wasted, since it increases the wear and tear of machinery and track. Therefore the engineer is justified in spending a certain sum of money in reducing grades which exceed $z$ to that limit. A calculation of the loss of power due to the use of brakes on a grade, and of the cost of that lost power, together with the resulting wear and tear per annum, will give the interest on the sum that may be justifiably spent in reducing the grade from its position of cheapest construction.

**74.** The limit $z$ is not constant, but depends on the weight of the maximum train, which in turn depends on $z'$. It will not be the same in both directions unless $A = a$, giving $z' = Z$. In the example §69, $E = 49.5$ and $W' + T' = 366.07$; hence, eq. ($15\frac{1}{2}$), $z = 21.72$ descending in the direction of the traffic $A$. Also $W' + \frac{a}{A} T' = 230.49$, whence $z = 23.34$ descending in the opposite direction. These are the limits in this case at which undulating grades cease to be profitable.

**75.** We have finally to consider the method for selecting the best line from several proposed routes. For this purpose we determine the most economical grade on each route thought worthy of consideration, and calculate the interest on the *entire cost* of constructing the line with that ruling grade, and also the *annual expense* of operating the line, and take the sum of the two. That route is best in respect to which this *sum* is the least.

**76.** The value of saving one mile in distance on any route is found by dividing the sum of the annual operating expense and the interest on the cost of construction by the rate of interest, and the quotient by the length of the line in miles.

**77.** We have now fully discussed the theory and developed the formulæ necessary to the determination of the most economical grades; but the value of the results in a given case depend upon the correctness of the engineer's estimates which enter into the formulæ. These may seldom prove precisely accurate, yet, if he can bring them within definite limits, he may determine the grades of maximum economy within corresponding limits. In the case of a finished road and in full operation, however, the elements of first cost, of traffic, and of operating expenses being known, an investigation by means of the foregoing formulæ becomes a critical test as to the economy of the location and grades; and should the road fail to pay dividends, or be forced to charge high rates of toll, we can determine, though perhaps too late, to what extent the location is chargeable with these results.

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## CHAPTER IV.

### Location.

**78.** A railroad is said to be located when its centre line is established on the ground in the position which it is intended finally to occupy. The location is made by an engineer corps similar in its organization to that employed on preliminary surveys. The instruments used are also the same, except that the transit is substituted for the compass, and usually the target rod for the self-reading rod. The magnetic needle is never used upon the centre line, except as a rough check on the transit work. It is used, however, to obtain the direction of property lines, roads, and other topographical data.

**79.** The remarks upon **transit work** in the preceding chapter apply to the running of straight lines on location. All field-work on location should be done with accuracy and fidelity. No guesswork, nor rude approximations, are to be tolerated. All transit points are made as secure and permanent as possible, and the more important ones are guarded by other transit points set in safe positions near by, their distances and directions from the main point being recorded.

The stakes for the stations are made neatly, and somewhat uniform in size, and they are firmly driven. Sometimes a small plug is driven down flush with the surface of the ground to indicate the station point, and the stake is then set near by as a witness.

In locating a very **long tangent** the greatest care is required to make it *straight.* If the tangent is produced from point to point by backsights and foresights, the observation should be repeated in every instance with reversed instrument, to eliminate any possible lack of adjustment, and to check any accidental error. (Indeed it is proper to observe this rule on curves, as well as on tangents.) When some object in the horizon can be used as a foresight, it is preferable to set the instrument by this rather than by a backsight. For final location, the line should be cleared to give as continuous a line of sight as possible, but in case of an obstacle which cannot be removed at the time, at least two independent methods of passing it should be employed, so that there may be a check upon the alignment beyond.

**80. The leveller** selects his benches far enough from the line to prevent their being disturbed during the construction of the road. They should be nearly at grade, as a rule, though it is well to leave a bench near a water-course for reference in laying out masonry or trestle-work. The rodman holds the rod at every station, and at every point on the centre line where the slope changes direction, so that these points may be accurately defined on the profile. When he uses a target rod, he sets the target as directed by the leveller, and after clamping it, takes the reading. He reads to thousandths upon turning points and benches, but only to tenths of a foot elsewhere, and announces the readings to the leveller for record. He also records the readings upon turning points and benches in his own book as a check. At the close of each day the leveller and rodman compare notes, and draw a profile of the line surveyed. (See also §§ 28, 29, 30.)

**81.** The **fixing** of the **grade-lines** upon the profile is one of the most important operations connected with the location. It is usually performed by the engineer in charge of the locating party, as being most conversant with the general character and detailed requirements of the line. The maximum gradients will have generally been determined in advance from the preliminary data by the principles laid down in the preceding chapter, but the position of each grade-line, relative to the profile of the surface, must be left to the judgment and skill of the engineer. In general, the grade-line is so placed as to equalize the amounts of excavation and embankment, but there are various exceptions to this rule. Thus, the excavation may be in excess: *first,* when it is necessary to pass under some other road or highway, the grade of which cannot be changed; *second,* when valuable property is to be avoided, the appropriation of which would cost more than the excavation; *third,* when the grade is at the maximum near a summit, and cannot be raised parallel to itself without incurring too great an expense for masonry, etc., at some other part of the line. The embankment may be in excess, *first,* when the country is flat and wet, in order to keep the road-bed well drained; (the grade-line should be at least two feet above the average level of the surface, or above high-water mark, if the district is subject to overflow;) *second,* in approaching a stream, where it is necessary to raise the grade above the requirements of navigation; *third,* when the cuttings on the line are largely in solid rock, and a cheaper material for embankments may be conveniently had at other points; *fourth,* in a district subject to heavy drifts of snow, by which deep cuts would be liable to be obstructed; *fifth,* in side-hill work, where there is danger of land-slips; *sixth,* when it is determined to supply the place of a portion of an embankment by a timber trestle-work or other viaduct.

The apparent equality of cut and fill on the profile does not represent an equality in fact, owing to the different bases and slopes of the sections adopted, and to the various inclinations of the natural surface transversely to the line. This is especially true in side-hill work, where there are both cut and fill at every point, while the profile shows very little of either. In the latter case it is an excellent plan to combine with the profile of the centre line the **profiles of parallel lines** ten or twenty feet either side of the centre, and drawn with different colored inks, as these will indicate tolerably well the relative amount of cut and fill required. But after the grade has been thus chosen, the only safe method in side-hill work is to actually compute the amounts of excavation and embankment from cross-sections, mark the amount for each cut and fill on the profile, and compare the results. Any changes required in the grade or alignment may then be discovered and effected before the work of construction has begun.

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# CHAPTER V.

## Simple Curves.

### *A. Elementary Relations.*

**82.** The centre line of a located road is composed alternately of straight lines and curves.

The straight lines are called **tangents** because they are laid exactly tangent to the curves. A tangent may be indefinitely long, but should never, as a rule, be shorter than 200 feet between two curves which deflect in opposite directions, nor shorter than 500 feet between curves which deflect in the same direction. A curve should not be less than 200 feet long. When a tangent is said to be *straight,* the meaning simply is that it has no deflections to the right or left; for since it follows the surface of the ground, it evidently has as many undulations as the ground. But if we conceive a vertical plane to be passed through the line, a horizontal trace of this plane will accurately represent the line; and so, if we conceive a vertical cylinder to be passed through a curve on the surface of the ground, a horizontal trace of that cylinder will accurately represent the curve, since all distances and angles are measured horizontally, whatever be the irregularities of the surface. In all problems, therefore, relating to this subject, we may consider the ground to be an absolutely level plain.

**83. A Simple curve** is a circular arc joining two tangents. It is always considered as limited by the two tangent points, and any part of it beyond these points is called the curve produced. The first tangent point, or the point where the curve begins, is called the *Point of Curve,* and is indicated by the initials *P. C.* The point where the curve ends, and the next tangent begins, is called the *Point of Tangent,* and is indicated by the initials *P. T.* When accessible, these points are always occupied by the transit in the course of the survey, and the plug driven to fix the point is guarded, not only by the usual stake bearing the number of the station, but also by another bearing the proper initials, the "degree" of the curve, and an "*R*" or "*L*" to indicate whether the deflection is to the Right or Left.

**84.** A simple curve is designated either by the radius, *R*, or the degree of curve, *D*.

**The Degree of Curve,** *D*, is an angle at the centre, subtended by a chord of 100 feet. It is expressed by the number of degrees and minutes in that angle, or in the arc of the curve limited by the chord of 100 feet. Therefore *D equals the number of degrees of arc per station.*

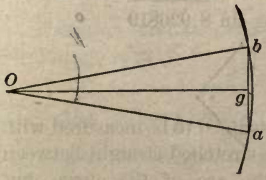

FIG. 3.

The radius *R* and degree of curve *D* can be expressed in terms of each other.

Let *ab*, Fig. 3, be a chord of 100 feet subtending an arc described with a radius $ao = R$ from the centre *o*. Then, by definition the angle $boa = D$. Bisect the angle *boa* by a line *og*, and this line will also bisect the chord *ab* and be perpendicular to it; and in the right-angled triangle *bgo* we have

$$bg = ob \times \sin bog$$

or

$$\frac{100}{2} = R \sin \tfrac{1}{2}D$$

*Hence, to find Radius in terms of Degree of Curve:*

$$R = \frac{50}{\sin \frac{1}{2}D} \qquad (16)$$

and *to find Degree of Curve in terms of Radius:*

$$\sin \tfrac{1}{2}D = \frac{50}{R} \qquad (17)$$

It is the practice of English engineers to assume the radius at some round number of feet and calculate the degree of curve, which is therefore fractional. In America, on the contrary, the degree of curve is assumed at some integral number of degrees or minutes, and the radius deduced from this.

*Example.*—What is the radius of a 3° 20′ curve?

| | | | |
|---|---|---|---|
| | 50 | log | 1.698970 |
| | $\frac{1}{2}D = 1°\ 40'$ | log sin | 8.463665 |
| *Ans.* | $R = 1719.12$ | log | 3.235305 |

Thus the second and third columns of Table IV. have been calculated.

*Example.*—What is the degree of curve when the radius is 600 feet?

| | | | |
|---|---|---|---|
| | 50 | log | 1.698970 |
| | $R = 600$ | log | 2.778151 |
| | $\frac{1}{2}D = 4°\ 46'\ 48''.73$ | log sin | 8.920819 |
| *Ans.* | $D = 9°\ 33'\ 37''.46$ | | |

## Measurement of Curves.

**85.** A railroad curve is always assumed to be measured with a 100-foot chain, and as the chain is stretched straight between stations it cannot coincide with the arc of the curve, but forms a chord to the arc, as in Fig. 3. Consequently the curve as measured from one tangent point to the other is an inscribed polygon of equal sides, each side being 100 feet. The sum of these sides (with any fraction of a side at either end of the curve) is called the *Length of curve, L.* This length $L$ is evidently a little less than the length of the actual arc between the same points, but the latter we very seldom have occasion to consider.

**86.** If the chain lengths were taken on the arc instead of as chords of the curve, the degree of curve would be inversely proportional to the radius, and since the arc whose length is equal to radius contains 57.3 degrees nearly, we should have

$$D : 57°.3 :: 100 : R.$$

or

$$R = \frac{5730}{D}$$

a convenient formula, but only approximately true when $D$ is small, and seriously at fault when $D$ is large; the error involved being proportional to the difference in length of a 100-foot chord, and the arc which it subtends.

**87. The Central Angle** of a simple curve is the angle at the centre included between the radii which pass through the tangent points ($P.C.$) and ($P.T.$). It is therefore equal to the number of degrees contained in the entire arc of the curve between those points. The central angle will be designated by the Greek letter $\Delta$ (delta).

From the definitions of the *length* and *degree* of curve we have the proportion,

$$D : \Delta :: 100 : L.$$

*Hence, to find the* **Length of curve** *in terms of the central angle:*

$$L = 100 \frac{\Delta}{D} \tag{18}$$

*Example.*—What is the length of a 4° curve when the central angle is 29°?

$D = 4°$ and $\Delta = 29°$ $\quad$ 4)2900

*Ans.* $L = 7$ stations $+ 25$ feet $\quad$ 725 feet.

*To find the* **Central angle** *in terms of the length and degree of curve:*

$$\Delta = \frac{DL}{100} \tag{19}$$

*Example.*—What is the central angle of a 5° curve 730 feet long?

$D = 5°$, $\quad L = 730$, $\quad \frac{5 \times 730}{100} = 36°.5$

*Ans.* $\Delta = 36°\ 30'$

*To find the* **Degree of curve** *in terms of the length and central angle:*

$$D = 100 \frac{\Delta}{L} \tag{20}$$

*Example.*—What is the degree of a curve 8 stations long, and having a central angle of 26° 40′?

$L = 800$, $\quad \Delta = 26°.666$, $\quad 100 \frac{26°.666}{800} = 3°.333$

*Ans.* $D = 3°\ 20'$

**88.** If two tangents, joined by a simple curve, are produced (one forward and the other backward) until they intersect, the point of intersection, $V$ (Fig. 4), is called the **vertex,** and the exterior or deflection angle which they make with each other is equal to the central angle, $\triangle$

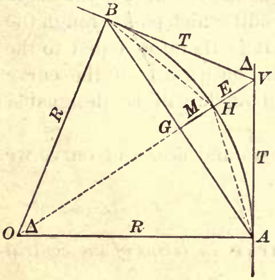


Fig. 4.

**The Tangent-distance,** $T$, is the distance from the vertex to either tangent point; thus in Fig. 4, $T = AV = VB$.

**The Long Chord,** $C$, is the line $AB$ joining the two tangent points.

**The Middle-ordinate,** $M$, is the line $GH$, joining the middle point of the long chord with the middle point of the curve.

**The External distance,** $E$, is the line $HV$, joining the middle point of the curve with the vertex.

We observe that both the middle-ordinate, $M$, and the external distance, $E$, are on the radial line joining the centre, $O$, with the vertex, $V$, and that this line is perpendicular to the long chord, $C$; also, that it bisects the central angle $AOB = \triangle$, and its supplement $AVB$. (Tab. I. 14.) We also observe that the angle $VAB = VBA = \frac{1}{2}\triangle$ (Tab. I. 20); and if in the figure we draw the two chords $AH$ and $BH$, the angle $BAH$ equals one half the angle $BOH$, or $BAH = ABH = \frac{1}{4}\triangle$ (Tab. I. 18); also the angle $VAH = VBH = \frac{1}{4}\triangle$.

**89.** If we have laid out two tangents on the ground, intersecting at $V$, and have measured the angle, $\triangle$, between them, we may then assume any other one of the elements of a simple curve before mentioned, and calculate the rest. If we assume $D$, for instance, we then find $R$ by eq. (16) or by Table IV.

Then, having $\triangle$ and $R$, we may proceed to calculate the other elements as they are needed.

**90.** *To find the* **Tangent-distance** *in terms of the Radius and Central Angle:*

In the right-angled triangle $VOA$, Fig. 4, we have

$$VA = OA \times \tan VOA$$
$$\therefore T = R \tan \tfrac{1}{2} \triangle \qquad (21)$$

*Otherwise, approximately:* In Table VI., opposite the central angle, take the value of $T$ for a 1° curve and divide it by the degree of curve $D$. If desirable, add the correction taken from Table V., corresponding to $D$.

*Example.*—What is the tangent distance of a 4° curve with a central angle of 30°?

| | | | |
|---|---|---|---|
| $D = 4°$ | R (Table IV.) | log | 3.156151 |
| $\triangle = 30°$, | $\tfrac{1}{2}\triangle = 15°$ | log tan | 9.428052 |
| *Ans.* $T = 383.89$ feet | | log | 2.584203 |

Otherwise:

| | |
|---|---|
| By Table VI. | 4)1535.3 |
| Approximate ans. | 383.82 |
| Correction from Table V. | .08 |
| *Ans.* $T =$ | 383.90 feet. |

**91.** *To find the* **Long Chord** *$C$, in terms of Radius and Central Angle:*

In the right-angled triangle $BOG$, Fig. 4, we have

$$BG = BO \times \sin BOG$$

or

$$\tfrac{1}{2}C = R \sin \tfrac{1}{2}\triangle$$

$$\therefore C = 2\, R \sin \tfrac{1}{2}\triangle \qquad (22)$$

But in case $\triangle$ can be divided by $D$ without a remainder, that is, if the curve contains an exact number of stations (not exceeding 12), we may take the long chord at once from Table VII.

*Example.*—What is the long chord of a 3° 20′ curve with a central angle of 36° 40′?

| | | |
|---|---|---|
| 2 | log | 0.301030 |
| $D = 3° 20'$, $R$ (Tab. IV.) | log | 3.235305 |
| $\triangle = 36° 40'$, $\tfrac{1}{2}\triangle = 18° 20'$ | log sin | 9.497682 |
| *Ans.* $C = 1081.48$ feet | log | 3.034017 |

Otherwise:

$$\frac{\triangle}{D} = \frac{36\frac{2}{3}^\circ}{3\frac{1}{3}^\circ} = 11 \text{ stations}$$

And by Table VII. $C = 1081.48$.

**92.** *To find the* **Middle-ordinate** *$M$, in terms of Radius and Central Angle:*

It is evident from the figure that if the radius $OH$ were unity, the line $GH$ would be the nat. versed sine of the arc $BH$. But the arc $BH$ measures the angle $BOH = \frac{1}{2}\triangle$, and $OH = R$;

$$\therefore\ M = R \text{ vers } \tfrac{1}{2}\triangle \qquad (23)$$

But in case $\triangle$ can be divided by $D$ without a remainder, that is, if the curve contains an exact number of stations (not exceeding 12), we may take the middle-ordinate at once from Table VIII.

*Example.*—What is the middle-ordinate of a 4° 30′ curve with a central angle of 40° 30′?

| | | |
|---|---|---|
| $D =$ 4° 30′, | $R$ (Tab. IV.) log | 3.105022 |
| $\triangle =$ 40° 30′, | $\frac{1}{2}\triangle =$ 20° 15′ log vers | 8.791049 |
| *Ans.* $M =$ 78.717 | | 1.896071 |

Otherwise:

$$\frac{\triangle}{D} = \frac{40.5}{4.5} = 9 \text{ stations}$$

and by Tab. VIII. $M = 78.717$

**93.** *To find the* **External Distance** *$E$ in terms of Radius and Central Angle.*

It is evident from the figure that if the radius $OA$ were unity, the portion $HV$ of the secant line $OV$ would be the external secant of the arc $AH$. But the arc $AH$ measures the angle $AOH = \frac{1}{2}\triangle$, and $OA = R$:

$$\therefore\ E = R \text{ ex sec } \tfrac{1}{2}\triangle \qquad (24)$$

*Otherwise, approximately:*

In Table VI., opposite the central angle, take the value of $E$ for a 1° curve, and divide it by the degree of curve $D$. If desirable, add the proper correction corresponding to $D$, taken from Table V.

*Example.*—What is the external distance $E$ of a 7° 30′ curve when the central angle is 60° ?

| | | | |
|---|---|---|---|
| $D = 7° 30'$, | $R$ (Tab. IV.) | log | 2.883371 |
| $\Delta = 60°$, | $\frac{1}{2}\Delta = 30°$ | log ex sec | 9.189492 |
| *Ans.* $E = 118.27$ feet | | log | 2.072863 |

*Otherwise:*

| | |
|---|---|
| By Tab. VI. | 7.5)886.38 |
| Approximate ans. | 118.184 |
| Correction for $D = 7° 30'$ (Tab. V.) | .084 |
| *Ans.* $E =$ | 118.268 |

**94.** But, instead of assuming $D$ or $R$, we may prefer, or may find it necessary to assume, some other element of the curve, the central angle being given.

If we assume the tangent distance, then:

**95.** *To find the* **Radius** *and* **Degree of Curve** *in terms of the Tangent-distance and Central Angle.*

From eq. (21), and by Table II. 40, we have

$$R = T \cot \tfrac{1}{2}\Delta \tag{25}$$

*Otherwise, approximately:*

Divide the tangent of a 1° curve found opposite the value of $\Delta$ in Table VI., by the assumed tangent distance; the quotient will be the degree of curve in degrees and decimals.

*Example.*—The exterior angle at the vertex is 54°, and the tangent distance must be about 700 feet. What shall be the degree of curve?

| | | | |
|---|---|---|---|
| $\Delta = 54°$, | $\frac{1}{2}\Delta = 27°$ | log cot | 0.292834 |
| | $T = 700$ | | 2.845098 |
| | $\log R =$ | | 3.137932 |

*Ans.* By Table IV. $D = 4° 10' +$

Otherwise:

| | |
|---|---|
| By Table VI. | 700)2919.4 |
| *Ans.* $D = 4° 10' 15''$ | 4.1706 |

But as it is difficult to lay out a curve when $D$ is fractional, we discard the fraction and assume 4° 10′ as the value of $D$.

This may require us to recalculate the value of $T$, which we do by eq. (21) and find $T = 700.8$ feet log 2.845596. If the other elements are required, they may be calculated by eqs. (22), (23). (24), or directly from $T$ and $\Delta$, as follows:

**96.** *To find the* **External distance** *$E$, in terms of the Tangent-distance and Central Angle.*

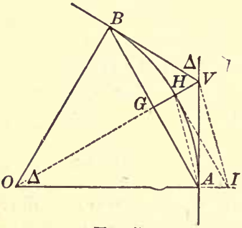


FIG. 5.

In Fig. 5 we have given $AOB = \Delta$ and $AV = T$, to find $HV = E$. In the diagram draw the chord $AH$, and through $H$ draw a tangent line to intersect $OA$ produced in $I$, and join $VI$.

Then $HI$ is parallel to $BA$, and since $HI = AV = T$, and $AI = HV = E$, $VI$ is parallel to $HA$, and $VIH = HAB = \frac{1}{4}\Delta$. (Tab. I. 18.)

In the right-angled triangle $VHI$ we have

$$HV = HI \times \tan VIH$$

or

$$E = T \tan \tfrac{1}{4}\Delta \qquad (26)$$

*Example.*—The angle at the vertex being 54° and the tangent-distance 700.80 feet, how far will the curve pass from the vertex?

| | | |
|---|---|---|
| | $T = 700.80$ (from last example) | 2.845596 |
| | $\Delta = 54°$, $\frac{1}{4}\Delta = 13° 30'$ log tan | 9.380354 |
| *Ans.* | $E = 168.25$ feet log | 2.225950 |

(For the formulæ by which to find the long chord and middle-ordinate in terms of the tangent-distance and central angle, see Table III. 12 and 13.)

**97.** Again, it may be necessary to assume the *external distance* in order to determine the proper degree of curve.

*To find the* **Radius** *and* **Degree of Curve** *in terms of the External distance and Central Angle:*

By eq. (24)

$$R = \frac{E}{\text{ex sec} \frac{1}{2}\Delta} \qquad (27)$$

*Otherwise:*

In Table VI. divide the external distance of a 1° curve, opposite the given value of $\Delta$, by the assumed external distance; the quotient is the degree of curve required.

*Example.*—The angle at the vertex being 24° 30′, the curve is desired to pass at about 65 feet from the vertex. What is the proper degree of curve ?

| | | | |
|---|---|---|---|
| | $E = 65$ | log | 1.812913 |
| $\Delta = 24° 30'$, | $\frac{1}{2}\Delta = 12° 15'$ | log ex sec | 8.367345 |
| | $\log R =$ | | 3.445568 |

*Ans.* By Table IV. $D = 2° 03' +$

*Otherwise:*

By Table VI. 65)133.50

*Ans.* $D = 2° 03' 14''$ 2°.0538

We may therefore assume a 2° curve, unless required by the circumstances to be more exact, when we might use a 2° 03′ curve. Assuming a 2° curve, we have by eq. (24)

$$E = 66.75 \quad \log 1.824460$$

Having decided on the degree of curve, we may calculate the remaining elements by eqs. (21), (22), (23), which is always the better way, but we may calculate them directly from $E$ and $\Delta$.

**98.** *To find the* **Tangent-distance** *in terms of the External distance and Central Angle:*

From eq. (26), and by Table II. 40,

$$T = E \cot \tfrac{1}{4}\Delta \qquad (28)$$

*Example.*—The angle at the vertex is 24° 30′, and the curve passes 66.75 feet from the vertex. How far are the tangent points from the vertex ?

| | | |
|---|---|---|
| $E = 66.75$ (from last example) | log | 1.824460 |
| $\Delta = 24° 30'$, $\frac{1}{4}\Delta = 6° 07' 30''$ | log cot | 0.969358 |
| *Ans.* $T = 622.04$ feet | | 2.793818 |

**99.** *Remark.*—Eqs. (27) and (28) are particularly useful in defining the curve of a railroad track where all **original**

**points are lost.** Produce the centre lines of the tangents of the curve to an intersection $V$, and there measure the angle $\Delta$. Bisect its supplement $AVB$, and measure the distance on the bisecting line from $V$ to the centre line of the track. This will give $VH = E$. Then $R$ and $T$ may be calculated, and the distance $T$ laid off from $V$ on the tangents, giving the tangent points $A$ and $B$.

(For the formulæ by which to find the long chord and middle-ordinate in terms of $E$ and $\Delta$, see Table III. 16 and 17.)

**100.** Again, having only the central angle given, we may assume the long chord, or the middle-ordinate, and from either of these and the central angle calculate the remaining elements. Or, finally, the central angle being *unknown*, we may suppose any two of the linear elements given, and from these calculate the rest. As such problems have little practical value, their discussion is omitted. The requisite formulæ for their solution are given in Table III., and the verification of them is suggested as a profitable exercise to the student.

*B. Location of Curves by Deflection Angles.*

**101.** In order that the stakes at the extremities of the 100-foot chords, by which the curve is measured, shall be set exactly on the arc of the curve by transit observation, it is necessary at the point of curve, $A$, to deflect certain definite angles from the tangent $AV$. Let us suppose that in the curve $AB$, Fig. 6, the points $A$, $a$, $b$, $c$, $d$, etc., indicate the proper positions of the stakes 100 feet apart, and that $OA$ is the radius of the curve. In the diagram join $Oa$, $Ob$, etc., and also $Aa$, $ab$, $bc$, etc.

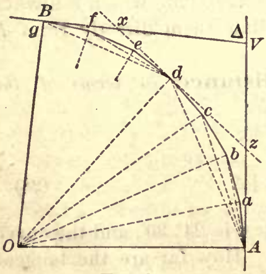

Fig. 6.

Then, by definition, the angle $AOa = D$, and by Geom. (Tab. I. 20 and 11) the angle $VAa = \frac{1}{2}D$. Therefore if we set the transit at $A$, and deflect from $AV$ the angle $\frac{1}{2}D$, we shall get the direction of the chord $Aa$, on which by measuring 100 feet from $A$ we fix the stake, $a$, in its true position on the curve. So again, since the angle $aOb$, at the centre, $= D$, the angle $aAb$, at the circumference, $= \frac{1}{2}D$.

If therefore, with the transit at $A$, we deflect the angle $\frac{1}{2}D$ from the chord $Aa$, we shall get the direction of the chord $Ab$; and when the stake $b$ is on this chord it will also be on the curve, if $b$ is 100 feet distant from $a$. Thus, in general, we may fix the position of any stake on the curve, by deflecting an angle $\frac{1}{2}D$ from the preceding stake, and at the same time measuring a chain's length from it,—the chain giving the distance, while the instrument at $A$ gives the direction of the point.

$\frac{1}{2}D$ is called the Deflection-angle of the curve; so that in any curve, *the deflection-angle is equal to one half the degree of curve.*

**102.** Since each additional station on the curve requires an additional deflection-angle, the *proper deflection* to be made at the tangent point *from the tangent* to any stake on the curve is equal to the deflection-angle of the curve multiplied by the number of stations in the curve up to that stake; or it is equal to one half the angle at the centre subtended by the included arc of the curve.

**103.** It may happen that all the stations of a curve are not visible from the tangent point, $A$. When this is the case a new transit-point must be prepared at some point on the curve, by driving a plug and centre in the usual manner, and the transit moved up to it. Let us suppose that the point $d$, Fig. 6, has been selected for a transit-point, and that the transit has been set up over it. Before the curve can be run any farther, it is necessary to find the direction of a tangent to the curve at the point $d$. For this purpose we deflect from chord $dA$ an angle $Adz$ equal to the angle $VAd$ previously deflected to fix the point $d$. (Tab. I. 16.) Or we may adopt the following

**Rule:** *To find the* **direction of the tangent** *to a curve at the extremity of a given chord, deflect from the chord an angle equal to one half the angle at the centre subtended by the chord.* (Tab. I. 20.)

Having thus found the direction of the auxiliary tangent $zdx$, we proceed to deflect from $dx$, $(\frac{1}{2}D)$ for the next station $e$, $2\,(\frac{1}{2}D)$ for station $f$, $3(\frac{1}{2}\mathrm{D})$ for station $g$, etc., as before. When the end of the curve is reached, a transit-point is set at the Point of Tangent, after which it only remains to find the direction of the tangent, by the above rule. Thus if $g$ is to be the point of tangent, we obtain the direction of the tangent by deflecting from the chord $gd$ an angle equal to $xdg$, or to $\frac{1}{2}\,dOg$. If this tangent $VB$ was already established, the line $gx$ thus obtained should coincide with it; and if it does so, the correctness of our work is proved.

**104.** The centre line is measured, and the stations numbered regularly and continuously through tangents and curves from the starting point to the end of the work. It therefore frequently happens that a curve will neither begin nor end at an even station, but at some intermediate point, or *plus* distance.

If the Point of Curve occurs a certain number of feet beyond a station, the first chord on the curve is composed of the remaining number of feet required to make 100.

Any chord less than 100 feet is called a **subchord.**

If a curve ends with a subchord, the remainder of the 100 feet must be laid off on the tangent from the Point of Tangent to give the position of the next station, so that the stations may everywhere be 100 feet apart.

**105.** *The deflection to be made for a subchord is equal to one half the arc it subtends.*

Let $c$ = length of any subchord in feet.

" $d$ = angle at centre subtended by subchord.

Then, from eq. (22), by analogy

$$c = 2R \sin \tfrac{1}{2}d \qquad (29)$$

But by eq. (16) $$2R = \frac{100}{\sin \frac{1}{2}D}$$

$$\therefore c = 100 \frac{\sin \frac{1}{2}d}{\sin \frac{1}{2}D} \qquad (30)$$

$$\therefore \sin \tfrac{1}{2}d = \frac{c}{100} \sin \tfrac{1}{2}D \qquad (31)$$

When $D$ does not exceed 8° or 10°, we may assume without serious error that the angles are to each other as their sines, and the last two equations become

(approx.) $$c = 100 \frac{d}{D} \qquad (32)$$

and $$\tfrac{1}{2} d = \frac{c}{100} (\tfrac{1}{2} D) \qquad (33)$$

In curves sharper than 10° per station, the error involved in this assumption becomes apparent and must be corrected.

**106.** If curves were measured on the actual arc, then eqs. (32) and (33) would be true in all cases; but since a curve is measured by 100-ft. chords, it is evident that if a 100-ft. chord between any two stations were replaced by two or more subchords, these taken together would be longer than 100 feet, since they are not in the same straight line. Let us conceive the actual arc of one station to be divided into 100 equal parts; since the arc is longer than the chord, each part will be slightly longer than one foot. Now if we take an arc containing any number of these parts (less than 100), the *nominal* length of the corresponding subchord in feet will *equal* the number of parts, and the deflection for the subchord will be *proportional* to the number of parts which the arc contains. The deflection therefore will be exactly given by eq. (33) if in that equation we let $c$ equal the number of parts in the arc, or the nominal length of the subchord in feet. Having thus obtained the correct value of $(\tfrac{1}{2} d)$, we may introduce it into eq. (29) or (30), and obtain the *true* value of the subchord, which will always be a little greater than its nominal value.

Suppose, for instance, that the arc of one station is to be divided into four equal portions; then each subchord will be *nominally* 25 feet long; and by eq. (33)

$$\tfrac{1}{2} d = \frac{25}{100} (\tfrac{1}{2} D) = \tfrac{1}{4} (\tfrac{1}{2} D) \qquad (34)$$

which is the correct value of the deflection, whatever be the degree of curve. Substituting this value in eq. (29) or (30) we obtain the *true value* of the subchord, $c$, a little greater than 25; the *excess* is called the *correction* of the nominal length.

**107.** This correction for any given subchord bears an almost constant ratio to the excess of arc per station, whatever be the degree of curve. These ratios are shown in the following table for a series of subchords, and Table VII. gives the length of actual arc per station for various degrees of curve. Subtracting 100 we have the excess of arc per station, and multiplying this *excess* by the *ratio* corresponding to the nominal length of subchord we obtain as a product the proper correction for the subchord.

TABLE OF THE RATIOS OF CORRECTIONS OF SUBCHORDS TO THE EXCESS OF ARC PER STATION.

| Nominal Length of Subchord. | Ratio. | Nominal Length of Subchord. | Ratio. | Nominal Length of Subchord. | Ratio. |
|---|---|---|---|---|---|
| 0 | .000 | 35 | .307 | 70 | .356 |
| 5 | .050 | 40 | .336 | 75 | .327 |
| 10 | .099 | 45 | .358 | 80 | .287 |
| 15 | .147 | 50 | .374 | 85 | .235 |
| 20 | .192 | 55 | .383 | 90 | .169 |
| 25 | .234 | 60 | .383 | 95 | .092 |
| 30 | .273 | 65 | .374 | 100 | .000 |

We observe that the largest correction is required by a subchord between 55 and 60 feet in length.

*Example.*—It is proposed to run a 14° curve with a 50-ft. chain. What correction must be added to the chain?

$$D = 14^\circ \qquad \tfrac{1}{2}D = 7^\circ \qquad \tfrac{1}{2}d = \frac{50}{100} \times 7^\circ = 3^\circ.5 \doteq 3^\circ\ 30'$$

By eq. (30)

$$c = 100\,\frac{\sin 3^\circ\ 30'}{\sin 7^\circ} = 50.093$$

*Ans.* Correction = .093

Or, by Table VII., length of arc = 100.249

excess of arc = .249

and by above table, ratio for 50 feet = .374

*Ans.* Correction = product = .093

*Example.*—The *P.C.* of an 18° curve is fixed at + 55 feet beyond a station. What are the nominal and true values of the first subchord, and what the proper deflection?

$$\text{Nominal value} = 100 - 55 = 45 \text{ feet}$$

$$\text{Deflection} = \tfrac{1}{2}d = \frac{45}{100} \times 9^\circ = 4^\circ.05 = 4^\circ\ 03'$$

and by eq. (30)

$$\text{True value} = c \doteq 100\,\frac{\sin 4^\circ\ 03'}{\sin 9^\circ} = 45.148$$

| | | |
|---|---|---|
| Or, by Table VII., | excess of arc = | .412 |
| by above table, | ratio for 45 feet = | .358 |
| | Correction = product = | .147 |
| *Ans.* True value of subchord | | = 45.147 |

*Example.*—The last deflection at the end of a 40° curve is found to be 6° 30′. What are the nominal and true values of the last subchord?

Here $\frac{1}{2}d = 6° \; 30'$, and by eq. (32)

$$\text{Nominal value, } c = 100 \, \frac{6.5}{20} = 32.5 \text{ feet}$$

By eq. (30)

$$\text{True value, } c = 100 \, \frac{\sin 6° \; 30'}{\sin 20°} = 33.098 \text{ feet}$$

| | | |
|---|---|---|
| Or by Table VII., | excess of arc 40° = | 2.060 |
| by above table, | ratio for 32.5 feet = | .290 |
| | Correction = product = | .597 |
| | Nominal value of subchord = | 32.5 |
| | True value = | 33.097 |

**108.** For convenience in making deflections, the zeros of the instrument should always be together when the line of collimation coincides with a tangent to the curve. Thus, in beginning a curve, **the transit** being set at the *P. C.* zeros together, and line of collimation on the tangent, the reading of the limb for any station on the curve has simply to be made equal to the proper deflection from the tangent for that station. After the transit is moved forward from the *P. C.* and set at another point of the curve, the vernier is set to a reading equal to the reading used to establish that point, *but on the opposite side of the zero of the limb*, and the line of collimation is set on the *P. C.* just left. Then by simply turning the zeros together again, the line of collimation will be made to coincide with a tangent to the curve through the new point, and the deflections for the succeeding stations can be read off directly, as before. Thus any number of transit points may be used in locating a curve by finding the direction of the tangent through each by a deflection from the preceding point, until finally the *P. T.* is reached, where another deflection gives the direction of the located tangent.

**109.** The assistant engineer keeps neat and systematic **field-notes** of all his operations with the transit in running curves. The numbers of the stations are written in regular order *up* the first column of the left-hand page of the field-book, using every line, or every other line, as may be preferred. The second column contains the initials of each transit point on the same line as the number of its station, or between lines, if the point occurs between two stations. In the third column, and opposite the initials in the second, is recorded the station and plus distance, if any, of each transit point. The fourth column contains, opposite the "*P.C.*," the degree of curve used, and an *R* or *L*, showing whether the curve deflects to the right or left; the fifth column contains the readings or deflections made from a tangent to set each station or point, written on the same line as the number of that station or point; and the sixth column contains the central angle of the whole curve, $\Delta$, written opposite the "*P.T.*"

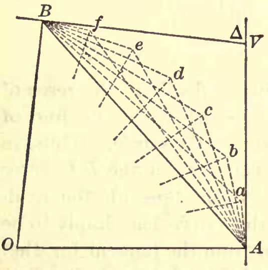


Fig. 7.

The plus distances recorded in the third column are always the *nominal* lengths of subchords, but if the true lengths have been calculated and laid off on the ground, these should also be recorded in parenthesis. On the right-hand page are recorded the calculated bearings of the tangents and their magnetic bearings; and on the centre line of the page, opposite the record of each transit point, a dot is made with a small circle around it, to show the relative position of the several points on the ground. Some slight topographical sketches may be made, indicating the more prominent objects, but the full sketches should be taken by the topographer in a separate book.

**110.** Since the deflections start from *zero* at each new transit point, *the* **sum** *of the deflections by which the transit points are located will be equal to* **one half the central angle** *of the curve.*

**111.** The stations on a curve may be located **by deflections only,** without linear measurements. For this purpose two transits are set at two transit points on the curve, as *A* and $B$, Fig. 7, and the proper deflections for any station are made with both instruments, the station being located by finding the intersection of the two lines of collimation.

This method requires that the two transit points shall have been previously established, that their distance from each other shall be known, that they shall be visible from each other, and that they shall both command a view of the stations to be located. It is not therefore generally useful, but may be resorted to to set stations which fall where chaining cannot be accurately done, as in water or swamps. The chord joining the two transit points becomes, in fact, a base-line, and the deflections form a series of triangulations.

*C. Location of Curves by Offsets.*

**112.** A curve may be located by linear measurement only, without angular deflections. There are four general methods, viz.:

*By offsets from the chords produced,*
*By middle-ordinates,*
*By offsets from the tangents,* and
*By ordinates from a long chord.*

## To locate a curve by offsets from the chords produced.

*When the curve begins and ends at a station.*

**113.** Let $A$, Fig. 8, be the $P. C.$ of a curve taken at a station, to locate the other stations, $a$, $b$, $c$, etc. The chords $Aa$, $ab$, $bc$, etc., each equal 100 feet, and since the angle $AOa = D$, the angle $VAa = \frac{1}{2}D$. (Tab. I. 20.) Taking an offset $ax = t$, perpendicular to the tangent, we have in the right-angled triangle $Axa$.

$$ax = Aa \times \sin \tfrac{1}{2}D$$

or

$$t = 100 \sin \tfrac{1}{2}D \qquad (34)$$

The offset $t$ is called the tangent offset, and its value is given for all degrees of curve in Tab. IV. col. 4.

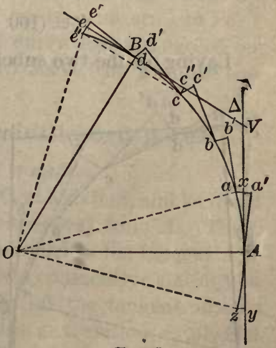


FIG. 8.

If the curve were produced backward from $A$, 100 feet to station $z$, the offset $zy$ would equal $t$; and if the chord $zA$ were produced 100 feet from $A$ to $a'$, the offset $a'x$ would also equal $t$. Therefore the distance $aa' = 2t$, and the angle $aAa' = D$. So if we produce the chord $Aa$ 100 feet to $b'$, the distance $bb' = 2t$.

*To lay out the curve*, stretch the chain from $A$, keeping the forward end at a perpendicular distance, $t$, from the line of the tangent to locate station $a$. Then find the point $b'$ by stretching the chain from $a$ in line with $a$ and $A$, and then stretching the chain again from $a$, fix its forward end at a distance from $b'$ equal to $2t$. This gives station $b$. In the same way find other stations.

When the last station, as $d$, of the curve is reached, produce the curve one station farther to $e''$. Then the tangent through $d$ is parallel to the chord $ce''$, and laying off $t$ from $c$ and $e''$ perpendicular to this chord, the tangent $c''e$ is found. If the work has been correctly done the tangent $c''e$ will coincide with the given tangent $VB$.

*When the curve begins or ends with a subchord.*

**114.** Let $A$, Fig. 9, be the $P\ C$. and $Aa$ the first subchord $= c$, and the angle $VAa = \frac{1}{2}d$, and let the offset $ax = t_1$. Then

$$t_1 = c \sin \tfrac{1}{2}d \qquad (35)$$

Producing the curve backward to the nearest station $z$, we have another subchord $Az = (100 - c)$, and the angle $yAz = \frac{1}{2}(D - d)$, and putting the offset $yz = t_{\prime\prime}$

$$t_{\prime\prime} = (100 - c) \sin \tfrac{1}{2}(D - d) \qquad (36)$$

Laying off the two subchords on the ground, and making the proper offsets, $t_\prime$ and $t_{\prime\prime}$, at the same time, we fix the position of the two stations $a$ and $z$ on the curve; after which we may produce the chord $za$ 100 feet to $b'$, and proceed as before until the curve is finished.

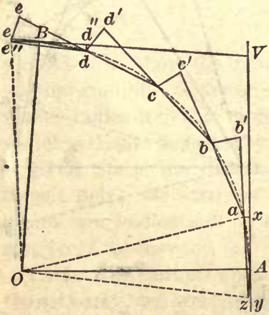


FIG. 9.

If the curve ends with a subchord, as $dB$, produce the curve to the first station beyond $B$, as $e''$, then calculate the two offsets for the two subchords $Bd$ and $Be''$, and lay them off from $d$ and $e''$

perpendicular to the supposed direction of the tangent. If the line $d''e$ so obtained coincides with the given tangent, $VB$, the work is correct.

**115.** We may find the values of $t_{\prime}$ and $t_{\prime\prime}$ otherwise than by the formulæ above, for in Fig. 8 we have shown that the angle $aAa' = aOA$, and since these triangles are isosceles, they are similar; therefore

Fig. 8, $OA : Aa :: Aa : aa'$

or $R : 100 :: 100 : 2t$

$$\therefore \qquad t = \frac{(100)^2}{2R} \qquad (37)$$

and similarly, Fig. 9,

$$t_{\prime} = \frac{c^2}{2R} \qquad (38)$$

Hence

$$t_{\prime} : t :: c^2 : (100)^2$$

$$\therefore \qquad t_{\prime} = \frac{c^2\, t}{(100)^2} \qquad (39)$$

Thus $t_{\prime}$ may be found by multiplying the square of the sub-chord by the value of $t$ given in Tab. IV., and dividing the product by 10000. As $c$ is always less than 100, so $t_{\prime}$ is always less than $t$.

**116.** In eqs. (35), (38), and (39) it is customary to use the *nominal* values of $c$, and this can produce no error in $t$ or $t_{\prime}$ exceeding ·005, when the degree of curve does not exceed ten degrees. In the case of a very sharp curve, the formulæ eqs. (40) and (41) are preferable.

## To locate a curve by middle-ordinates.

*When the curve begins and ends at a station.*

**117.** In Fig. 10, let $A$ be the $P.C.$ at a station, and let $a$ and $z$ be the next stations on the curve either way from $A$. Then, since $zy = ax = t$, the chord $za$ is parallel to the tangent $AV$, and $Ag = t$. Hence, having any two consecutive stations on the curve, as $z$ and $A$, we may lay off the tangent offset $t$ from $A$ to $g$ on the radius, and find the next station, $a$, 100 feet from $A$ on the line $zg$ produced. Then laying off $ah = t$ on the radius $aO$, a point on the line $Ah$ produced and 100 feet from $a$ will be the next station $b$.

On reaching the end of the curve, the tangent is found precisely as described in the method by chords produced, § 113.

In Fig. 10, we observe that if the radius $OA$ were unity, $gA$ would be the versed sine of the angle $aOA = D$. But $gA = t$,

$$\therefore t = R \text{ vers } D \qquad (40)$$

*When the curve begins or ends with a subchord.*

**118.** Let $A$, Fig. 11, be the $P.C.$, and $a$ and $z$ the nearest

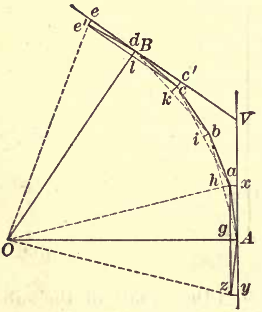


FIG. 10.

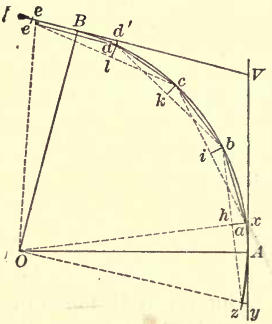


FIG. 11.

stations. Then $Aa = c$, the first subchord, and $aOA = d$, and by analogy, we have from the last equation, if $ax = t_{\prime}$ and $zy = t_{\prime\prime}$

$$\left.\begin{aligned} t_{\prime} &= R \text{ vers } d \\ t_{\prime\prime} &= R \text{ vers } (D-d) \end{aligned}\right\} \qquad (41)$$

or eq. (39) may be used if preferred.

Having found the two stations, $a$ and $z$, on the curve, lay off from the forward station $a$, $ah = t$ on the radius, and so continue the curve as described above.

When the end of the curve is reached, produce the curve to the next station beyond, and find the tangent by offsets as described in the previous method, § 114.

## To locate a curve by offsets from the tangents.

*When the curve begins at a station.*

**119.** Let $A$, Fig. 12, be the $P.C.$ at a station. Then the next station $a$ is located by the tangent offset $t$, taken from

Tab. IV., or calculated by eq. (40). To calculate the distances and offsets for the following stations, $b$, $c$, etc., in the diagram draw lines through the points $b$, $c$, etc., parallel to the tangent $AV$, intersecting the radius $AO$ in $g'$, $g''$, etc., and draw the lines $bx'$, $cx''$, etc., perpendicular to the tangent.

Then

$$Ax' = g'b = Ob \sin bOA$$

or

$$\left.\begin{array}{l} Ax' = R \sin 2D \\ Ax'' = R \sin 3D \\ \text{etc.} \quad \text{etc.} \end{array}\right\} \qquad (42)$$

and

Also,

$$bx' = g'A = Ob \text{ vers. } bOA$$

or

$$\left.\begin{array}{l} t' = R \text{ vers } 2D \\ t'' = R \text{ vers } 3D \\ \text{etc.} \quad \text{etc.} \end{array}\right\} \qquad (43)$$

and

But these calculations may be avoided, for as twice $ag$ equals the chord of two stations, so twice $bg'$ equals the chord of four stations, and twice $cg''$ the chord of six stations, etc. So also as $Ag$ is the middle-ordinate of two station, $Ag'$ is the middle-ordinate of four, and $Ag''$ the middle-ordinate of six stations, etc. Hence the rule:

*The distance on the tangent from the tangent point to the perpendicular offset for the extremity of any arc is equal to one half the long chord for twice that arc; and the offset from the tangent to the extremity of any arc is equal to the middle-ordinate of twice that arc.*

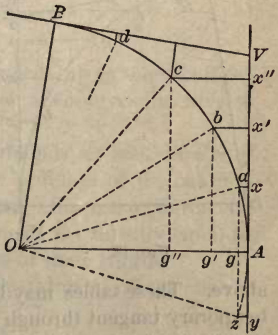

FIG. 12.

The long chords and middle-ordinates may be taken from Tables VII. and VIII. for 2, 4, 6, 8, etc., stations, when the *P.C.* is at a station, or for 1, 3, 5, 7, etc., stations, when the *P.C.* is at + 50, or half a station.

If the offsets from the first tangent $AV$ prove inconveniently long, the second half of the curve may be located from the other tangent $BV$, beginning at the point of tangent $B$, and closing on a station located from the first tangent.

*When the curve begins with a subchord.*

**120.** If $d$ = the angle at centre, subtended by the first subchord, we have for the distances on the tangent (Fig. 13)

$$\left.\begin{aligned} Ax &= R \sin d \\ Ax' &= R \sin (d + D) \\ Ax'' &= R \sin (d + 2D) \\ \text{etc.} & \qquad \text{etc.} \end{aligned}\right\} \qquad (44)$$

and for the offsets (Fig. 11)

$$\left.\begin{aligned} t_{\prime} &= R \text{ vers } d \\ t' &= R \text{ vers } (d + D) \\ t'' &= R \text{ vers } (d + 2D) \\ \text{etc.} & \qquad \text{etc.} \end{aligned}\right\} \qquad (45)$$

If the first subchord equals 50 feet (nominal), then $d = \frac{1}{2}D$, and the Tables VII. and VIII. may be used as explained

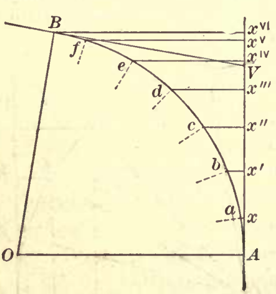


FIG. 13.

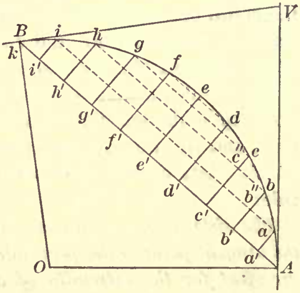


FIG. 14.

above. These tables may be used in any case, by adopting a temporary tangent through any station, and laying off the distances on this, and making the offsets from it.

When a curve is located by offsets the chain should be carried around the curve, if possible, to prove that the stations are 100 feet apart.

## To locate a curve by ordinates from a long chord.

*When the curve begins and ends at a station.*

**121.** In Fig. 14 draw the long chord $AB$, joining the tangent points, and from this draw ordinates to all the stations on the curve. We then require to know the several distances on the long chord $Aa'$, $a'b'$, $b'c'$, etc., and the length of ordinate at each point.

Let $C =$ the long chord $AB$, then eq. (22)

$$C = 2R \sin \tfrac{1}{2} \triangle$$

If $a$ is the second station and $i$ next to the last on the curve, join $ai$, and let the chord $ai = C'$. Then since the arc $Aa = ik = D$, the angle at the centre subtended by $C'$ is $(\triangle - 2D)$

$$\therefore\ C' = 2R \sin \tfrac{1}{2} (\triangle - 2D)$$

Again, if we join $b$ and $h$ the next stations and let $bh = C''$

$$C'' = 2R \sin \tfrac{1}{2} (\triangle - 4D)$$

and so on for other chords.

Since $Aa' = ki$, $C = C' + 2Aa'$

$$\therefore\ Aa' = \frac{C - C'}{2}$$

Similarly,

$$a'\,b' = \frac{C' - C''}{2}$$

Thus we continue to find the distances up to the middle of the curve, after which they repeat themselves in inverse order.

**122.** When the long chord $C$, subtends an *even number of stations* (as 10 in Fig. 14), the middle ordinate of the chord is the ordinate of the middle station, as $e$. Since the chords $AB$ and $ai$ are parallel, the ordinate $a'a$ or $i'i$ is evidently equal to the difference of the middle ordinates of these chords.

Let $M$, $M'$, $M''$, etc., be the middle-ordinates of the chords $C$, $C'$, $C''$, etc. Then eq. (23)

$$\begin{aligned} M &= R \text{ vers } \tfrac{1}{2} \triangle \\ M' &= R \text{ vers } \tfrac{1}{2} (\triangle - 2D) \\ M'' &= R \text{ vers } \tfrac{1}{2} (\triangle - 4D) \\ &\text{etc.,} \qquad \text{etc.} \end{aligned}$$

And

$$\begin{aligned} a'a &= i'i = M - M' \\ b'b &= h'h = M - M'' \\ &\text{etc.} \quad \text{etc.} \quad \text{etc.} \end{aligned}$$

The values of the chords and middle-ordinates may be taken at once from Tables VII. and VIII.

*Example.*—It is required to locate a 4 degree curve of ten stations by offsets from the long chord.

By Table VII.:

| | | Diff. | ½Diff. |
|---|---|---|---|
| 10 sta. | $C = 980.014$ | | |
| 8 " | $C^{i} = 789.803$ | 190.211 | $95.105 = Aa' = ki'$ |
| 6 " | $C^{ii} = 595.744$ | 194.059 | $97.030 = a'b' = i'h$ |
| 4 " | $C^{iii} = 398.782$ | 196.962 | $98.481 = b'c' = h'g'$ |
| 2 " | $C^{iv} = 199.878$ | 198.904 | $99.452 = c'd' = g'f$ |
| 0 " | $C^{v} = 000.000$ | 199.878 | $99.939 = d'e' = f'e'$ |

From Table VIII.:

| | | Diff. | |
|---|---|---|---|
| 10 sta. | $M = 86.402$ | | |
| 8 " | $M^{i} = 55.500$ | 30.902 | $= a'a = i'i$ |
| 6 " | $M^{ii} = 31.308$ | 55.094 | $= b'b = h'h$ |
| 4 " | $M^{iii} = 13.943$ | 72.459 | $= c'c = g'g$ |
| 2 " | $M^{iv} = 3.490$ | 82.912 | $= d'd = f'f$ |
| 0 " | $M^{v} = 0.000$ | 86.402 | $= e'e$ |

**123.** When the long chord $C$ subtends an *odd number of stations*, the middle ordinate will fall half-way between two stations, and need not be laid off.

If the ordinates near the middle of the curve prove inconveniently long, we may subtract $M - M'$, $M' - M''$, etc., and so obtain in Fig. 14 $a'a$, $b''b$, $c''c$, etc. We then lay off $Aa'$, $a'a$, $ab''$, $b''b$, $bc''$, etc., turning a right angle at every point. The chain should be carried along the curve at the same time to make the stations 100 feet apart.

*Example.*—It is required to locate a 10-degree curve of nine stations by offsets from the long chord.

By Table VII.:

| | | Diff. | ½Diff. |
|---|---|---|---|
| 9 sta. | 811.314 | | |
| 7 " | 658.105 | 153.209 | $76.604 = Aa'$ |
| 5 " | 484.900 | 173.205 | $86.603 = a'b'$ |
| 3 " | 296.962 | 187.938 | 93.969 etc. |
| 1 " | 100.000 | 196.962 | 98.481 |
| 0 " | 0.000 | 100.000 | 50.000 |

By Table VIII.:

| | | | Diff. | |
|---|---|---|---|---|
| 9 | sta. | 168.029 | 64.279 | $= a'a$ |
| 7 | " | 103.750 | 50.000 | $= b''b$ |
| 5 | " | 53.750 | 34.202 | $= c''c$ |
| 3 | " | 19.548 | 17.365 | etc. |
| 1 | " | 2.183 | 2.183 | |
| 0 | " | 0.000 | | |

**124.** The tables can be used equally well when the curve both begins and ends with **a half station**; also to locate half-station points throughout the curve, but in the latter case the numbers are taken from *consecutive* columns of the tables instead of from *alternate* columns, as in the above examples.

*When the curve begins or ends with any subchord.*

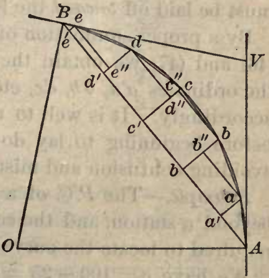


Fig. 15.

**125.** Let $A$, Fig. 15, be the $P.C.$ and $Aa = c$ the first subchord, and $d$ the angle it subtends at the centre. In the diagram draw the long chord $AB$, and the ordinates to each station, and through each station draw a line parallel to $AB$, and let $AOB = \triangle$.

Since the angle $VAB = \frac{1}{2}\triangle$ and $VAa = \frac{1}{2}d$, the angle $aAB = \frac{1}{2}(\triangle - d)$. The deflection angle from the subchord $Aa$ produced to the chord $ab$ is $\frac{1}{2}(d + D)$, the deflection angle between any two consecutive chords of 100 feet is $\frac{1}{2}(D + D) = D$. Therefore the angle

$$bab'' = \tfrac{1}{2}(\triangle - d) - \tfrac{1}{2}(d + D) = \tfrac{1}{2}(\triangle - 2d - D)$$

$$cbc'' = \tfrac{1}{2}(\triangle - 2d - D) - \tfrac{1}{2}(2D) = \tfrac{1}{2}(\triangle - 2d - 3D)$$

$$cdd'' = \tfrac{1}{2}(\triangle - 2d - 3D) - \tfrac{1}{2}(2D) = \tfrac{1}{2}(\triangle - 2d - 5D)$$

etc. etc. etc.

Solving the several right-angled triangles we have, Fig. 15.

$$\left.\begin{aligned} Aa' &= c. \quad \cos \tfrac{1}{2}(\triangle - d) \\ ab'' &= 100 \cos \tfrac{1}{2}(\triangle - 2d - D) \\ bc'' &= 100 \cos \tfrac{1}{2}(\triangle - 2d - 3D) \\ dd'' &= 100 \cos \tfrac{1}{2}(\triangle - 2d - 5D) \\ &\text{etc.,} \qquad\qquad \text{etc.,} \end{aligned}\right\} \qquad (46)$$

And also

$$\left.\begin{aligned} a'a &= c. \quad \sin \tfrac{1}{2}(\triangle - d) \\ b''b &= 100 \sin \tfrac{1}{2}(\triangle - 2d - D) \\ c''c &= 100 \sin \tfrac{1}{2}(\triangle - 2d - 3D) \\ d''c &= 100 \sin \tfrac{1}{2}(\triangle - 2d - 5D) \\ &\text{etc.,} \qquad\qquad \text{etc.,} \end{aligned}\right\} \qquad (47)$$

When the middle point of the curve is passed the minus quantities in the parentheses become greater than $\triangle$, making the parentheses negative, and, therefore, the sines negative, and indicating that such values as are determined by them must be laid off *toward* the long chord $AB$.

By a proper summation of the quantities determined by eqs. (46) and (47) we obtain the distances $Aa'$, $Ab'$, $Ac'$, etc., and the ordinates $a'a$, $b'b$, $c'c$, etc., and the curve may be located accordingly. It is well to make all the necessary calculations before beginning to lay down the lines on the ground, thus avoiding confusion and mistakes.

*Example.*—The *P.C.* of a 3° 20′ curve is fixed at + 25 feet beyond a station, and the central angle is 16° 24′ = $\triangle$. It is required to locate the curve by ordinates from the long chord.

We have $c = 100 - 25 = 75$ and $d = 2° \; 30'$ and $D = 3° \; 20'$. Hence, eqs. (46)

| | |
|---|---|
| $Aa' = 75 \cos 6° \; 57' = 74.449$ | $74.449 = Aa'$ |
| $ab'' = 100 \cos 4° \; 02' = 99.752$ | $174.201 = Ab'$ |
| $bc'' = 100 \cos 0° \; 42' = 99.993$ | $274.194 = Ac'$ |
| $d''d = 100 \cos(-2° \; 38') = 99.894$ | $374.088 = Ad'$ |
| $e''e = 100 \cos(-5° \; 58') = 99.458$ | $473.546 = Ae'$ |
| $e'B = 17 \cos(-7° \; 55') = 16.838$ | $490.384 = AB$ |

By eqs. (47)

| | |
|---|---|
| $a'a = 75 \sin 6° \; 57' = 9.075$ | $9.075 = a'a$ |
| $b''b = 100 \sin 4° \; 02' = 7.034$ | $16.109 = b'b$ |
| $c''c = 100 \sin 0° \; 42' = 1.222$ | $17.331 = c'c$ |
| $cd'' = 100 \sin(-2° \; 38') = -4.594$ | $12.737 = d'd$ |
| $de'' = 100 \sin(-5° \; 58') = -10.395$ | $2.342 = e'e$ |
| $ee' = 17 \sin(-7° \; 55') = -2.341$ | $0.000$ . . . . |

The same formulæ can be used when the curve begins at a station by making $c = 100$ and $d = D$.

**126.** The methods of locating curves by linear measurements do not require the use of a transit, although one may be used to advantage for giving true lines, turning right angles, etc. When a transit is not used the alignments should be made across plumb-lines suspended over the exact points previously marked on top of the stakes. **A right angle** may easily be obtained, without an instrument, by laying off on the ground the three sides of either of the right-angled triangles represented in the following table (or any multiples of them), always making the *base* coincide with the given line.

TABLE OF RIGHT-ANGLED TRIANGLES.

| Base. | Hypothenuse. | Perpendicular. |
|---|---|---|
| 4 | 5 | 3 |
| 12 | 13 | 5 |
| 20 | 29 | 21 |
| 24 | 25 | 7 |
| 40 | 41 | 9 |
| 60 | 61 | 11 |
| 84 | 85 | 13 |

### *D. Obstacles to the Location of Curves.*

**127.** *To locate a curve joining two tangents when the* **intersection** *V* **is inaccessible.** Fig. 16.

From any transit point $p$ on one tangent run a line $pq$ to intersect the other tangent; measure $pq$ and the angles it makes with the tangents. Then the sum of the deflections at $p$ and $q$ equals the central angle $\Delta$. Solve the triangle $pqV$ and find $Vp$. Having decided on the radius $R$ of the curve, calculate the tangent distance $VA$ by eq. (21), and lay off from $p$ the distance $pA = VA - Vp$ to locate the point of curve. The point $p$ being assumed at random, $Vp$ may exceed $VA$, in which case the difference $pA$ is to be laid off *toward V.*

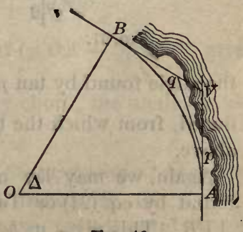

FIG. 16.

In case obstacles prevent the direct alignment of any line $pq$, a line of several courses may be substituted for it (as explained in §§ 46, 47, 48,) from which the length of $pq$ will be deduced. The algebraic sum of the several deflections will equal $\Delta$.

**128.** *To locate a curve when the* **point of curve is inaccessible.** Fig. 17.

Assume any distance $Ap$ on the curve which will reach to an accessible point $p$. Then by eq. (19) the angle

$$pOA = \frac{D \times Ap}{100}$$

$$Ap' = R \sin pOA$$

$$p'p = R \operatorname{vers} pOA$$

$$Vp' = VA - Ap'$$

Measure $Vp'$ and $p'p$ to locate a transit point at $p$; and measure an equal offset from some transit point on the tangent, as $qq'$. This gives a line $pq'$, parallel to the tangent, from which deflect at $p$ an angle equal to $pOA$ for the direction of a tangent through the point $p$.

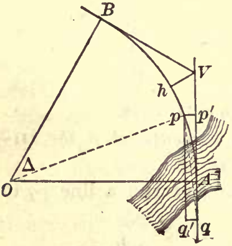

FIG. 17.

Instead of measuring the second offset $qq'$ we may deflect from $pq$ an angle found by $\tan qpq' = \frac{pp'}{qp'}$ and so obtain the line $pq'$ parallel to the tangent. Or we may deflect from $pV$ the angle found by $\tan pVp' = \frac{pp'}{Vp'}$ to obtain the line $q'p$ produced, from which the tangent to the curve at $p$ is found as above.

Again, we may lay off from $V$, the external distance $Vh$ found by eq. (24) or Tab. VI on a line bisecting the angle $AVB$. This gives us $h$, the middle point of the curve, and a line at right angles to $hV$ is tangent to the curve at $h$, from which the curve may be located in either direction.

**129.** *To locate a curve when both the* **Vertex** *and* **Point of curve are inaccessible.** Fig. 18.

From any point $p$ on the tangent run a line $pq'$ to the other tangent, and so determine $pA$ as in § 127. Suppose the curve produced backward to $p'$ on the perpendicular offset $pp'$.

Then

$$\sin p'OA = \frac{pA}{R} \text{ and } pp' = R \text{ vers } p'OA$$

Having located the point $p'$, a parallel chord $p'q$ may be laid off, giving a point $q$ on the curve, since $p'q = 2 \times pA$. At $q$ deflect from $qp'$ an angle equal to $p'OA$ for a tangent to the curve at $q$.

If any obstacle prevents using the chord $p'q$, any other

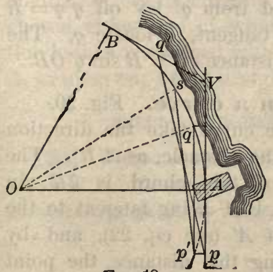

FIG. 18.

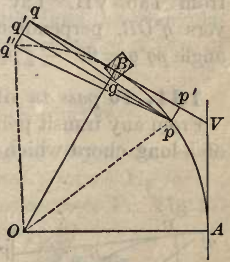

FIG. 19.

chord as $p's$ may be used, by deflecting from $p'q$ the angle $qp's = \frac{1}{2}(qOs)$ and laying off its length,

$$p's = 2R \sin (p'OA + qp's).$$

At $s$ a deflection from the chord $sp'$ of $(p'OA + qp's)$ will give the tangent at $s$.

If obstacles prevent the use of any chord, the methods described in § 131 may be resorted to.

**130.** *To pass from a curve to the forward tangent when the* **Point of Tangent is inaccessible.** Fig. 19.

From any transit point $p$ on the curve, near the end of the curve, run a chord parallel to the tangent. The middle point $g$ of the chord will be on the radius through the point of tangent $B$. At any convenient point beyond this an offset equal to $pp' = R$ vers $pOB$ may be made to the tangent, and at some other point an equal offset will fix the direction of the tangent.

Otherwise, if an unobstructed line $pq$ can be found intersecting the tangent at a reasonable distance from $B$, measure the angle $q'pq = pqp'$, and lay off the distance

$$pq' = \frac{pp'}{\sin q'pq}$$

to fix the point $q$. Then

$$Bq = p'q - p'B = pp' \cot q'pq - R \sin pOB.$$

*Otherwise;* assume an arc of any number of stations from $p$ to $q''$ on the curve produced, and take the length of chord from Tab. VII. Lay off $pq''$, and from $q''$ lay off $q''q = R$ vers $q''OB$, perpendicular to the tangent, to locate $q$. The angle $pq''q = 90° - q'pq''$, and the distance $qB = R \sin q''OB$.

**131.** *To pass an* **obstacle on a curve.** Fig. 20. From any transit point $A'$ on the curve take the direction of a long chord which will miss the obstacle, as $A'B'$. The length of this chord is $2R \sin V'A'B'$, $V'A'$ being tangent to the curve at $A'$ (see eq. 22), and by measuring this distance, the point $B'$ on the curve is obtained. If the angle $V'A'B'$ is made equal to the deflection for an exact number of stations, the chord may be taken from Tab. VII.

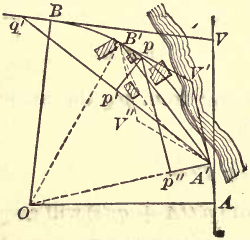

Fig. 20.

If the chord which will clear the obstacles would be too long for convenience, as $A'q'$, we may measure a part of it as $A'p'$, and then, by an ordinate to some station, regain the curve at $p$. The distance on the curve from $A'$ to $p$ being assumed, the distances $A'p'$ and $p'p$ are calculated by the methods given in § 121 to § 125. If $p'p$ can be made a middle ordinate the work will be much simplified. If more convenient the middle ordinate may first be laid off from $A'$ to $p''$, and the half chord afterwards measured from $p''$ to locate $p$.

Again, we may calculate the auxiliary tangent $A'V'$ for any assumed length of curve $A'B'$, and lay off the distance $A'V$ and $V'B'$, deflecting at $V'$ an angle eoual to twice

$V'A'B'$. But if the point $V'$ should prove inaccessible, we may conceive the auxiliary tangents to be revolved about the chord $A'B'$ as an axis, so that $V'$ will fall at $V''$, and the lines $A'V''$ and $V''B'$ may be laid out accordingly. If these in turn meet obstructions, we may run a curve from $A'$ to $B'$ of same radius as the given curve, but tangent to $A'V''$ and $V''B'$.

Again, the entire curve or any portion of it may be laid out by offsets from the tangents, or by ordinates from a long chord, as already explained, § 119 to § 126.

In case any distance on a curve must be measured by a triangulation, as in crossing a stream, a long chord may be chosen, either end of which is accessible, and the triangulation is then performed with respect to this chord or a part of it, as upon any other straight line.

### SPECIAL PROBLEMS IN SIMPLE CURVES.

**132.** *Given: a curve joining two tangents, to find the change required in the radius* **R**, *and external distance* **E**, *for an assumed change in the value of the tangent distance* **T.** Fig. 21.

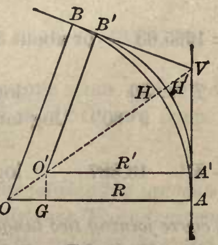


FIG. 21.

Let $T = AV = VB$ and $T' = A'V = VB'$
" $R = AO$ " $R' = A'O'$
" $E = VH$ " $E' = VH'$

Then $T - T' = AA' =$ the given change.

By eq. (25) $R = T \cot \frac{1}{2}\Delta$

$R' = T' \cot \frac{1}{2}\Delta$

$$\therefore \quad OG = R - R' = (T - T') \cot \tfrac{1}{2}\Delta \qquad (48)$$

By eq. (26), similarly,

$$HH' = E - E' = (T - T') \tan \tfrac{1}{2}\Delta \qquad (49)$$

Eqs. (48) (49) give the changes in $R$ and $E$ for any change in $T$. When $T$ is increased $R$ and $E$ will be increased also, and *vice versa.*

*Example.*—A 4° curve joins two tangents, making an angle of $38° = \Delta$, and it is necessary to shorten the last tangent distance 80 feet. What will be the change in the radius and in the external distance?

| | | | | |
|---|---|---|---|---|
| Eq. (48) | $T - T' = 80$ | | log | 1.903090 |
| | $\frac{1}{2}\Delta$ | 19° | log cot | 0.463028 |
| *Ans.* | $R - R'$ | 232.34 | log. | 2.366118 |
| | $R$ | 1432.69 | | |
| | $R' =$ | 1200.35 | or about $4° 46' = D'$. | |

If the tangent distance had been increased 80 feet we should add the above to $R$.

$\therefore \qquad R' = 1665.03 \qquad$ or about $3° 26' = D'$

| | | | | |
|---|---|---|---|---|
| Eq. (49) | $T - T' = 80$ | | log | 1.903090 |
| | $\frac{1}{4}\Delta$ | 9° 30′ | log tan | 9.223607 |
| *Ans.* | $E - E'$ | 13.387 | log | 1.126697 |

**133.** *Given: a curve joining two tangents, to find the change required in the radius* **R,** *and tangent distance* **T,** *for any assumed change in the value of the external distance* **E.** Fig. 21.

We suppose $HH'$ given to find $OG$ and $AA'$.

By eq. (24)

$$E = R \text{ ex sec } \tfrac{1}{2}\Delta$$
$$E' = R' \text{ ex sec } \tfrac{1}{2}\Delta$$

$$\therefore \qquad OG = R - R' = \frac{E - E'}{\text{ex sec } \frac{1}{2}\Delta} \qquad (50)$$

By eq. (49)

$$AA' = T - T' = (E - E') \cot \tfrac{1}{2}\Delta \qquad (51)$$

*Example.*—A 4° curve joins two tangents, making an angle of 38° = $\Delta$, and it is necessary to bring the middle point of the curve 25 feet nearer the vertex $V$. What changes are required in the radius and point of curve?

| | | | | |
|---|---|---|---|---|
| Eq. (50) | $E - E' =$ | 25 | log | 1.397940 |
| | $\frac{1}{2}\Delta$ | 19° | log ex sec | 8.760578 |
| *Ans.* | $R - R'$ | 433.87 | log | 2.637362 |
| | $R$ | 1432.69 | | |
| | $R'$ | 998.82 or about 5° 44′ = $D'$ | | |

| | | | | |
|---|---|---|---|---|
| Eq. (51) | $E - E'$ | 25 | log | 1.397940 |
| | $\frac{1}{2}\Delta$ | 9° 30 | log cot | 0.776393 |
| | $T - T'$ | 149.39 | | 2.174333 |

or the *P.C.* will be moved toward the vertex 149.39 feet.

But if the point $H$, Fig. 21, were to be moved 25 feet further from the vertex $V$, then

$$R' = 1866.56 \text{ or about } 3^\circ\ 04' = D'$$

and the *P.C.* will be moved 149.39 feet further from the vertex.

It is preferable to assume some radius from Table IV. near the value of $R'$ found as above, and from this calculate the value of $T'$ by eq. (21).

**134.** *Given: a curve joining two tangents, to find the change made in the tangent distance* **T,** *and external distance* **E,** *by any assumed change in the value of the radius* **R.** Fig. 21.

By eq. (48)

$$AA' = T - T' = (R - R') \tan \tfrac{1}{2}\Delta \qquad (52)$$

By eq. (50)

$$HH' = E - E' = (R - R') \text{ ex sec } \tfrac{1}{2}\Delta \qquad (53)$$

The changes calculated by eqs. (52) (53) will be added to or subtracted from $T$ and $E$ respectively, according as the radius is increased or diminished.

**135.** Since for a constant value of the central angle $\Delta$, the homologous parts of any two curves are proportional to each other, we may write at once

$$\left.\begin{aligned} R' &= R\frac{T'}{T} = R\frac{E'}{E} = R\frac{C'}{C} = R\frac{M'}{M} \\ T' &= T\frac{R'}{R} = T\frac{E'}{E} = T\frac{C'}{C} = T\frac{M'}{M} \end{aligned}\right\} \quad (54)$$

etc. etc. etc.

**136.** *Given: a curve joining two tangents, to change the position of the* **Point of curve** *so that the curve may end in a* **parallel tangent.** Fig. 22.

Let $AB$ be the given curve, $AV$, $VB$ the tangents, and $V'B'$ the parallel tangent. Then $VV'$ is the distance from one vertex to the other; and since there is no change in the form or dimensions of the curve, we may conceive it to be moved bodily, parallel to the line $AV$, until it touches the line $V'B'$, when every point of the curve will have moved a distance equal to $VV'$. Hence $AA' = OO' = BB' = VV'$. Therefore, run a line from $B$ parallel to $AV$, intersecting the new tangent in $B'$, measure $BB'$, and lay off the distance from $A$ to find $A'$. In the figure the new tangent is taken outside the curve, and so $A'$ falls beyond $A$, but if the new tangent were taken inside the curve at $V''B''$, the new $P.C.$ would fall back of $A$ at some point $A''$.

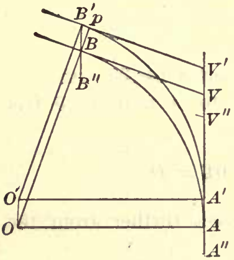

FIG. 22.

If the parallel tangent is defined by a perpendicular offset from $B$, as $Bp$; since the angle $BB'p = \Delta$

$$AA' = BB' = \frac{Bp}{\sin \Delta} \quad (55)$$

**137.** *Given: a curve joining two tangents, to find the* **radius** *of a curve that, from the same Point of curve, will end in a* **parallel tangent.** Fig. 23.

Let $AB$ be the given curve, $AV$, $VB$ the tangents, and $V'B'$ the parallel tangent; and let $AO = R$ and $AO' = R'$.

Since the central angle $\Delta$ remains unchanged, the angle $\frac{1}{2}\Delta$ between the tangent and long chord remains unchanged; therefore $V'AB' = VAB$, and the new point of tangent is on the long chord $AB$ produced. Find on the ground the intersection of $V'B'$ with $AB$ produced and measure $BB'$. In the diagram draw $Be$ parallel to $AO$, then $BeB' = \Delta$, and by eq. (22)

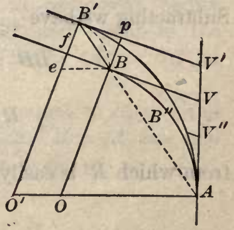

FIG. 23.

$$BB' = 2Be \sin \tfrac{1}{2}\Delta$$

but

$$Be = OO' = R' - R$$

$$\therefore \quad R' = R + \frac{BB'}{2 \sin \frac{1}{2}\Delta} \qquad (56)$$

The $+$ sign is used when $B'$ is beyond $B$, as in the figure; but if the parallel tangent is within the given curve it will cut the chord in some point $B''$, and then the $-$ sign must be used, since $R'$ will evidently be less than $R$.

If the parallel tangent is defined by a perpendicular offset, as $Bp = B'f$; since $BeB' = \Delta$

$$Bp = Be \text{ vers } \Delta = (R' - R) \text{ vers } \Delta$$

$$\therefore \quad R' = R + \frac{Bp}{\text{vers } \Delta} \qquad (57)$$

Add or subtract as explained above.

If the long chord $C = AB$ is known, then the new long chord $C' = AB'$ or $AB'' = C \pm BB'$, and by eq. (54)

$$R' = R\,\frac{C \pm BB'}{C} \qquad (58)$$

**138.** *Given: a curve joining two tangents, to change the* **radius,** *and also the* **Point of curve,** *so that the new curve may end in a* **parallel tangent directly opposite** *the given Point of tangent.* Fig. 24.

Let $AB$ be the given curve, $AV$, $VB$ the tangents, $V'B'$ the parallel tangent, and $B'$ the given tangent point on the radius $OB$ produced.

In the diagram, produce the tangent $AV$ and the radius $OB$ to intersect at $K$. Then

$$BK = R \text{ exsec } \Delta$$

$$B'K = R' \text{ exsec } \Delta$$

Subtracting we have

$$BB' = (R - R') \text{ exsec } \Delta$$

$$\therefore \qquad R - R' = \frac{BB'}{\text{exsec } \Delta} \qquad (59)$$

from which $R'$ is easily determined, as in §§ 132 and 133.

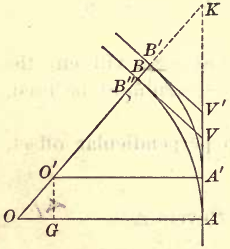


FIG. 24.

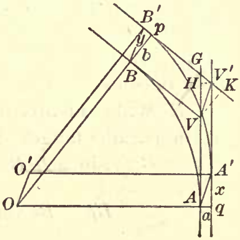


FIG. 25.

To find the change $AA'$ of the $P. C.$, in the diagram draw $O'G$ parallel to $A'A$; then

$$O'G = OG \tan \Delta$$

or

$$AA' = (R - R') \tan \Delta \qquad (60)$$

By substituting the value of $(R - R')$ from eq. (59) and observing Table II. 42 we have

$$AA' = BB' \times \cot \tfrac{1}{2}\Delta \qquad (61)$$

Observe that eqs. (59), (60), and (61) may be derived directly from eqs. (50), (52), and (51) respectively by writing $\Delta$ for $\frac{1}{2}\Delta$.

**139.** *Given: a curve joining two tangents; to find the* **new tangent points** *after* **each tangent** *has been* **moved parallel to itself** *any distance in either direction.* Fig. 25

Let $A$ and $B$ be the given tangent points, and $A'$ and $B'$ the new tangent points required. Let the known perpendicular distances $Aq = a$, and $Bp = b$. We then require the unknown parallel distances $qA' = x$ and $pB' = y$.

Since the form and dimensions of the curve remain unchanged we may conceive the curve to be moved bodily into its new position on lines parallel and equal to the line $VV'$ joining the vertices. Then $AA' = OO' = BB' = VV'$.

In the diagram draw $VK$ parallel and equal to $Bp = b$ and $V'H$ parallel and equal to $Aq = a$. Then $VH = qA' = x$, and $V'K = B'p = y$. Since $VGV' = \Delta$, we have

$$VG = \frac{b}{\sin\Delta} \text{ and } GH = \frac{a}{\tan\Delta}$$

and since

$$VH = VG - GH = x$$

Similarly

$$\left.\begin{aligned} x &= \frac{b}{\sin\Delta} - \frac{a}{\tan\Delta} \\ y &= \frac{b}{\tan\Delta} - \frac{a}{\sin\Delta} \end{aligned}\right\} \qquad (62)$$

When the new tangents are outside of the given curve, the offsets $a$ and $b$ are considered positive; if either new tangent were inside of the given curve its offset would be considered negative. In solving eqs. (62) if $x$ and $y$ are found to be positive they are to be laid off *forwards* from $q$ and $p$, as in Fig. 25; if either is found to be negative it is to be laid off in the opposite direction.

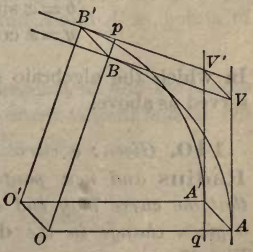

FIG. 26.

*Example.*—A certain curve has a central angle of $50° = \Delta$, and it is proposed to move the first tangent *in* 20 feet and the second tangent *out* 12 feet. Required, the distances on the tangents from the old tangent points to the new. Fig. 26.

Here $a = -20$ and $b = +12$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $+b$ | 12 | | 1.079181 | $-a$ | 20 | | 1.301030 |
| $\Delta$ | 50° | log sin | 9.884254 | $\Delta$ | 50° | log tan | 0.076186 |
| | 15.665 | | 1.194927 | $-$ | 16.782 | | 1.224844 |

$$\therefore \quad x = 15.665 - (-16.782) = +32.450$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $+b$ | 12 | | 1.079181 | $-a$ | 20 | | 1.301030 |
| $\Delta$ | 50° | log tan | 0.076186 | $\Delta$ | 50° | log sin | 9.884254 |
| | 10.069 | | 1.002995 | $-$ | 26.108 | | 1.416776 |

$$\therefore \quad y = 10.069 - (-26.108) = +36.177$$

For $+a$ and $-b$ $\begin{cases} x = -32.450 \\ y = -36.177 \end{cases}$

For $+a$ and $+b$ $\begin{cases} x = -\ \ 1.120 \\ y = -15.939 \end{cases}$

For $-a$ and $-b$ $\begin{cases} x = +\ \ 1.120 \\ y = +15.939 \end{cases}$

If we have $a$ and $x$ given to find $b$ and $y$: Solving eqs. (62) for $b$ and $y$ we obtain

$$\left.\begin{aligned} b &= x \sin \Delta + a \cos \Delta \\ y &= x \cos \Delta - a \sin \Delta \end{aligned}\right\} \qquad (63)$$

In which the algebraic signs of the quantities must be observed as above.

**140.** *Given: a curve joining two tangents, to find a new* **Radius** *and new position of the* **Point of curve,** *such that the curve may end at the same point as before, but with a given change in the* **direction** *of the forward tangent.* Fig. 27.

Let $AB$ be the given curve, $AV$, $VB$ the given tangents, $V'B$ the new tangent, and $VBV'$ the given change in direction. Let $\Delta' = \Delta + VBV'$.

In the diagram draw $BG$ perpendicular to $AV$ produced; then

$$BG = R \text{ vers } \Delta$$
$$= R' \text{ vers } \Delta'$$

Hence

$$R' = R \frac{\text{vers } \Delta}{\text{vers } \Delta'} \qquad (64)$$

and

$$AA' = AG - A'G = R \sin \Delta - R' \sin \Delta' \qquad (65)$$

In the figure the change in direction of tangent makes $\Delta'$ greater than $\Delta$; therefore $V'$ falls beyond $V$, and $A'$ beyond

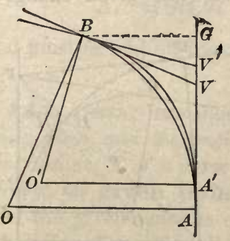


FIG. 27.

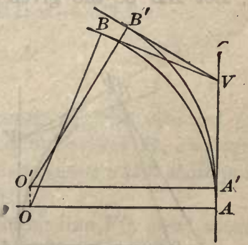


FIG. 28.

$A$; but if the change made $\Delta'$ less than $\Delta$, then $V'$ and $A'$ would fall behind $V$ and $A$ respectively, and $R'$ would be greater than $R$.

The same formulæ apply to the converse problem in which $B$ is taken as the point of curve, and $A$ and $A'$ as points of tangent.

**141.** *Given a curve joining two tangents, to find the change in the* **Point of curve** *when the forward tangent takes a new* **direction** *from the* **vertex V.** Fig. 28.

By eq. (21)

$$VA = R \tan \tfrac{1}{2}\Delta, \quad VA' = R \tan \tfrac{1}{2}\Delta'$$

$$\therefore \qquad AA' = R\,(\tan \tfrac{1}{2}\Delta - \tan \tfrac{1}{2}\Delta') \qquad (66)$$

**142.** *Given: a curve joining two tangents, to find the new*

**radius, R′,** *when the forward tangent takes a new* **direction** *from the* **vertex, V.** Fig. 29.

By eqs. (21) (25)

$$VA = R \tan \tfrac{1}{2}\Delta, \quad R' = VA \cot \tfrac{1}{2}\Delta'$$

$$\therefore \qquad R' = R \tan \tfrac{1}{2}\Delta \cot \tfrac{1}{2}\Delta' \qquad (67)$$

**143.** *Given: a curve joining two tangents, and a given change in the* **direction** *of the forward tangent from the vertex, to find the* **radius** *and* **point of curve** *of a curve that shall pass at the* **same distance, VH,** *from the vertex.* Fig. 30.

Let $AB$ be the given curve, $BVB'$ the given change in

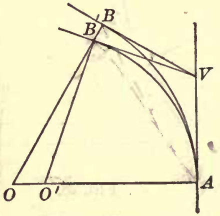


FIG. 29.

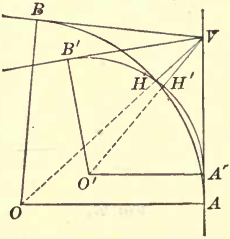


FIG. 30.

direction of tangent, and $VH' = VH$. Let $\Delta' = \Delta + BVB'$, then eq. (24)

$$VH = R \text{ ex sec } \tfrac{1}{2}\Delta = VH' = R' \text{ ex sec } \tfrac{1}{2}\Delta'$$

$$\therefore \qquad R' = R \frac{\text{exsec } \frac{1}{2}\Delta}{\text{exsec } \frac{1}{2}\Delta'} \qquad (68)$$

By eq. (28)

$$VA = VH \cot \tfrac{1}{2}\Delta, \quad VA' = VH' \cot \tfrac{1}{2}\Delta'$$

$$\therefore \qquad AA' = VH (\cot \tfrac{1}{2}\Delta - \cot \tfrac{1}{2}\Delta') \qquad (69)$$

But in case $\Delta' = \Delta - BVB'$, $AA'$ becomes negative and must be laid off backward from $A$.

*Example.*—Given a 2° curve, $\Delta = 80°$ and $BVB' = -10°$ $\therefore\ \Delta' = 70°$

| | | | |
|---|---|---|---|
| $R$ | | | log 3.457114 |
| $\frac{1}{2}\Delta$ | 40° | | log exsec 9.484879 |
| $VH$ | 874.97 | | 2.941993 |
| $\frac{1}{2}\Delta'$ | 35° | | log exsec 9.343949 |
| $R'$ | 1° 27′ nearly | | 3.598044 |
| $\frac{1}{4}\Delta$ | 20° | cot 2.74748 | |
| $\frac{1}{4}\Delta'$ | 17° 30′ | cot 3.17159 | |
| | | − 0.42411 | |

$$\therefore \quad AA' = 874.97 \times (-.42411) = -371.08$$

and must be laid off backward from $A$.

**144.** *Given: two indefinite tangents, a point situated between them, and the angle* $\Delta$, *to find the radius* **R,** *and tangent distance* **T** *of a curve joining the tangents which shall pass through the* **given point.** Fig. 31.

If the given point is on the bisecting line $VO$, as $H$, measure $VH = E$, and find $R$ and $T$ as in §§ 97, 98.

When the given point, as $P$ is not on the bisecting line $VO$; if a line $GK$ is passed through $P$ perpendicular to $VO$, it will be parallel to any long chord, as $AB$, and the angle $VGK = \frac{1}{2}\Delta$. The curve passing through $P$ will intersect $GK$ in some other point $P'$; the line $GK$ is bisected by the line $VO$ at $I$, and $PI = P'I$.

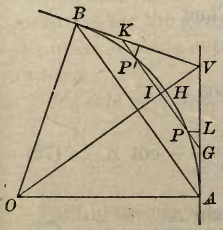

FIG. 31.

If the given point $P$ is located by a perpendicular offset from the tangent, as $PL$; in the triangle $PLG$, $LG = PL \cot \frac{1}{2}\Delta$. Lay off $LG$, and at $G$ deflect $VGK = \frac{1}{2}\Delta$, and measure $GP$ and $PK$. Since by Geom. (Tab. I. 24) $\overline{GA}^2 = GP' \times GP$, and $GP' = PK$;

$$\therefore \quad GA = \sqrt{GP \times PK} \qquad (70)$$

Lay off $GA$; and $A$ is the Point of curve, $AV = T$, and $R = AV \cot \frac{1}{2}\Delta$.

If the given point were located by an offset from $BV$, find $B$ first, and make $VA = BV$.

If the given point $P$ is located by a perpendicular offset $IP$ from the bisecting line $VO$; produce $IP$ to intersect the tangent at $G$ and measure $PG$. Since $P'G = GP + 2PI$

$$\therefore \qquad GA = \sqrt{GP(GP + 2PI)} \qquad (71)$$

whence we have the point of curve $A$, as before.

**145.** *Given: a curve, AP, and the* **radial offset PP'** *to find a curve which shall pass through the* **point P',** *starting from the same point of curve* **A.** Fig. 32.

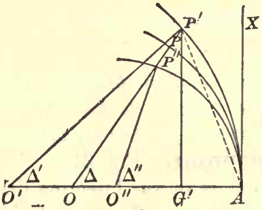


FIG. 32.

Let $b = PP'$, and in the diagram draw $P'G'$ parallel to the common tangent $AX$, and join $AP'$. Then

$$P'G' = (R \pm b) \sin \Delta$$
$$G'A = R - (R \pm b) \cos \Delta$$

$$\therefore \qquad \tan \tfrac{1}{2}\Delta' = \frac{G'A}{P'G'} = \frac{R}{(R \pm b) \sin \Delta} - \cot \Delta \qquad (72)$$

$$R' = \frac{P'G'}{\sin \Delta'} = \frac{(R \pm b) \sin \Delta}{\sin \Delta'} \qquad (73)$$

When the offset is *outward* use $R + b$, when it is *inward* use $R - b$.

*Example.*—Given: a 3° curve of 16 stations and a radial offset of 205 feet inward from the *P.T.* to find the radius of the curve passing through the extremity of the offset.

Here $\Delta = 3° \times 16 = 48°$; and $b = 205$.

| | | | |
|---|---|---|---|
| $R$ 3° = | 1910.08 | | |
| $R - b$ | 1705.08 | log | 3.231745 |
| $\Delta$ 48° | | log sin | 9.871073 |
| $P'G'$ | | | 3.102818 |
| $R$ 3° | | log | 3.281051 |
| | 1.50742 | | 0.178233 |
| $\Delta$ 48° cot | .90040 | | |
| $\frac{1}{2}\Delta'$ tan | .60702 = 31° 15½′ | | |
| | 2 | | |
| $\Delta'$ | 62° 31′ | log sin | 9.947995 |
| $P'G'$ | | log | 3.102818 |
| $R'$ (about 4° 01′). *Ans.* | | | 3.154823 |

If the same offset were made *outside* of the curve we should find $R'$ log 3.438350, or about a 2° 05′ curve.

This solution is inconveniently long for ordinary field practice. When the offset is small compared with the length of curve, we may use the following

**Approximate Rule:** Divide twice the offset $b$ by the length of curve, look for the quotient in the table of nat. sines, and take out the corresponding angle, which multiply by 100, and divide by the length of curve. The *quotient* is the *correction* for the given degree of curve; to be *subtracted* when the offset is made *outward*, and *added* when the offset is made *inward*.

This rule is expressed by the formula

$$D' = D \mp \frac{100}{L} \sin^{-1} \frac{2b}{L} \tag{74}$$

Taking the same example, we have

$$\frac{2b}{L} = \sin 14° \; 51'$$

$$\text{and correction} = 14° \; 51' \times \frac{100}{1600} = \mp 0° \; 56'$$

Hence $D' = 3° \; 56'$ or $D' = 2° \; 04'$

### THE VALVOID.

**146.** *Given: any number of circular curves of equal length L, all starting from a common point of curve A, in a common tangent AX, to find the* **equation of the curve** *joining their extremities.* Fig. 33.

Let $AP$ be any one of the given curves,
" $R =$ its radius $AO$,
" $D =$ its degree of curve,
" $\Delta =$ its central angle $AOP$,
" $C =$ its long chord $AP$.

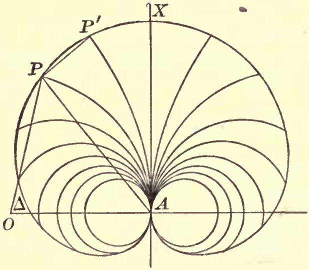


FIG. 33.

By substituting the value of $R$ from eq. (16) in eq. (22) we have

$$C = 100 \frac{\sin \frac{1}{2}\Delta}{\sin \frac{1}{2}D} \qquad (75)$$

Substituting in this the value of $D$ from eq. (20) and letting (theta) $\theta = \frac{1}{2}\Delta$, (rho) $\rho = \frac{C}{100}$ and $N = \frac{L}{100}$, we have for the polar equation of the required curve

$$\rho = \frac{\sin \theta}{\sin \frac{\theta}{N}} \qquad (76)$$

in which $\rho$ is the radius-vector $AP$, $\theta$ the variable angle $XAP$, the unit of measure is one side of the inscribed polygon by which the circular curve $AP$ is measured, and $N$ the number of these sides in the length of the curve $AP$. By the conditions of the problem $N$ is constant, but $\theta$ may have any value whatever. If we let $\theta$ vary from $0^\circ$ to $+180^\circ$ and from $0^\circ$ to $-180^\circ$ the point $X$ will describe the curve $XP'PA$ shown in the figure, which is called the *Valvoid* from its resemblance to the shell of a bivalve. All circular curves tangent to $AX$ at $A$ and having a length $L = AX$ will terminate in the valvoid, and the line $PP'$ joining the extremities of any two of them is a chord of the valvoid.

**147.** *To find a* **tangent to the valvoid** *at any point* **P.** Fig. 34. See Appendix.

Differentiating eq. (76)

$$\frac{d\rho}{d\theta} = \rho\left(\cot\theta - \frac{1}{N}\cot\frac{\theta}{N}\right) \tag{77}$$

which is essentially negative, since $\rho$ is a decreasing function of $\theta$.

Let (phi) $\varphi = APG$, the angle between the radius vector and the normal $PG$.

$$\therefore \qquad \tan\varphi = \frac{1}{N}\cot\frac{\theta}{N} - \cot\theta \tag{78}$$

The line $PK$ perpendicular to $PG$ is tangent to the valvoid at $P$, and $PV$ perpendicular to $PO$ is tangent to the curve $AP$.

Then $APV = \theta$ and $VPG = \theta - \varphi$, and letting $i = OPK = VPG$.

$$\therefore \qquad i = \theta - \varphi = \tfrac{1}{2}\Delta - \varphi \tag{79}$$

Therefore, to obtain the direction of a tangent to the valvoid at any point $P$, deflect from the radius $PO$ an angle equal to $i = (\frac{1}{2}\Delta - \varphi)$, on the side of $PO$ farthest from the point of curve $A$.

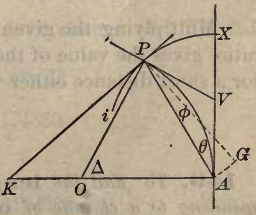

FIG. 34.

The value of $i$ may be found by eqs. (78) (79), but we are saved this somewhat tedious calculation by the use of Table X. 1, which contains values of the ratio $\frac{i}{\Delta} = u$ for various values of $\Delta$, and length of curve $L$. Multiplying $\Delta$ by the proper tabulated number gives the value of $i = OPK$ at once; or

$$i = (\tfrac{1}{2}\Delta - \varphi) = u\Delta \tag{80}$$

**148.** *To find the* **radius of curvature** *of the valvoid at any point* **P.** See Appendix.

Differentiating eq. (77) we have

$$\frac{d^2\rho}{d\theta^2} = \rho\left[-1 - \frac{2}{N}\cot\theta\cot\frac{\theta}{N} + \frac{1}{N^2}\left(2\cot^2\frac{\theta}{N} + 1\right)\right]$$

The general formula for the radius of curvature of polar curves is

$$r = \frac{\left(\rho^2 + \frac{d\rho^2}{d\theta^2}\right)^{\frac{3}{2}}}{\rho^2 + 2\frac{d\rho^2}{d\theta^2} - \rho\frac{d^2\rho}{d\theta^2}}$$

Substituting in this the values of $\rho$, $\frac{d\rho}{d\theta}$, and $\frac{d^2\rho}{d\theta^2}$, and putting

$\left(\frac{1}{N}\cot\frac{\theta}{N} - \cot\theta\right) = a$ we have after reduction,

$$r = \frac{\rho}{2} \cdot \frac{(1 + a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} - a\cot\theta} \qquad (81)$$

This formula being too complicated for convenient use in the field, its use is avoided by referring to Table X. 2, which contains values of the ratio $\frac{r}{L} = v$ for various values of $\triangle$ and $L$. Multiplying the given value of $L$ by the proper tabular ratio, gives the value of the radius of curvature of the valvoid for a short distance either way from the given point $P$; or,

$$r = vL \qquad (82)$$

**149.** *To find the* **length of arc** *of the valvoid corresponding to a change of* **one degree** *in the value of the angle* $\triangle$. Fig. 35.

From any chord $AP$ suppose a deflection of $\frac{1}{4}$ degree to be made each way to $Ap'$ and $Ap''$; then the angle $p'Ap'' = \frac{1}{2}° =$ the change in $\theta$, and since $\triangle = 2\theta$, this makes a change of 1° in the value of $\triangle$. We then require to know the length of the arc $p'p''$, and we may, without sensible error, consider it to be described by the radius of curvature $r = Pv$ for the point $P$, through an angle $p'op''$. Now

$$p'op'' = Xop' - Xop'' = \left(\frac{\Delta'}{2} + \varphi'\right) - \left(\frac{\Delta''}{2} - \varphi''\right) =$$
$$\frac{\Delta'}{2} - \frac{\Delta''}{2} + \varphi' - \varphi''$$

By eq. (80)

$$\varphi' = \frac{\Delta'}{2}(1 - 2u') \quad \text{and} \quad \varphi'' = \frac{\Delta''}{2}(1 - 2u'')$$

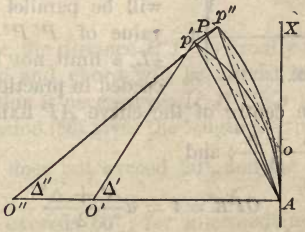

FIG. 35.

and since $\varphi'$ is so nearly equal to $\varphi''$ we may assume $u' = u'' = u$; hence $\varphi' - \varphi'' = \dfrac{\Delta' - \Delta''}{2}(1 - 2u)$ and $p'op'' = (\Delta' - \Delta'')(1 - u)$.

But the condition of the problem requires $\Delta' - \Delta'' = 1°$, hence $p'op'' = (1 - u)°$.

Therefore the length of arc $p'p''$ for a change of 1° in the value of $\Delta$ is

$$l_{,} = r(1 - u) \times \text{arc } 1°$$

or (Tab. XVII.) $\quad l_{,} = r(1 - u)\ .0174533$

and since $r = vL$ (Tab. X. 2),

$$l_{,} = v(1 - u)\ L\ .0174533 \qquad (83)$$

By this formula Table X. 3 has been prepared, for various values of $\Delta$ and $L$.

**150.** *Given:* **two curves** *of the same length $L$ but of different radii, starting from the same point of curve in a* *common tangent, to determine the* **direction** *and* **length** *of a line* **joining their extremities.** Fig. 36.

Let $AX$ be the common tangent, and $AP'$, $AP''$ the two curves, to determine the direction and length of $P'P''$.

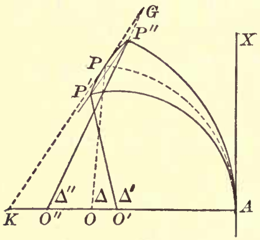


FIG. 36.

If we take the point $P$ on the arc $P'P''$ determined by the angle $\Delta = \frac{\Delta' + \Delta}{2}$ and draw a tangent $PK$ to the valvoid at $P$, we may assume without material error that the chord $P'P''$ will be parallel to $PK$ for any value of $P'P''$ not exceeding $\frac{1}{4}L$, a limit not likely to be exceeded in practice.

Let $O$ be the centre of the curve $AP$ fixing the point $P$; then $AOP = \frac{\Delta' + \Delta''}{2}$, and

$$OPK = i = u\frac{\Delta' + \Delta''}{2}$$

$$PKO = K = \frac{\Delta' + \Delta''}{2} - i = \frac{\Delta' + \Delta''}{2}(1 - u)$$

Since $P'P''$ is assumed parallel to $PK$,

$$P'P''O'' = KGO'' = \Delta'' - K = \Delta'' - \frac{\Delta' + \Delta''}{2}(1 - u)$$

$$\therefore \quad P'P''O'' = i'' = \frac{\Delta''(1 + u'') - \Delta'(1 - u'')}{2} \qquad (84)$$

Similarly producing $P''P'$ to any point $H$,

$$HP'O' = i' = \frac{\Delta'(1 + u'') - \Delta''(1 - u'')}{2} \qquad (85)$$

whence also

$$i' = i'' + \Delta' - \Delta'' \qquad (85)'$$

The slight error involved in the above assumption is corrected by taking out the value of $u$ (Table X. 1) corresponding to $\Delta''$, the *less* of the two given central angles; we have therefore written $u$ with the double accent in equations (84) and (85).

When $i'$ and $i''$ are positive, they will be deflected as in Fig. 36, on the side of the radius *farthest from A*; should $i''$ be negative it will of course be deflected from $P''O''$ *toward A*.

The arc $P'P''$ corresponds to a change of the central angle from $\Delta'$ to $\Delta''$; hence

$$1^\circ : \Delta' - \Delta'' :: l_{,} : P'P''$$

or

$$P'P'' = (\Delta' - \Delta'')\, l_{,} \qquad (86)$$

in which $l_{,}$ is taken from Table X. 3 for $L = AP$, and $\Delta = \dfrac{\Delta' + \Delta''}{2}$.

As in practice, the distance $P'P''$ is usually small compared with $L$, the arc and chord will be almost identical and no further calculation is necessary. If $P'P''$ is large, it will be found that equation (86) gives the length of *arc* very correctly when $\dfrac{\Delta' - \Delta''}{2}$ does not exceed 20°, and the length of *chord* when $\dfrac{\Delta' + \Delta''}{2}$ exceeds 60°; for intermediate mean angles it gives a value to $P'P''$ between that of the arc and chord. The arc $P'P''$ may be considered to be described by the radius $r = vL$, $v$ being taken for $\dfrac{\Delta' + \Delta''}{2}$ (Table X. 2), and its total curvature is found by multiplying its length by the degree of curve corresponding to $r$ (Table IV).

*Example.* Given, a 2° 30′ curve, and a 1° curve of 12 stations each from the same $PC$, to determine the distance between their extremities.

$$\Delta' = 2\tfrac{1}{2}^\circ \times 12 = 30^\circ, \qquad \Delta'' = 12^\circ, \qquad \frac{\Delta' + \Delta''}{2} = 21^\circ,$$

$$\Delta' - \Delta'' = 18^\circ, \qquad u'' = .33446$$

Eq. (84). $i'' = 2^\circ.9737 \qquad = 2^\circ 58' 25''$

Eq. (85)′. $i' = i'' + \Delta' - \Delta'' = 20^\circ.9737 = 20^\circ 58' 25''$

Eq. (86). Arc $P'P'' = 18^\circ \times 10.425 \qquad = 187.65$ ft. *Ans.*

Eq. (82). $r = 1200 \times .7479 = 897.48$ ft. = (say) a 6°23′ curve.

Total curvature, $P'P'' = 6^\circ.383 \times 1.8765 = 11^\circ.9777$.

(The distance $P'P''$ may be found by solving the triangle formed by itself and the long chords of the curves $AP'$, $AP''$.)

**151.** *Given: a curve* **AP**, *to find a curve starting from the same point* **A**, *that shall shift the station* **P** *any desired distance* **PP′** *to the right or left.* Fig. 36.

Before we can determine what distance $PP'$ is desired, we must know (approximately) its direction. We have given, therefore, $D$, $L$, and $\Delta$ to find the angle $OPP'$, and (after measuring $PP'$) to find $\Delta'$ and $D'$.

The solution is necessarily somewhat approximate, yet close enough for all practical purposes. For if the required value of $D'$ were obtained *precisely*, it would probably involve some seconds, and would therefore be discarded in favor of some value in even minutes.

**When P′ is inside** the given curve :

Eq. (80). $i = OPK = u\Delta$. Table X. 1.

Eq. (82). $r = Po = vL$. Table X. 2.

Let $\delta$ (delta) = degree of curve corresponding to $r$, by Table IV.

$$\therefore \qquad OPP' = i - \frac{PP'}{100} \cdot \tfrac{1}{2}\delta \text{ nearly.}$$

Eq. (86). $\Delta' = \Delta + \dfrac{PP'}{l_{,}}$. Table X. 3.

Instead of taking $l_{,}$ from Table X. 3 for the exact value of $\Delta$ it is well to take it for the *estimated* value of $\dfrac{\Delta' + \Delta}{2}$.

Eq. (20). $D' = \dfrac{100}{L}\Delta'$

**When P′ is outside** of the given curve :

$$i = u\Delta, \qquad r = vL,$$

$$180° - OPP' = i + \frac{PP'}{100} \cdot \tfrac{1}{2}\delta \text{ nearly.}$$

$$\Delta' = \Delta - \frac{PP'}{l_{,}}, \qquad D' = \frac{100}{L}\Delta'$$

*Example.* Given, a 4° curve of 800 feet, or $\Delta = 32°$ to find a curve from the same $P.C.$ which shall shift the last station *in*, about 55 feet. (Fig. 36.)

$$i = 32° \times .3355 = 10°.736$$

$$r = 800 \times .7450 = 596, \quad \therefore \ \delta = 9° \ 36' = 9°.6$$

$$OPP' = 10°.736 - \frac{55}{100} \times 4°.8 = 8° \ 06'$$

$$\Delta' = 32° + \frac{55}{6.87} = 40°$$

$$D' = \frac{40°}{8} = 5°. \quad \textit{Ans.}$$

For a 5° curve, the true distance $PP' = 55.53$
" " 4°59' " " " " $PP' = 54.60$

which proves this method practically correct.

**152.** *Given: a tangent and curve, and a* **straight line intersecting** *them, making a given angle with the tangent at a given point, to determine the* **distance on the line** *from the tangent to the curve.* Fig. 37.

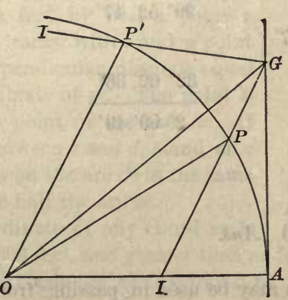


FIG. 37.

We have $OA$, $AG$, and the angle $AGP$ to find $GP$.

$$\tan AGO = \frac{R}{AG} \qquad PGO = AGO - AGP$$

$$\sin OPI = \frac{OG}{R} \sin PGO = \frac{\sin PGO}{\sin AGO}$$

$$PG = R\,\frac{\sin(OPI - PGO)}{\sin PGO}$$

When $AGP = AGO$, eq. (24),

$$GP = R \text{ exsec } (90° - AGO)$$

When $AGP = 90°$, §§ (92), (119),

$$GP = R \text{ vers } POA, \qquad \sin POA = \frac{GA}{R}$$

When $AGP' > AGO$, we have

$$P'GO = AGP' - AGO$$

but the other formulæ remain unchanged.

*Example.*—Let $R = 955.37$, $AG = 350$, $AGP = 40°$

| | | | |
|---|---|---|---|
| $R$ | 955.37 | | log 2.980170 |
| $AG$ | 350. | | log 2.544068 |
| $AGO$ | | 69° 52′ 47″ | log tan 0.436102 |
| $AGP$ | | 40° | |
| $PGO$ | | 29° 52′ 47″ | log sin 9.697387 |
| $AGO$ | 69° 52′ 47″ | | log sin 9.972653 |
| $OPI$ | | 32° 02′ 36″ | log sin 9.724734 |
| $POG$ | | 2° 09′ 49″ | log sin 8.576953 |
| | | | 8.879566 |
| $R$ | | | log 2.980170 |
| $PG$ | 72.40 *Ans.* | | log 1.859736 |

This problem may be used in passing from a tangent to a curve when the tangent point is obstructed. The distance $AP$ on the curve is defined by the angle $AOP$, which is readily found.

If $AGP' > 2AGO$ the line will not cut the curve.

**153.** *Given: a curve and a* **distant point** *to find a* **tangent** *that shall pass* **through the point.** Fig. 38.

We have the curve *adg* and the point $P$ visible, but distance unknown, to find the point of tangent $B$.

Any chord, as *bf*, parallel to the required tangent, if produced will pass the point *P* at a perpendicular distance equal to the middle ordinate of that chord. Ranging across every two consecutive stakes on the curve we at first find the range falling outside of the required tangent, as *bcG*, *cdH*, etc.; but finally the range falls inside, as *deK*. We then know that the required point is between *c* and *e*. If the range *ce* falls inside the point *P*, a perpendicular distance equal to the middle ordinate of *ce*, the tangent point is at *d*. If the perpendicular distance is greater than this, the point *B* is between *c* and *d*. If less, or if the range *ce* falls outside of *P*, the point *B* is between *d* and *e*. The middle ordinate for *ce* (200 feet) equals the tangent offset for 100 feet, given in Tab. IV., and it is generally so small that it can be estimated at *P* without going to lay it off.

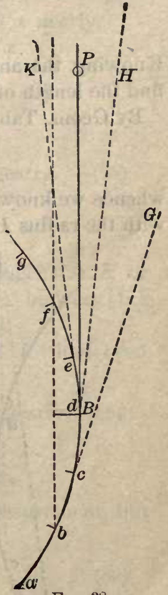

Fig. 38.

To find the exact point *B*, when it falls between *d* and *e*, find by trial a point *x* on the arc *cd* in range with *e* and a point inside of *P* a perpendicular distance equal to the middle ordinate of *ex*. The point *B* is at the middle point of the arc *ex*. If the point *B* is between *c* and *d*, stand at *c* and find a point *x* on the arc *de* in the same way. *B* is at one half the arc *cx*.

The middle ordinate of any chord *ex* is less than *M* for 200 feet, and greater than *m* for 100 feet. If necessary, its exact value *m'* can be found by

$$m' = \frac{m \times \overline{ex}^2}{10000} \qquad (87)$$

and this equation is nearly true when *ex* is as great at 300 or 400 feet. That is, middle ordinates on the same curve are to each other as the squares of their chords *very nearly*.

By this method the point *B* is found without the use of the transit, so that the plug can be driven at *B* before the transit is brought up from the rear. It is therefore preferable to the following solution. Fig. 39.

From any two points *a* and *c* of the curve measure the angles to the point *P*, so that with the chord *ac* as a base, and the measured angles, we may find *cP* by the formula

$$cP = ac \frac{\sin caP}{\sin cPa}$$

Knowing the angle *c* that *cP* makes with a tangent at *c*, we find the length of the chord *cd* by $cd = 2R \sin c$.

By Geom. Tab. I. 24,

$$PB = Pe = \sqrt{cP \times dP}$$

whence we know *ce*. Opposite *e*, or on the arc *eB* described with the radius *Pe*, we find *B*.

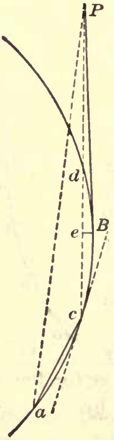


FIG. 39.

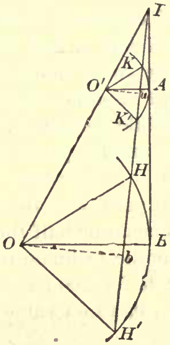


FIG. 40.

**154.** *Given:* **two curves exterior** *to each other. to find the tangent points of a line* **tangent to both** *and its* **length** *between tangent points.* Fig. 40.

Let *B* and *A* be the required tangent points. Let $OB = R$, and $O'A = R'$.

On the curve of greater radius *R* select a point *H* supposed to be near the unknown tangent point *B*, and knowing the direction of the radius $OH$, find on the other curve a point $K$ having a radius $O'K$ parallel to $OH$, and measure $HK$. In the diagram draw $Ob$ and $O'a$ perpendicular to $HK$. Then the angle $KO'a = 90° - HKO' = KO'A$ nearly, which is the angle required. We have therefore to find the correction $aO'A = x$, and apply it to $KO'a$.

$$Aa = R' \text{ vers } KO'a; \qquad Bb = R \text{ vers } KO'a \text{ nearly.}$$
$$Ka = R' \sin KO'a; \qquad Hb = R \sin KO'a$$

$$\therefore \quad Bb - Aa = (R-R') \text{ vers } KO'a$$
$$ab = HK + (R-R') \sin KO'a$$

$$\sin x = \frac{(R-R') \text{ vers } KO'a}{HK + (R-R') \sin KO'a} \text{ nearly.} \qquad (88)$$

$$KO'A = (KO'a - x) = HOB$$

Observe that $KO'a$ = the angle between the tangent at $K$ or $H$ and the line $HK$; and $KO'A$ = the angle between the tangent at $K$ or $H$ and the required tangent $BA$.

If, instead of $H$ and $K$, the points $H'$ and $K'$ had been selected, then

$$\sin x = \frac{(R-R') \text{ vers } H'Ob}{H'K' - (R-R') \sin H'Ob} \text{ nearly,} \qquad (88)'$$

and

$$H'OB = K'O'A = H'Ob + x.$$

The length of $BA$ should be obtained by measurement, but it may be calculated by

$$AB = ab - (R-R') \sin x \qquad (89)$$

When $R = R'$, $x = 0$, and $HK$ is parallel to $BA$.

*In case the* **curves** *are* **reverse** *to each other, as in Fig.* 41,

$$\sin x = \frac{(R+R') \text{ vers } KO'a}{HK + (R+R') \sin KO'a} \text{ nearly.} \qquad (90)$$

$$KO'A = HOB = KO'a - x$$

If the points $H'$ and $K'$ are selected, Fig. 41,

$$\sin x = \frac{(R+R') \text{ vers } H'Ob}{H'K' - (R+R') \sin H'Ob} \text{ nearly.} \qquad (91)$$

$$H'OB = K'O'A = H'Ob + x.$$

The lines $HK$, $AB$, and $OO'$ all intersect in a common point $I$, Fig. 41.

$$HI = \frac{HK \times R}{R + R'} \tag{92}$$

$$IB = \sqrt{HI(HI + 2R \sin HOb)} \tag{93}$$

$$AB = IB \frac{R + R'}{R} \tag{94}$$

These last three equations furnish **another method** of solving the same problem. They may be applied to Fig. 40 by changing the sign of $R'$.

In Fig. 41, if $R = R'$, then $HI = \frac{1}{2}HK$ and $AB = 2IB$.

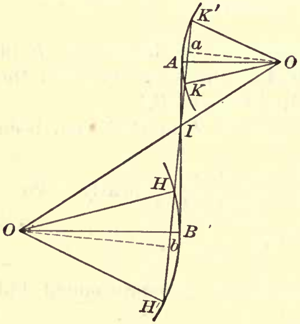


FIG. 41.

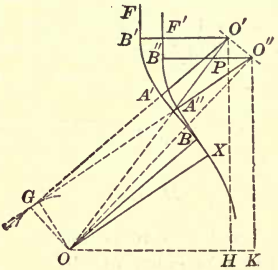


FIG. 42.

**155.** *Given:* **two curves, O and O′, reverse** *to each other, joined by a tangent* **BA′**, *and terminating in another tangent,* **B′F ; to change** the position of the **Point of Tangent B** *of the first curve, so that the second curve may terminate in a given* **parallel tangent, B″F′.** Fig. 42.

Let $X$ be the required new position of $B$.

" $O''$ be the corresponding position of $O'$.

" $\triangle' = A'O'B'$ and $\triangle'' = A''O''B''$.

Since the radii and the connecting tangent are unchanged in length, and all rotate together about $O$ as a centre, $O''$ will be on a circle passing through $O'$, described with a radius $OO'$, and the required angle $BOX = O'OO''$.

In the diagram, produce $O'A'$ and draw the perpendicular $OG$, and let $\alpha =$ the angle $OO'G$. Also, draw $OK$ parallel and $O''K$ and $O'H$ perpendicular to $B'O'$. In the triangle $OO'G$ we have

$$\cot OO'G = \frac{GO'}{GO}, \quad \text{or} \quad \cot \alpha = \frac{R + R'}{BA'} \tag{95}$$

and

$$OO' = \frac{R + R'}{\cos \alpha} \tag{96}$$

The angle $KOO' = OO'B' = \alpha + \Delta'$.
The angle $KOO'' = OO''B'' = \alpha + \Delta''$.

$$KO = OO''. \cos(\alpha + \Delta''), \quad HO = OO'. \cos(\alpha + \Delta').$$

$$\therefore \quad HK = OO' [\cos(\alpha + \Delta'') - \cos(\alpha + \Delta')] = B'F'$$

$$\therefore \quad \cos(\alpha + \Delta'') = \cos(\alpha + \Delta') + \frac{B'F'}{OO'} \tag{97}$$

$$BOX = O'OO'' = (\alpha + \Delta') - (\alpha + \Delta'') \tag{98}$$

If we conceive a line to be drawn through $O$ bisecting the arc $O'O''$, the angle it makes with $B''O''$ is a mean between $B'O'O$ and $B''O''O$; hence the chord $O'O''$, perpendicular to this line, makes an angle with $O'P$ perpendicular to $B'O'$ of

$$PO'O'' = \tfrac{1}{2} [(\alpha + \Delta') + (\alpha + \Delta'')]$$

and since

$$O'P = PO'' \cot PO'O''$$

$$F'B'' = B'F' \cot \tfrac{1}{2} [(\alpha + \Delta') + (\alpha + \Delta'')] \tag{99}$$

which gives the distance, measured on the parallel tangent, between the old tangent point and the new.

This problem occurs in practice when both the connecting tangent and the radius of the last curve are at their *minimum limit*, and the parallel tangent is *inside* of the old one, as in the figure. Should the new tangent be *outside*, the same formulæ apply, only changing the sign of $B'F'$ in eq. (97). But in this last case it is usually preferable to employ problem § 136 or § 137.

*Example.*—A 1° 40′ curve is followed by a tangent of 200 ft., and that by a 4° curve of 10 stations ending in a tangent;

and the offset to the given parallel tangent is 80 ft. on the inside. Required, the position of the new tangent points $X$ and $B''$.

Here $R = 3437.87$, $R' = 1432.69$, $BA' = 200$, $B'F' = 80$.

| | | | |
|---|---|---|---|
| Eq. (95) | $R + R'$ | 4870.56 | log 3.687579 |
| | $BA'$ | 200. | log 2.301030 |
| $\therefore$ | $\alpha$ | 2° 21′ | log cot 1.386549 |
| Eq. (96) | $\alpha$ | 2° 21′ | log cos 9.999635 |
| $\therefore$ | $OO'$ | | 3.687944 |
| Eq. (97) | $B'F'$ | 80 | 1.903090 |
| | | .01641 | 8.215146 |
| | $\alpha + \Delta'$ | 42° 21′ cos .73904 | |
| | $\alpha + \Delta''$ | 40° 56′ cos .75545 | |

Eq. (98) $BOX$ 1° 25′ $\therefore$ $BX = 85$ ft. *Ans.*
Eq. (99) $PO'O''$ 41° 38′ 30″ cot $1.12468 \times 80 = 89.97 = F'B''$

**156.** When the tangents of a proposed road are to be in general much longer than the curves, it is desirable to establish the tangents first in making the location, and afterwards determine suitable curves. On the other hand, if the curves necessarily predominate, they should be first selected and adjusted to the ground with reference to grade and easy alignment, and afterwards joined by tangents. In the latter case the field work cannot be successfully accomplished unless the location has been previously worked out upon a correct map constructed from the preliminary surveys. The map should show contours of the surface, and also the grade contour, or intersection of the surface and plane of the grade. In side-hill work the grade contour indicates approximately the degree and position of the necessary curves. In the work of selecting proper curves upon the map, **templets** or pattern curves are almost indispensable. The templets are cut to form a series of curves, the radii being taken from Table IV. to a scale corresponding to the scale of the map, which ranges from 400 to 100 feet per inch, according to the difficulty of the location. The templets should represent *convenient* curves, or those in which the number of minutes per station bear a simple ratio to 100. Curves of 50′ and multiples of 50′ are most convenient; 40′ curves and multiples standing next in order, and 30′ curves and multiples next.

TABLE OF CONVENIENT CURVES.

| D. | Ratio of Min. to Feet. | D. | Ratio of Min. to Feet. | D. | Ratio of Min. to Feet. |
|---|---|---|---|---|---|
| 50′ | 1 : 2 | 40′ | 2 : 5 | 30′ | 3 : 10 |
| 1° 40′ | 1 : 1 | 1° 20′ | 4 : 5 | 1° 00′ | 3 : 5 |
| 2° 30′ | 3 : 2 | 2° 00′ | 6 : 5 | 1° 30′ | 9 : 10 |
| 3° 20′ | 2 : 1 | 2° 40′ | 8 : 5 | 2° 00′ | 6 : 5 |
| 4° 10′ | 5 : 2 | 3° 20′ | 2 : 1 | 2° 30′ | 3 : 2 |
| 5° 00′ | 3 : 1 | 4° 00′ | 12 : 5 | 3° 00′ | 9 : 5 |
| 5° 50′ | 7 : 2 | 4° 40′ | 14 : 5 | 3° 30′ | 21 : 10 |
| 6° 40′ | 4 : 1 | 5° 20′ | 16 : 5 | 4° 00′ | 12 : 5 |
| 7° 30′ | 9 : 2 | 6° 00′ | 18 : 5 | 4° 30′ | 27 : 10 |
| 8° 20′ | 5 : 1 | 6° 40′ | 4 : 1 | 5° 00′ | 3 : 1 |
| 9° 10′ | 11 : 2 | 7° 20′ | 22 : 5 | 5° 30′ | 33 : 10 |
| 10° 00′ | 6 : 1 | 8° 00′ | 24 : 5 | 6° 00′ | 18 : 5 |

After drawing the curves and tangents upon the map, the tangent points and central angles are carefully determined, the latter being compared with the lengths of the curves obtained by a pair of stepping dividers set *precisely* by scale to the length of one station. Field notes are then prepared from the map, and if the work has been well done these notes may be followed in the field with scarcely any alterations.

No ordinary protractor will measure the angles closely enough for this purpose ; it is better to use a radius as large as convenient, of 50 parts. The chord of any arc drawn with this radius equals 100 times the sine of one half the angle subtended.

The importance of having absolutely straight-edged rulers in such work is obvious. In case a very long line is to be projected upon the map, it is well to use a piece of fine sewing silk for the purpose. See §§ 53, 54.

# CHAPTER VI.

## COMPOUND CURVES.

### *A. Theory.*

**157.** A compound curve consists of two or more consecutive circular arcs of different radii, having their centres on the same side of the curve; but any two consecutive arcs must have a common tangent at their meeting point, or their radii at this point must coincide in direction. The meeting point is called the point of compound curve, or *P.C.C.* Compound curves are employed to bring the line of the road upon more favorable ground than could be done by the use of any simple curve.

When a compound curve of two arcs connects two tangent lines, the tangent points are at unequal distances from the intersection or vertex, the shorter distance being on the line which is tangent to the arc of shorter radius.

**158.** Let *VA*, *VB* (Fig. 43) be any two right lines intersecting at *V*, and let $\triangle$ be the deflection angle between them. Let *A* and *B* be the tangent points of a compound curve (*VA* less than *VB*), and let *AP*, *PB* be the two arcs of the curve. The centre $O_1$ of the arc *AP* will be found on *AS*, drawn perpendicular to *VA*; the centre $O_2$ of the arc *PB* will be found on *BS* produced perpendicular to *VB*; and the angle *ASB* will evidently equal $\triangle$. Join *VS*, and on *VS* as a diameter describe a circle; it will pass through the points *A* and *B*, since the angles *VAS*, *VBS* are right angles in a semicircle. Draw the chord *VQ*, bisecting the angle *AVB*, and join *AQ*, *BQ*. Then *AQ*, *BQ* are equal, since they are chords subtending the equal angles *AVQ*, *BVQ*. From *Q* as a centre, and with radius *QA*, describe a circle; it will cut the tangent lines at *A* and *B*, and also at two other points *G* and *Y*, such that $VG = VA$, and $VY = VB$. Hence $BG = AY$, and the parallel chords *AG*, *BY* are perpendicular to *VQ*. Join *AB*; then $AQB = ASB = \triangle$, since both angles are subtended by the same chord *AB*.

In the triangle *VAB*, the sum of the angles at *A* and *B* is equal to the exterior angle $\triangle$ between the tangents; while their difference $(A - B)$ is equal to the angle at the centre *Q* subtended by the chord $BG$, which is the difference of the sides $(VB - VA)$. For the angle $VAB = VAG + GAB$, and the angle $VBA = VBY - ABY$. But $VAG = VBY$ and $GAB = ABY$, and by subtraction $VAB - VBA = 2GAB = GQB$, since $A$ is on the circumference and $Q$ at the centre.

**159.** THEOREM.—*The circle YAGB, whose centre is Q, is the* locus *of the point of compound curve P, whatever be the relative lengths of the arcs AP, PB composing the curve.*

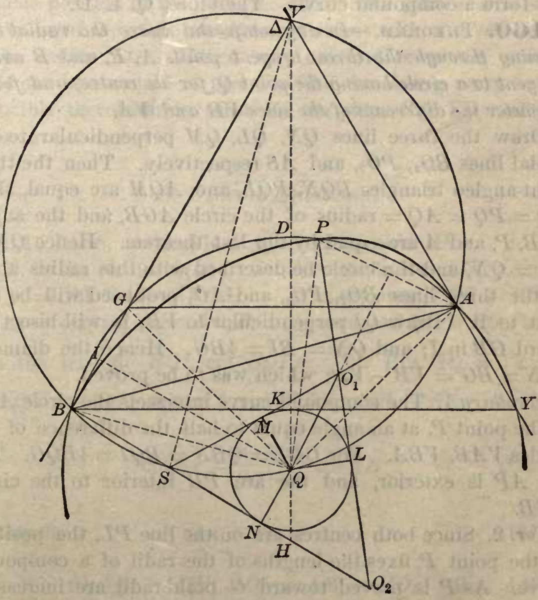


FIG. 43.

On the circle $YAGB$, and between $A$ and $G$, take any point $P$, and on $AS$ find a centre $O_1$, from which a circular arc may be drawn cutting the circle at $A$ and $P$; also on $BS$ produced find a centre $O_2$, from which a circular arc may be drawn cutting the circle at $B$ and $P$. Join $PQ$, $PO_1$ and $PO_2$. Since when two circles intersect, the angles are equal between radii drawn to the points of intersection, $QPO_1 = QAO_1$

and $QPO_2 = QBO_2$. Draw the chord $QS$ and it subtends the equal angles $QAO_1 = QBO_2$. Hence $QPO_1 = QPO_2$ and the radius $PO_1$ coincides in direction with the radius $PO_2$, which is the condition essential to a compound curve.

Now, if we imagine another point $P'$ to be taken on $QP$ or on $QP$ produced, and the arcs $AP'$ $BP'$, drawn from centres found on $AS$ and $BS$, it is evident that the equality of angles found in respect to $P$ could not exist in respect to $P'$. Hence the arcs would intersect in $P'$ at some angle $O_1PO_2$ and would not form a compound curve. Therefore, Q. E. D.

**160.** THEOREM.—*In any compound curve the radial lines passing through the three tangent points A, P, and B are all tangent to a circle having the point Q for its centre, and for its diameter the difference of the sides VB and VA.*

Draw the three lines $QN$, $QL$, $QM$ perpendicular to the radial lines $BO_2$, $PO_2$, and $AS$ respectively. Then the three right-angled triangles $BQN$, $PQL$, and $AQM$ are equal, since $BQ = PQ = AQ =$ radius of the circle $AGB$, and the angles at $B$, $P$, and $A$ are equal by the last theorem. Hence $QM = QL = QN$, and if a circle be described with this radius about $Q$, the three lines $BO_2$, $PO_2$, and $AO_1$ produced will be tangent to it. Draw $QI$ perpendicular to $VB$; it will bisect the chord $GB$ in $I$; and $QN = BI = \frac{1}{2}BG$. Hence the diameter $2QN = BG = VB - VA$; which was to be proved.

*Corollary* 1. The compound curve intersects the circle $AGB$ in the point $P$, at an angle equal to half the difference of the angles $VAB$, $VBA$. For $QPL = QBN = BQI = \frac{1}{2}BQG$. The arc $AP$ is exterior, and the arc $PB$ interior to the circle $AGB$.

*Cor.* 2. Since both centres are on the line $PL$, the position of the point $P$ fixes the lengths of the radii of a compound curve. As $P$ is moved toward $G$ both radii are increased, until when $P$ reaches $G$, $AO_1$ becomes $AK$, a *maximum*, while $BO_2$ becomes infinite. As $P$ moves toward $A$ both radii are diminished, but the least value of the arc $AP$ depends upon the least radius allowed on the road. If in the diagram we make $AO_1$ equal to the least radius allowed, a right line drawn through the point $O_1$ tangent to the circle $LMN$ fixes the corresponding *minimum* value of the arc $AP$, and also of the radius $BO_2$ for given values of $VA$, $VB$, and $\Delta$. Between these limits any desired values of the radii may be employed.

*Cor.* 3. In the triangle $SO_1O_2$, the sum of the two central angles $AO_1P$ and $PO_2B$ is equal to the exterior angle $ASB = \Delta$; consequently, as the central angle of one arc is increased by any change in the position of the point $P$, the central angle of the other will be diminished an *equal amount.*

*Cor.* 4. Only one value of the angle $AO_1P$ is consistent with a given value of the radius $AO_1$, since both depend on the variable position of the line $PL$; and for the same reason only one value of the angle $BO_2P$ is consistent with a given value of the radius $BO_2$. Hence only one radius or one central angle can be assumed at pleasure, the remaining parts being deducible therefrom in terms of the sides $VA$, $VB$, and the angle $\Delta$.

### B. *General Equations.*

**161.** Let $S_1$ = the side $VA$, $S_2$ = the side $VB$
Let $R_1$ = the radius $AO_1$ $R_2$ = the radius $BO_2$
" $\gamma$ = diff. $VAB - VBA$, $\Delta$ = the sum $VAB + VBA$
" $\Delta_1$ = central angle $AO_1P$, $\Delta_2$ = central angle $BO_2P$.

In the triangle $BQI$, $\cot BQI = \frac{IQ}{BI}$. But $IQ = VI \times \cot IQV = \frac{1}{2}(S_2 + S_1) \cot \frac{1}{2}\Delta$, and $BI = \frac{1}{2}(S_2 - S_1)$.

$$\therefore \qquad \cot \tfrac{1}{2}\gamma = \frac{S_2 + S_1}{S_2 - S_1} \cot \tfrac{1}{2}\Delta \tag{100}$$

By Cor. 3,

$$\Delta_1 + \Delta_2 = \Delta \tag{101}$$

In the triangle $AQM$, $AO_1 = AM - MO_1$. But $AM = MQ \cot \frac{1}{2}\gamma$, and $MO_1 = MQ \cot \frac{1}{2}\Delta_1$.

$$\left.\begin{aligned} \therefore \qquad R_1 &= \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\gamma - \cot \tfrac{1}{2}\Delta_1) \\ \text{Similarly,} \qquad R_2 &= \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\gamma + \cot \tfrac{1}{2}\Delta_2) \end{aligned}\right\} \tag{102}$$

Subtracting,

$$R_2 - R_1 = \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\Delta_2 + \cot \tfrac{1}{2}\Delta_1) \tag{103}$$

$$\text{From (102),}\quad \left.\begin{aligned} \cot \tfrac{1}{2}\Delta_1 &= \cot \tfrac{1}{2}\gamma - \frac{R_1}{\tfrac{1}{2}(S_2 - S_1)} \\ \cot \tfrac{1}{2}\Delta_2 &= \frac{R_2}{\tfrac{1}{2}(S_2 - S_1)} - \cot \tfrac{1}{2}\gamma \end{aligned}\right\} \qquad (104)$$

In the triangle $ABG$,

$$BG = \frac{AB \sin BAG}{\sin AGV}$$

or

$$\tfrac{1}{2}(S_2 - S_1) = \frac{\tfrac{1}{2}AB \sin \tfrac{1}{2}\gamma}{\sin \tfrac{1}{2}\Delta} \qquad (105)$$

by which we find $\frac{1}{2}(S_2 - S_1)$, when, instead of the sides and $\Delta$, we have given $AB$, and the angles $VAB$ and $VBA$.

$$\text{From (103),}\quad \tfrac{1}{2}(S_2 - S_1) = \frac{R_2 - R_1}{\cot \tfrac{1}{2}\Delta_2 + \cot \tfrac{1}{2}\Delta_1} \qquad (106)$$

$$\text{From (102),}\quad \left.\begin{aligned} \cot \tfrac{1}{2}\gamma &= \frac{R_1}{\tfrac{1}{2}(S_2 - S_1)} + \cot \tfrac{1}{2}\Delta_1 \\ \cot \tfrac{1}{2}\gamma &= \frac{R_2}{\tfrac{1}{2}(S_2 - S_1)} - \cot \tfrac{1}{2}\Delta_2 \end{aligned}\right\} \qquad (107)$$

$$\text{From (100),}\quad \tfrac{1}{2}(S_2 + S_1) = \frac{\tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\gamma}{\cot \tfrac{1}{2}\Delta} \qquad (108)$$

$S_2$ and $S_1$ are found by adding and subtracting the values found by eqs. (106), (108).

$$\text{From (105),}\quad \tfrac{1}{2}AB = \frac{\tfrac{1}{2}(S_2 - S_1) \sin \tfrac{1}{2}\Delta}{\sin \tfrac{1}{2}\gamma} \qquad (109)$$

which may be used instead of (108) when the sides are not required. $VAB = \frac{1}{2}(\Delta + \gamma)$ and $VBA = \frac{1}{2}(\Delta - \gamma)$.

**162. Given:** *the sides* $VA = S_1$ *and* $VB = S_2$ *and the angle* $\Delta$; *assuming the shorter radius* $R_1$, **to find** $\Delta_1$, $\Delta_2$, *and* $R_2$.

Use equations (100), (104), (101), (102), and (18).

*Example.*—Let $VA = 1899.90$, $VB = 1091.12$, $\Delta = 74°$, and assume $R_1 = 955.37$.

| | | | | |
|---|---|---|---|---|
| (100) $\frac{1}{2}(S_2 + S_1)$ 1495.51 | | | log | 3.174789 |
| $\frac{1}{2}(S_2 - S_1)$ 404.39 | | | " | 2.606800 |
| | | | " | 0.567989 |
| $\frac{1}{2}\Delta$ | 37° | | cot " | 0.122886 |
| ∴ $\frac{1}{2}\gamma$ | 11° 31′ 01″.5 | cot 4.90769 | " " | 0.690875 |
| (104) $R_1$ $(D = 6°)$ | | | " | 2.980170 |
| $\frac{1}{2}(S_2 - S_1)$ | | | " | 2.606800 |
| | | 2.36249 | " | 0.373370 |
| ∴ $\frac{1}{2}\Delta_1$ | 21° 27′ | cot 2.54520 | | |
| (101) $\frac{1}{2}\Delta$ | 37° | | | |
| ∴ $\frac{1}{2}\Delta_2$ | 15° 33′ | " 3.59370 | | |
| (102) $\frac{1}{2}\gamma$ | | " 4.90769 | | |
| | | 8.50139 | " | 0.929490 |
| $\frac{1}{2}(S_2 - S_1)$ | | | " | 2.606800 |
| ∴ $R_2$ $(D = 1° 40')$ | | | | 3.536290 |

(18) ∴ $\Delta_1 = 42° 54'$, $L_1 = 715$; $\Delta_2 = 31° 06'$, $L_2 = 1866$.

**163. Given:** *the line AB, and the angles VAB, VBA; assuming the longer radius* $R_2$, **to find** $\Delta_2$, $\Delta_1$, *and* $R_1$.

*Example.*—Let $AB = 2437.82$, $VAB = 48° 31'$, $VBA = 25° 29'$, and assume $R_2 = 3437.87$.

| | | | | |
|---|---|---|---|---|
| (105) $\frac{1}{2}AB$ 1218.91 | | | log | 3.085972 |
| $\frac{1}{2}\gamma$ | 11° 31′ | | sin " | 9.300276 |
| | | | " | 2.386248 |
| $\frac{1}{2}\Delta$ | 37° | | " " | 9.779463 |
| ∴ $\frac{1}{2}(S_2 - S_1)$ 404.38 | | | " | 2.606785 |
| (104) $R_2$ | | | | 3.536289 |
| | | 8.50166 | " | 0.929504 |
| $\frac{1}{2}\gamma$ | 11° 31′ | cot 4.90785 | | |
| ∴ $\frac{1}{2}\Delta_2$ | 15° 33′ | cot 3.59381 | | |
| (101) $\frac{1}{2}\Delta$ | 37° | | | |
| ∴ $\frac{1}{2}\Delta_1$ | 21° 27′ | cot 2.54516 | | |
| (102) $\frac{1}{2}\gamma$ | | " 4.90785 | | |
| | | 2.36269 | log | 0.373407 |
| $\frac{1}{2}(S_2 - S_1)$ | | | | 2.606785 |
| ∴ $R_1$ $(D = 6°)$ | | | | 2.980192 |

**164.** Usually a compound curve is fitted by trial to the shape of the ground, after which it may be desirable **to calculate** the sides *VA*, *VB*, or the line *AB*, and the angles *VAB*, *VBA*.

*Example.*—From the point of curve *A*, a 6° curve is run 715 feet to the *P.C.C.*; thence a 1° 40′ curve is run 1866 feet to the *P.T.* *Required*, the sides *VA*, *VB*, and the line *AB*, and angles *VAB*, *VBA*. Here $R_1 = 955.37$, $\Delta_1 = 42° 54'$, $R_2 = 3437.87$, $\Delta_2 = 31° 06'$.

| | | | | | |
|---|---|---|---|---|---|
| (106) $R_2 - R_1$ | 2482.50 | | | log | 3.394889 |
| $\frac{1}{2}\Delta_1$ | | 21° 27′ | cot 2.54516 | | |
| $\frac{1}{2}\Delta_2$ | | 15° 33′ | " 3.59370 | | |
| | | | 6.13886 | " | 0.788088 |
| ∴ $\frac{1}{2}(S_2 - S_1)$ | 404.39 | | | " | 2.606801 |
| (107) $R_1$ | | | | " | 2.980170 |
| | | | 2.36248 | " | 0.373369 |
| $\frac{1}{2}\Delta_1$ | | 21° 27′ | cot 2.54516 | | |
| ∴ $\frac{1}{2}\gamma$ | | 11° 31′ 01″.7 | " 4.90764 | " | 0.690873 |
| (108) $\frac{1}{2}(S_2 - S_1)$ | | | | | 2.606801 |
| | | | | " | 3.297674 |
| $\frac{1}{2}\Delta$ | | 37° | | cot " | 0.122886 |
| ∴ $\frac{1}{2}(S_2 + S_1)$ | 1495.51 | | | " | 3.174788 |
| $S_2$ | 1899.90 | | | | |
| $S_1$ | 1091.12 | | | | |
| *VAB* | | 48° 31′ | | | |
| *VBA* | | 25° 29′ | | | |
| (109) $\frac{1}{2}(S_2 - S_1)$ | | | | " | 2.606801 |
| $\frac{1}{2}\Delta$ | | 37° | | sin " | 9.779463 |
| | | | | | 2.386264 |
| $\frac{1}{2}\gamma$ | | 11° 31′ 01″.7 | | sin " | 9.300294 |
| ∴ $\frac{1}{2}AB$ | 1218.91 | | | " | 3.085970 |
| *AB* | 2437.82 | | | | |

**165. Given:** *the radii* $R_1$, $R_2$, *the angle* $\Delta$, *and one side*, *VA*, *or* *VB*, **to find** *the other side and the central angles* $\Delta_1$, $\Delta_2$. Fig. 43.

In the triangle $AMQ$, $AO_1 = AM - MO_1 = IQ - MQ \cot MO_1Q$; or

$$R_1 = \tfrac{1}{2}(S_2 + S_1) \cot \tfrac{1}{2}\Delta - \tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\Delta_1$$

whence

$$\tfrac{1}{2}(S_2 + S_1) = \tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\Delta_1 \tan \tfrac{1}{2}\Delta + R_1 \tan \tfrac{1}{2}\Delta$$

By eq. (106)

$$\tfrac{1}{2}(S_2 - S_1) = (R_2 - R_1) \frac{\sin \tfrac{1}{2}\Delta_2 \sin \tfrac{1}{2}\Delta_1}{\sin \tfrac{1}{2}\Delta}$$

Substituting this above, subtracting and reducing

$$S_1 = (R_2 - R_1) \sin \tfrac{1}{2}\Delta_2 \frac{\sin \tfrac{1}{2}(\Delta - \Delta_1)}{\tfrac{1}{2}\sin \Delta} + R_1 \tan \tfrac{1}{2}\Delta$$

But $\tfrac{1}{2}(\Delta - \Delta_1) = \tfrac{1}{2}\Delta_2$ and $2 \sin^2 \tfrac{1}{2}\Delta_2 = \text{vers } \Delta_2$, whence

$$S_1 = \frac{(R_2 - R_1) \text{ vers } \Delta_2 + R_1 \text{ vers } \Delta}{\sin \Delta} \tag{110}$$

Transposing,

$$\text{vers } \Delta_2 = \frac{S_1 \sin \Delta - R_1 \text{ vers } \Delta}{R_2 - R_1} \tag{111}$$

Similarly, from the triangle $BQO_2$

$$R_2 = \tfrac{1}{2}(S_2 + S_1) \cot \tfrac{1}{2}\Delta + \tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\Delta_2$$

from which and eq. (106) we derive

$$S_2 = \frac{R_2 \text{ vers } \Delta - (R_2 - R_1) \text{ vers } \Delta_1}{\sin \Delta} \tag{112}$$

and

$$\text{vers } \Delta_1 = \frac{R_2 \text{ vers } \Delta - S_2 \sin \Delta}{R_2 - R_1} \tag{113}$$

*Example.*—Given : $VA = S_1 = 1091.12$, $\Delta = 74°$, and the radii $R_1 = 955.37$, $R_2 = 3437.87$, to find $\Delta_1$, $\Delta_2$, and $S_2$.

| | | | | | |
|---|---|---|---|---|---|
| (111) $S_1$ | 1091.12 | | | log | 3.037873 |
| $\Delta$ | | 74° | | sin " | 9.982842 |
| | | | 1048.85 | " | 3.020715 |
| $R_1$ | | | | " | 2.980170 |
| $\Delta$ | | 74° | | vers " | 9.859956 |
| | | | 692.03 | " | 2.840126 |
| | | | 356.82 | " | 2.552449 |
| $R_2 - R_1$ | 2482.50 | | | " | 3.394889 |
| ∴ $\Delta_2$ | | 31° 06′ | | vers " | 9.157560 |
| ∴ $\Delta_1$ | | 42° 54′ | | " " | 9.427254 |
| (112) $R_2 - R_1$ | | | | " | 3.394889 |
| | | | 663.96 | " | 2.822143 |
| $R_2$ | | | | " | 3.536289 |
| $\Delta$ | | | | vers " | 9.859956 |
| | | | 2490.26 | " | 3.396245 |
| | | | 1826.30 | " | 3.261572 |
| $\Delta$ | | | | sin " | 9.982842 |
| ∴ $S_2$ | | | 1899.90 | " | 3.278730 |

**166. Given :** *one side, and the radius and central angle of the adjacent arc,* **to find** *the other radius and side.*

From eqs. (111), (113) we have

$$\left.\begin{aligned} R_2 - R_1 &= \frac{S_1 \sin \Delta - R_1 \operatorname{vers} \Delta}{\operatorname{vers} \Delta_2} \\ R_2 - R_1 &= \frac{R_2 \operatorname{vers} \Delta - S_2 \sin \Delta}{\operatorname{vers} \Delta_1} \end{aligned}\right\} \quad (114)$$

by one of which the required radius may be found; the required side is then found by eq. (110) or (112), as in the last problem.

*Example.*—Given : $VA = S_1 = 1091.12$ $\Delta = 74°$, $R_1 = 955.37$ and $\Delta_1 = 42°54'$; to find $R_2$ $\Delta_2 = 74° - 42° 54' = 31° 06'$.

| | | | | | |
|---|---|---|---|---|---|
| (114) $S_1$ | 1091.12 | | | log | 3.037873 |
| $\Delta$ | | 74° | | " | sin 9.982842 |
| | | | 1048.85 | " | 3.020715 |
| $R_1$ | 955.37 | | | " | 2.980170 |
| $\Delta$ | | 74° | | " | vers 9.859956 |
| | | | 692.03 | " | 2.840126 |
| | | | 356.82 | " | 2.552449 |
| $\Delta_2$ | | 31°06 | | " | vers 9.157556 |
| $\therefore R_2 - R_1$ | 2482.52 | | | " | 3.394893 |
| $\therefore R_2$ | 3437.89 | | | | |

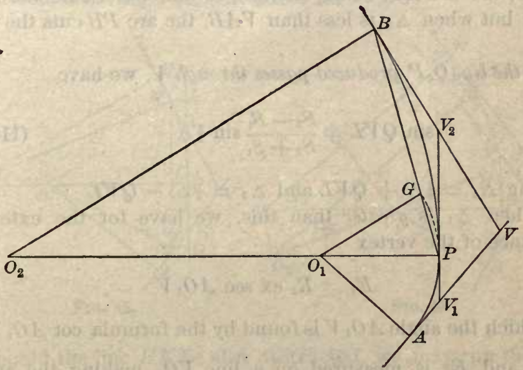


FIG. 44.

**Otherwise:** Fig. 44. If convenient in the field, a tangent $PV_2$ may be run from the point $P$ to intersect the farther tangent. The distance $PV_2$ multiplied by cot $\frac{1}{2}\Delta_2$ will equal the radius $R_2$ by eq. (25).

**167.** *Remarks.*—If the first arc $AP$ be produced to $G$, Fig. 44, so that $AO_1G = \Delta$, then $G$ is the tangent point of a tangent parallel to $VB$, and by §137, the tangent point $B$ must be on the line $PG$ produced. Conversely, if the point B is assumed, and the arc $AG$ given, the point $P$ must be on the line $BG$ produced. The radius $R_2$ may be found by

$R_2 = \frac{BP}{2 \sin \frac{1}{2} \Delta_2}$, $BP$ being measured on the ground; or by similar triangles $R_2 : R_1 :: BP : GP$.

The distance $VD$, Fig. 43, from the vertex to the circle $AGB$ is expressed by the formula

$$VD = S_1 \cos \frac{\Delta}{2} \left( \tan \frac{\Delta}{2} - \tan \frac{\Delta - \gamma}{4} \right) \qquad (115)$$

*If the point P falls at D*, then $VD$ is also the distance of the curve from the vertex measured on the line $VQ$. But when $P$ falls at $D$, the radius $PO_2$ is perpendicular to the line $AB$, and $\Delta_1 = VAB$, and $\Delta_2 = VBA$. When $\Delta_1$ is greater than $VAB$, the arc $AP$, being exterior to the circle, cuts the line $VD$; but when $\Delta_1$ is less than $VAB$, the arc $PB$ cuts the line $DQ$.

*If the line $O_2P$ produced passes through V*, we have

$$\sin QVL = \frac{S_2 - S_1}{S_2 + S_1} \sin \tfrac{1}{2} \Delta \qquad (116)$$

giving $\Delta_1 = \frac{1}{2}\Delta + QVL$ and $\Delta_2 = \frac{1}{2}\Delta - QVL$.

When $\Delta_1$ is *greater* than this, we have for the external distance of the vertex

$$E_1 = R_1 \text{ ex sec } AO_1V$$

in which the angle $AO_1V$ is found by the formula $\cot AO_1V = \frac{R_1}{S_1}$, and $E_1$ is measured on a line $VO_1$, making the angle $AVO_1 = 90° - AO_1V$.

When $\Delta_1$ is less than $(\frac{1}{2}\Delta + QVL)$, we have similar expressions with respect to the arc $BP$ and centre $O_2$.

**168.** *To locate a compound curve when the point of compound curve is inaccessible.* Fig. 45.

Each arc being in itself a simple curve is located as such. When the *P.C.C.* is accessible, the transit is placed over it, and the direction of the common tangent found, from which the second arc is then located.

When the *P.C.C.* is not accessible, the common tangent $V_1V_2$ may be found by locating the points $V_1$ and $V_2$, which may be easily done, since $V_1A = V_1P = R_1 \tan \frac{1}{2}\Delta_1$, and

$V_2B = V_2P = R_2 \tan \frac{1}{2} \Delta_2$, from which each arc may then be located by offsets or otherwise, as in the case of simple curves.

Should the points $V_1 V_2$ be obstructed, the common tangent may be found by an offset $HG = LP$ from any convenient point $H$, for knowing the angle $HO_1P$, we have $HG = R_1$ vers $HO_1P$, and $GP = R_1 \sin HO_1P$.

If the entire tangent $V_1 V_2$ is too much obstructed for use, the parallel line $HK$ may be employed, observing that the angle $PO_2K$ is found by vers $PO_2K = \frac{LP}{R_2}$, and the distance $LK$ by $LK = R_2 \sin PO_2K$, by which a point $K$ on the second arc is found having a tangent offset $KI = HG$.

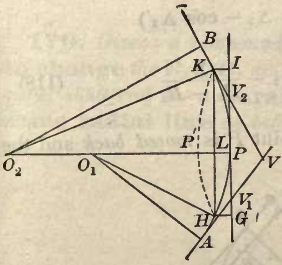


FIG. 45.

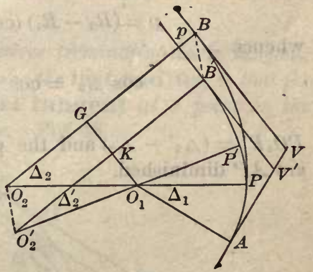


FIG. 46.

Should the line $HK$ be also obstructed, we may run the inverted curve $HP' = HP$ and $P'K = PK$ to find the point $K$ from which so much of the second arc as is accessible may be located.

### *C. Special Problems in Compound Curves.*

**169.** *Given: a compound curve ending in a tangent;* **to change** *the* **P.C.C.** *so that the curve may end in a given* **parallel tangent.** Fig. 46.

Let $APB$ be the given curve ending in $VB$,
" $V'B'$ be the given parallel tangent,
" $p$ = perpendicular distance between tangents.

It is required to change the point $P$, and with it the values of $\Delta_1$ and $\Delta_2$, so that with the same radii $R_1$ and $R_2$ the new curve $AP'B'$ may end in the parallel tangent $V'B'$.

**a.** *When the tangent $V'B'$ is* **inside** *of $VB$:*

Let $\Delta_1 = AO_1P$, $\Delta_1' = AO_1P'$, $\Delta_2 = PO_2B$, $\Delta_2' = P'O_2'B'$, and in the diagram draw $O_1G$ perpendicular to $BO_2$; then $GO_2 = O_1O_2 \cos \Delta_2$, $KO_2' = O_1O_2' \cos \Delta_2'$. Subtracting, since $O_1O_2 = O_1O_2' = (R_2 - R_1)$, and $KO_2' - GO_2 = GB - KB' = p$,

$$p = (R_2 - R_1)(\cos \Delta_2' - \cos \Delta_2)$$

whence

$$\cos \Delta_2' = \frac{p}{R_2 - R_1} + \cos \Delta_2 \qquad (117)$$

$PO_1P' = (\Delta_2 - \Delta_2')$ and the point $P$ is *advanced.*

**b.** *When the tangent $V'B'$ is* **outside** *of $VB$:*

$$p = (R_2 - R_1)(\cos \Delta_2 - \cos \Delta_2')$$

whence

$$\cos \Delta_2' = \cos \Delta_2 - \frac{p}{R_2 - R_1} \qquad (118)$$

$PO_1P' = (\Delta_2' - \Delta_2)$ and the point $P$ is *moved back* and the arc $AP$ diminished.

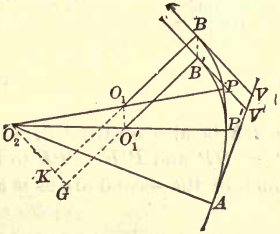


FIG. 47.

*In case the curve* **terminates with** *the arc of* **shorter radius,** *or $R_1$ follows $R_2$.* Fig. 47.

**c.** *When $V'B'$ is* **inside** *of $VB$:*

$$p = (R_2 - R_1)(\cos \Delta_1 - \cos \Delta_1')$$

whence

$$\cos \Delta_1' = \cos \Delta_1 - \frac{p}{R_2 - R_1} \qquad (119)$$

$PO_2P' = (\Delta_1' - \Delta_1)$ and the point $P$ is *moved back.*

**d.** *When* $V'B'$ *is* **outside** *of* $VB$:

$$p = (R_2 - R_1)(\cos \Delta_1' - \cos \Delta_1)$$

whence

$$\cos \Delta_1' = \cos \Delta_1 + \frac{p}{R_2 - R_1} \qquad (120)$$

$PO_2P' = (\Delta_1 - \Delta_1')$ and the point $P$ is *advanced*.

*Example.*—Let $R = 2292.01$, $R_1 = 1432.69$, $\Delta_2 = 28°$, and $p = 20.07$ inside of $VB$; case **a.**

| | | | | |
|---|---|---|---|---|
| | $p$ | 20.07 | | log 1.302547 |
| (117) | $R_2 - R_1$ | 859.32 | | " 2.934155 |
| | | | .023356 | " 8.368392 |
| | $\Delta_2$ | 28° | cos .88295 | |
| ∴ | $\Delta'_2$ | 25° | " .906306 | |
| ∴ | $PO_1P'$ | 3° | | |

**170.** *Given: a compound curve terminating in a tangent,* **to change** *the* **P.C.C.** *and also the* **last radius,** *so that the curve shall end in a* **parallel tangent** *at a point on the* **same radial line** *as before.* Fig. 48.

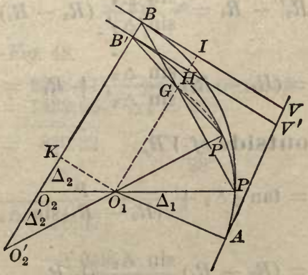


FIG. 48.

Let $APB$ be the given curve ending in the tangent $VB$; let $V'B'$ be the given parallel tangent; and let $p = BB' = HI =$ the perpendicular distance between tangents.

It is required to change the point $P$ to $P'$, and also the value of $R_2$ to $R_2'$, so that the new curve may end in $V'B'$ at $B'$ **inside** of $VB$ on the same radial line $BO_2$.

In the diagram produce the arc $AP$ to $G$ to meet $O_1G$ drawn parallel to $O_2B$; then $PO_1G = \Delta_2$. Draw the chord $PB$, and it will pass through $G$. Lay off the distance $p$ from

$B$ on $BO_2$ to find $B'$; draw $B'G$ and produce it to intersect the arc $APG$ in $P'$. Then $P'$ is the $P.C.C.$ required. Join $P'O_1$ and produce it to meet $BO_2$ produced in $O_2'$. Then $P'O_2' = B'O_2' = R_2'$ the new radius, with which describe the arc $P'B'$.

By Geom. Tab. I. 18:

$PBV = \frac{1}{2} PO_2B = \frac{1}{2}\Delta_2$, and $GB'V' = \frac{1}{2}P'O_2'B' = \frac{1}{2}\Delta_2'$.

$$\therefore \qquad PGP' = BGB' = \tfrac{1}{2}(\Delta_2 - \Delta_2')$$

Draw $O_1K$ perpendicular to $BO_2$.

Then $O_1K = B'H = BI = O_1O_2 \sin \Delta_2 = (R_2 - R_1) \sin \Delta_2$

$$\tan \tfrac{1}{2}\Delta_2 = \frac{GI}{BI} \qquad \tan \tfrac{1}{2}\Delta_2' = \frac{GH}{B'H} = \frac{GI - p}{B'H}.$$

$$\therefore \qquad \tan \tfrac{1}{2}\Delta_2' = \tan \tfrac{1}{2}\Delta_2 - \frac{p}{(R_2 - R_1)\sin \Delta_2} \qquad (121)$$

In the triangle $O_1O_2O_2'$

$$\sin \Delta_2' : \sin \Delta_2 :: O_1O_2 : O_1O_2' :: (R_2 - R_1) : (R_2' - R_1)$$

$$R_2' - R_1 = \frac{\sin \Delta_2}{\sin \Delta_2'}(R_2 - R_1)$$

and

$$R_2' = (R_2 - R_1)\frac{\sin \Delta_2}{\sin \Delta_2'} + R_1 \qquad (122)$$

*If $B'V'$ were* **outside** *of $VB$;*

$$\tan \tfrac{1}{2}\Delta_2' = \tan \tfrac{1}{2}\Delta_2 + \frac{p}{(R_2 - R_1)\sin \Delta_2} \qquad (123)$$

$$R_2' = (R_2 - R_1)\frac{\sin \Delta_2}{\sin \Delta_2'} + R_1 \qquad (122)$$

*When the* **smaller radius** *$R_1$ follows $R_2$: If the given tangent $B'V'$ is* **inside** *of $BV$.* Fig. 49.

$$\tan \tfrac{1}{2}\Delta_1' = \tan \tfrac{1}{2}\Delta_1 + \frac{p}{(R_2 - R_1)\sin \Delta_1} \qquad (124)$$

$$R_1' = R_2 - (R_2 - R_1)\frac{\sin \Delta_1}{\sin \Delta_1'} \qquad (125)$$

*If B′ V′ is* **outside** *of BV:*

$$\tan \tfrac{1}{2}\Delta_1' = \tan \tfrac{1}{2}\Delta_1 - \frac{p}{(R_2 - R_1)\sin \Delta_1} \qquad (126)$$

$$R_1' = R_2 - (R_2 - R_1)\frac{\sin \Delta_1}{\sin \Delta_1'} \qquad (125)$$

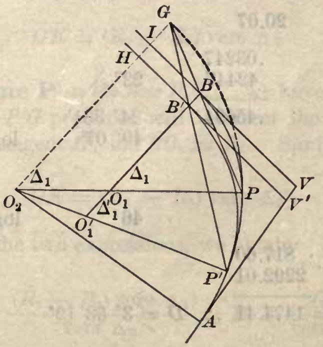


FIG. 49.

*Example* 1.—*Fig.* 48.

Let $R_2 = 2292.01$ $\quad p = 20.07$ *inside.*
" $R_1 = 1432.69$ $\quad \Delta_2 = 28°$

| | | | |
|---|---|---|---|
| (121) $R_2 - R_1 =$ | 859.32 | | log 2.934155 |
| $\Delta_2$ | | 28° | log sin 9.671609 |
| | | | 2.605764 |
| $p$ | 20.07 | | 1.302547 |
| | .04975 | | 8.696783 |
| $\tan \frac{1}{2}\Delta_2$ | .24933 | | |
| $\therefore \tan \frac{1}{2}\Delta_2'$ | .19958 | 11° 17′ | |
| (122) $\Delta_2'$ | | 22° 34′ | sin 9.584058 |
| $(R_2 - R_1)$ | | | 2.934155 |
| | | | 3.350097 |
| $\Delta_2$ | | 28° | sin 9.671609 |
| $(R_2' - R_1)$ | 1051.25 | | 3.021706 |
| $R_1$ | 1432.69 | | |
| *Ans.* $R_2'$ | 2483.94 $\therefore D = 2° 18' 25''$ | | |

$PO_1P = 28° - 22° 34' = 5° 26'$ $\therefore PP' = 135.88$ ft.

*Example* 2.—*Fig*. 49.

Let $R_2 = 2292.01 \qquad p = 20.07$ inside.
$R_1 = 1432.69 \qquad \Delta_1 = 46°$

| | | | |
|---|---|---|---|
| (124) $R_2 - R_1$ | 859.32 | | log 2.934155 |
| $\Delta_1$ | | 46° | log sin 9.856934 |
| | | | 2.791089 |
| $p$ | 20.07 | | 1.302547 |
| | .03247 | | 8.511458 |
| $\tan \frac{1}{2}\Delta_1$ | .42447 | 23° | |
| $\therefore \tan \frac{1}{2}\Delta_1'$ | .45694 | 24° 33½′ | |
| $\therefore \Delta_1'$ | | 49° 07′ | log sin 9.878547 |
| $R_2 - R_1$ | | | 2.934155 |
| | | | 3.055608 |
| $\Delta_1$ | | 46° | log sin 9.856934 |
| | 817.60 | | 2.912542 |
| $R_2$ | 2292.01 | | |

*Ans.* $R_1' = 1474.41 \quad \therefore \; D = 3° \, 53' \, 12''$

$$PO_2P' = \Delta_1' - \Delta_1 = 3° \, 07' \; \therefore \text{arc } PP' = \frac{3°.1166}{2.5} = 124.67 \text{ ft.}$$

Observe that in either figure both tangents must be on the same side of the point $G$, in order to a solution.

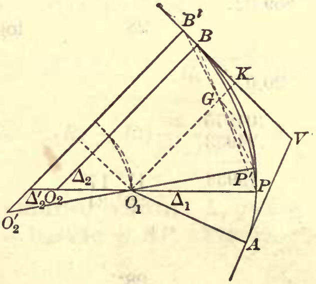


FIG. 50.

**171.** *Given: a compound curve ending in a tangent, to change the* **last radius** *and also the position of the* **P.C.C.,** *so that the curve may end in the* **same tangent.** Fig. 50.

I. *When the curve ends with the* **greater** *radius* $R_2$.

Let $APB$ be the compound curve in which $R_1$ $R_2$ $\Delta_1$ and $\Delta_2$ are known.

In the diagram draw the chord $PB$ and produce the first arc $AP$ to meet it in $G$; draw $O_1G$, and produce it to meet the tangent in $K$. Then by § 137 $O_1K$ is parallel to $O_2B$, and by eq. (57)

$$GK = (R_2 - R_1) \text{ vers } \Delta_2 \qquad (127)$$

*If we* **assume P**$'$ *as the new P.C.C.*, we have $\Delta_2' = P'O_2'B'$, and the chord $P'G$ produced will intersect the tangent at the new point of tangent $B'$, and $BO_2' = R_2'$. Similar to eq. (127) we have

$$GK = (R_2' - R_1) \text{ vers } \Delta_2'$$

and equating the two expressions, we obtain

$$R_2' = R_1 + \frac{(R_2 - R_1) \text{ vers } \Delta_2}{\text{vers } \Delta_2'} = R_1 + \frac{GK}{\text{vers } \Delta_2'} \qquad (128)$$

*If we* **assume R**$_2'$, *we have*

$$\text{vers } \Delta_2' = \frac{R_2 - R_1}{R_2' - R_1} \text{ vers } \Delta_2 = \frac{GK}{R_2' - R_1} \qquad (129)$$

In the two right-angled triangles $BKG$ and $B'KG$, we have

$$BK = GK \cot \tfrac{1}{2} \Delta_2$$
$$B'K = GK \cot \tfrac{1}{2} \Delta_2'$$

and by subtraction,

$$BB' = GK (\cot \tfrac{1}{2} \Delta_2' - \cot \tfrac{1}{2} \Delta_2) \qquad (130)$$

in which $GK$ is obtained from eq. (127).

When $BB'$ as given by eq. (130) is *negative*, the point $B'$ falls between $B$ and $V$.

*If we* **assume** *the distance* **BB**$'$ *on the tangent*, we have from the last equation,

$$\cot \tfrac{1}{2} \Delta_2' = \cot \tfrac{1}{2} \Delta_2 \pm \frac{BB'}{GK} \qquad (131)$$

$GK$ being obtained from eq. (127) and $R_2'$ from eq. (128). In eq. (131) use the $+$ sign when $B'$ is beyond $B$ as in the Fig. 50.

II. *When the given curve ends with the* **smaller radius** $R_1$. Fig. 51.

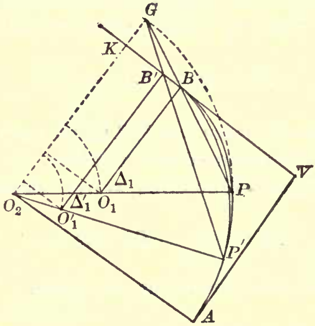


FIG. 51.

We have by a similar reasoning

$$GK = (R_2 - R_1) \text{ vers } \Delta_1 \qquad (132)$$

$$R_1' = R_2 - \frac{(R_2 - R_1) \text{ vers } \Delta_1}{\text{vers } \Delta_1'} = R_2 - \frac{GK}{\text{vers } \Delta_1'} \qquad (133)$$

$$\text{vers } \Delta_1' = \frac{R_2 - R_1}{R_2 - R_1'} \text{ vers } \Delta_1 = \frac{GK}{R_2 - R_1'} \qquad (134)$$

$$BB' = GK (\cot \tfrac{1}{2}\Delta_1 - \cot \tfrac{1}{2}\Delta_1') \qquad (135)$$

$$\cot \tfrac{1}{2}\Delta_1' = \cot \tfrac{1}{2}\Delta_1 \pm \frac{BB'}{GK} \qquad (136)$$

using the $-$ sign when $B'$ is beyond $B$.

*Example.—Fig.* 51.

Let $R_2 = 2292.01$, $R_1 = 1432.69$, $\Delta_1 = 46°$, and let the *P.C.C.* be moved back 200 feet from $P$ to $P'$; hence $PO_2'P' = 5°$ and $\Delta_1' = 51°$; to find the new radius $R_1'$ and the distance $BB'$.

| | | | | |
|---|---|---|---|---|
| Eq. (132) $R_2 - R_1$ | 859.32 | | log | 2.934155 |
| $\Delta_1$ | | 46° | " vers | 9.484786 |
| $\therefore GK$ | | | log | 2.418941 |
| eq. (133) $\Delta_1'$ | | 51° | " vers | 9.568999 |
| $R_2 - R_1'$ | 707.85 | | | 2.849942 |
| $R_2$ | 2292.01 | | | |
| $\therefore R_1'$ | 1584.16 | and $D = 3° 37'$ | | |
| eq. (135) $GK$ | | | log | 2.418941 |
| $\cot \frac{1}{2}\Delta_1$ | 2.35585 | 23° | | |
| $\cot \frac{1}{2}\Delta_1'$ | 2.09654 | 25° 30′ | | |
| | 0.25931 | | log | 9.413819 |
| $\therefore BB'$ | 68.04 | | | 1.832760 |

**172.** *Given: a compound curve ending in a tangent, the last radius being the* **greater, to change** *the* **last radius** *and also the position of the* **P.C.C.** *so that the curve may end at the* **same tangent point,** *but with a given difference in the* **direction** *of the tangent.* Fig. 52.

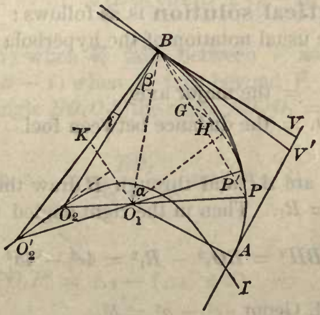


FIG. 52.

Let $APB$ be the given compound curve, $PO_1 = R_1$ and $PO_2 = R_2 > R_1$.

Let $V'B$ be the new tangent, and the angle $VBV' = i$, the given difference in direction: to find $BO_2' = R_2'$, $BO_2'P' = \Delta_2'$ and the angle $PO_1P'$.

We have

$$BO_2 - O_1O_2 = R_2 - (R_2 - R_1) = R_1$$

$$BO_2' - O_1O_2' = R_2' - (R_2' - R_1) = R_1$$

From which we see that whatever may be the value of the new radius, the *difference* of the distances from $B$ and $O_1$ to the new centre is *constant*, and equal to $R_1$. We therefore conclude that the centres $O_2$ and $O_2'$ are on an *hyperbola* of which $B$ and $O_1$ are the foci, and $R_1$ the major axis.

This suggests an easy **graphical method** of solving the problem.

Through $B$ draw a line perpendicular to the new tangent $V'B$ which will give the direction of the required centre $O_2'$. On this line lay off $BK$ equal to $R_1$, and since $(R_2' - R_1) = O_1O_2' = KO_2'$, if we join $KO_1$, the triangle $KO_2'O_1$ is isosceles; therefore bisect $KO_1$ and erect a perpendicular from the middle point to intersect the line $BK$ produced in $O_2'$. Draw $O_2'O_1$ and produce it to intersect the arc $AP$ (produced if necessary) in $P'$. Then $P'$ is the new $P.C.C.$ required, and $BO_2' = P'O_2' = R_2'$, the new radius.

**The analytical solution** is as follows:
Adopting the usual notation of the hyperbola

Let $2a = R_1$ = the major axis,
" $2c = BO_1$ = the distance between foci.

Produce the arc $AP$ and through $B$ draw the tangent $BH$, and join $HO_1 = R_1$. Then in the right-angled triangle $BHO_1$

$$BH^2 = BO_1^2 - R_1^2 = 4c^2 - 4a^2$$

Now by Anal. Geom., $c^2 - a^2 = b^2$.
Therefore $2b = BH$ = the minor axis.
Draw the chord $PB$ and produce the arc $AP$ to cut it in $G$. Then by Geom. (Table I. 24)

$$BH^2 = PB \times GB = 2R_2 \sin \tfrac{1}{2}\Delta_2 \times 2(R_2 - R_1) \sin \tfrac{1}{2}\Delta_2$$

$$\therefore BH = 2 \sin \tfrac{1}{2}\Delta_2 \sqrt{R_2 (R_2 - R_1)} \qquad (137)$$

Let $\alpha =$ the angle $HO_1B$, then

$$\tan \alpha = \frac{BH}{R_1} \text{ and } BO_1 = \frac{R_1}{\cos \alpha} \tag{138}$$

In the triangle $BO_1O_2$ let $O_1BO_2 = \beta$; then

$$\sin \beta = \frac{R_2 - R_1}{BO_1} \sin \Delta_2 \tag{139}$$

The polar equation of the hyperbola for the branch $IO_2O_2'$, taking the pole at $B$ and estimating the variable angle $v$ from the line $BO_1$, is

$$r = \frac{b^2}{c \, . \cos v - a}$$

When $v = \beta \pm i$, $r = R_2'$, and substituting the values of $a$, $b$, and $c$ found above, we have

$$R_2' = \frac{BH^2}{2\,(BO_1 \cos (\beta \pm i) - R_1)} \tag{140}$$

using $(\beta + i)$ when $V'$ falls between $V$ and $A$, as in the figure, and $(\beta - i)$ when $V'$ falls beyond $V$.

In the triangle $BO_1O_2'$, the angle $BO_2'O_1 = \Delta_2'$ and

$$\sin \Delta_2' = \frac{BO_1}{R_2' - R_1} \sin (\beta \pm i) \tag{141}$$

Finally

$$PO_1P' = \Delta_2 - (\Delta_2' \pm i) \tag{142}$$

*Remark.*—When $V'$ falls between $V$ and $A$, as in Fig. 52, if the angle $i$ be greater than the angle $VBH$, the curve ceases to be a compound, and becomes reversed. Therefore $VBH = \alpha - \beta$ is the maximum value of $i$ possible in this case. When $V'$ falls beyond $V$, the point $P'$ will fall between $P$ and $A$; and the largest possible value of $i$ will then be that which renders $PO_1P' = \Delta_1$, and makes the point $P'$ coincide with $A$.

*Example.*—Fig. 52. Let $R_1 = 1432.69$ $\Delta_1 = 31°$
$i = 6°$ $R_2 = 2292.01$ $\Delta_2 = 56°$

| | | | | |
|---|---|---|---|---|
| (137) | $R_2 - R_1$ | 859.32 | | log 2.934155 |
| | $R_2$ | 2292.01 | | 3.360217 |
| | | | | 2 ) 6.294372 |
| | | | | 3.147186 |
| | $\frac{1}{2}\Delta_2$ | | 28° | log sin 9.671609 |
| | 2 | | | 0.301030 |
| ∴ | $BH$ | | | 3.119825 |
| (138) | $R_1$ | 1432.69 | | 3.156151 |
| ∴ | $\alpha$ | | 42° 36′ 23″.7 | log tan 9.963674 |
| | $\alpha$ | | 42° 36′ 23″.7 | log cos 9.866889 |
| ∴ | $BO_1$ | | | 3.289262 |
| (139) | $R_2 - R_1$ | | | 2.934155 |
| | | | | 9.644893 |
| | $\Delta_2$ | | 56° | log sin 9.918574 |
| ∴ | $\beta$ | | 21° 28′ 06″.3 | log sin 9.563467 |
| (140) | $\beta + i$ | | 27° 28′ 06″.3 | log cos 9.948053 |
| | $BO_1$ | | | 3.289262 |
| | | 1727.09 | | 3.237315 |
| | $R_1$ | 1432.69 | | |
| | | 294.40 × 2 = 588.80 | | 2.769968 |
| | $BH^2$ | | | 6.239650 |
| ∴ | $R_2'$ | 2949.05 | | 3.469682 |

(141) ∴ $\Delta_2' = 36° 18' 26''$

(142) ∴ $PO_1P' = 13° 41' 34'' = 342.3$ feet.

*Remark*—This problem may also be solved by first finding the new sides $V'A$, $V'B$, from which and the new central angle ($\Delta \pm i$), and the radius $R_1$, may be found $\Delta_1'$, $\Delta_2'$, and $R_2'$, as in § 162. The new sides are readily found from the old ones by solving the triangle $VBV'$. If the original sides are not given, they must be calculated as in § 164.

**173.** *Given: a compound curve ending in a tangent, the last radius being the* **less,** *to change the* **last radius** *and the position of the* **P.C.C.** *so that the curve may end at the* **same tangent point,** *but with a* **given difference** *in the* **direction** *of tangent.* Fig. 53.

Let $APB$ be the given curve, and $PO_2 = R_2$, and $PO_1 = R_1 < R_2$. Let $V'B$ be the new tangent, and $VBV' = i$, the given angle; to find $BO_1' = R_1'$, $BO_1'P' = \Delta_1'$, and $PO_2P'$.

We have

$$BO_1 + O_1O_2 = R_1 + (R_2 - R_1) = R_2$$

$$BO_1' + O_1'O_2 = R_1' + (R_2 - R_1') = R_2$$

from which we infer that the locus of the centre $O_1'$ is an *ellipse*, of which $B$ and $O_2$ are the foci, and $R_2$ the major axis,

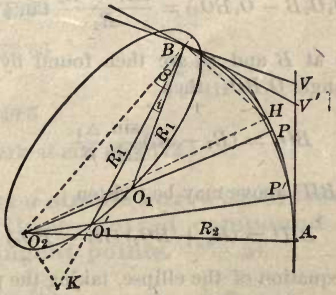


FIG. 53.

since the *sum* of the distances $BO_1'$ and $O_2O_1'$ is always equal to $R_2$.

This suggests an easy **graphical solution** of the problem, as follows:

Perpendicular to $V'B$ draw the indefinite line $BK$, which will contain the required centre $O_1'$, and lay off $BK = R_2$. Join $KO_2$, bisect it, and from the middle point erect a perpendicular to intersect $BK$ in $O_1'$. Join $O_2O_1'$, and produce the line to intersect the arc $AP$ (produced if necessary) in $P'$, which is the new $P.C.C.$ required. $P'O_1' = BO_1' = R_1'$, the required radius, and $P'O_1'B = \Delta_1'$.

**The analytical solution** is as follows: Adopting the usual notation of the ellipse,

let $2a = R_2$ = the major axis,

" $2c = BO_2$ = the distance between foci.

At $B$ erect $BH$ perpendicular to $BO_2$ to intersect the arc $AP$

(produced if necessary) in $H$, and join $HO_2 = R_2$. Then

$$BH^2 = R_2^2 - BO_2^2 = 4a^2 - 4c^2$$

But by Anal. Geom., $a^2 - c^2 = b^2$.

Hence $2b = BH =$ the minor axis.

In the triangle $BO_1O_2$ we know $BO_1 = R_1$, and $O_1O_2 = R_2 - R_1$, and the included angle $BO_1O_2 = 180° - \triangle_1$; hence by Trig. (Tab. II. 25)

$$\tan \tfrac{1}{2}(O_1O_2B - O_1BO_2) = \frac{2R_1 - R_2}{R_2} \tan \tfrac{1}{2} \triangle_1 \qquad (143)$$

The angles at $B$ and $O_2$ are then found by (Tab. II. 26). Let $\beta =$ the angle $O_1BO_2$; then

$$BO_2 = (R_2 - R_1)\frac{\sin \triangle_1}{\sin \beta} \qquad (144)$$

The value of $BH^2$ above may be written

$$BH^2 = (R_2 + BO_2)(R_2 - BO_2) \qquad (145)$$

The polar equation of the ellipse, taking the pole at $B$, and estimating the variable angle $v$ from the axis $BO_2$, is

$$r = \frac{b^2}{a - c \,.\, \cos v}$$

When $v = \beta \mp i$, then $r = R_1'$, and substituting the values of $a$, $b$, and $c$, given above, we have

$$R_1' = \frac{BH^2}{2(R_2 - BO_2 \cos(\beta \mp i))} \qquad (146)$$

using $(\beta - i)$ when $V'$ falls between $V$ and $A$, as in Fig. 53, and $(\beta + i)$ when $V'$ falls beyond $V$.

In the triangle $BO_1'O_2$, the angle $O_1'BO_2 = (\beta \mp i)$, and the exterior angle $BO_1'P' = \triangle_1'$; hence

$$\sin \triangle_1' = \frac{BO_2}{R_2 - R_1'} \sin(\beta \mp i) \qquad (147)$$

Finally $\quad PO_2P' = (\triangle_1 \mp i) - \triangle_1' \qquad (148)$

When $V'$ is on $AV$, then $PO_2P'$ is negative, showing that it must be laid off from $P$ toward $A$; but when $V'$ is beyond

$V$, then $PO_2P'$ is positive, and $P'$ will be on $AP$ produced. The only limits imposed on the angle $i$ are that the resulting value of $PP'$ shall not exceed $PA$, and tnat $R_1'$ shall not be less than a practical minimum.

*Example.—Fig.* 53.

Let $D_2 = 3° 20'$ $R_2 = 1719.12$ $\Delta_2 = 23° 20'$
$D_1 = 6°$ $R_1 = 955.37$ $\Delta_1 = 48°$ $i = 7° 45'$

The resulting values are as follows:

| | | | |
|---|---|---|---|
| $\beta$ | | 21° 09′ 32″.6 | |
| $BO_2$ | 1572.42 | | 3.196567 |
| $BH^2$ | | | 5.683829 |
| $R_1'$ | 1273.65 | | 3.105052 |
| $\Delta_1'$ | | 54° 56′ | |
| $PO_2P'$ | | 14° 41′ | |
| $PP'$ | 440.5 | | |

(See also remark at end of § 172.)

**174.** *Given a* **simple curve** *joining two tangents, to replace it by a* **three-centred compound** *curve between the* **same tangent points.** Fig. 54.

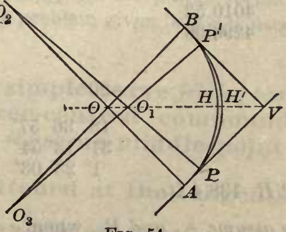


FIG. 54.

Let $R = AO$ = radius of simple curve.

$$R_1 = PO_1 = P'O_1 < R \quad \Delta_1 = PO_1P'$$

$$R_2 = AO_2 = BO_3 > R \quad \Delta_2 = AO_2P = BO_3P'$$

$$\Delta = AOB$$

Since $AO_2$ is made equal to $BO_3$ and $VA = VB$, $AO_2P$ *must* equal $BO_3P'$, and the compound curve will be symmetrical about the bisecting line $VO$; and the centre $O_1$ will be on the line $VO$.

We have at once from the figure,

$$2\Delta_2 + \Delta_1 = \Delta \qquad (149)$$

In the triangle $OO_1O_2$ we have

$$O_1O_2 : OO_2 :: \sin AOV : \sin PO_1V$$

whence

$$R_2 - R_1 = \frac{(R_2 - R) \sin \frac{1}{2} \Delta}{\sin \frac{1}{2} \Delta_1} \qquad (150)$$

which expresses the general relation between the quantities, $R$ and $\Delta$ being given.

*We may now assume values for* $R_1$ *and* $R_2$ subject to the above conditions, viz., $R_1 < R$ and $R_2 > R$; whence

$$\sin \tfrac{1}{2} \Delta_1 = \frac{(R_2 - R) \sin \frac{1}{2} \Delta}{R_2 - R_1} \qquad (151)$$

In selecting values for $R_1$ and $R_2$, the degree of curve $D_1$ should be but little greater than $D$ of the simple curve, say from 30 to 60 minutes, while $D_2$ may be taken at $\frac{1}{2}D$ to $\frac{1}{4}D$.

*Example.*—Given: $R = 1719.12 \quad D = 3° 20' \quad \Delta = 40°$

Let $R_1 = 1432.69 \quad D_1 = 4°$
" $R_2 = 5729.65 \quad D_2 = 1°$

| | | | | |
|---|---|---|---|---|
| ∴ | $R_2 - R$ | 4010.53 | | log 3.603202 |
| | $R_2 - R_1$ | 4296.96 | | " 3.633161 |
| | | | | " 9.970041 |
| | $\frac{1}{2}\Delta$ | | 20° | log sin 9.534052 |
| ∴ | $\frac{1}{2}\Delta_1$ | | 18° 36′ 57″ | " " 9.504093 |
| | $\Delta_1$ | | 37° 13′ 54″ | |
| ∴ | $\Delta_2$ | | 1° 23′ 03″ | |
| | $AP = P'B$ | 138.4 ft. | | |

*Again we may assume* $\Delta_2$ *and* $R_1$, whence

$$\Delta_1 = \Delta - 2\Delta_2$$

and

$$R_2 = \frac{R \sin \frac{1}{2}\Delta - R_1 \sin \frac{1}{2}\Delta_1}{\sin \frac{1}{2}\Delta - \sin \frac{1}{2}\Delta_1} \qquad (152)$$

*Example.*—Given: $R = 1719.12 \quad \Delta = 40°$
Let $R_1 = 1432.69 \quad \Delta_2 = 1° \quad \therefore \Delta_1 = 38°$
*Ans.* $R_2 = 7387.24 \quad \therefore D_2 = 0° 46\frac{1}{2}' \quad AP = 129.$

*Finally we may assume* $\Delta_2$ *and* $R_2$, and deduce $\Delta_1$ and $R_1$ from eqs. (149) (150); but this is the least desirable because the value of $R_1$ so found will not usually give a convenient value to the degree of curve $D_1$.

**175.** *To determine the* **distance HH′** *between the middle points of a simple curve and a three-centred compound curve joining the* **same tangent points** *AB.* Fig. 54.

In the triangle $OO_1O_2$, we have

$$OO_1 = (R_2 - R_1)\frac{\sin \Delta_2}{\sin \frac{1}{2}\Delta}$$

$$HH' = OO_1 + O_1H' - OH$$

$$\therefore\ HH' = (R_2 - R_1)\frac{\sin \Delta_2}{\sin \frac{1}{2}\Delta} - (R - R_1) \qquad (153)$$

In the first example given above $HH' = 14.55$, and in the second $HH' = 17.05$ ft.

In many instances the distance $HH'$ is so great as to render this problem practically useless, unless the distance $HH_1$ is discounted beforehand by putting the simple curve $AHB$ a sufficient distance inside of the proper location through the point $H'$. But the problem given below is usually preferable.

**176.** *Given, a* **simple curve** *joining two tangents to replace it by a* **three-centred compound** *curve which shall pass through the* **same middle point H.**

I. *The curve* **flattened at the tangents.** Fig. 55.

Let $R = AO$, the radius, and $\Delta$ = the central angle of the simple curve $AHB$, and let $H$ be the middle point.

Let $R_1 = PO_1 = HO_1$ $\qquad \Delta_1 = PO_1P'$

" $R_2 = PO_2 = A'O_2 = B'O_3$ $\qquad \Delta_2 = PO_2A' = P'O_3B'$

" $A'$ and $B'$ be the new tangent points required.

We have at once, as in the last problem,

$$2\Delta_2 + \Delta_1 = \Delta. \qquad (154)$$

Since the curve is to be symmetrical about $VO$, $HP = HP'$; $PA = P'B$, and $AA' = BB'$.

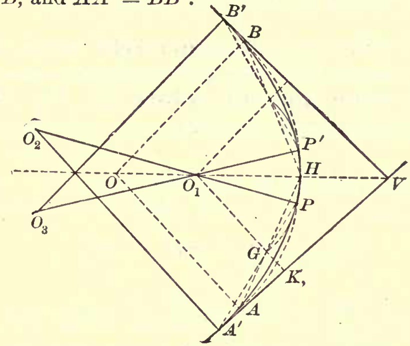


FIG. 55.

In the diagram produce the arc $HF$ to $G$, and draw $O_1G$ parallel to $OA$, and produce it to $K$. Then a tangent line at $G$ will be parallel to $VA$; and by § 137 the point $G$ will be on the long chord $HA$, and on the long chord $PA'$. $GK$ is the perpendicular distance between parallel tangents, and the problem is similar to that given in § 171; whence by eq. (57) we have, in this case,

$$GK = (R_2 - R_1) \text{ vers } \Delta_2 = (R - R_1) \text{ vers } \tfrac{1}{2}\Delta. \quad (155)$$

for the general equation in which $R$ and $\Delta$ are given.

Analagous to eq. (130) we have

$$AA' = KA' - KA = GK \cot GA'K - GK \cot GAK.$$

$$\therefore AA' = GK (\cot \tfrac{1}{2}\Delta_2 - \cot \tfrac{1}{2}\Delta) \quad (156)$$

in which $GK$ is obtained from (155).

*We may now assume values for* $R_1$ *and* $R_2$, making $R_1 < R$ and $R_2 > R$, and deduce the values of $\Delta_2$, $\Delta_1$, and $AA'$.

Solving eq. (155)

$$\text{vers } \Delta_2 = \frac{(R - R_1) \text{ vers } \frac{1}{2}\Delta}{R_2 - R_1} = \frac{GK}{R_2 - R_1} \quad (157)$$

Eq. (154) gives $\Delta_1$, and eq. (156) gives $AA'$.

*Example.—Fig.* 55.

| | | | | |
|---|---|---|---|---|
| | Given: $R =$ | 764.489 | $D = 7° \ 30'$ | $\Delta = 40°$ |
| | Let $R_1 =$ | 716.779 | $D_1 = 8°$ | |
| | " $R_2 =$ | 3437.870 | $D_2 = 1° \ 40'$ | |
| (155) | $R - R_1$ | 47.71 | | log 1.678609 |
| | $\frac{1}{2}\Delta$ | | 20° | log vers 8.780370 |
| ∴ | $GK$ | | | log 0.458979 |
| | $R_2 - R_1$ | 2721.091 | | " 3.434743 |
| ∴ | $\Delta_2$ | | (say) 2° 38′ | log vers 7.024236 |
| ∴ | $A'P$ | 158.00 | $\Delta_1 = 34° \ 44'$ | |
| (156) | $\frac{1}{2}\Delta_2$ | 43.5081 | = cot 1° 19′ | |
| | $\frac{1}{4}\Delta$ | 5.6713 | cot 10° | |
| | | 37.8368 | | log 1.577914 |
| | $GK$ | | | " 0.458979 |
| ∴ | $AA'$ | 108.87 | | " 2.036893 |

*Again, we may assume* $\Delta_2$ and $R_1 < R$; whence

$$\Delta_1 = \Delta - 2\Delta_2$$

and

eq. (155) $\quad GK = (R - R_1) \text{ vers } \frac{1}{2}\Delta$

and

$$R_2 = R_1 + \frac{GK}{\text{vers } \Delta_2} \qquad (158)$$

Eq. (156) gives $AA'$.

*Again, we may assume* $\Delta_2$ *and the distance* $AA'$; whence, from eq. (156)

$$GK = \frac{AA'}{\cot \frac{1}{2}\Delta_2 - \cot \frac{1}{4}\Delta} \qquad (159)$$

eq. (155) $\quad R_1 = R - \dfrac{GK}{\text{vers } \frac{1}{2}\Delta}$

eq. (158) gives $R_2$.

*Again, we may assume* $R_1 < R$ *and* $AA'$; then, eq. (155)

$$GK = (R - R_1) \text{ vers } \frac{1}{2}\Delta$$

and eq. (156)

$$\cot \frac{1}{2}\Delta_2 = \cot \frac{1}{4}\Delta + \frac{AA'}{GK} \qquad (160)$$

and eq. (158) gives $R_2$.

*Example.—Fig* 55.

Given: $R = 764.489$ $\quad D = 7° 30'$ $\quad \Delta = 40°$
Let $R_1 = 716.779$ $\quad D_1 = 8°$
" $AA' = 110.$

Hence by last example,

| | | | |
|---|---|---|---|
| $GK$ | | | log 0.458979 |
| eq. (160) $AA'$ | 110. | | 2.041393 |
| | 38.2309 | | 1.582414 |
| $\cot \frac{1}{2}\Delta$ | 5.6713 | 10° | |
| $\therefore \cot \frac{1}{2}\Delta_2$ | 43.9022 | 1° 18′ 18″ | log 1.642486 |
| (158) $\Delta_2$ | | (say) 2° 37′ | log vers 7.018147 |
| $GK$ | | | 0.458979 |
| $R_2 - R_1$ | 2759.5 | | 3.440832 |
| $\therefore R_2$ | 3476.3 | $D_2 = 1° 39'$ | |
| $\therefore AP'$ | 157. | $\Delta_1 = 34° 46'$ | |

II. *The curve* **sharpened at the tangents.** Fig. 56.

This case will only occur when, with a given external distance $VH$, a simple curve would absorb too much of the tangents.

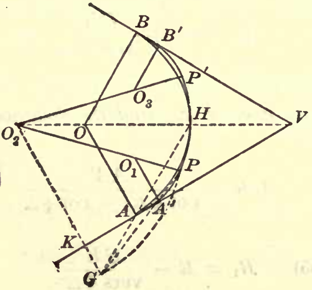


FIG. 56.



Let $AHB$ be the simple curve, and
" $A'PHP'B'$ the required compound curve.
" $R_2 = PO_2 = HO_2$; $\quad \Delta_2 = PO_2P'$
" $R_1 = PO_1 = A'O_1 = B'O_3$; $\Delta_1 = A'O_1P = P'O_3B'$.

We have from the figure,

$$2\Delta_1 + \Delta_2 = \Delta. \qquad (161)$$

In the diagram draw $O_2G$ parallel to $OA$ cutting the tangent at $K$, and produce the arc $HP$ to $G$. Draw the chords $GH$ and $GP$, passing through $A$ and $A'$ respectively. We have then a discussion similar to the preceding case, and to the problem § 171, Fig. 51, whence we derive the general formulæ:

$$GK = (R_2 - R_1) \text{ vers } \Delta_1 = (R_2 - R) \text{ vers } \tfrac{1}{2}\Delta \qquad (162)$$

and

$$AA' = GK(\cot \tfrac{1}{2}\Delta_1 - \cot \tfrac{1}{2}\Delta) \qquad (163)$$

1. Assuming $R_1 < R$ and $R_2 > R$

$$\text{vers } \Delta_1 = \frac{GK}{R_2 - R_1} = \frac{R_2 - R}{R_2 - R_1} \text{ vers } \tfrac{1}{2}\Delta \qquad (164)$$

2. Assuming $\Delta_1 < \frac{1}{2}\Delta$ and $R_1 < R$

$$R_2 = \frac{R \text{ vers } \tfrac{1}{2}\Delta - R_1 \text{ vers } \Delta_1}{\text{vers } \tfrac{1}{2}\Delta - \text{vers } \Delta_1} \qquad (165)$$

3. Assuming $\Delta_1 < \frac{1}{2}\Delta$ and $AA'$

$$GK = \frac{AA'}{\cot \tfrac{1}{2}\Delta_1 - \cot \tfrac{1}{2}\Delta} \qquad (166)$$

$$R_2 = R_1 + \frac{GK}{\text{vers } \tfrac{1}{2}\Delta} \qquad (167)$$

$$R_1 = R_2 - \frac{GK}{\text{vers } \Delta_1} \qquad (168)$$

4. Assuming $R_2 > R$ and $AA'$

$$GK = (R_2 - R) \text{ vers } \tfrac{1}{2}\Delta$$

$$\cot \tfrac{1}{2}\Delta_1 = \cot \tfrac{1}{2}\Delta + \frac{AA'}{GK} \qquad (169)$$

The third assumption will usually secure most readily the desired curve. $AA'$ should be assumed as small as the nature of the case will allow, and $\Delta_1$ should not be much smaller than $\frac{1}{2}\Delta$.

It is evidently not *necessary* that the new curve should be symmetrical; for having laid out the curve $A'PH$, the simple curve $HB$ may then be used, or, if desirable, some compound curve $HP'B'$ determined by an assumed value of $BB'$ *not* equal to $AA'$.

These formulæ (154) to (169) are readily adapted to the case of substituting a compound for a simple curve when it is necessary to keep one tangent point fixed, but to move the other a certain distance in either direction on the tangent. For if in Figs. 55, 56, we draw a tangent at $H$, and make $H$ the fixed point of tangent, it is evident that the central angle of the curve will then be $AOH$. The only change necessary, therefore, to adopt the formulæ to this case is to write $\Delta$ in place of $\frac{1}{2}\Delta$, and to observe, instead of eqs. (154) (161), that

$$\Delta_1 + \Delta_2 = \Delta.$$

*Example.—Fig.* 55.

| | | | | |
|---|---|---|---|---|
| Let | $R =$ 1910.08 | $\Delta = 84°$ | | |
| Assume | $AA' =$ 260. | $\Delta_1 = 38°$ | $\therefore\ \Delta_2 = 8°$ | |
| Eq. (166) | $AA' =$ 260. | | log | 2.414973 |
| | $\cot\frac{1}{2}\Delta_1$ 2.90421 | 19° | | |
| | $\cot\frac{1}{4}\Delta$ 2.60509 | 21° | | |
| | .29912 | | log | 9.475846 |
| $\therefore$ | $GK$ | | " | 2.939127 |
| Eq. (167) | $\frac{1}{2}\Delta$ | 42° | " vers | 9.409688 |
| | 3384.07 | | | 3.529439 |
| | $R$ 1910.08 | | | |
| $\therefore$ | $R_2$ 5294.15 | | $D =$ say 1° 05′ | |
| Eq. (168) | $GK$ | | log | 2.939127 |
| | $\Delta_1$ | 38° | " vers | 9.326314 |
| | 4100.27 | | | 3.612813 |
| $\therefore$ | $R_1$ 1193.88 | | $D = 4°\ 48'$ | |
| | $A'P$ 791.67 | | $PH = 369.23$ | |

**177.** *Given,* **two curves** *joined by a common tangent* **to replace the tangent by a curve** *compounded with the given curves.* Fig. 57.

Let $R_1 = BO_1$ the radius of one curve,

" $R_3 = AO_3$ the radius of the other curve, $> R_1$,

" $l = BA$ the common tangent,

" $R_2 = PO_2 = P'O_2$ the radius of connecting curve.

" $\Delta_2 = PO_2P'$ the central angle of " "

" $\alpha = AO_3P'$ and $\beta = BO_1P$.

" $i = AO_3O_1$.

In the diagram join $O_1O_3$ and draw $O_1G$ parallel to $BA$. Then in the right-angled triangle $O_1GO_3$ we have,

$$\cot i = \frac{GO_3}{GO_1} = \frac{R_3 - R_1}{l} \qquad (170)$$

$$O_1O_3 = \frac{R_3 - R_1}{\cos i} = \frac{l}{\sin i} \qquad (171)$$

which gives the distance between the centres of the given curves.

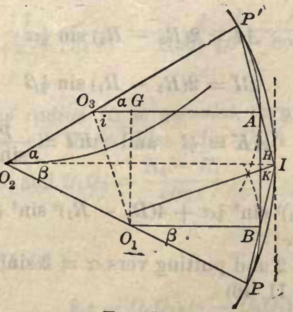


FIG. 57.

We shall now assume the following geometrical truths, which may be easily demonstrated.

If two circles intersect in one point, they intersect in two points; and the line joining the two points is the common chord.

The common chord is perpendicular to the line joining the centres, and when produced it bisects the common tangents.

If a third circle is drawn touching the two circles, a tangent to the third circle, parallel to the common tangent, will have its tangent point on the common chord produced.

Conversely, therefore, if the tangent $BA$ be bisected at $K$, and a line, $KI$, drawn perpendicular to $O_1O_3$, $KI$ will coincide with the common chord produced, and the angle $IKA = AO_3O_1 = i$. If on $KI$ we assume a point $I$ through which it is desirable that the connecting curve should pass, then $I$ is the tangent point of a tangent parallel to $BA$; consequently a line through $I$ perpendicular to $BA$ contains the required centre $O_2$.

I. Let $p = HI =$ the perpendicular distance between the tangents.

If in the diagram we join $IA$ and $IB$, and produce the chords to intersect the given curves in $P$ and $P'$, then $P$ and $P'$ are the points of compound curvature; and the lines $PO_1$ and $P'O_3$ produced will intersect $IO_2$ in the same point $O_2$; and the angles $P'O_2I = \alpha$ and $PO_2I = \beta$.

In the triangle $AIB$ the line $KI$ bisects the base $AB$, and we have by Geom. Tab. I. 25.

$$AI^2 + BI^2 = 2AK^2 + 2KI^2$$

By eq. (56) $$AI = 2(R_2 - R_3) \sin \tfrac{1}{2}\alpha$$

$$BI = 2(R_2 - R_1) \sin \tfrac{1}{2}\beta$$

$$AK = \tfrac{1}{2}l \quad \text{and} \quad KI = \frac{p}{\sin i}$$

$$\therefore\ 4(R_2 - R_3)^2 \sin^2 \tfrac{1}{2}\alpha + 4(R_2 - R_1)^2 \sin^2 \tfrac{1}{2}\beta = \tfrac{1}{2}l^2 + \frac{2p^2}{\sin^2 i}$$

Dividing by 2 and putting vers $\alpha = 2 \sin^2 \frac{1}{2}\alpha$ and vers $\beta = 2 \sin^2 \frac{1}{2}\beta$ (Tab. II. 46)

$$(R_2 - R_3)^2 \text{ vers } \alpha + (R_2 - R_1)^2 \text{ vers } \beta = \tfrac{1}{4}l^2 + \frac{p^2}{\sin^2 i}$$

But by eq (57)

$$(R_2 - R_3) \text{ vers } \alpha = (R_2 - R_1) \text{ vers } \beta = p \qquad (172)$$

$$\therefore\ p\,(2R_2 - (R_3 + R_1)) = \tfrac{1}{4}l^2 + \frac{p^2}{\sin^2 i}$$

$$2R_2 = (R_3 + R_1) + \frac{l^2}{4p} + \frac{p}{\sin^2 i} \qquad (173)$$

From (172)

$$\text{vers } \alpha = \frac{p}{R_2 - R_3}\,; \quad \text{vers } \beta = \frac{p}{R_2 - R_1} \qquad (174)$$

and from the figure

$$\Delta_2 = \alpha + \beta \qquad (175)$$

These formulæ solve the problem when $p$ is assumed. If desirable we may find $\alpha$ and $\beta$ independently of $R_2$, for in the triangle $AIB$, $IAB = \frac{1}{2}\alpha$ and $IBA = \frac{1}{2}\beta$; and since $HK = p \cot i$,

$$\cot \tfrac{1}{2}\alpha = \frac{AH}{HI} = \frac{\frac{1}{2}l - HK}{p} = \frac{l}{2p} - \cot i \qquad (176)$$

$$\cot \tfrac{1}{2}\beta = \frac{BH}{HI} = \frac{\frac{1}{2}l + HK}{p} = \frac{l}{2p} + \cot i \qquad (177)$$

II. *In case $\alpha$ or $\beta$ is assumed,* we have from the last equation

$$p = \frac{l}{2(\cot \frac{1}{2}\alpha + \cot i)} = \frac{l}{2(\cot \frac{1}{2}\beta - \cot i)} \qquad (178)$$

III. *In case the radius $R_2$ is assumed,* then in the triangle $O_1O_2O_3$ we know all three sides; for $O_1O_2 = (R_2 - R_1)$, $O_2O_3 = (R_2 - R_3)$, and $O_1O_3 = \dfrac{R_3 - R_1}{\cos i}$

By Trig. (Table II. 31.)

$$\text{vers } \triangle_2 = \frac{2(s - O_1O_2)(s - O_2O_3)}{O_1O_2 \times O_2O_3}$$

in which $s = \frac{1}{2}$ sum of the three sides.

Substituting values, and reducing, observing that,

$$\left(\frac{1}{\cos i} - 1\right)\left(\frac{1}{\cos i} + 1\right) = \sec^2 i - 1 = \tan^2 i$$

and that $(R_3 - R_1) \tan i = l$, we have

$$\text{vers } \triangle_2 = \frac{l^2}{2(R_2 - R_1)(R_2 - R_3)} \qquad (179)$$

In the same triangle.

$$\sin O_3O_1O_2 = \sin \triangle_2 \frac{O_3O_2}{O_1O_3} = \sin(i - \beta) \qquad (179)'$$

for from the figure $O_3O_1O_2 = i - \beta$, and taking the value of $O_1O_3$ from eq. (171).

$$\sin(i - \beta) = \frac{(R_2 - R_3)\sin \Delta_2 \sin i}{l} \qquad (180)$$

We then find $\alpha$ from eq. (175) and $p$ from (172).

The angles $\alpha$ and $\beta$ may be found otherwise, for by Trig (Tab. II. 27) we have in the triangle $O_1O_2O_3$

$$\sin \tfrac{1}{2}(O_1O_3O_2 - O_3O_1O_2) = \frac{O_1O_2 - O_2O_3}{O_1O_3} \cos \tfrac{1}{2}\Delta_2$$

or

$$\sin\left(90° - (i + \frac{\alpha - \beta}{2})\right) = \frac{(R_3 - R_1)\cos i \ \cos \frac{1}{2}\Delta_2}{R_3 - R_1}$$

$$\therefore \cos\left(i + \frac{\alpha - \beta}{2}\right) = \cos i \,.\, \cos \tfrac{1}{2}\Delta_2 \qquad (181)$$

which is a convenient formula when $i$ and $\Delta_2$ are not too small. Having obtained $\frac{\alpha - \beta}{2}$, we have

$$\alpha = \tfrac{1}{2}\Delta_2 + \frac{\alpha - \beta}{2} \qquad \beta = \tfrac{1}{2}\Delta_2 - \frac{\alpha - \beta}{2} \qquad (182)$$

For a constant value of $l$ the *less* the difference of $R_3 - R_1$ the *greater* will be the value of the angle $i$. When $R_3 = R_1$, $\cot i = 0$ and $i = 90°$ and the tangent point $I$ will be on a perpendicular to $BA$ drawn through the middle point $K$; and $\alpha = \beta$. On the contrary, as $(R_3 - R_1)$ increases, $i$ becomes less, and the foot, $H$, of the perpendicular $HI$ moves toward $B$, the tangent point of the curve of smaller radius $R_1$. The distance $HK = p \cot i$. The connecting curve is farthest from the tangent $BA$ at $I$. To find the ordinate from $BA$ to the curve at any other point, subtract from $p$ the tangent offset for the length of curve from $I$ to the ordinate in question. §115, eq. (39) may be used on flat curves with tolerable accuracy, even when the distance equals several hundred feet.

IV. It is evident that in this problem $R_2$ must be greater than either $R_1$ or $R_3$. As the centre $O_2$ is taken nearer the line $O_1 O_3$, $R_2$ grows less, and is a minimum when $O_2$ falls on the line $O_1 O_3$. In this case we have $\Delta_2 = 180°$, and

$$R_2 = \tfrac{1}{2}(R_3 + R_1 + O_1 O_3); \text{ a minimum.} \qquad (183)$$

This limit must be regarded in assuming the value of $R_2$. Since

$$O_1 O_2 - O_2 O_3 = (R_2 - R_1) - (R_2 - R_3) = (R_3 - R_1)$$

a constant value, independent of $R_2$, we infer that the centre $O_2$ is always on a hyperbola of which $O_1$ and $O_3$ are the foci; $(R_3 - R_1)$ equals the diameter on the axis joining the foci; and $l$ equals the diameter at right angles to it, for in the triangle $O_1 G O_3$,

$$l^2 = \overline{O_1 O_3}^2 - (R_3 - R_1)^2 \qquad (184)$$

*Example.*—Fig. 57.

Given: $R_1 = 1432.69$ $R_3 = 1910.08$ and $l = 400.$
Assume $p =$ 11.4 to find $R_2, \alpha$ and $\beta$.

| | | | | |
|---|---|---|---|---|
| Eq. (170) | $R_3 - R_1$ | 477.39 | | log 2.678873 |
| | $l$ | 400. | | " 2.602060 |
| ∴ | $i$ | | 39° 57′ 34″ | log cot 0.076813 |
| Eq. (173) | $i$ | | 39° 57′ 34″ | " sin 9.807701 |
| | $i$ | | 39° 57′ 34″ | " sin² 9.615402 |
| | $p$ | 11.4 | | log 1.056905 |
| | * | 27.64 | | " 1.441503 |
| | $\frac{1}{4} l^2$ | | | " 4.602060 |
| | $p$ | | | " 1.056905 |
| | * | 3508.77 | | " 3.545155 |
| | $R_3 + R_1$ | 3342.77 | | |
| | 2) | 6879.18 | | |
| ∴ | $R_2$ | 3439.59 | (say) 3437.87 | |
| Eq. (174) | $p$ | 11.4 | | " 1.056905 |
| | $R_2 - R_3$ | 1527.79 | | " 3.184064 |
| ∴ | $\alpha$ | | 7° 00′ | log vers 7.872841 |
| | $p$ | 11.4 | | log 1.056905 |
| | $R_2 - R_1$ | 2005.18 | | " 3.302153 |
| ∴ | $\beta$ | (nearly) | 6° 07′ | log vers 7.754752 |
| ∴ | $\Delta_2$ | | 13° 07′ | |

*Example.*—Fig 57.

Given: $R_1 = 1432.69$, $R_3 = 1910.08$, and $l = 400$.
Assume $R_2 = 3437.87$, to find $\triangle_2, \beta, \alpha$ and $p$.

| | | | | |
|---|---|---|---|---|
| Eq. (179) | | 2. | | log 0.301030 |
| | $R_2 - R_1$ | 2005.18 | | " 3.302153 |
| | $R_2 - R_3$ | 1527.79 | | " 3.184064 |
| | | | | " 6.787247 |
| | $l^2$ | | | 5.204120 |
| ∴ | $\triangle_2$ | | 13° 07′ 22″ | log vers 8.416873 |
| Eq. (170) | $R_2 - R_1$ | 477.39 | | log 2.678873 |
| | $l$ | 400. | | " 2.602060 |
| ∴ | $i$ | | 39° 57′ 34″ | log cot 0.076813 |
| Eq. (180) | $i$ | | 39° 57′ 34″ | log sin 9.807701 |
| | $\triangle_2$ | | 13° 07′ 22″ | " " 9.356099 |
| | $R_2 - R_3$ | 1527.79 | | log 3.184064 |
| | | | | log sin 2.347864 |
| | $l$ | 400. | | log 2.602060 |
| ∴ | $i - \beta$ | | 33° 50′ 39″ | log sin 9.745804 |
| ∴ | $\beta$ | | 6° 06′ 55″ | |
| Eq. (175) | $\alpha$ | | 7° 00′ 27″ | |
| Eq. (172) | $R_2 - R_3$ | | | log 3.184064 |
| | $\alpha$ | | 7° 00′ 27″ | log vers 7.873309 |
| ∴ | $p$ | 11.41 | | 1.057373 |

**178.** *Given: a three-centred compound curve* **to replace the middle arc** *by an arc of different radius.*

I. *When the radius of the middle arc is the* **greatest.** Fig. 57.

First find the length and direction of the common tangent *AB.* Let $\triangle_2$ = central angle of the middle arc, $R_2$ = its radius, and $R_1$ and $R_3$ the radii of the other arcs. From eq. (179).

$$l = \sqrt{2(R_2 - R_1)(R_2 - R_3) \text{ vers } \triangle_2} \qquad (185)$$

Then find $i$ by eq. (170), $\alpha$ and $\beta$ by eqs. (179)′ (175) and $p$ by eq. (172).

For the new arc we may now assume a new value for $p$, or for $R_2$, or for $\alpha$. Indicating the new values by an accent, if **we assume p′** we proceed as in the last problem, using eqs. (173), etc. If we assume $R_2$, we use eq. (179), etc. If we assume $\alpha'$, we use eq. (178).

II. *When the radius of the middle arc is the* **least** *of the three.* Fig. 58.

In this case the middle arc is within the other two produced; and for the same values of $R_1R_3$ and $O_1O_3$, the *locus*

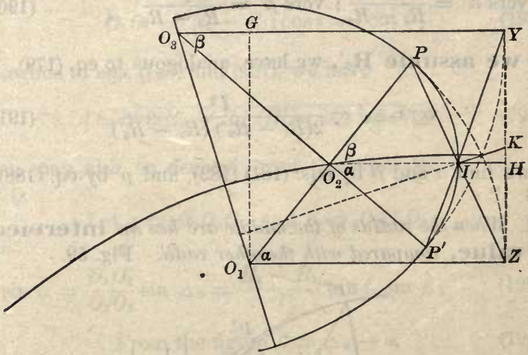


FIG. 58.

of the centre $O_2$ is the opposite branch of the hyperbola found in §177. When the centre $O_2$ falls on the line $O_1O_3$, $\Delta_2 = 180°$, and

$$R_2 = \tfrac{1}{2}(R_3 + R_1 - O_1O_3), \text{ a maximum.} \qquad (186)$$

Analogous to eq. (185), we have

$$l = \sqrt{2(R_1 - R_2)\,(R_3 - R_2) \text{ vers } \Delta_2} \qquad (187)$$

which gives the length of the common tangent $YZ$.

We then have the values of $i$ and of $O_1O_3$ by eqs. (170) (171), and of $\alpha$ and $\beta$ by eqs. (181) (182), and analogous to eq. (172),

$$p = (R_1 - R_2) \text{ vers } \alpha = (R_3 - R_2) \text{ vers } \beta \qquad (188)$$

in which $p$ is the perpendicular distance $HI$ between parallel tangents.

For the new arc we may now assume a new value for $p$, for $R_2$, or for $\alpha$. Indicating the new values by an accent, **if we assume p′,** we have, analogous to eq. (173)

$$2R_2' = R_3 + R_1 - \left(\frac{l^2}{4p'} + \frac{p'}{\sin^2 i}\right) \tag{189}$$

and from eq. (188)

$$\text{vers } \alpha' = \frac{p'}{R_1 - R_2}\,; \text{ vers } \beta' = \frac{p'}{R_3 - R_2} \tag{190}$$

**If we assume $R_2'$,** we have, analogous to eq. (179),

$$\text{vers } \Delta_2' = \frac{l^2}{2(R_1 - R_2')(R_3 - R_2')} \tag{191}$$

and we find $\alpha$ and $\beta$ by eqs. (181) (182), and $p'$ by eq. (188).

III. *When the radius of the middle arc has an* **intermediate value,** *compared with the other radii.* Fig. 59.

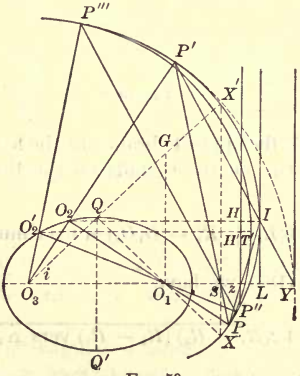


FIG. 59.

In this case, whatever be the value of $R_2$, we have

$$O_3O_2 + O_2O_1 = (R_3 - R_2) + (R_2 - R_1) = (R_3 - R_1)$$

a constant value independent of $R_2$; hence we infer that the *locus* of $O_2$ is an ellipse, of which $O_1$ and $O_3$ are the foci, and $(R_3 - R_1)$ equal to the transverse axis.

Let $l = QQ'$ = the conjugate axis, and let $i = QO_3O_1 = QO_1O_3$. Then $QO_3 = QO_1 = \frac{1}{2}(R_3 = R_1)$.

Produce $O_3Q$ to $G$, making $QG = O_3Q$, and join $GO_1$.

Then by similar triangles $GO_1$ is perpendicular to $O_1O_3$, and $GO_1 = l$; and in the right-angled triangle $GO_3O_1$

$$\sin i = \frac{GO_1}{GO_3} = \frac{l}{R_3 - R_1} \tag{192}$$

$$O_1O_3 = (R_3 - R_1)\cos i = l \cot i \tag{193}$$

Analogous to eqs. (185) and (187), we have

$$l = \sqrt{2(R_3 - R_2)(R_2 - R_1) \operatorname{vers} \Delta_2} \tag{194}$$

which may also be derived from the triangles $O_1O_2O_3$ and $O_1O_3Q$.

Let $\alpha = O_2O_3O_1$, and $\beta = O_2O_1O_3$

Then

$$\sin \alpha = \frac{O_1O_2}{O_1O_3} \sin \Delta_2 = \frac{R_2 - R_1}{l} \tan i . \sin \Delta_2 \tag{195}$$

From the figure $\beta = \Delta_2 - \alpha$ (196)

In the diagram produce the line $O_3O_1$ and it will intersect all the arcs. At the points $Z$ and $Y$, where it cuts the inner and outer arcs, draw tangent lines perpendicular to $O_3O_1$. Draw the radius $O_2I$ parallel to $O_3O_1$, and the tangent line $IL$ at $I$.

Let $q = ZY$ and $p = ZL = HI$

Then by the theory of parallel tangents, §137, the point $I$ is on the chord $PZ$ produced, and it is also on the chord $P'Y$; and we have

$$p = ZL = (R_2 - R_1) \operatorname{vers} \beta . \tag{197}$$

$$q - p = LY = (R_3 - R_2) \operatorname{vers} \alpha \tag{198}$$

and $q$ equals the *sum* of these. But $q = ZY$ is the shortest distance between the inner and outer arcs, and has a constant value independent of $R_2$. If we assume $R_2 = \frac{1}{2}(R_3 + R_1)$ the centre $O_2$ will be at $Q$, and $\alpha = \beta = i$, and $p = \frac{1}{2} q$. Making these substitutions above,

$$q = (R_3 - R_1) \operatorname{vers} i. \tag{199}$$

Also, from the figure,

$$ZY = O_3Y - O_1Z - O_1O_3,$$

or,

$$q = R_3 - R_1 - O_1O_3. \tag{200}$$

In the triangle $ZIY$ we have by Geom. Tab. I. 26,

$$ZI^2 = IY^2 + ZY^2 - 2ZY(ZY - ZL)$$

or

$$ZY^2 - 2ZY.ZL = IY^2 - ZI^2$$

Now,

$$ZI^2 = 4(R_2 - R_1)^2 \sin^2 \tfrac{1}{2}\beta = 2(R_2 - R_1)^2 \text{ vers } \beta$$

$$IY^2 = 4(R_3 - R_2)^2 \sin^2 \tfrac{1}{2}\alpha = 2(R_3 - R_2) \text{ vers } \alpha$$

Hence

$$ZI^2 = 2(R_2 - R_1)\,p \text{ and } IY^2 = 2(R_3 - R_2)\,(q - p)$$

Substituting these values, and solving for $p$, we have

$$p = \frac{q(R_3 - R_2 - \frac{1}{2}q)}{R_3 - R_1 - q} = \frac{q(R_3 - R_2 - \frac{1}{2}q)}{O_1O_3} \tag{201}$$

Also

$$R_2 = (R_3 - \tfrac{1}{2}q) - p \, . \, \frac{O_1O_3}{q} \tag{202}$$

For any other value of $R_2$, we have

$$R_2' = (R_3 - \tfrac{1}{2}q) - p' \frac{O_1O_3}{q}$$

Hence

$$R_2' - R_2 = \frac{O_1O_3}{q}(p - p') \tag{203}$$

which gives the change in $R_2$ for a given change in the value of $p$

Observe that as $p$ diminishes $R_2$ increases and *vice versa.*

Having determined the value of $R_2'$, we find $p'$ by substituting $R_2'$ for $R_2$ in eq. (201); and from eqs. (197) (198) we have

$$\text{vers } \beta' = \frac{p'}{R_2' - R_1} \tag{204}$$

$$\text{vers } \alpha' = \frac{q - p'}{R_3 - R_2'} \tag{205}$$

and the change in the points of compound curvature is found by $(\beta - \beta')$ and $(\alpha' - \alpha)$.

*Remark.*—When $R_2 = \frac{1}{2}(R_3 + R_1)$, $\triangle_2 = 2i$, a minimum, and the long chord $PP'$ is perpendicular to $O_1O_3$. When $R_2$ is greater than this, $\alpha$ is greater than $\beta$, and *vice versa*. Whatever be the value of $R_2$, the long chord $PP'$ always cuts the line $O_1O_3$ produced in the same point $S$, at a distance from $Z$ of

$$ZS = R_1 \text{ vers } i;$$

or from $O_1$ of $\qquad O_1S = R_1 \cos i.$

This item will be found useful in solving the problem graphically.

*Example.*

Let $R_1 = 781.84$ $\quad D_1 = 7° 20'$
" $R_2 = 1375.40$ $\quad D_2 = 4° 10'$ $\quad \triangle_2 = 48°$
" $R_3 = 1910.08$ $\quad D_3 = 3° 00'$
Let $p - p' = 11.30$

| | | | | |
|---|---|---|---|---|
| Eq. (194) | 2 | | | log 0.301030 |
| | $R_3 - R_2$ | 534.68 | | " 2.728094 |
| | $R_2 - R_1$ | 593.56 | | " 2.773465 |
| | $\triangle_2$ | | 48° | log vers 9.519657 |
| | | | | 2) 5.322246 |
| ∴ | $l$ | 458.27 | | log 2.661123 |
| (192) | $R_3 - R_1$ | 1128.24 | | " 3.052402 |
| ∴ | $i$ | | 23° 57′ 55″ | log sin 9.608721 |
| (193) | $i$ | | 23° 57′ 55″ | log cos 9.960847 |
| | $R_3 - R_1$ | | | log 3.052402 |
| ∴ | $O_1O_3$ | 1030.98 | | log * 3.013249 |
| (195) | $R_2 - R_1$ | | | log 2.773465 |
| | $\triangle_2$ | | 48° | log sin 9.871073 |
| | | | | log * 2.644538 |
| ∴ | $\alpha$ | | 25° 19′ 52″ | log sin 9.631289 |
| (196) | $\beta$ | | 22° 40′ 08″ | |
| (203) | $O_1O_3$ | | | log 3.013249 |
| (200) | $q$ | 97.26 | | 1.987934 |
| | $\frac{O_1O_3}{q}$ | | | 1.025315 |
| | $p - p'$ | 11.30 | | log 1.053078 |
| ∴ | $R_2' - R_2$ | 119.78 | | " 2.078393 |
| ∴ | $R_2'$ | 1495.18 (say) 1494 95 for 3° 50′ curve. | | |

| | | | | |
|---|---|---|---|---|
| (201) | $R_3 - R_2' - \frac{1}{2}q$ | 366.50 | | log 2.564074 |
| | $\frac{O_1 O_3}{q}$ | | | " 1.025315 |
| $\therefore$ | $p'$ | 34.57 | | " 1.538759 |
| (197) | $R_2' - R_1$ | 713.11. | | " 2.853157 |
| | $\beta'$ | | 17° 55′ | log vers 8.685602 |
| (198) | $q - p'$ | 62.69 | | log 1.797198 |
| | $R_3 - R_2'$ | 415.13 | | " 2.618184 |
| | $\alpha'$ | | 31° 54′ | log vers 9.179014 |
| | $\Delta_2'$ | | 49° 49′ | |

$$\alpha' - \alpha = 6° 34', \therefore P'P''' = 218.89$$
$$\beta - \beta' = 4° 45' \therefore PP'' = 64.77$$

The practical difficulty in changing the middle arc of three centred curves lies in the difference of measurement that ensues. Thus, in the last problem, although the total central angle is the same, the new curve is 6.56 feet shorter than the original, making a fractional station at $P''$. If the change is made during the location, it is well to re-run the last arc from $P'''$ to the tangent following, so as to eliminate the fractional station from the curve.

Instead of the solution given above on this page we may obtain $\Delta_2'$ by

$$\text{vers } \Delta_2' = \frac{l^2}{2(R_3 - R_2')(R_2' - R_1)}$$

derived from eq. (194); and then find $\alpha'$ by eq. (195).

*Graphical Solution.*—On any well drawn plan of the curves we may try various curve templets touching the first and third curves until we find a new middle curve to suit the required conditions.

We then take the value of its radius $R_2'$ from Table IV, subtract from $R_3$ and $R_1$ and with the differences, from the centres $O_3$ and $O_1$, draw short arcs to intersect, thus locating $O_2'$. We then join this point with $O_1$ and $O_3$ and produce the lines to intercept the given curves in $P''$ and $P'''$. Finally draw the long chord $P''P'''$, which must pass through the point $S$. The angles may then be scaled, but are better computed as before.

## CHAPTER VII.

### TURNOUTS.

**179.** A turnout is a curved track by which a car may leave the main track for another. At the point where the outer rail of the turnout crosses the rail of the main track a *frog* is introduced which allows the flanges of the wheels to pass the rails. A frog consists essentially of a solid block of iron or steel having two straight channels crossing each other on the upper surface, in which the flanges of the wheels pass. The triangular portion of the upper surface formed by the channels is called the *tongue* of the frog, and the angle which the channels make with each other is called the *frog-angle*. Every railroad is provided with a set of frogs of different angles, from which may be selected one best adapted to any particular case.

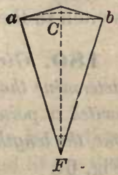

FIG. 60.

The frogs may be designated by their angles, but it is customary to designate them by numbers expressing the ratio of the bisecting line $FC$ of the tongue to the base line $ab$, Fig. 60. Observe that $F$ is at the intersection of the edges produced, and not at the blunt point of the tongue.

In the triangle $aFC$,

$$\frac{FC}{aC} = \cot \tfrac{1}{2}\, aFb$$

and if we let $n =$ the number of the frog, and $F =$ the frog angle, then

$$n = \frac{FC}{ab} = \frac{FC}{2aC} = \tfrac{1}{2}\cot \tfrac{1}{2}F \qquad (206)$$

On some roads, however, the frogs are numbered arbitrarily, or according to their length in feet, while on others they are designated by letters of the alphabet. In any case the true number ($n$) of a frog may be determined by the above formula.

The first rail of the turnout is common to both tracks, and is called the *switch-rail.* It has one end free, so as to be shifted from one track to the other as required; the free end, $D$ (Fig. 61), is called the *point of switch.* The tangent point of the turnout, at $A$, is called the *heel of switch,* and the distance, $AD$, is the *length of switch.* The switch-rail should be several feet longer than $AD$, and the excess be spiked down in the line of the main track back of the point $A$. Then if the point $D$ is thrown over to meet the rail of the turnout at $K$, the switch rail is sprung into an arc, which coincides with the arc of the turnout, provided that the length of switch $AD$ has been properly taken. The distance $DK$ through which the point moves is called the *throw* of the switch. It varies on different roads from 4½ to 6 inches, but is usually made about 5 inches, or 0.42 feet. A turnout should be a simple curve from the heel of the switch to the point of the frog.

**180.** *Given: a main track, straight, and a frog angle* $F$, *to determine the distance* **BF,** *on the main track from the heel of switch to point of frog, the radius,* **r,** *of the centre line of the turnout, the length of chord* **af,** *and the proper length of switch* **AD.** Fig. 61.

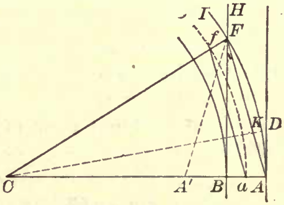


FIG. 61.

Let $C$ be the centre of the turnout.

" $F =$ the frog angle, $HFI = FCB$.

" $g =$ the gauge of track $AB$.

" $r =$ radius, $aC = fC$.

" $DK =$ the throw of switch.

Then the radius of the gauge side of the outer rail is $(r + \frac{1}{2}g)$, and we have

$$AB = FC \,.\, \text{vers}\, FCB$$

or,

$$g = (r + \tfrac{1}{2}g)\ \text{vers F}$$

whence

$$(r + \tfrac{1}{2}g) = \frac{g}{\text{vers}\ F} \tag{207}$$

The angle $AFB = \frac{1}{2}F$

and $BF = AB \cot AFB = g \,.\, \cot \frac{1}{2}F$ (208)

Again, in the triangle $FCB$

$$BF = FC \,.\, \sin FCB = (r + \tfrac{1}{2}g) \sin F \tag{209}$$

The chord $af$ is evidently

$$af = 2r \sin \tfrac{1}{2}F \tag{210}$$

Similar to eq. (207), we have

$$\text{vers}\, ACD = \frac{DK}{KC} = \frac{DK}{r + \frac{1}{2}g}$$

But since the inside rail has the same throw, while its radius is $(r - \frac{1}{2}g)$, we may, if convenient, drop the $\frac{1}{2}g$, and hence the length of switch is

$$AD = r \,.\, \sin ACD \tag{211}$$

The degree of curve corresponding to $r$ is found from Table IV., or by eq. (17), and the centre line of the turnout may be located by transit deflections from the tangent point $a$, using chords of 20 or 25 feet + the correction found in §§ 106, 107; or the deflection for a 20-foot chord may be calculated at once by

$$\sin (\tfrac{1}{2}d_{20}) = \frac{10}{r} \tag{212}$$

**181.** Simple as these formulæ are, they may be rendered still more convenient by introducing the **number of the frog,** $n$. By eq. (206) we have $\cot \frac{1}{2}F = 2n$, which substituted in eq. (208) gives

$$BF = 2gn \tag{213}$$

Drawing the chord $AF$ to the outer rail,

$$AF = \sqrt{AB^2 + BF^2} = g\sqrt{1 + 4n^2} \tag{214}$$

Make $BA' = AB$ and join $FA'$; then by similar triangles, $AA'F$ and $AFC$,

$$AA' : AF :: AF : FC$$

whence

$$FC = \frac{AF^2}{AA'}$$

or $$(r + \tfrac{1}{2}g) = \tfrac{1}{2}g\,(1 + 4n^2) \qquad (215)$$

whence $$r = 2gn^2 = BF \,.\, n \qquad (216)$$

The chord $af$ to the arc of the centre line is to $AF$ as $r$ is to $(r + \frac{1}{2}g)$; hence $af = \frac{AF \,.\, r}{r + \frac{1}{2}g}$, and substituting values from eqs. (214) (215) we have

$$af = \frac{2r}{\sqrt{1 + 4n^2}} \qquad (217)$$

Assuming that, for small angles, the tangent offsets vary as the squares of their distances from the tangent point, which will lead to no material error in this case;

$$AB : DK :: BF^2 : AD^2$$

whence $$AD = BF\sqrt{\frac{DK}{AB}}$$

or $$AD = \sqrt{4n^2\,g \,.\, DK} = \sqrt{2r \,.\, DK} \qquad (218)$$

It is not necessary to determine the degree of curve in order to locate the turnout, for having fixed the position of $BF$, the position of $af$ is found by laying off $Ba$, and $Ff$, each equal to $\frac{1}{2}g$. Whatever be the length of the chord $af$, found by eq. (217) or (210), its middle ordinate is always $\frac{1}{4}g$, and the ordinates at the quarter points, $\frac{3}{4} \,.\, \frac{1}{4}g = \frac{3}{16}g$. Thus for the standard gauge of 4.708 the middle ordinate is 1.177, and the side ordinates 0.883.

By the preceding formulæ Table XI. has been calculated, which gives the required parts of a turnout for various frogs when the gauge is 4 feet $8\frac{1}{2}$ inches and the throw 5 inches; also for a gauge of 3 feet and throw of 4 inches. For any other *throw*, only $AD$ must be calculated. For a different gauge the engineer will do well to construct a similar table, adapted to the frogs used on the road.

In the table the frog angle is given to seconds, in order that the results may agree, whether found by equations in § 180 or § 181; but in practice the nearest minute is sufficiently exact. The frogs most used for single turnouts are those from No. 7 to No. 9, inclusive.

**182.** *In case of a* **double turnout** *from the same switch* three frogs are required, as at $F, F'$ and $F''$, Fig. 62., and the

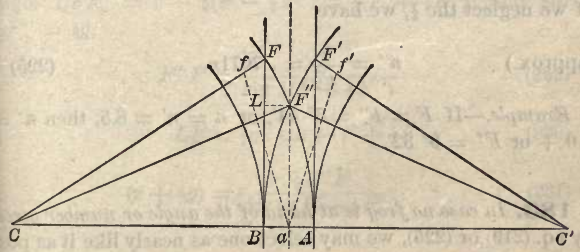


FIG. 62.

switch is called a *three-throw switch*, because its point takes three positions. The frogs $F$ and $F'$ are usually alike, and placed exactly opposite each other in the main track. The other frog $F''$ is placed on the centre line of the main track. Its angle $F''$ and its distance from $a$ are now to be determined in terms of $F$.

In the figure we have vers $F''Ca = \frac{Aa}{F''C}$ or

$$\text{vers } \tfrac{1}{2}F'' = \frac{g}{2(r + \frac{1}{2}g)} \qquad (219)$$

The distance $$aF'' = (r + \tfrac{1}{2}g) \sin \tfrac{1}{2}F'' \qquad (220)$$

also $$aF'' = r \,.\, \tan \tfrac{1}{2}F'' \qquad (221)$$

All the parts of the turnout required to locate the frogs $F$ and $F''$ are calculated by the formulæ in the preceding sections, or are taken from Table XI.

If we let $n''$ = the number of the frog $F''$, then by eq. (206) $\tan \frac{1}{2}F'' = \frac{1}{2n''}$, which substituted in eq. (221) gives

$$aF'' = \frac{r}{2n''} \qquad (222)$$

Also, in the triangle $aF''C$,

$$aF'' = \sqrt{(r + \tfrac{1}{2}g)^2 - r^2} = \sqrt{g(r + \tfrac{1}{4}g)} \qquad (223)$$

Equating these and replacing $r$ by $2gn^2$, we obtain

$$n'' = \sqrt{\frac{n^4}{2n^2 + \frac{1}{4}}} \qquad (224)$$

If we neglect the $\frac{1}{4}$, we have

$$\text{(approx.)} \qquad n'' = \frac{n}{\sqrt{2}} = .7071n \qquad (225)$$

*Example.*—If $F = F' = 6° \ 44'$, or $n = n' = 8.5$, then $n'' =$ 6.0 + or $F'' = 9° \ 32'$.

**183.** *In case no frog is at hand of the angle or number given* by eq. (219) or (225), we may select one as nearly like it as possible, and locate the turnout as a **compound curve,** provided that $F''$ is less than $2F$. Fig. 63.

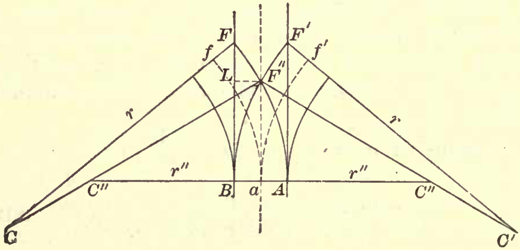


FIG. 63.

Let $r'' = C''a$, and $r = r' = Cf = Cf'$

Then analogous to the equations of § 180,

$$(r'' + \tfrac{1}{2}g) = \frac{\frac{1}{2}g}{\text{vers } \frac{1}{2}F''} \qquad (226)$$

$$\therefore r'' = \frac{\frac{1}{2}g}{\text{exsec } \frac{1}{2}F''} \qquad (227)$$

$$aF'' = (r'' + \tfrac{1}{2}g) \sin \tfrac{1}{2}F'' = r'' \tan \tfrac{1}{2}F'' \qquad (228)$$

The length of the switch, by eq. (218), is

$$AD = \sqrt{2r''\,DK}$$

The curvature of the rail between the frogs $F''$ and $F$ is $F''CF = (F - \frac{1}{2}F'')$.

Draw the chord $F''F$ and the perpendicular $F''L$; then the angle $LFF'' = F - \frac{1}{2}(F - \frac{1}{2}F'') = \frac{1}{2}(F + \frac{1}{2}F'')$; and since $LF'' = \frac{1}{2}g$,

$$\therefore\ F''F = \frac{\frac{1}{2}g}{\sin\frac{1}{2}(F + \frac{1}{2}F'')} \tag{229}$$

$$LF = \tfrac{1}{2}g\ .\ \cot\tfrac{1}{2}\,(F + \tfrac{1}{2}F'') \tag{230}$$

$$(r + \tfrac{1}{2}g) = \frac{\frac{1}{2}F''F}{\sin\frac{1}{2}\,(F - \frac{1}{2}F'')} \tag{231}$$

*Example.*—Let $F = 6°\ 44'$ $F'' = 10°\ 24'$

| | | | | |
|---|---|---|---|---|
| Eq. (226) | $\frac{1}{2}g$ | 2.354 | | log 0.371806 |
| | $\frac{1}{2}F''$ | | 5° 12′ | log exs 7.616224 |
| ∴ | $r''$ | 569.616 | | 2.755582 |
| Eq. (228) | $\frac{1}{2}F''$ | | 5° 12′ | log tan 8.959075 |
| ∴ | $aF''$ | 51.839 | | 1.714657 |
| Eq. (229) | $\frac{1}{2}g$ | 2.354 | | log 0.371806 |
| | $\frac{1}{2}(F + \frac{1}{2}F'')$ | | 5° 58′ | log sin 9.016824 |
| ∴ | $F''F$ | 22.645 | | 1.354982 |
| Eq. (231) | $\frac{1}{2}(F - \frac{1}{2}F'')$ | | 0° 46′ | log sin 8.126471 |
| | $2(r + \frac{1}{2}g)$ | 1692.432 | | 3.228511 |
| ∴ | $r$ | 843.862 | | |

When $n'' > .707n$, $r$ will be less than $r''$. Should $F'$ not equal $F$, ($F''$ being given), then $r'$ and $L'F'$ must be calculated also, by substituting $F'$ for $F$ in eqs. (230) and (231).

**184.** *From the same switch in a straight track it is required to lay* **two turnouts on the same side.** Fig. 64.

If we assume $F' = F$, and that these two frogs shall be opposite each other, we calculate all the distances of the first turnout for the angle $F$ (or number $n$) by § 180, 181, whence we have the radius $r = Ca$.

Let $r' = C'a$, the radius of the centre line of the second turnout. The angle $ACF = F$, and since $F' = F$, the angle $CF'C' = F$, and the triangle $CF'C'$ is isosceles, and $C'F' = C'C$. But $C'F' = C'A = \frac{1}{2}CA$.

or
$$(r' + \tfrac{1}{2}g) = \tfrac{1}{2}(r + \tfrac{1}{2}g) \tag{232}$$

$\therefore$
$$r' = \tfrac{1}{2}(r - \tfrac{1}{2}g) \tag{233}$$

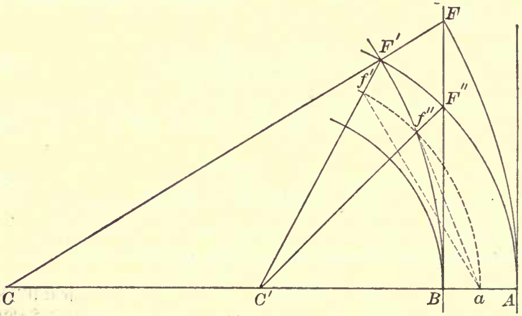

FIG. 64.

To calculate the remaining frog at $F''$, we have from eq. (207)

$$\text{vers } F'' = \frac{g}{r' + \frac{1}{2}g} \tag{234}$$

or from eq. (216)

$$n'' = \sqrt{\frac{r'}{2g}} \tag{235}$$

$$BF'' = (r' + \tfrac{1}{2}g) \sin F = 2gn'' \tag{236}$$

$$af'' = 2r' \sin \tfrac{1}{2}F'' = \frac{2r'}{\sqrt{1 + 4n''^2}} \tag{237}$$

and since $AC'F' = 2F$,

$$af' = 2r' \sin F \tag{238}$$

The length of switch may be calculated by either $r$ or $r'$, since for $r'$, which is about $\frac{1}{2}r$, the throw of switch is *double*, thus giving practically identical results.

If we compare the values of $F''$ as obtained by eqs. (234) and (219), we shall find them almost identical for given values of $F$ and $g$; and since this may also be proved analytically by assuming that vers $\frac{1}{2}F'' = \frac{1}{4}$ vers $F''$, which is very nearly true for ordinary values of $F''$, we conclude that a set of frogs ($F = F'$, and $F''$) which is adapted to a double turnout in opposite directions from a straight line (as in Fig. 62) is also adapted to a double turnout on one side (as in Fig. 64), the curves being simple curves in every case. But this being true, the set is also adapted to a double turnout in opposite directions *from any curved track* the radius of which is not less than $r$ as given for $F$, since any such case is intermediate between the two cases named. When, therefore, a certain frog, F, is adopted for general use on any road, another frog should also be adopted, whose angle, F'', is determined by eq. (219), or whose number $n$ is determined by eq. (225). Thus, if $F = 6° 44'$, or $n = 8\frac{1}{2}$, then $F''$ should be $9° 32'$, or $n'' = 6$.

**185.** *In case no frog is at hand of the angle or number given by eqs.* (234) (235), we may select one as near the same angle as possible, and, calling this $F''$, calculate the distance $BF''$ and the radius $C''F''$ (Fig. 65) as for a single turnout; § 180.

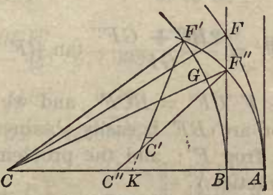


FIG. 65.

Then assuming any other frog $F'$, whether equal to $F$ or not, it is required to find the chord $F''F'$, and the radius $C'F'$ of the arc $F''F'$. The point $F'$ may fall either side of the radius $CF$, according to the values given to $F''$ and $F'$.

**a.** *In case $F'$ falls beyond the radius CF*, we will assume *first*, that the entire rail from $B$ to $F'$ is laid with *the same radius BC*, and centre $C$. (This investigation also applies to the case when $F'$ falls between $B$ and the line $CF$.)

In the diagram (Fig. 65) draw $CF''$. We then have

$$\tan BCF'' = \frac{BF''}{BC} = \frac{BF''}{r - \frac{1}{2}g} \tag{239}$$

and

$$GF'' = (r - \tfrac{1}{2}g) \text{ exsec } BCF'' \tag{240}$$

In the triangle $F''CF'$,

$$F''C - F'C : F''C + F'C :: \tan \tfrac{1}{2}(F''F'C - F'F''C) : \cot F''CF'$$

Now, since $C'F'C = F'$, and $BC''F'' = F''$,

$$\therefore \quad F''F'C = F''F'C' + F'$$

and

$$F'F''C = F'F''C'' - C''F''C = F''F'C' - (F'' - BCF'')$$

Letting $\qquad U = C''F''C = (F'' - BCF'')$

and subtracting, we have

$$F''F'C - F'F''C = F' + U$$

Hence the above proportion may be written

$$GF'' : 2BC + GF'' :: \tan \tfrac{1}{2}(F' + U) : \cot \tfrac{1}{2}F''CF'$$

whence

$$\cot \tfrac{1}{2}F''CF' = \frac{2BC + GF''}{GF''} \tan \tfrac{1}{2}(F' + U) \tag{241}$$

(Since $BCF'' + F''CF' = BCF'$, and we know the radius $BC$, the chord or arc $BF'$ is easily obtained, which fixes the position of the frog $F'$; and the problem may end here, frequently, in practice.)

Now in the same triangle $F''CF'$, *the half sum* of $F''F'C$ and $F'F''C$ is $90° - \frac{1}{2}F''CF'$; while, as we have just seen, the *half difference* is $\frac{1}{2}(F' + U)$; and by subtracting we have the less, or

$$F'F''C = 90° - \tfrac{1}{2}(F' + U + F''CF') \tag{242}$$

Now $$F''F' = \frac{F'C \sin F''CF'}{\sin F'F''C}$$

or

$$F''F' = \frac{BC \,.\, \sin F''CF'}{\cos \frac{1}{2}(F' + U + F''CF')} \tag{243}$$

*To find the angle* $F''C'F'$; produce the line $F'C'$ in the diagram to intersect the line $BC$ at $K$. Then the two triangles $KC''C'$ and $KCF'$ have the angle $K$ common, and the sum of the other angles will be equal; that is,

$$KC''C' + C''C'K = KCF' + CF'K$$

or

$$F'' + F''C'F' = BCF' + F'$$

and since

$$BCF' = BCF'' + F''CF'$$

$$\therefore\ F''C'F' = F''CF' + F' - U \qquad (244)$$

If we denote the radius $F'C'$ by $r' + \frac{1}{2}g$

$$r' + \tfrac{1}{2}g = \frac{\frac{1}{2}F''F'}{\sin \frac{1}{2}F''C'F'} \qquad (245)$$

*Example.*—Given: the three frogs $F = 6^\circ\ 43'\ 59''$, $F' = 6^\circ\ 01'\ 32''$, and $F'' = 8^\circ\ 47'\ 51''$ to lay a double turnout on one side of a straight track. Fig. 65.

By Tab. XI. $BF = 80.036$ $r = 680.306$ $AD = 23.82$
$BF'' = 61.204$ $r'' = 397.826$

| | | | | | |
|---|---|---|---|---|---|
| Eq. (239) | $BF''$ | 61.204 | | log | 1.786779 |
| | $(r - \frac{1}{2}g)$ | 677.952 | | " | 2.831199 |
| ∴ | $BCF''$ | | 5° 09′ 38″ | log tan | 8.955580 |
| Eq. (240) | $BCF''$ | | 5° 09′ 38″ | log exsec | 7.609587 |
| | $(r - \frac{1}{2}g)$ | 677.952 | | log | 2.831199 |
| | $GF''$ | 2.760 | | " | 0.440786 |
| Eq. (241) | $(2BC + GF'')$ | 1358.664 | | " | 3.133112 |
| | | | ($U$ = 3° 38′ 13″) | | 2.692326 |
| | $\frac{1}{2}(F' + U)$ | | 4° 49′ 52″.5 | log tan | 8.926968 |
| ∴ | $\frac{1}{2}(F''CF')$ | | 1° 22′ 35″ | " cot | 1.619294 |
| Eq. (243) | $F''CF'$ | | 2° 45′ 10″ | " sin | 8.681481 |
| | $r - \frac{1}{2}g$ | 677.952 | | | 2.831199 |
| | | | | | 1.512680 |
| | $\frac{1}{2}(F' + U + F''CF')$ | | 6° 12′ 27″.5 | " cos | 9.997446 |
| ∴ | $F''F'$ | 32.752 | | | 1.515234 |
| Eq. (245) | $\frac{1}{2}F''C'F'$ | | 2° 34′ 14″.5 | " sin | 8.651781 |
| ∴ | $2(r' + \frac{1}{2}g)$ | 730.219 | | | 2.863453 |
| | $r'$ | 362.755 | | | |

**b.** *We assume, secondly, that the middle track is straight beyond F, and tangent to the curve at F.* Fig. 66.

Then whenever the value of $F''$ is *less* than that given by eq. (234), the arc $AF''$, produced with the same radius $AC''$, will intersect the straight rail $HF'$ at some point $F'$, and the frog angles $F$ and $F'$ will be equal.

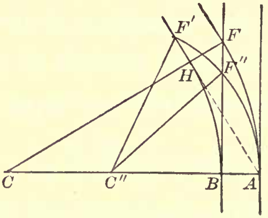


FIG. 66.

For the straight rail $HF'$ produced backwards, passes through the point $A$, making an angle $F$ with the main track, since the triangles $CBF$ and $CHA$ are equal, and $AH = BF$. Now any circle, tangent to the main rail at $A$, will intersect the line $AH$ in some point $F'$, and since $AF'$ is the chord of the arc, the angle at $F'$ equals the angle at $A$, which is $F$. Hence $F = F'$; and the angle $AC''F' = 2F$.

The length of the chord $AF'$ is

$$AF' = 2AC'' \sin F \tag{246}$$

$$\text{The chord } F''F' = 2F''C'' \sin \tfrac{1}{2}(F''C''F')$$

$$= 2AC'' \sin \tfrac{1}{2}(2F - F'')$$

Hence,
$$F''F' = 2(r'' + \tfrac{1}{2}g) \sin(F - \tfrac{1}{2}F'') \tag{247}$$

*Example.*—Let $F' = F = 6° 43' 59''$ and $F'' = 8° 47' 51''$

| | | | |
|---|---|---|---|
| By Table XI. $r'' = 397.826$ | | | |
| Eq. (247) $2(r'' + \frac{1}{2}g) = 800.360$ | | log | 2.903285 |
| $F - \frac{1}{2}F''$ | $2° 20' 03''.5$ | log sin | 8.609915 |
| ∴ $F''F'$ 32.60 | | | 1.513200 |

If the frog $F'$ is required to be different from $F$, then the inside curve must be compounded at $F''$, giving other values to the length and radius of the arc $F''F'$.

**c.** We assume, *thirdly*, that the curve of the *middle track is reversed at F*. Fig. 67.

In the diagram, let $Q$ be the centre of the reversed portion, and $F'$ the proper position of the frog $F'$, and $C'$ the centre of the required arc $F''F'$. Then $Q$ is on the radial line $CF$, produced, and $C'$ is on the radial line $F''C''$ produced. Join $FQ$ and $F'Q$, and produce $C''F''$ to intersect these lines in $L$ and $M$ respectively. Also join $F''Q$, and denote the angle $LF''Q$ by $U$ and the angle $F'QF''$ by $Q$.

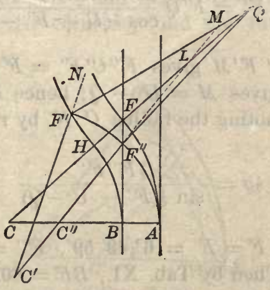


FIG. 67.

In the triangle $FF''Q$ we know $F''F = BF - BF''$, and the side $FQ$ is given; and the included angle $F''FQ = 90° + F$. Hence we may calculate (Tab. II. 25) the angle $F''QF$ and the side $F''Q$.

The triangle $CC''L$ gives the angle at $L = F'' - F$; and the triangle $F''LQ$ gives $LF''Q = L - F''QF$

$$\therefore \quad U = F'' - F - F''QF \tag{248}$$

In the triangle $F'QF''$ we have

$$F'Q - F''Q : F'Q + F''Q :: \tan \tfrac{1}{2}(F'F''Q - F''F'Q)$$
$$: \cot \tfrac{1}{2}(F'QF'')$$

But $F'F''Q = F'F''L + U$ and $F''F'Q = F''F'N - F'$, and since $F''F'N = F'F''L$, we have by subtraction,

$$F'F''Q - F''F'Q = U + F'$$

Hence $$\cot \tfrac{1}{2}Q = \frac{F'Q + F''Q}{F'Q - F''Q} \tan \tfrac{1}{2}(U + F') \tag{249}$$

(Now the angle $FQF' = Q - F''QF$, and is subtended by the chord $HF'$, which is therefore easily found, and serves to locate the frog $F'$, and frequently this is all that will be required.)

In the triangle $F''QF'$, the half sum of $QF''F'$ and $QF'F''$ is $90° - \frac{1}{2}Q$, while, as we have just seen, the *half difference* is $\frac{1}{2}(U + F')$; hence by adding, we have the greater, or

$$QF''F' = 90° + \tfrac{1}{2}(U + F' - Q)$$

$$\therefore\ F''F' = F'Q\,\frac{\sin Q}{\cos \frac{1}{2}(U + F' - Q)} \qquad (250)$$

The triangle $C'F'M$ gives $F''C'F' = F' - M$, while the triangle $F''MQ$ gives $M = U + Q$; hence $F''C'F' = F' - (U + Q)$; and denoting the radius $C'F'$ by $r' + \frac{1}{2}g$,

$$r' + \tfrac{1}{2}g = \frac{\frac{1}{2}F''F'}{\sin \frac{1}{2}(F' - U - Q)} \qquad (251)$$

*Example.*—Let $F = F' = 6° 43' 59''$, $F'' = 8° 47' 51''$, and $FQ = 953.012$. Then by Tab. XI., $BF = 80.036$ and $BF'' = 61.204$; hence $F''F = 18.832$; and the included angle is $96° 43' 59''$.

Solving the triangle $FF''Q$ we find $F''QF = 1° 07' 18''$, $FF''Q = 82° 08' 43''$, and $F''Q = 955.402$. Now $F'Q = FQ + g = 957.720$.

| | | | | | |
|---|---|---|---|---|---|
| (249) | $F'Q + F''Q$ | 1913.122 | | log | 3.281743 |
| | $F'Q - F''Q$ | 2.318 | | " | 0.365113 |
| | | | ($U$ 0° 56′ 34″) | " | 2.916630 |
| | $\frac{1}{2}(U + F')$ | | 3° 50′ 16″.5 | log tan | 8.826231 |
| ∴ | $\frac{1}{2}Q$ | | 1° 02′ 08″.4 | " cot | 1.742861 |
| (250) | $Q$ | | 2° 04′ 16″.8 | " sin | 8.558033 |
| | $\frac{1}{2}(U + F' - Q)$ | | 2° 48′ 08″.1 | " cos | 9.999480 |
| | | | | | 8.558553 |
| | $F'Q$ | 957.720 | | log | 2.981239 |
| ∴ | $F''F'$ | 34.633 | | | 1.539892 |
| (251) | $\frac{1}{2}(F' - U - Q)$ | | 1° 51′ 34″.1 | log sin | 8.511191 |
| | $2(r' + \frac{1}{2}g)$ | 1068.32 | | | 3.028701 |
| ∴ | $r'$ | 531.81 | | | |

**186.** *Given: a main track, curved, and a frog-angle F, to locate a turnout on the* **inside** *of the curve.* Fig. 68.

Let $R = Oa$ = radius of main track.

" $r = Ca$ = radius of turnout.

" $F = CFO$ = the frog angle.

In the diagram draw the chord $AF$ and produce it to intersect the outer rail at $G$; and draw $FO$ and $GO$. Since the chords $AF$ and $AG$ coincide, and the radii $AC$ and $AO$

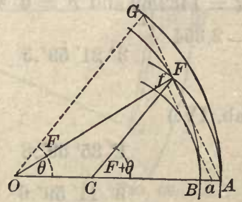


FIG. 68.

coincide, the chords subtend equal angles at $C$ and $O$ respectively, and $GO$ is parallel to $FC$. (See § 137.) Hence, $FOG = CFO = F$. Let $\theta$ = the angle $FOA$.

In the triangle $FOA$, $\theta = GFO - FAO = GFO - FGO$; and in the triangle $GFO$, $GO + FO : GO - FO :: \tan \frac{1}{2}(GFO + FGO) : \tan \frac{1}{2}(GFO - FGO)$, or $2R : g :: \cot \frac{1}{2}F : \tan \frac{1}{2}\theta$

$$\therefore \tan \tfrac{1}{2}\theta = \frac{g}{2R} \cot \tfrac{1}{2}F = \frac{gn}{R} \qquad (252)$$

In the triangle $CFO$,

$$(r + \tfrac{1}{2}g) = (R - \tfrac{1}{2}g) \frac{\sin \theta}{\sin (F + \theta)} \qquad (253)$$

In the triangle $BOF$,

$$BF = 2(R - \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta \qquad (254)$$

In the triangle $aCf$,

$$af = 2r \sin \tfrac{1}{2}(F + \theta) \qquad (255)$$

*The length of switch AD*, for a given throw $DK$, may be found thus: from Table IV. take the tangent offsets, $t$ and $t'$, corresponding to $R$ and $r$ respectively, and assuming that the offsets may vary as the squares of their distances from the tangent point, we have

$$t - t' : DK :: (100)^2 : AD^2$$

$$\therefore AD = \sqrt{\frac{10000\ DK}{t - t'}} \qquad (256)$$

This result is practically the same as that found for length of switch in a turnout from a straight line with the same frog, when $R$ is large.

*Example.*—Let $R = 1432.69$ and $F = 6° 43' 59''$.

| | | | | |
|---|---|---|---|---|
| Eq. (252) | $\frac{1}{2}g$ | 2.354 | | log 0.371806 |
| | $\frac{1}{2}F$ | | 3° 21′ 59″.5 | log cot 1.230440 |
| | | | | log 1.602246 |
| | $R$ (Tab. IV.) | | | " 3.156151 |
| ∴ | $\frac{1}{2}\theta$ | | 1° 35′ 59″.8 | log tan 8.446095 |
| Eq. (254) | $\theta$ | | 3° 11′ 59″.6 | " sin 8.746786 |
| | $F + \theta$ | | 9° 55′ 58″.6 | " " 9.236778 |
| | | | | 9.510008 |
| | $R - \frac{1}{2}g$ | 1430.336 | | 3.155438 |
| ∴ | $r + \frac{1}{2}g$ | 462.856 | | 2.665446 |
| | $r$ | 460.502 | | |
| (254) | 2 | | | log 0.301030 |
| | $(R - \frac{1}{2}g)$ | 1430.336 | | " 3.155438 |
| | $\frac{1}{2}\theta$ | | 1° 35′ 59″.8 | log sin 8.445924 |
| ∴ | $BF$ | 79.872 | | log 1.902392 |
| (255) | $2r$ | 921.004 | | " 2.964262 |
| | $\frac{1}{2}(F + \theta)$ | | 4° 57′ 59″.3 | log sin 8.937381 |
| ∴ | $af$ | 79.734 | | log 1.901643 |

The values of $BF$ and $af$ are found to be so nearly identical in this case with those determined in case of a turnout from a straight line, that the values given in Table XI may be used at once for ordinary values of $R$; and the *degree of curve* of the turnout in this problem is *approximately* the *sum* of the degree of curve of the main track and the degree of curve given in Table XI. opposite $F$. Thus, in the example $4° + 8° 26' = 12° 26'$ ∴ $r = 461.7$ nearly.

**187.** *Given: a main track, curved, and a frog-angle $F$, to locate a turnout on the* **outside** *of the curve.* Fig. 69.

In the diagram draw the chord $AF$, and produce it to meet the inner rail at $G$; and draw $FO$ and $GO$. The triangles $CAF$ and $OAG$ are both isosceles, and have the angles at $A$ equal; hence they are similar, and $FCA = AOG$. Hence $FOG = HFO = F$. Let $R = Oa$, $r = Ca$, and $\theta = FOA$.

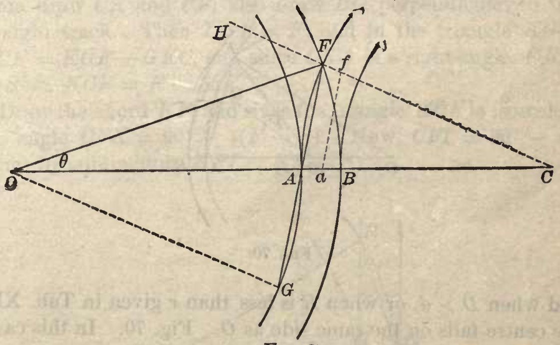


FIG. 69.

In the triangle $FOA$, $\theta = OAG - AFO = FGO - GFO$; and in the triangle $FOG$; $FO + GO : FO - GO ::$ tan $\frac{1}{2}(FGO + GFO)$ : tan $\frac{1}{2}(FGO - GFO)$, or $2R : g ::$ cot $\frac{1}{2}F$ : tan $\frac{1}{2}\theta$

$$\therefore \tan \tfrac{1}{2}\theta = \frac{g}{2R} \cot \tfrac{1}{2}F = \frac{gn}{R} \qquad (257)$$

which is identical with (252).

In the triangle $CFO$

$$(r + \tfrac{1}{2}g) = (R + \tfrac{1}{2}g) \frac{\sin \theta}{\sin (F - \theta)} \qquad (258)$$

In the triangle $BOF$,

$$BF = 2(R + \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta \qquad (259)$$

In the triangle $aCf$,

$$af = 2r \,.\, \sin \tfrac{1}{2}(F - \theta) \qquad (260)$$

For a given throw, the length of switch will be

$$AD = \sqrt{\frac{10000\ DK}{t + t'}} \qquad (261)$$

in which $t$ and $t'$ are the tangent offsets (Tab. IV.) corresponding to $R$ and $r$.

In this problem, as in the preceding, we may, for ordinary values of $R$, assume the values for $BF$ and $af$ given in Tab. XI. The *degree of curve* of this turnout is, *approximately*, $d - D$, taking $d$ from Tab. XI. and $D$ from Tab. IV. corresponding to $R$. Should $D = d$, this turnout becomes a straight line;

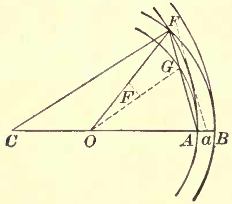


FIG. 70.

and when $D > d$, or when $R$ is less than $r$ given in Tab. XI., the centre falls on the same side as $O$. Fig. 70. In this case, using the same notation, $\frac{1}{2}\theta$ is given by eq. (257).

$$(r - \tfrac{1}{2}g) = (R + \tfrac{1}{2}g)\frac{\sin\theta}{\sin(\theta - F)} \qquad (262)$$

Eq. (259) $$BF = 2(R + \tfrac{1}{2}g)\sin\tfrac{1}{2}\theta$$

$$af = 2r\sin\tfrac{1}{2}(\theta - F) \qquad (263)$$

**188. A tongue-switch** is a short, stiff switch which, when moved, revolves at the heel as on a pivot. When it is thrown over to the turnout track, it makes an abrupt angle with the main track, called the *switch angle;* but in this position it should be tangent to the turnout curve. The use of this switch is generally confined to yards and warehouses, where but little space can be afforded, and where the motion of the cars is always slow.

**189.** *Given: a straight track, a frog-angle* **F**, *and the length and throw of a* **tongue-switch,** *to locate the turnout.* Fig. 71.

Let $AD$ be the length, and $DK$ the throw of switch, and let $S$ denote the switch-angle $DAK$.

Then $$\sin S = \frac{DK}{AD} \text{ or } S^\circ = 57^\circ.3\,\frac{DK}{AD} \qquad (264)$$

(Compare § 86.)

Let $C$ be the centre of the required turnout, and in the diagram draw $CK$ and $CF$; also draw $DG$ perpendicular to the straight track. Then $DGF = F$; and in the triangle $KGC$, $KCF = KGF - GKC$, and since $CKA$ is a right-angle, $GKC = S \therefore KCF = F - S$.

Draw the chord $KF$, and since the triangle $KCF$ is isosceles, the angle $CFK = 90^\circ - \frac{1}{2}(F - S)$. Now, $CFI = 90^\circ - F$; hence by subtraction, $KFI = \frac{1}{2}(F + S)$.

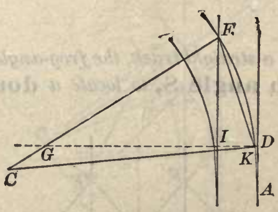


FIG. 71.

If $g$ denote the gauge, we know $KI = g - DK$; and in the right-angled triangle $KIF$, we have

$$IF = KI \,.\, \cot \tfrac{1}{2}(F + S) \qquad (265)$$

$$KF = \frac{KI}{\sin \frac{1}{2}(F + S)} \qquad (266)$$

$$r + \tfrac{1}{2}g = \frac{\frac{1}{2}KF}{\sin \frac{1}{2}(F - S)} \qquad (267)$$

These equations are analogous to eqs. (229) (230) (231).

**190.** *Given: a* **double turnout** *with* **tongue-switch,** *from a straight track; to find the angle, $F''$, of the middle frog.*

Assuming $F' = F$ calculate $(r + \frac{1}{2}g)$ by the last equations. Since the rails of the turnouts intersect on the centre line of the straight track, as in Fig 63; if we substitute the value of $F'' F''$, eq. (229) in eq. (231), we have

$$(r + \tfrac{1}{2}g) = \frac{\tfrac{1}{2}g}{2 \sin \tfrac{1}{2}(F + \tfrac{1}{2}F'') \sin \tfrac{1}{2}(F - \tfrac{1}{2}F'')}$$

and by Trig. Table II.

$$r + \tfrac{1}{2}g = \frac{\tfrac{1}{2}g}{\cos \tfrac{1}{2}F'' - \cos F}$$

whence $$\cos \tfrac{1}{2}F'' = \cos F + \frac{\tfrac{1}{2}g}{(r + \tfrac{1}{2}g)} \qquad (268)$$

If the angle of the middle frog to be used does not agree with $F''$ found by the last equation, the turnout will be compounded at $F''$.

**191.** *Given: a straight track, the frog-angles F, F' and F'', and the* **switch angle S,** *to locate a* **double turnout.** Fig. 72.

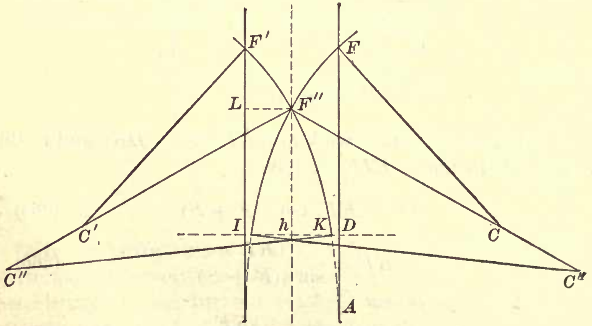


FIG. 72.

Assuming that $F''$ shall be placed on the centre line of the straight track, let $h$ be a point on the centre line at the point of switch. Then $hK = \tfrac{1}{2}g - DK$; and since the angle $F''$ is bisected by the centre line the necessary formulæ in this case are obtained from § 189 by simply replacing $F$ by $\tfrac{1}{2}F''$ and $KI$ by $hK$; and in the first members $IF$ by $hF''$ and $r$ by $r''$. This is obvious by the similarity of the figures.

Hence $$hF'' = hK \,.\, \cot \tfrac{1}{2}(\tfrac{1}{2}F' + S) \qquad (269)$$

$$KF'' = \frac{hK}{\sin \frac{1}{2}(\frac{1}{2}F'' + S)} \qquad (270)$$

$$r'' + \tfrac{1}{2}g = \frac{\frac{1}{2}KF''}{\sin \frac{1}{2}(\frac{1}{2}F'' - S)} \qquad (271)$$

The location of the remaining frogs is a problem already discussed, § 183, eq. (229), etc.

**192.** *Given: a straight track, the frog angles F, F', F'', and the* **switch angle S,** *to locate a* **double turnout on one side.** Fig. 73.

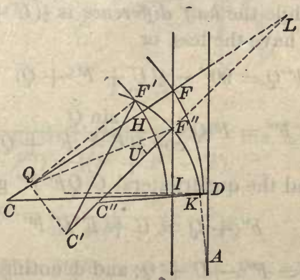


FIG. 73.

The frog $F$ is located by § 189; but for the frog $F''$ we have evidently a double throw; hence eqs. (265) (266) (267) become

$$IF'' = (g - 2DK) \cot \tfrac{1}{2}(F'' + 2S) \qquad (272)$$

$$KF'' = \frac{g - 2DK}{\sin \frac{1}{2}(F' + 2S)} \qquad (273)$$

$$r'' + \tfrac{1}{2}g = \frac{\frac{1}{2}KF''}{\sin \frac{1}{2}(F'' - 2S)} \qquad (274)$$

*To locate the remaining frog* $F'$: when $F'$ falls beyond the line $CF$, there are three cases.

**a. The middle track reversed beyond F.**

We find the distance $F''F$ by subtracting $IF''$, eq. (272) from $IF$, eq. (265); after which the solution is identical with that given § 185, **c.,** Fig. 67.

**b. The middle track compounded at F.**

Let $Q$ be the centre of the curve beyond $F$, and also let $Q =$ the angle $F''QF''$; and let $U =$ the angle $C''F''Q$.

Then by a course of reasoning analogous to that of case **a**, we derive

$$U = F'' - F + F''QF \tag{275}$$

$$\cot \tfrac{1}{2}Q = \frac{F''Q + F'Q}{F''Q - F'Q} \tan \tfrac{1}{2}(U + F') \tag{276}$$

Now since the radius $F'Q$ is given, and the angle $FQF' = Q - FQF''$, we readily determine the distance $HF'$, and so locate the frog $F'$.

In the triangle $F''QF'$, the *half sum* of $QF''F'$ and $QF'F''$ is $90° - \tfrac{1}{2}Q$, while the *half difference* is $\tfrac{1}{2}(U + F')$; hence by subtraction we have the less, or

$$F'F''Q = 90° - \tfrac{1}{2}(U + F' + Q)$$

Hence
$$F'F'' = F'Q \frac{\sin Q}{\cos \tfrac{1}{2}(U + F' + Q)} \tag{277}$$

Join $C'Q$, and the quadrilateral $C'QF'F''$ gives

$$F' + Q = U + F''C'F'$$

hence $F''C'F' = F' - U + Q$; and denoting the radius $C'F'$ by $r' + \tfrac{1}{2}g$, we have

$$r' + \tfrac{1}{2}g = \frac{\tfrac{1}{2}F''F'}{\sin \tfrac{1}{2}(F' - U + Q)} \tag{278}$$

**Cor.** Since the centre $Q$ is assumed at pleasure, it may be made to coincide with the centre $C$, and then the compound curve becomes a simple curve. Then also, the above formulæ will apply when $F'$ is such that the frog will come on the arc $IH$. But as $FQF''$ will be greater than $Q$, the difference $FQF'$ will be *negative*, indicating that the distance $HF'$ is to be laid off *backwards* from $H$.

**c. The middle track straight beyond F,** *and tangent to the curve at F.* Fig. 74.

Let $F'$ be the required position of the frog $F'$. A tangent to the curve at $F'$ makes an angle $(F' + F)$ with the main track, and a tangent at $F''$ makes an angle of $F''$ with the same; hence the angle they make with each other is

$(F' + F - F'')$, and this is the curvature of the arc $F''F'$, and equals the angle $F''C'F'$.

Produce the straight line $F'H$ backwards to $G$, and draw $F''G$ perpendicular to it. Then $F''G = FH - F''F \,.\, \sin F$, or

$$F''G = g - F''F \,.\, \sin F \qquad (279)$$

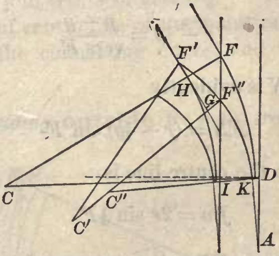


FIG. 74.

In the right-angled triangle $F'GF''$, the angle $F''F'G = F' - \frac{1}{2}(F' + F - F'') = \frac{1}{2}(F' + F'' - F)$.

$$\therefore \qquad F''F' = \frac{F''G}{\sin \frac{1}{2}(F' + F'' - F)} \qquad (280)$$

and $$GF' = F''F' \,.\, \cos \frac{1}{2}(F' + F'' - F) \qquad (281)$$

Observe that $GF'$ cannot be less than $GH = F''F \,.\, \cos F$.

**193.** *Given: a turnout with a frog angle* **F**, *and the perpendicular distance* **p** *between the centre lines of the main and side*

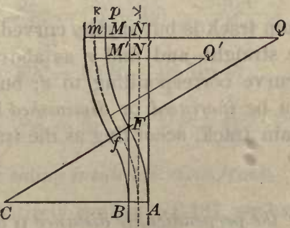


FIG. 75.

*tracks; to find the radius* **r** *of the* **curve connecting the turnout with the side track.** Fig. 75.

Let the reversing point be taken at $F$, and let $Q$ on $CF$ produced be the centre of the required curve, and draw $QM$ perpendicular to the main track. Then $QM = QF = r - \frac{1}{2}g$; the point $M$ is the point of tangent, and the angle $FQM = F$.

Now $N$ being the intersection of the rail $BF$ with the radius $QM$, we have $MN = QF$ vers $F$, but $MN = p - g$; hence

$$r - \tfrac{1}{2}g = \frac{p - g}{\text{vers } F} \tag{282}$$

The distance $FN$ is evidently

$$FN = (r - \tfrac{1}{2}g) \sin F \tag{283}$$

and the chord to the centre line is

$$fm = 2r \sin \tfrac{1}{2}F \tag{284}$$

*Should the distance FN consume too much of the track*, it may be lessened by introducing a short tangent at $F$, denoted by $k$; then by eq. (48) the radius will be shortened by an amount equal to $k \cdot \cot \frac{1}{2}F$, and the distance $FN$ will be shortened by $k$.

Since the tangent $k$ reduces the length of the tangent offset of the entire curve by $k \cdot \sin F$, we have for the new radius $r'$

$$r' - \tfrac{1}{2}g = \frac{p - g - k \sin F}{\text{vers } F} \tag{285}$$

When $r'$ is fixed by a limit, we obtain $k$ by resolving eq. (285)

$$\therefore \quad k = \frac{p - g - (r' - \frac{1}{2}g) \text{ vers } F}{\sin F} \tag{286}$$

In case the main track is but *slightly* curved, we may at first assume it to be straight, and find $r$ as above, eq. (282), and the degree of curve corresponding to $r$; but this degree of curve must then be *increased* or *diminished* by the degree of curve of the main track, according as the track is *concave* or *convex* toward $Q$.

**194.** *Given: the perpendicular distance* **p** *between the centre lines of a curved main track and a parallel side track, and the frog angle* **F** *of a turnout; to find the radius* **r** *of the connecting curve, and the length* **FN**, *or* **fm**, *of the curve.* Fig. 76.

Let $FN$ be the rail of the main track, and $GM$ the rail of the siding, adjacent to each other; let $O$ be the centre of the main track, and $Q$ the centre of the connecting curve. Then the connecting curve will terminate at $m$, on the line $OQ$ produced.

In the diagram draw $MF$, and produce it to intersect the rail $MG$ at $G$, and join $GO$, $FO$, and $FQ$.

Let $R$ = radius of centre line of the main track; $r$ = radius of centre line of the connecting curve; and $\theta$ = the angle $FOM$.

**Case a.**—*The siding* **outside** *the main track.* Fig. 76.

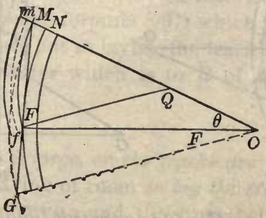


FIG. 76.

By similarity of the triangles $GOM$ and $FQM$, $GO$ is parallel to $FQ$, and the angle $GOF = F$; and by a process similar to that of § 186, we have

$$\tan \tfrac{1}{2}\theta = \frac{p-g}{2R+p} \cot \tfrac{1}{2}F \qquad (287)$$

$$r - \tfrac{1}{2}g = (R + \tfrac{1}{2}g) \frac{\sin \theta}{\sin (F+\theta)} \qquad (288)$$

$$FN = 2\,(R + \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta \qquad (289)$$

$$fm = 2r \,.\, \sin \tfrac{1}{2}(F+\theta) \qquad (290)$$

**Case b.**—*The siding inside the main track.* Fig. 77.

By a process entirely similar to § 187, we have

$$\tan \tfrac{1}{2}\theta = \frac{p-g}{2R-p} \cot \tfrac{1}{2}F \qquad (291)$$

$$r - \tfrac{1}{2}g = (R - \tfrac{1}{2}g)\frac{\sin\theta}{\sin(F - \theta)} \tag{292}$$

$$FN = 2(R - \tfrac{1}{2}g)\sin\tfrac{1}{2}\theta \tag{293}$$

$$fm = 2r\sin\tfrac{1}{2}(F - \theta) \tag{294}$$

When $\theta = F$ in the last equations, $\sin(F - \theta) = 0$, and $r - \frac{1}{2}g$ is infinite, and the curve $FM$ becomes a straight line.

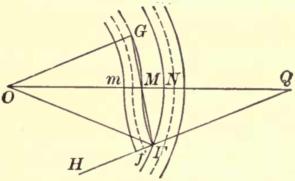


Fig. 77.

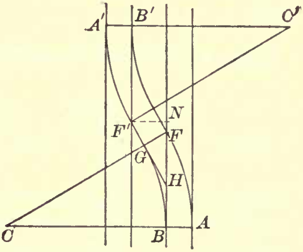


Fig. 78.

When $\theta > F$, $\sin(F - \theta)$ is negative, and the centre $Q$ falls on the same side of the track as $O$, and we have

$$r + \tfrac{1}{2}g = (R - \tfrac{1}{2}g)\frac{\sin\theta}{\sin(\theta - F)} \tag{295}$$

$$fm = 2r \,.\, \sin\tfrac{1}{2}(\theta - F) \tag{296}$$

Equations (291) and (293) remain unchanged.

**195. To locate a crossing** *between parallel tracks.* Fig. 78.

When a turnout from one track enters a parallel track by means of another frog and switch, the whole is called a crossing. The frogs are alike, and the calculation for one end of the crossing answers for the other. §§ 180, 181. We have only to find the length of track between the two frogs.

In the diagram let $AF$ be one turnout, and $A'F'$ the other, connected by the straight track $F'G$. It is required to determine the length $F'G$, or the distance $FN$ measured on the main track from $F$ to a perpendicular through $F'$. Producing the line $F'G$ to intersect the rail $NF$ at $H$, we have two right-angled triangles $GFH$ and $F'NH$, having the common angle at $H = F$. Let $p =$ the perpendicular distance between centre lines of main tracks, and $g =$ gauge. Then $GF = g$, and $F'N = (p - g.)$

$$F'G = F'H - GH = \frac{F'N}{\sin F} - GF \cot F$$

or
$$F'G = k = \frac{p - g}{\sin F} - g \cot F \tag{297}$$

So
$$FN = NH - FH = (p - g) \cot F - \frac{g}{\sin F} \tag{298}$$

*When the main tracks are curved* the distance $F'G$ may be calculated by the same formula (297) which gives a value only a fraction too small, but in laying the track the rail $F'G$ must be curved to a *radius* which is to $R$ of the main track as $F'G : NF$.

**196.** *When* **p** *is large, or the tracks are very wide apart,* it will effect some saving of room *to lay the crossing in the form of a* **reversed curve;** and the frogs being alike, the two arcs will be equal, and the point of reversed curve $P$ will be midway between $F$ and $F'$. Fig. 79.

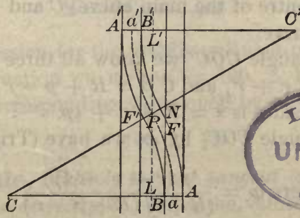


FIG. 79.



In the diagram we have $aPa'$ the centre line of the crossing, and $PL$ the centre line between tracks; $aL = \frac{1}{2}p$, and $aC = a'C' = r$. The radius $r$ having been found by § 180 or § 181, we have

$$\text{vers } aCP = \frac{\frac{1}{2}p}{r} \tag{299}$$

and
$$PL = r \sin aCP \tag{300}$$

The distance between frogs, $FN$, measured on the main track is evidently

$$FN = 2(PL - BF) \tag{301}$$

in which $BF$ is determined by eqs. (209), (213), or by Tab. XI.

**197.** *To lay a* **crossing** *in the form of a* **reversed curve,** *when the parallel tracks are* **on a curve.** Fig. 80.

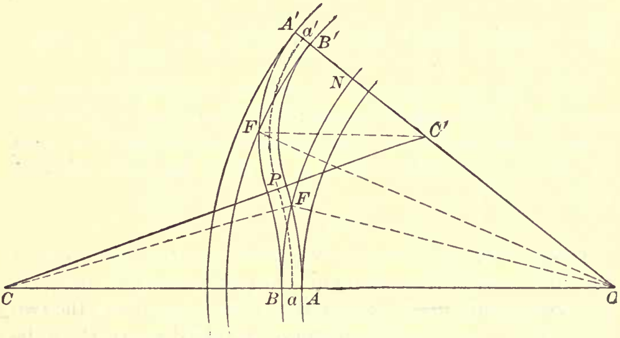


FIG. 80.

Let $O$ be the centre of the main curve, $C$ and $C'$ the centres of the reversed curve.

Then in the triangle $COC'$ we know all three sides; for $CO = R + r$; $CC' = r + r'$, and $C'O = R + p - r'$; and the half sum of the three sides is $s = R + r + \frac{1}{2}p$.

Denoting the angle $COC'$ by $\varphi$, we have (Trig. Tab. II. 31)

$$\text{vers}\ \varphi = \frac{p\,(r + r' - \frac{1}{2}p)}{(R + r)\,(R + p - r')} \tag{302}$$

The angle $\varphi$ determines the length of the arc $BN$ described with the radius $(R + \frac{1}{2}g)$ and so fixes the position of the point $A'$ from $A$.

By a formula similar to the above,

$$\text{vers}\ C'CO = \frac{p\,(R - r' + \frac{1}{2}p)}{(R + r)\,(r + r')} \tag{303}$$

The angle $C'CO$ determines the length of the arc $aP$ described with the radius $r$; the angle $(\varphi + C'CO) = CC'A'$ determines the length of the arc $Pa'$, and $P$ is the point of reversed curve.

In this problem $R$ is known, $r$ is found by § 187, and $r'$ is found by § 186, only observing that in this case the value of $R$ must be increased by $p$. The frog angles $F$ and $F'$ may be equal or otherwise, only taking care that the point $P$ shall be included between the radii $C'F'$ and $CF$.

The angle $FOC = \theta$ is given by eq. (257), and the angle $F'OC' = \theta'$ is given by eq. (252) (in which the value of $R$ is to be increased by $p$); hence the angle $FOF' = \varphi - (\theta + \theta')$, which determines the distance between the frogs, measured on the main track.

**198.** *To find the* **middle ordinate** *m,* **for 1 station,** *or* 100 *feet, on any curve, in terms of the degree of curve D.*

Referring to Fig. 4 we have in the right triangle $AGH$

$$GH = GA \,.\, \tan GAH$$

But $GA = \frac{1}{2}AB = \frac{1}{2}C$, and (Tab. I. 18) $GAH = \frac{1}{4}AOB = \frac{1}{4}\Delta$; hence

$$M = \tfrac{1}{2}C \,.\, \tan \tfrac{1}{4}\Delta \qquad (304)$$

a general expression for the middle ordinate of any chord.

If in this equation we make $C = 100$, $\Delta$ becomes $D$; and denoting the corresponding value of $M$ by $m$, we have

$$m = \tfrac{1}{2}100 \tan \tfrac{1}{4}D \qquad (305)$$

whence the **rule,** *Multiply the nat. tangent of* $\frac{1}{4}$ *the degree of curve by* 100 *and divide by* 2. Thus the values of $m$ in the 5th column of Tab. IV. have been calculated

**199.** *To find the* **middle ordinate** *for any chord* **in terms of the chord** *and radius*

Referring to Fig. 4 we have

$$GH = OE - OG = OE - \sqrt{AO^2 - GA^2}$$

or

$$M = R - \sqrt{R^2 - \left(\frac{c}{2}\right)^2} \qquad (306)$$

When $C = 100$ we have for the middle ordinate of one station

$$m = R - \sqrt{R^2 - 2500} \qquad (307)$$

For any subchord $c$, less than 100, we have for the middle ordinate,

$$\left.\begin{aligned} m_1 &= R - \sqrt{R^2 - \left(\frac{c}{2}\right)^2} \\ \text{or} \quad m_1 &= R - \sqrt{\left(R + \frac{c}{2}\right)\left(R - \frac{c}{2}\right)} \end{aligned}\right\} \qquad (308)$$

By adding $\frac{c^4}{64R^2}$ to the quantity under the radical in eq. (308) it becomes a perfect square, giving

$$m_1 = \frac{c^2}{8R} \text{ nearly,} \qquad (309)$$

which is a very useful formula, although approximate. The error in $m_1$ does not exceed .002 for any subchord $c$ when the radius is greater than 800. On a 20° curve the error will be .002 for a chord of 50 feet; and on a 40° curve the error in $m_1$ will be only .003 for a chord of 33 feet. Equation (309) is therefore practically correct in all cases *for finding the middle ordinates of rails.* Table XII. is calculated by eq. (308).

**200. Curving Rails.** Before any rail is spiked to its place in a curve, it must be evenly bent from end to end, so that it will assume the proper curvature when lying free. The bending may be done by using sledges, but is best accomplished, especially for turnouts and other sharp curves, by using a bending machine made especially for this purpose.

The proper curvature of a rail is tested by measuring its middle ordinate from a small cord stretched from end to end and touching the side of the rail-head. The cord should also be stretched from the middle point of the rail to either end, and the middle ordinate of each half length measured, to test the *uniformity* of curvature.

From the last equation it appears that, with a given radius, the middle ordinate varies nearly as the square of the chord.

We may therefore find the middle ordinate of a rail whose length is $c$ by the proportion

$$(100)^2 : c^2 :: m : m_1$$

or,
$$m_1 = \frac{c^2\,m}{10000} \text{ nearly,} \qquad (310)$$

in which $m$ is obtained from Tab. IV., col. 5, for the given radius or degree of curve.

*Example.*—What is the middle ordinate of a 30 ft. rail when curved for a 20° curve?

Eq. (310)
$$m_1 = \frac{900 \times 4.374}{10000} = .394 = 4\tfrac{3}{4} \text{ in.}$$

When a long rail is bent for a sharp curve, observe that $c$ is the length of the chord of the rail—not of the rail itself.

For the chord of half a rail the middle ordinate is one-fourth the middle ordinate of the whole rail. Thus, in the above example it would be .099 or $1\tfrac{3}{16}$ inches.

Instead of using the chord of the whole rail, it may be more convenient to assume a chord shorter than the rail, especially when the chord is not an exact number of feet, knotting the string to the length assumed, and applying it to different portions of the rail successively.

## 201. Elevation of the outer rail on curves.

When a car passes around a curve, a centrifugal force is developed which presses the flanges of the wheels against the outer rail. This force acts horizontally, and varies as the square of the velocity, and inversely as the radius of the curve. Denoting the centrifugal force by $f$, we have from the theory of mechanics $f = \dfrac{wv^2}{32.166\,R}$, in which $w$ = weight of loaded car in pounds, $v$ = velocity in feet per second, and $R$ = radius of curve in feet.

In Fig. 81, let $ab$ represent a level line at right angles to the track, let $a$ and $c$ be the tops of rails on a curve, let $bc = e =$ elevation of outer rail $c$, and let the point $d$ be the centre of gravity of the car. The force $f$ acts in the direction $ab$, and if $f'$ = the component of $f$ in the direction $ac$, then

$$f' : f :: ab : ac.$$

The weight $w$, resting on the inclined plane $ac$, developes a component in the direction $ca$, and denoting this by $w'$, we have by similar triangles,

$$w' : w :: bc : ac.$$

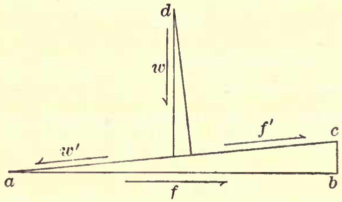


FIG. 81.

Since equilibrium requires that $w'$ shall equal $f'$, we have after dividing one proportion by the other $\frac{f}{w} = \frac{bc}{ab}$, or $f = \frac{w \cdot e}{ab}$. Equating this value of $f$ with that given above we find,

$$e = \frac{ab \cdot v^2}{32.166\,R}$$

But $ab = \sqrt{\overline{ac}^2 - e^2}$, and $ac$ = distance between rail centres = gauge + one rail head $= g + 0.188$. Also $v = \frac{5280}{3600} V$, if $V$ denote the velocity in miles per hour. Making these substitutions and reducing, we have

$$e = (g + .188) \frac{.06688 \frac{V^2}{R}}{\sqrt{1 + \left(.06688 \frac{V^2}{R}\right)^2}} \qquad (311)$$

By this formula Table XIII. is calculated for the standard gauge $g = 4'\ 8\frac{1}{2}''$, $= 4.708$.

An approximate formula may be obtained by assuming that $ab = g$ for practicable values of $e$. Substituting this in the first value of $e$ given above, and replacing $v$ by $\frac{5280}{3600} V^2$ we have

$$\text{(approx.)} \qquad e = .06688 \frac{g V^2}{R} \qquad (312)$$

which is the formula generally employed.

In laying a new track, the transverse inclination is first given to the ballast by grade pegs driven either side of the centre line at a distance of $(g + .188)$ each side of the centre; the outside peg being set higher, and the inside peg lower than the grade of ballast on the centre line, by the proper elevation selected from Table XIII. But in re-surfacing an old track, the inner rail is taken as grade and the outer rail is raised the necessary amount.

**202.** The proper **elevation** may be **found mechanically** by the following method:

*To find, on a curved track, the length of a chord whose middle ordinate shall equal the proper elevation of the outer rail for any velocity V in miles per hour.*

By the conditions of the problem, we have $m_1$ in eq. (309) equal to $e$ in eq. (312), or

$$\frac{c^2}{8R} = \frac{g V^2 .06688}{R}$$

$$\therefore \qquad c = .73144\, V \sqrt{g} \qquad (313)$$

When $g = 4.708$,

$$c = 1.587\, V \qquad (314)$$

Lay off the chord, $c$, upon the rail of the track, stretch a piece of twine between the points so found, and measure the middle ordinate; it will equal the proper elevation.

**203.** The velocity assumed in the preceding formulæ should be that of the fastest regular trains which will pass over the curve in question, since the flanges would be forced against the outer rail were there no centrifugal force developed, by reason of the wheels being rigidly attached to the axles, and the axles being parallel.

The rails on tangents should be level transversely, except near curves, where for 50 or 100 feet from the curve one rail is gradually raised, so that at the *P.C.* or *P.T.* it may have the full elevation due to the curve. At a *P.C.C.* the elevation should be an *average* of the elevations due to the two arcs. Owing to the difficulty of properly adjusting the elevation of rail, it is objectionable to have arcs of very dissimilar radii join each other; and the objection is much greater in the case of reversed curves unless separated by a short tangent. See § 82.

On the other hand, a short tangent between arcs which curve in the same direction should be avoided, since it makes a "flat place" both in line and levels, at once unsightly and injurious to the rolling stock.

In the case of turnouts, however, no elevation of rail is possible (except when both tracks curve in the same direction); hence reversed curves are allowable, the speed of trains being usually quite low also.

**204. The coning of the wheels,** by which the wheel on the outer rail gains a diameter enough larger than the other to compensate for the superior length of the outer rail, although a theoretically perfect device, is gradually going into disuse. To be effective for the sharpest curves, the coning must be so great as to produce an unsteady motion on tangents, very objectionable at high speeds. Moreover, it is undesirable to seek for an equilibrium of lateral forces in a car on a curve, since the flanges are then sure to strike the inner and outer rails alternately with damaging force, as that equilibrium is momentarily disturbed. It is far better that the flange should press steadily against the outer rail, while that pressure is modified and reduced somewhat by the elevation of the rail. For these and other reasons, car-wheels are now made nearly cylindrical.

# CHAPTER VIII.

## LEVELLING.

**205.** The field operations with the Engineer's Level are of a more simple character than those performed with the transit, yet require equal skill and nicety of manipulation in order to produce trustworthy results. The transit is used to ascertain the relative horizontal position of points, the level to obtain their relative vertical position.

**206.** In order to express the elevation of points, they must be referred to some *level surface* of known (or assumed) elevation; and in order that the elevations may all be positive upward, this surface of reference should be selected below all the points to be considered. The level surface of reference is called **the datum.**

*The elevation of the datum is always zero. The elevation of any point is its vertical height above the datum.*

Near the coast the sea level is usually adopted as the datum; inland, the low water mark of a river or lake, etc.; but it is not necessary that the *datum* should coincide with a water surface. If any points whose elevations are to be ascertained are below the water surface, the latter may be assumed to have an elevation of 100 or 1000 feet instead of zero; that is, we remove the datum, in imagination, to 100 or 1000 feet below the level of the water surface.

**207.** In case of a survey commencing at a point quite remote from any important water surface, *any permanent point* may be selected as the original point of reference, and its elevation may be assumed at 100 or any other number of feet; that is, we fix the datum at the same number of feet below that point. The point of reference is called a *bench*, or **bench-mark,** and is designated by the initials *B.M.* Other benches are established at intervals during a survey, and their elevations determined instrumentally. They are then convenient points of known elevation for future reference. We cannot *assume* the elevation of more than one bench on the same survey, else we should have more than one datum, and all the results would be thrown into confusion.

**208.** Having established the first bench and recorded its elevation, the next step is to set up the instrument firmly at a moderate distance from the bench, so that the telescope shall be somewhat higher than the bench, and in full view of a rod held vertically upon it. The instrument having been tested for its several adjustments, and found to be correct, the *line of sight* through the intersection of the cross-hairs is known to be horizontal when the bubble stands at the middle of its tube. Turning the line of sight upon the rod, the point of the rod covered by the horizontal cross-hair is known to be on a level with the cross-hair; and the latter is therefore *higher* than the bench by the distance intercepted on the rod from its lower end. Adding this distance to the elevation of the bench, we obtain the elevation of the cross-hair, known technically as the **"Height of Instrument,"** and designated by the initials *H.I.*

**209.** The distance intercepted on a rod from its lower end by the line of sight, when the rod is held vertically on any given point, is called the **reading** *of the rod* at that point.

**210.** Having obtained the height of instrument, the elevation of any point somewhat lower than the cross-hair is easily ascertained by taking a reading of the rod upon it. The reading subtracted from the height of instrument gives the elevation of the point above the datum. The elevation of any number of other points may be similarly obtained. But the elevation of points on the ground higher than the cross-hair, or farther below it than the length of the rod, cannot be determined, because in either case the line of sight will not cut the rod, and hence there can be no reading. In order to observe such points, the instrument must be removed to a new position, higher or lower than before, as the case may require.

**211.** Before the instrument is removed to a new position, a *temporary bench*, called a **Turning Point** (and designated by *T.P.* or "*Peg*") must be established, and its elevation ascertained as for any other point, but with more care. A turning point must be a *firm* and *definite* point whose position cannot readily be altered in the least, nor lost sight of. A small stake firmly driven, or a point of rock projecting upward, is frequently used. The reading having been taken on the turning point, the instrument is carried forward to a new position, levelled up properly, and the new Height of Instrument obtained by a new reading on the same turning point. Since the cross-hair is higher than the point (otherwise there could be no reading) the reading, added to the elevation of the point, gives the Height of Instrument.

**212.** In general, the intersection of the cross-hairs being higher than any point on which a reading is taken:

*To find the Height of Instrument,* **add** *the reading on a point to the elevation of the point; and*

*To find the Elevation of a point,* **subtract** *the reading on it from the Height of Instrument.*

A reading taken for the purpose of finding the Height of Instrument is called a **Backsight** (*B.S*). A reading taken for the purpose of finding the elevation of a turning-point (or of a bench used as such) is called a **Foresight** (*F.S*). Hence Backsights are always *plus*, and Foresights always *minus*.

**213. The form of field-book** used for the survey of a railroad, or other continuous line, is shown below. The *first* column contains the numbers of the stations on the line and of plus distances to other points on the line where readings are taken—also the initials of benches and turning points, in order, as they occur. The *second* column contains the backsights, taken on points of known elevation only. The *third* column contains the height of instrument, recorded on the same line as the elevation of the turning point (or bench) from which it is calculated. The *fourth* column contains the foresights, taken on new turning points, and benches used as such, only. The *fifth* column contains the readings taken on all other points noted in the first column. The *sixth* column contains the elevations of all points observed. The right-hand page is reserved for remarks, descriptive of the benches and their location—of objects crossed by the line, as roads, streams, swamps, ditches, etc.; the depths of streams, etc.

LEVEL BOOK.

| Sta. | B.S. | H.I. | F.S. | Rod. | Elev. | Remarks. |
|---|---|---|---|---|---|---|
| B.M. | 4.683 | 204.683 | | | 200.000 | White oak, 115 R. |
| 0 | | | | 2.1 | 202.6 | |
| 1 | | | | 3.4 | 201.3 | |
| + 50 | | | | 5.2 | 199.5 | |
| Peg | 1.791 | 197.260 | 9.214 | | 195.469 | |
| 2 | | | | 3.7 | 193.6 | |
| + 25 | | | | 7.0 | 190.3 | Brook 5 wide; 1 deep |
| + 50 | | | | 3.1 | 194.2 | |
| 3 | | | | 0.5 | 196.8 | |
| Peg | 11.750 | 208.574 | 0.436 | | 196.824 | |
| Peg | 11.933 | 219.528 | 0.979 | | 207.595 | |
| + 90 | | | | 3.5 | 216.0 | |
| 4 | | | | 2.6 | 216.9 | |
| B.M. | | | | 2.075 | 217.453 | Maple, 78 L. |
| 5 | | | | 1.7 | 217.8 | |
| 6 | | | | 0.9 | 218.6 | |
| Peg | 9.005 | 227.801 | 0.732 | | 218.796 | |
| 7 | | | | 6.2 | 221.6 | |
| | 39.162 | | 11.361 | | | |

When a bench is not used as a turning point, the reading on it is recorded in the fifth column.

The numbers in the second, fourth, and fifth columns come directly from the rod, those in the third are obtained by addition, those in the sixth by subtraction, according to the rule given above. The additions and subtractions made on each page should be *proved* before proceeding to the calculations of the next. When correct, the difference of the sums of the backsights and foresights on the page equals the difference of the first and last elevations on the page. Thus, in the form given

$$(39.162 - 11.361) = (227.801 - 200.000) = 27.801$$

In this proof we ignore all elevations except those of turning points, and benches used as such, and the height of instrument.

At the end of the survey, as well as at the end of each day's work, a bench is established from which the survey may be resumed at any future time See §§ 28, 29, and 80.

**214.** The object of making such a survey with level and rod is to furnish a **profile** or vertical section of the entire line, showing in detail the rise and fall of the surface over which it passes. The profile is plotted on profile-paper published for the purpose, the horizontal scale being usually 400 feet to an inch, and the vertical scale 30 feet to an inch. This distortion of scale magnifies the vertical measures so that slight changes in the elevation of the surface may be seen distinctly.

**215.** When only the difference of level of two extreme points is required, the survey is more simple. No readings are taken except on turning-points, the backsights and foresights being recorded in separate columns. No calculation is required until the survey is finished, when—the first reading having been taken on one of the given points, and the last on the other—the difference of the sums of the backsights and foresights is the difference in elevation of the two points, according to the method of proof mentioned in § 213. Thus the difference in level of any two benches established on a previous survey may be tested, and, if found correct, all the intermediate elevations on the line may be assumed to be correct also. The discrepancy should not exceed one tenth of a foot in any case, and is usually much less.

**216.** Any lack of adjustment in the instrument gives the line of sight a slight angle of elevation or depression, causing a slight error in every reading, proportional to the distance of the rod from the instrument. But the errors being equal for equal distances, and the backsights and foresights having opposite signs in our calculations, the errors cancel when the distances are equal. Hence, to avoid errors in elevation, each new turning-point should be as nearly as possible at the same distance from the instrument as the point on which the last backsight was taken. For precise reading, the rod should not be more than 400 feet from the instrument.

**217.** Another cause of error in readings is want of verticality in the rod. This may be avoided by the use of a disk-level, or in the absence of wind, by balancing the rod. The rod may be plumbed one way by the vertical cross-hair of the level, and to ensure a vertical reading in the plane of the line of sight, the rod may be gently waved each side of the vertical toward and from the instrument, the *shortest* reading being the correct one; or in case of a target rod, the target should rise *to*, but not *above* the horizontal cross-hair, as the rod is waved.

**218.** When very long sights are required to be taken with the level, another source of error must be considered, namely, the curvature of the earth.

*A level line* is parallel to a great circle of the earth, and is therefore an arc of a circle, or may be so considered.

*A horizontal line* is a straight line parallel to the plane of the horizon. Therefore the line of sight, being a horizontal line, is tangent to the circle of a level line passing through the instrument.

*To find the correction in elevation due to* **curvature of the earth** *for any distant station.* Fig. 82.

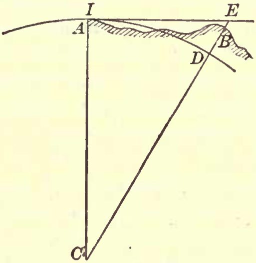


FIG. 82.

Let $A$ be the station of the instrument $I$, and $B$ the distant station observed.

Let $R_{\circ} = CI =$ the radius of curvature of the earth, or of the parallel arc $ID$. Let $L_{\circ} = ID =$ the level distance between $A$ and $B$. Then $IE$, perpendicular to $CI$, is the line of sight, $BE$ is the reading of the rod, and $DE = E_{\circ} =$ the correction due to curvature.

By Tab. I., 24, $IE^2 = DE\ (DE + 2R_{\circ})$; but since $DE$ is very small compared with $2R_{\circ}$, it may be omitted from the parenthesis, and since $IE = ID = L_{\circ}$ very nearly, because the angle $ACB$ is very small, we have $L_{\circ}^2 = 2R_{\circ}E_{\circ}$.

$$\therefore \qquad E_{\circ} = \frac{L_{\circ}^2}{2R_{\circ}} \qquad (315)$$

$E_{\circ}$ is to be *added* to the apparent elevation of station $B$.

**219. Refraction.** In observing distant stations the line of sight passing through the atmosphere is refracted from the straight line *IE*, Fig. 82, and takes the form of a curve, which, for practical purposes, may be considered as the arc of a circle, concave downwards. Its radius, depending on the conditions of the atmosphere, varies from 5½ to 7½ times the radius of curvature of the earth. $7R_\circ$ is considered a good average value.

Refraction causes the observed object to appear too high, while the curvature of the earth causes it to appear too low;—the effects being contrary, the correction for curvature is reduced by the correction for refraction. If we let $H_\circ =$ the total correction for both curvature and refraction, to be *added* to the apparent elevation of the observed object, then

$$H_\circ = \frac{6}{7} E_\circ = \frac{3L_\circ^2}{7R_\circ} \qquad (316)$$

Table XVII. is calculated by this formula, assuming a mean value of $R_\circ = 20{,}913{,}650$ feet.

**220. The form of the earth** is approximately an ellipsoid of revolution. Its meridian section at the mean level of the sea is an ellipse, the semi-axes of which are, according to Clarke,

at the equator $A = 6378206$ metres [6.8046985]

at the poles $B = 6356584$ " [6.8032238]

According to the same authority

1 metre = 3.280869 feet [0.5159889]

Therefore the semi-axes expressed in feet are

$A = 20\ 926\ 058$ feet [7.3206874]

$B = 20\ 855\ 119$ " [7.3192127]

Then the radius of curvature of the meridian

at the equator, $\frac{B^2}{A} = R_\circ = 20\ 784\ 422$ ft. [7.3177379]

at the poles, $\frac{A^2}{B} = R_\circ = 20\ 997\ 240$ " [7.3221622]

In latitude 40° the radius of curvature of the meridian is 20 871 900, and of a section at right angles to the meridian, 20 955 400; the mean value, or $R_0 = 20\,913\,650$ [7.320430], being adopted for general use. The error in the correction $H_0$ eq. (316) due to this assumption will usually be much less than that due to the assumed value of the radius of refraction.

**221. Levelling by Transit or Theodolite.** When a transit has a level-tube attached to the telescope, it may be used as a Theodolite for levelling, and for taking vertical angles. If the instrument be in perfect adjustment, the line of sight will be horizontal when the bubble stands at the middle point of the tube, and the reading of the vertical circle will be zero. Should there be a small reading when the line of sight is horizontal it is called the *index error*. When the line of sight is not horizontal, the angle which it makes with the plane of the horizon is called an angle of elevation, or of depression, according as the object upon which the line of sight is directed is above or below the telescope. This angle is measured on the vertical circle, being the *difference* of the reading and the index error, when both are on the same side of the zero mark, and their *sum*, when they are on opposite sides. When the distance to an observed object is known, and its angle of elevation or depression is measured, we may calculate its vertical height above or below the telescope.

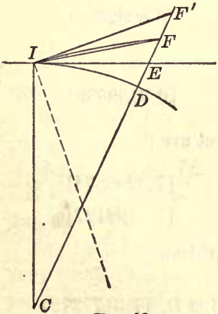

FIG. 83.

Let $\pm\,\alpha$ = angle of {elevation / depression}

" $L$ = the horizontal distance

" $L'$ = the distance parallel to line of sight

" $h$ = difference in elevation of object and instrument.

Then for short distances,

$$h = L \tan \alpha = L' \sin \alpha \qquad (317)$$

For long distances the curvature of the earth and refraction must be considered. Fig. 83.

Let $I$ be the place of the instrument, and $F$ the object observed.

Let $L_\circ$ = the distance, measured on the chord of the level arc $ID$, passing through the instrument; and let $\psi$ = the number of seconds in the arc $ID$; hence, since for ordinary distances the chord and arc are sensibly equal,

$$\psi = \frac{L_\circ}{R_\circ}\ 206264''.8 \qquad [5.314425]$$

or giving to $R_\circ$ its mean value, § 220,

$$\psi = L_\circ \times .0098627 \qquad [7.993995]$$

or a fraction less than 1″ per 100 feet.

Let $IF$ be the arc of the refracted ray, and assuming that its radius is $7R_\circ$, the arc will contain $\frac{1}{7}$th the number of seconds of the arc $IF$

$IF'$, tangent to $IF$, is the direction of the telescope; $IF$ is the chord of the arc $IF$, and $IE$ is the horizontal.

Let $\alpha = EIF'$ = observed angle of elevation. Then $EIF$ = true angle of elevation $= EIF' - F'IF = \alpha - \frac{1}{2} \cdot \frac{1}{7}\psi = \alpha - .071\psi$.

The angle $EID = \frac{1}{2}\psi \ \therefore\ DIF = \frac{1}{2}\psi + \alpha - .071\psi$; and $IDF = 90° + \frac{1}{2}\psi \ .\ \therefore\ IFD = 90° - (\psi + \alpha - .071\psi)$.

We now solve the triangle $IFD$ for the side $DF = h$, and find

$$h = L_\circ \frac{\sin\left(\frac{1}{2}\psi + \alpha - .071\psi\right)}{\cos\left(\psi + \alpha - .071\psi\right)} \qquad (318)$$

For an observed angle of depression make $\alpha$ negative in the formula.

The coefficient .071 is called the coefficient of refraction, this being a fair average value, while its extreme range is from .067 to .100 under varying conditions of the atmosphere, and values of the angle $\alpha$.

When the difference in elevation of two or more distant objects is required, we obtain the elevation of each separately, and subtract one elevation from another. The elevation of the observed object is given by $(H.\ I.) \pm h$.

**222.** *To find the* **Height of Instrument** *of a transit or theodolite* **by an observation of the horizon.** Fig. 84.

Let $I$ be the place of the instrument, and let $\alpha$ = observed angle of depression of the horizon.

Let $F$ be the point where the refracted ray meets the level surface, and draw the chords $IF$ and $AF$.

Let $\psi$ = the angle $ACF$, let $h = AI$, and let $k$ = the coefficient of refraction.

In the triangle $IAF$,

$$IAF = 90° + \tfrac{1}{2}\psi, \quad AFI = \tfrac{1}{2}\psi - k\psi, \quad AIF = 90° - (\psi - k\psi)$$

Hence $FIE = \psi - k\psi$. But $FIE = \alpha + k\psi$

$$\therefore \qquad \psi = \frac{\alpha}{1 - 2k} \qquad (319)$$

Let $F''$ be the tangent point of a right line drawn through $I$;

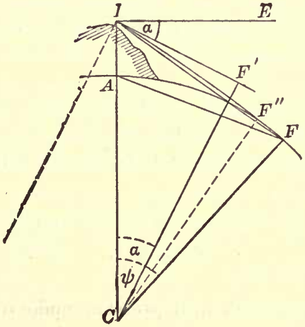


FIG. 84

then $AI = CF''$ exsec $ACF''$, but $CF'' = R_\circ$, and, since $\psi$ is always very small, $ACF'' = \tfrac{1}{2}(\psi + \alpha)$ very nearly $= \dfrac{1 - k}{1 - 2k}\alpha$

$$\therefore \qquad h = R_\circ \text{ exsec } \frac{1 - k}{1 - 2k}\alpha \qquad (320)$$

Giving to $R_\circ$ its mean value, § 220, and assuming $k = \frac{1}{14}$

$$\log h = 7.320430 + \log \text{exsec } 1.0801\,\alpha \qquad (321)$$

**Otherwise,** we may solve the triangle $AIF$ since

$$AF = 2R_{\circ} \sin \tfrac{1}{2}\psi = 2R_{\circ} \sin \frac{\alpha}{2(1-2k)}$$

and
$$h = AF \frac{\sin (\frac{1}{2}\psi - k\psi)}{\cos (\psi - k\psi)}$$

$$\therefore \qquad h = 2R_{\circ} \sin \frac{\alpha}{2(1-2k)} \cdot \frac{\sin \frac{1}{2}\alpha}{\cos \dfrac{1-k}{1-2k}\alpha} \qquad (322)$$

When $k = \frac{1}{14}$

$$h = 2R_{\circ} \sin \tfrac{7}{12}\alpha \,.\, \frac{\sin \frac{1}{2}\alpha}{\cos \frac{13}{12}\alpha} \qquad (323)$$

*Example.*—The observed dip of the sea horizon is $24' = \alpha$. What is the height of the instrument above the sea?

| | | |
|---|---|---|
| By eq. (321) | $1.0801 \times \alpha \times 60 = 1555''.34$ | 3.191825 |
| | | 2 |
| | | 6.383650 |
| | Table XXVI. $(q - 2l)$ | 9.070130 |
| | $R_{\circ}$ | 7.320430 |
| $\therefore$ | $h = 594.58$ | 2.774210 |

Methods of determining heights by distant observations cannot be relied on for more than approximate results, since they necessarily involve the uncertain element of refraction, and usually a lack of precision in the vertical angle, the arc reading only to minutes in ordinary instruments. These methods, however, are useful where no great accuracy is required, as for a temporary purpose until levels can be taken in the regular way, or for interpolating between points of established elevation.

## 223. Stadia Measurements.

It is sometimes convenient to determine distances by instrumental observation For this purpose two additional cross hairs may be placed in the telescope parallel to each other and equidistant from the central cross-hair. These are called stadia hairs, and distances determined by them are called stadia measurements. The stadia hairs are adjusted so as to intercept a certain space on a rod held at a certain distance from the instrument and perpendicular to the line of sight. For any other place of the rod, the distances and intercepted spaces are nearly proportional. The exact relation is given below. Fig. 85.

Let $l = AB$, the distance of the rod from the vertical axis of the instrument; $c =$ the distance from the axis to the object glass of the telescope; $a =$ the distance from the object-

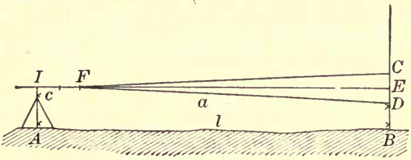


FIG. 85.

glass to the rod; $i =$ the space between the stadia hairs; $s = CD$ the space intercepted by them on the rod; and $f =$ the focal distance of the object-glass. We then have by optics, $\frac{s}{i} = \frac{a-f}{f}$, whence $a - f = \frac{f}{i}s$; and since $a = l - c \therefore l - (f + c) = \frac{f}{i}s$. Now in any given instrument the focal distance $f$, and the space between the stadia hairs $i$ are constant, while $s$ and $c$ vary with $l$. For any other distance $l'$, we then have $l' - (f + c') = \frac{f}{i}s'$, and combining the two equations

$$l - (f + c) = \frac{s}{s'}[l' - (f + c')] \qquad (324)$$

$s'$ is usually assumed at 1 foot and $l' - (f + c')$ at 100 feet. and the stadia hairs are then adjusted accordingly. The focal distance $f$ may be found by removing the object glass and exposing it to the rays of the sun and noting at what distance from the surface of the lens the rays form a perfect and minute image of the sun on a smooth surface; the distance $c'$ is measured on the telescope when the rod is clearly in focus, at the assumed distance.

To measure any other distance, the rod is again observed at the desired point, and the space $s$ noted, which, placed in eq. (324), gives $l - (f + c)$ at once. We then measure $c$ on the telescope, and adding $(f + c)$, obtain $l$, the distance required.

But inasmuch as $c$ has but a small range of values, it will usually be sufficient to assume for it a mean value, as a constant. In this case we may find the value of $(f + c) = IF$ for the instrument used. Making $c' = c$ in eq. (324), and solving for $(f + c)$, we have

$$f + c = \frac{sl' - s'l}{s - s'} \qquad (325)$$

and by laying off on level ground any two distances from the instrument for $l'$ and $l$, as 100 and 500, and observing the corresponding spaces $s'$ and $s$ intercepted on a rod, we insert them in eq. (325) and find $(f + c)$.

Having found $(f + c)$, lay off $(100 + f + c)$ from the instrument and adjust the stadia hairs to inclose just one foot on the rod at that distance. Any other distance is then found by the formula,

$$l = 100\,s + (f + c) \qquad (326)$$

*Example.*—At $l' = 100$ we find $s' = 1.00$, and at $l = 500$ we find $s = 5.061$.

Hence, eq. (325) $\quad f + c = \dfrac{506.1 - 500}{4.061} = 1.502$

and eq. (326) $l = 100\,s + 1.5$; *provided* the stadia hairs be adjusted so as to intercept 1 foot at 101.5 feet distance from the centre of the instrument.

**224.** The foregoing formulæ are all that are necessary for horizontal sights, but since the line of collimation is generally inclined more or less to the horizon, it follows that the stadia hairs will intercept a larger space on the **vertical rod** than that due to the true horizontal distance. We therefore require a **formula for reducing inclined measurements to the horizontal.** Fig. 86.

Let $\alpha = EFG$ = the angle of inclination of the line of collimation $IG$;

" $\theta = CFD$ = the visual angle defined by the stadia hairs;

" $s = CD$ = space intercepted on a vertical rod.

Then (Fig. 85),

$$\tan \tfrac{1}{2}\theta = \frac{C'E}{EF} = \tfrac{1}{2} \cdot \frac{s'}{l' - (f + c)} \qquad (327)$$

In Fig. 86

$$s = CE - DE = EF\,[\tan(\alpha + \tfrac{1}{2}\theta) - \tan(\alpha - \tfrac{1}{2}\theta)]$$

while the true value (for the same distance) would be

$$C'D' = 2EF \tan \tfrac{1}{2}\theta$$

Dividing one by the other we derive

$$\frac{C'D'}{s} = \frac{2 \tan \tfrac{1}{2}\theta}{\tan(\alpha + \tfrac{1}{2}\theta) - \tan(\alpha - \tfrac{1}{2}\theta)}$$

By giving to $s'$ and $l' - (f + c)$ in eq. (327) their customary

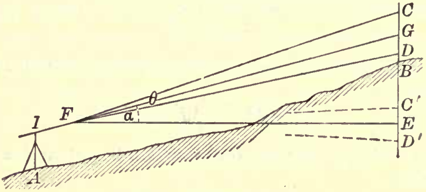


FIG. 86.

values, *viz.*, 1 and 100, we have $\tan \tfrac{1}{2}\theta = .005 \quad \therefore \theta = 34' \, 22''.63$ and by Trig. Table II. 70,

$$\tan(\alpha + \tfrac{1}{2}\theta) - \tan(\alpha - \tfrac{1}{2}\theta) = \frac{\sin \theta}{\cos(\alpha + \tfrac{1}{2}\theta)\cos(\alpha - \tfrac{1}{2}\theta)}$$

Since $\theta$ is small, we have sensibly

$$\sin \theta = 2 \tan \tfrac{1}{2}\theta, \text{ and } \cos(\alpha + \tfrac{1}{2}\theta)\cos(\alpha - \tfrac{1}{2}\theta) = \cos^2 \alpha$$

and the last equation reduces sensibly to

$$\frac{C'D'}{s} = \cos^2 \alpha \qquad (328)$$

which is the **coefficient of reduction** required by which to multiply the observed space $s$ in case of inclined sights.

Hence the formula for distance (eq. 326) becomes in this case without sensible error

$$l = 100\, s \cos^2 \alpha + (f + c) \qquad (329)$$

Tables XVIII. and XIX. have been calculated by the exact formula for the coefficient.

*Example.*—Given : $\alpha = 8° 20'$ and $s = 9.221$: what is the horizontal distance to the rod?

| | | | |
|---|---|---|---|
| Eq. (329) | 100 | | log. 2. |
| $s$ | 9.221 | | " 0.964778 |
| $\alpha$ | | 8° 20′ Tab. XIX. | " 9.990780 |
| | 902.7 | | 2.955558 |
| $f+c$ | 1.5 | ∴ *Ans.* 904.2 ft. | |

The rodman should have a disk level to insure keeping the rod vertical.

**225. Another method** of procedure is that in which the rod is always held perpendicular to the line of collimation, however much inclined the latter may be. To secure this position of the rod, a small brass bar is attached, having sights upon it through which the rodman watches the instrument during an observation, the line of sight being at right angles to the rod. The distance thus obtained is of course parallel to the line of collimation, and requires to be reduced to the horizontal.

For this purpose, we have (Fig. 87).

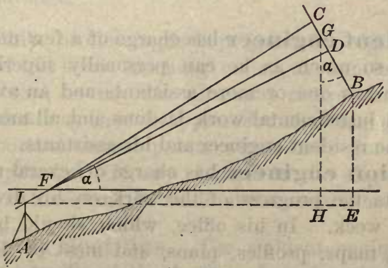


FIG. 87.

$$IE = IG \cos \alpha + BG \sin \alpha$$

or $$IE = (100\,s + f + c) \cos \alpha + r \sin \alpha \qquad (330)$$

in which $r$ is the reading of the rod by the line of collimation.

For the elevation of the point $B$ above $I$,

$$EB = HG - GB \cos \alpha$$

or $$EB = (100\,s + f + c) \sin \alpha - r \cos \alpha \qquad (331)$$

When the distances are sufficiently great, correction must be made for curvature of the earth and refraction, as already explained.

This method is employed by the topographical parties of the U. S. Coast Survey in connection with the plane table. Their instruments, however, are so constructed as to give distances in metres, and heights in feet, requiring a modification of the above formulæ.

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## CHAPTER IX.

### CONSTRUCTION.

**226. The engineer department** of a railway company is usually reorganized for the construction of the road, as follows: Chief engineer, Division engineers, Resident engineers, Assistant engineers. On some roads the division engineers are styled "Principal Assistants;" the resident engineers, "Assistants;" and the assistant engineers are designated according to their duties, as "leveller," "rodman," etc.

**A resident engineer** has charge of a few miles of line, limited to so much as he can personally superintend and direct. He has one or more assistants and an axman in his party. All instrumental work is done and all measurements taken by the resident engineer and his assistants.

**A division engineer** has charge of several residencies, and inspects the progress of the work on his division once or twice a week. In his office, which should be centrally located, all maps, profiles, plans, and most of the working drawings required on his division are prepared. To him the resident engineers make detailed reports once a month, or oftener if necessary, which he passes upon as to their correctness, and from which he makes up a monthly report, or estimate, of the amount and value of the work done and materials provided by each contractor on his division. The estimates are forwarded about the first of each month to the chief engineer, who examines and approves them, returning for modification any that seem to require it.

**The chief engineer** has charge of the entire work, and directs the general business of the engineer department. He occasionally inspects the work along the line.

**227. Clearing and Grubbing.** The first step in the work of construction is to clear off all growth of timber within the limits of the right of way. The resident engineer with his party passes over the line, making offsets to the right and left, and blazing the trees which stand on, or just within, the limits of the company's property. The blazed spot is marked with a letter *C*, as a guide to the contractor. After felling, the valuable timber should be piled near the boundary lines, to be saved as the property of the company. The brushwood is burned.

Where a deep cut is to be made, the stumps are left to be removed as the earth is excavated. In very shallow cuts and fills the contractor will generally prefer to tear up the trees by their roots at once, rather than to grub out the stumps after clearing. Where the embankments will be over three feet high, grubbing is not necessary; but the trees require to be *low-chopped*, leaving no stump above the roots. The engineer should indicate to the contractor the localities where each process is suitable.

**228.** While the clearing is in progress, the engineer should run a line of test levels touching on all the benches to verify their elevations; he may also rerun the centre line, replacing any stakes that may have disappeared, and setting guard plugs to any important transit points which may not have been previously guarded. If any changes in the alignment have been ordered, these may be made at the same time.

**229. Cross Sections.** The resident engineer is furnished with a profile of the portion of the line in his charge, upon which is plainly indicated by line and figures the established grade. From this he calculates the elevation of grade at each station, and by subtracting this from the elevation of the surface, he derives the depth of cut or fill (+ or −) to be made at each point. The grade given on the profile is that which is subsequently called the subgrade, being the surface of the road-bed. The final or true grade is the upper surface of the ties after the track is laid.

*The base* of a cross section is identical with the width of the road-bed. It is made wider in cuts than in fills to allow for the side ditches. Six feet should be allowed in earth, and four feet in rock cuts. **The ratio of the side slopes** depends upon the material. The usual slope ratio for earth is $1\frac{1}{2}$ horizontal to 1 vertical for both excavation and embankment. Damp clay and solid gravel beds will stand for a time in cuts at 1 to 1, or an angle of 45°, but this cannot be permanently depended on. On the other hand, fine sand and very wet clay may require slopes of $1\frac{3}{4}$ to 1 or 2 to 1. Exceptional cases require slopes of 3 or 4 to 1. In rock work the slopes are usually made at $\frac{1}{4}$ to 1 for solid, $\frac{1}{2}$ to 1 for loose, and 1 to 1 for very loose rock, liable to disintegrate. Rock embankments stand at 1 to 1.

**230.** All cross sections are taken in vertical planes at right angles to the direction of the centre line. Figs. 88, 89.

**Formulæ.**

Let $b = AB$, the base of section, or road-bed.

" $s = \frac{BH}{DH}$ = the slope ratio

" $d = CG$ = the cut (or fill) at the centre stake.

" $h = DH$ or $EN$ = the cut (or fill) at the side stake.

" $x = CD$ = the "distance out" from centre to side stake.

" $y = h - d = KD$.

We have at once from the figures the general formula

$$x = \tfrac{1}{2}b + sh \qquad (332)$$

*When the ground is level transversely;*

$$h = d, \text{ and } x = \tfrac{1}{2}b + sd.$$

For embankment use the same formula, considering $d$ or $h$ as positive in this case also, the figure being simply inverted.

*When the ground is inclined transversely;*

$$h = CG + DK = d + y \quad \text{on the } \textit{upper side in cuts;}$$

$$\therefore \quad x = \tfrac{1}{2}b + sd + sy \qquad (333)$$

and $$h = EN = d - y \quad \text{on the } \textit{lower side in cuts}$$

$$\therefore \quad x = \tfrac{1}{2}b + sd - sy \qquad (334)$$

*For embankments* use the same formulæ, but apply eq. (333) to the *lower* side and eq. (334) to the *upper* side, the figure being inverted. The points $D$ and $E$ on the ground are usually found by trial, such that the corresponding values of $x$ and $y$ will verify the formulæ.

*When the natural slope FD or LE is uniform* its ratio $s'$ may be found by measuring along the section the horizontal distance necessary to change the reading of the rod 1 foot (or half the distance necessary to change it 2 feet, etc.). Then, having found the depths of cut (or fill) at $F$ and $L$, distant $\frac{1}{2}b$ from the centre $C$, we have

$$BH = sh = s'(h - BF)$$

and

$$AN = sh = s'(AL - h)$$

From these we have, for the *upper* side in cuts, and *lower* side in fills.

$$h = \frac{s'}{s' - s} BF \therefore x = \tfrac{1}{2}b + \frac{ss'}{s' - s} BF \tag{335}$$

also, for the *lower* side in cuts, and *upper* side in fills,

$$h = \frac{s'}{s' + s} AL \therefore x = \tfrac{1}{2}b + \frac{ss'}{s' + s} AL \tag{336}$$

We also have

$$\left.\begin{aligned} h - BF &= \frac{s}{s' - s} BF \\ \text{and} \qquad AL - h &= \frac{s}{s' + s} AL \end{aligned}\right\} \tag{337}$$

whence the points $D$ and $E$ may be found by the level.

But points $D$ and $E$ thus calculated should have their positions verified by the general formula, eq. (332), lest the slope $s'$ may not have been perfectly uniform.

*When the natural surface intersects the base* between the points $A$ and $B$, the section is said to be in side hill work, Fig. 90. Both portions of the section are then determined by eq. (333), or where the slope $s'$ is regular, by eq. (335) measuring in every case from the centre stake $C$; but observing that when the centre is in *cut* and one side in fill, or *vice versa*, that $d$ must be considered *negative* for that side, whence eq. (333) becomes for this case

$$x = \tfrac{1}{2}b - sd + sy \tag{333'}$$

**231. Staking out Earthwork.** Beginning at a point on the centre line where the grade cuts the natural surface, the engineer drives a grade stake (marked 0.0) and notes the point in the cross-section book. If the line of intersection of the road-bed and surface would make an acute angle with the centre line, he also finds the points where the *edges* of the proposed road-bed will intersect the surface, drives grade stakes, and also stakes out a cross section through each of those points, if necessary.

Then advancing to the next point on the centre line where a section is required, he finds its elevation with the level (verifying or correcting the elevation taken on the location), calculates the depth of cut or fill $CG$, which is then marked upon the back of a stake there driven; a *cut* being designated by $C$ and a *fill* by $F$.

*If the ground is level transversely* (Fig. 88), he calculates $x$ by

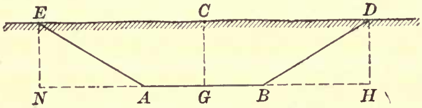


FIG. 88.

eq. (332) and lays off this distance at right angles to the centre line, driving slope stakes at the points $D$ and $E$, marked with the depth of cut or fill. The marked side of slope stakes should face the centre line.

*If the ground is inclined transversely* (Fig. 89), he first measures

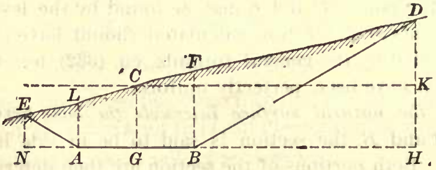


FIG. 89.

the distance, $\frac{1}{2}b$, to $F$, and finds the depth $BF$ for record. He then proceeds to find the point $D$. If the natural slope be uniform, $D$ may be found by eq. (335) or (337), verifying the result by eq. (332). The point $E$ of the other slope may be found similarly, using eq. (336) or eq. (337); verifying by eq. (332).

**232.** *If the ground be irregular*, the depth of cut or fill is found not only at the centre and edges of the road-bed, but also at every other *point* along the cross section *where the surface slope changes*, all of which depths are recorded, together with their respective distances from the centre. *To find the point D:* assume a point supposed to be near $D$, and there take a reading of the rod. The difference of the readings at that point and at $C$ equals $y'$ for that point, which inserted in eq. (333) gives a value $x'$. If $x'$ agrees with the horizontal distance of the assumed point from $C$, the true position of $D$ has been found. If $x'$ be *greater* than this, by subtracting the eq. $x' = \frac{1}{2}b + sd + sy'$ from eq. (333) we derive

$$x = x' + s(y - y') \qquad (338)$$

the last term of which shows the correction to be added to $x'$. Now in advancing from the assumed point to the extremity of $x'$, the rise of the surface is approximately $(y - y')$, and if, in going the additional distance, $s(y - y')$, a further rise is encountered, this last, multiplied by $s$, must also be added to $x'$, and so on until the additional advance makes no change in the value of $y$. The point thus found, verified by eq. (332), is the point $D$ required.

But if $x'$ be *less* than the distance of the assumed point from $C$, we have

$$x = x' - s(y' - y) \qquad (338)'$$

the corrections being subtractive.

The point $E$ on the other slope is found in a similar manner, using eq. (334) for the value of $x'$; if $x'$ be *greater* than the assumed distance, we have

$$x = x' - s(y - y') \qquad (339)$$

the corrections being *subtractive;* but if $x'$ be *less* than the assumed distance,

$$x = x' + s(y' - y) \qquad (339)'$$

the corrections being *additive.*

**233. In side-hill work** (Fig. 90) proceed in the same manner, using eqs. (333) or (333)' and (338) in all cases of uneven ground. When the surface slope $s'$ is uniform, eq. (335) may be used, if preferred, on either side. In addition to the centre and side stakes, a grade stake is driven at the point $O$, where the surface intersects the grade, the stake facing down hill.

*To find a grade point,* set the target to a reading equal to the height of instrument *less* the elevation of grade, and stand the rod at various points along the given line until the target coincides with the line of collimation.

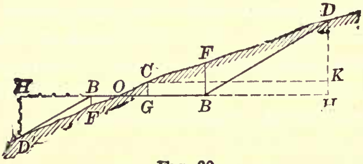


FIG. 90.

**234.** When two materials are found in the same section, as rock overlaid with earth, each material requires its own slope, and a **compound section** is the result. *To stake out work of this description,* the depth of earth to the rock must be known, and may be nearly ascertained by reference to an adjacent section already excavated. Fig. 91.

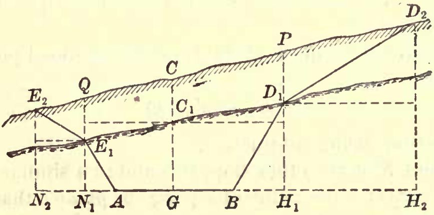


FIG. 91.

Let $a_1$ be the depth of earth at $C$
" $a_2$ " " " $P$ or $Q$
" $s_1$ be the ratio of rock slope
" $s_2$ " " earth slope

Then $$x = \tfrac{1}{2}b + s_1(d - a_1 \pm y_1) + s_2(a_2 \pm y_2) \qquad (340)$$

in which $y_1$ = difference of rod readings on the *rock* at $C_o$ and $D_1$, or $C_o$ and $E_1$; and $y_2$ = difference of rod readings on the *surface* at $P$ and $D_2$, or at $Q$ and $E_2$. The upper sign applies to the upper side, the lower sign to the lower.

It is better, however, to make an indefinite cross profile at first, driving two reference stakes quite beyond the section limits; and when the contractor has removed the earth from between $D_1$ and $E_1$, indicate to him those exact points by marks on the rock, and also set the slope stakes at $D_2$ and $E_2$.

**235. The frequency** with which cross sections should be taken depends entirely upon the form of the surface; where this is regular, a section at each station is sufficient. A cross section should be taken, not only at every point on the centre line where there is an angle in the profile, but also wherever an angle would be found in the profile of a line joining a series of slope stakes on either side, even though the profile of the centre line may be quite regular at the corresponding point:—the object being, not only to indicate the proper outlines of the earthwork, but to furnish the data necessary to calculate correctly the quantities of material removed. Rockwork will generally require more frequent sections than earthwork.

**236. Vertical Curves.**—The grades as given on the profile are right lines, which intersect each other with angles more or less abrupt. These angles require to be replaced by *vertical curves*, slightly changing the grade at and near the point of intersection. A vertical curve rarely need extend more than 200 feet each way from that point. Fig. 92.

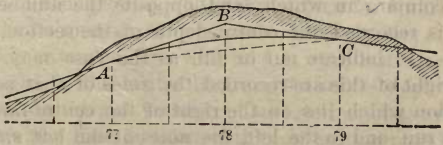


FIG. 92.

Let $AB$, $BC$, be two grades in profile, intersecting at station $B$, and let $A$ and $C$ be the adjacent stations. It is required to join the grades by a vertical curve extending from $A$ to $C$. Suppose a chord drawn from $A$ to $C$;—the elevation of the middle point of the chord will be a mean of the elevations of grade at $A$ and $C$; and one half of the difference between this and the elevation of grade at $B$ will be the middle ordinate of the curve. Hence we have

$$M = \frac{1}{2}\left(\frac{\text{grade } A + \text{grade } C}{2} - \text{grade } B\right) \qquad (341)$$

in which $M =$ the correction in grade for the point $B$. The correction for any other point is proportional to the square of its distance from $A$ or $C$. Thus the correction at $A + 25$ is $\frac{1}{16}M$; at $A + 50$ it is $\frac{1}{4}M$; at $A + 75$ it is $\frac{9}{16}M$; and the same for corresponding points on the other side of $B$. The corrections in the case shown are *subtractive*, since $M$ is negative. They are *additive* when $M$ is positive, and the curve concave upward.

These corrections are made at the time the cross sections are taken, and the corrected grades are entered in the field-book opposite the numbers of the respective stations.

**237. Form of Field-book.**—A complete record of all cross-section work is kept in the cross-section book. On the left-hand page is recorded, in the *first column*, the numbers of the stations and other points where sections are taken; *in the second*, the elevations of those points, copied in part from the location level-book, but verified or corrected at the time the section is taken; *in the third*, the elevation of the grade for the same points; *in the fourth*, the width of base $b$; *in the fifth*, the slope ratios, $s$; and *in the sixth*, the surface ratio $s'$ when uniform. The right-hand page has a central column, in which, and opposite the number of the station, is recorded the centre-depth of the section, marked + or −, to indicate cut or fill, as the case may require. To the right of this are recorded the notes of that portion of the section which lies on the right of the centre line, as the line was run, and to the left, the notes of the left side. The distance from the centre to each point noted is recorded as the numerator of a fraction, and the cut or fill at the point as the denominator, prefixed by a + or − as the case may require. The denominator for a grade point is zero. The numbers of the stations should increase *up* the page, as in a transit book, so that there may be no confusion as to the right and left side of the line. The several points being noted in order as they occur from the centre outwards, the notes farthest from the centre of the page usually appertain to the slope stakes; but in case the cross profile is extended beyond the slope stake, the note of the latter should be surrounded by a circle to distinguish it. The following form is a specimen of a right-hand page, with the first column only of the left-hand page:

| Sta. | Cross | | | | | Sections. | | | |
|---|---|---|---|---|---|---|---|---|---|
| 83 | 22.9 / + 8.6 | 16.5 / + 14 | 10 / +17.7 | 5 / + 21 | 0 / +21.5 | 10 / +20.8 | 20 / +25.6 | 32 / +28.3 | 55.6 / +30.4 |
| + 60 | | 17.5 / + 5.0 | 10 / + 10 | 4 / +13.2 | 0 / + 14 | 10 / +14.7 | 24 / +20.1 | 42.6 / +21.7 | |
| 82 | | | 14.2 / + 2.8 | 10 / + 5.4 | 0 / + 9.4 | 6 / + 8.5 | 10 / +11.6 | 31.6 / +14.4 | |
| + 38 | | | | 10 / 0 | 0 / + 2.8 | 10 / + 3.8 | 19.3 / + 6.2 | | |
| + 27 | | | | | 0 | | | | |
| + 19 | | | 21.7 / − 9.8 | 7 / − 5.6 | 0 / − 4.7 | 10 / 0 | | | |
| 81 | | | 25.9 / −12.6 | 7 / −11.2 | 0 / − 12 | 7 / −10.6 | 15 / − 5.3 | | |
| 80 | | | 33.4 / −17.6 | 7 / −16.4 | 0 / −17.6 | 7 / −19.6 | 18 / −19.1 | 25.6 / −12.4 | |

**238.** In case there is a liability to land-slips, the profiles of cross sections should be carried beyond the slope stakes, on the upper side of the cut, to any distance thought necessary to reach firm ground, and stakes driven for future reference. When a number of consecutive cross profiles are to be considerably extended, it is well to first run, instrumentally, a line parallel to the centre line, and set stakes opposite the stations, taking their elevations. The intermediate surface of the sections may then be taken with cross-section rods if more convenient. See § 37.

**239.** In case of **inaccessible ground,** preventing a regular staking out, an indefinite profile of the section may generally be obtained, referred to the *datum* for elevation and to the centre line for position, which being plotted on cross-section paper, and the grade line and side slopes added, shows to scale where the slope stakes should be.

**240. Any isolated mass** of rock or earth which occurs within the limits of the slope stakes, but not included in the regular notes, is separately measured and noted, so that its contents may be computed and added to the sum of the same material found in the cross sections.

**241. Borrow-pits.**—When the excavations will not suffice to complete the embankments, material may be taken from other localities, termed *borrow-pits.* These should be staked out by the engineer and their contents calculated, unless the contractor is to be paid for work by embankment measurements. A number of cross profiles are taken of the original surface, and (on the same lines) of the bottom of the pit after it is excavated, which furnish the depth of cutting at each required point. Borrow-pits should be regularly excavated, so that they may not present an unsightly appearance when abandoned. Borrow-pits may be avoided by widening the cut uniformly at the time it is staked out, so that it may furnish sufficient material; *provided* the material is suitable, the embankment accessible, and the distance not too great. When the excavation is in excess, the surplus material should be uniformly distributed by widening the adjacent embankments, if possible; otherwise it is deposited at convenient places indicated by the engineer and is said to be *wasted.*

**242. Shrinkage.**—In estimating the relative amounts of excavation and embankment required, allowance must be made for difference in the spaces occupied by the material before excavation and after it is settled in embankment. The various earths will be *more* compact in embankment, rock *less* so. The difference in volume is called *shrinkage* in the one case, and *increase* in the other.

| *Material.* | *Shrinkage* in 1000 cu. yds. Of excavation. | Of settled embkt. |
|---|---|---|
| Sand and gravel.............. | 80 C. Yds. | 87 C. Yds. |
| Clay........................ | 100 " | 111 " |
| Loam........................ | 120 " | 136 " |
| Wet soil.................... | 150 " | 200 " |
| | *Increase* in 1000 cu. yds. | |
| Rock, large fragments......... | 600 C. Yds. | 375 C. Yds. |
| " medium fragments...... | 700 " | 413 " |
| " small ...... | 800 " | 444 " |

Thus, an excavation of sand and gravel measuring 1000 cubic yards will form only about 920 cubic yards of embankment; or an embankment of 1000 cubic yards will require 1087 cubic yards of sand or gravel measured in excavation to fill it; but will require only 587 cubic yards of rock excavation, the rock being broken into medium-sized fragments; while 1000 cubic yards of the latter, measured in excavation, will form 1700 cubic yards of embankment.

**The lineal settlement** of an earth embankment will be about in the ratio given above, therefore the contractor should be instructed in setting his poles to guide him as to the height of grade on an earth embankment, to add 10 per cent (average) to the fill marked on the stakes. In rock embankments this is not necessary. The engineer should see that all embankments are made full width at first, out to the slope stakes, and by measure at or above grade, so that the whole may settle in a compact mass. Additions to the width made subsequently are likely to slide off.

**243.** The cross-section notes should be traced in ink at the first opportunity to secure their permanence. An office copy should also be made to serve in case of loss or damage to the original.

**244. Alteration of Line.**—Inasmuch as the centre line at grade is the base of reference for all measurements and calculations in earthwork, any change made in it after the work of grading has begun should be most carefully recorded and explained. The centre stakes of the old line should be left standing until after the new line is established, so that the perpendicular offset from the old line to the new, at each station, may be measured, as also the distance that the new station may be in advance of, or behind the old one. The *date* of the change should be recorded. The original cross sections are extended any amount requisite, the distance out being still reckoned from the *old* centre, while a marginal note states the amount by which the centre has been shifted.

The difference in length of the lines will make a long or short station at the point of closing. The exact length of such a station should be recorded, so that it may be observed in retracing the line at any time, and in calculating the quantity of earthwork. The original transit notes of the altered line should be preserved, but marked as "abandoned," with a reference to the notes of the new line on another page.

**245. Drains and Culverts.**—The engineer should examine the nature and extent of each depression in the profile with reference to the kind of opening required for the passage of water. For small springs, and for a limited surface of rainfall, cement pipes, in sizes varying from 12 to 24 inches diameter, serve an excellent purpose as drains. These are easily laid down, and if properly bedded, with the earth tamped about them, are very permanent; but their upper surface should be at least 2½ feet below grade. The embankment is protected at the upper end of the drain by a bit of vertical wall, enclosing the end of the pipe. If necessary, a paved gutter may lead to it.

Where stone abounds, the bed of a dry ravine may be partly filled with loose stone, extending beyond the slopes a few feet, which will prevent the accumulation of water.

When the flow of water is estimated to be too great for two lines of the largest cement pipe, or when the embankment is too shallow to admit them safely, a culvert is required. A pavement is laid one foot thick, protected by a curb of stone or wood 3 feet deep at each end, and wide enough to allow the walls to be built upon it. It should have a uniform slope, usually between the limits of 50 to 1 and 100 to 1 to ensure the ready flow of water. In firm soils the foundation pit is excavated one foot below the bed of the stream, but if mud is found this must be removed and the space filled with riprap, the upper course of which is arranged to form the pavement at the proper level. In a V-shaped ravine, requiring too much excavation at the sides, and where the fall is considerable, riprap may be used to advantage, the bed of the stream above the culvert being graded up by the same material to meet the pavement. In some cases a curtain, or cross wall, is necessary on the lower end to retain the riprap.

Culverts should be laid out at right angles to the centre line whenever practicable, the bed of the stream being altered if necessary. The length of an open culvert is the entire distance between slope stakes, the walls being parallel throughout, or the length may be taken somewhat less than this, and the walls turned at right angles on the upper end, forming a facing to the foot of the slope. The walls are carried up to grade for the width of the road-bed, and are stepped down to suit the slopes. A course is afterwards added to retain the ballast.

In box culverts the span varies from 2 to 5 feet, the height in the clear from 2 to 6 feet; the thickness of walls from 3 to 4 feet; the thickness of cover from 12 to 18 inches, and its length at least 2 feet greater than the span. The walls terminate in short head-walls built parallel to the centre line, the top course being a continuation of the cover. The length of a head-wall, measured on the outer face, is equal to the height of the culvert in the clear multiplied by the slope ratio of the embankment. The perpendicular distance from the centre line to the face of a head-wall is equal to one half the road-bed, *plus* the depth of the top of the wall below grade multiplied by the slope ratio, or $\frac{1}{2}b + sk$. A coping is sometimes added.

**246. Arch culverts** are used when the span required is more than 5 feet, and the embankment too high to warrant carrying the walls up to grade as an open culvert. The span varies from 6 to 20 feet; the arch is a semicircle, the thickness varying from 10 or 12 inches to 18 or 20 inches. The height of abutments to the springing line varies from 2 to 10 feet, the thickness at the springing line from 3 to 5 feet, and at the base from 3 to 6 feet, the back of the abutment receiving the batter. The foundations are laid broader and deeper than in box culverts, each abutment having its own pit, carried to any depth found necessary. The half length of the culvert is $\frac{1}{2}b + sk$, in which $k$ is the depth of the crown of the arch below grade. The abutments are carried up half way from the spring to the level of the crown of the arch, and thence sloped off toward the crown. The face walls are carried up to the crown, and coped. The wing walls stand at an angle of 30° with the axis of the culvert; they receive a batter on the face, and are stepped (or sloped) down to suit the embankment. Their thickness, at the base, is the same as that of the abutment; at the outer end 3 feet. They stop about 3 feet short of the foot of the slope. They need not be curved in plan.

Any stone structure of dimensions greater than those given above, scarcely comes under the head of culverts, and should be made the subject of a special design by the engineer.

**247. Staking out Foundation Pits.—For box culverts.**—The engineer having decided upon the size of culvert required, makes a diagram of it in plan, on a page of his masonry book, recording all the dimensions, stating the station and *plus* at which its centre is taken, the span and height of the opening, etc. He then sets the transit at the centre *A*, Fig. 93, measures the angle between the centre line and axis,

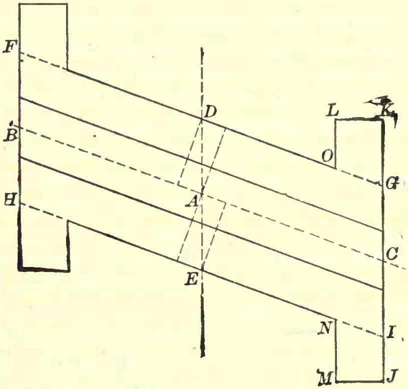


FIG. 93.

(making it 90° if practicable); on the axis he lays off the distances to the ends of the culvert and drives stakes at *B* and *C*. Perpendicular to *BC* he lays off the half widths of the pit, setting stakes at *D* and *E*, and laying off *DF* and *EH* = *AB*; and *DG* and *EI* = *AC*. On *IG* produced he lays off *CJ* = *CK*, and perpendicular to this *JM* and *KL*, and finds the intersections *O* and *N*. A stake is driven at each angle, and upon it is marked the cut required to reach the assumed level for the foundation. These cuts are recorded on the corresponding angles of the diagram. The pit is thus no larger than the plan of the proposed masonry, and the sides are vertical, which answers the purpose for shallow pits.

**For arch culverts.**—The pit for each abutment when shallow may be of the same dimensions as the lower foundation course; if more than five feet deep, it should be enlarged by an extra space of one foot all around. In Fig. 94 the inside lines show the plan of the abutments at the neat-lines; the outside lines represent the pits. Having prepared a plan of the structure suited to the locality, and made a diagram of the same in the masonry book, set the transit at $A$, and drive stakes at $D, E, N$ and $O$ on the centre line. Then turning to the axis $BC$, lay off $AC$, and set stakes at $G$ and $I$. With $G$ as a centre, and a radius equal to $2DE$, describe on the ground

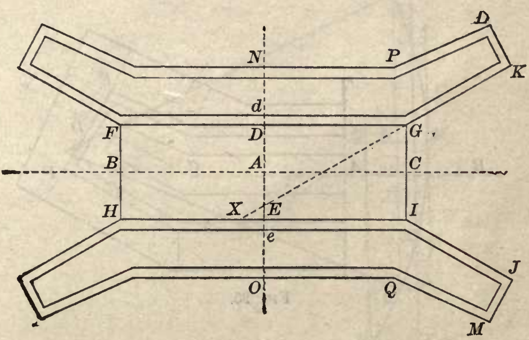


Fig. 94.

an arc cutting $EI$ in $X$ or ($IX = DE$ . cot 30°) may be calculated; and on $XG$ produced lay off $GK$, and perpendicular to this, $KL$. From $N$ lay off $NP$, parallel to $AC$, and measure $PL$ as a check. Drive a stake at each angle, marked with the proper cutting, and record the same on the diagram. The locality may require the wings to be of different lengths and angles, of which the engineer will judge. Guard-plugs should be driven in line with the intended face of one or both abutments, so that the neat-lines can be readily given when required. In case the material is not likely to stand vertically, the pit must be staked out with sloping sides, as described below.

**For bridge abutments.**—A design for every important structure is usually prepared in the office after a survey of the site. The foundation pit is then laid out from dimensions furnished on a tracing, but a diagram of the pit should be made in the masonry book as usual. *When the bridge is on a tangent*, Fig. 95, set the transit at $A$ on the centre line at its intersection with the axis $BC$ of the abutment *at the level of the seat.*

Deflect from the tangent the angle giving the direction of *BC*, and lay off *AC*, *AB*, setting plugs at *B* and *C*, and reference plugs (two on each side) on *BC* produced. After staking out the sides of the pit parallel to *BC*, set the transit at *C*, and deflect the angle for the wing, laying off *CD*, and driving stakes at the corners *E* and *F*. Two reference points are then set on the line *CD* produced. The other wing being

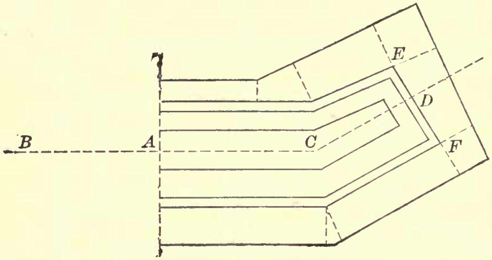


FIG. 95.

staked out in the same manner, the cut is found at each stake and marked and recorded. Cross sections are then taken near each corner, perpendicular to each side, and slope stakes (marked "slope") are driven where the slope runs out. Intermediate sections are taken when the unevenness of the ground makes it necessary, and the lines joining the slope stakes are produced to intersect, and other stakes are driven at the intersections. The position of each stake is shown on the diagram, and the cut recorded.

A slope of 1 to 1 is usually sufficient for pits. If the material will not stand at 1½ to 1, or if space cannot be spared for the slope, the sides may be carried down vertically, supported by sheet piling braced from within.

The reference points should be so chosen that the points *A*, *B* and *C* may be found by intersection, on any course of the masonry, during the progress of construction.

**When the bridge is on a curve,** the bridge-chord should be found and the abutments laid out from this. Fig. 96. The bridge-chord is a line *AB*, midway between the chord of the curve *CD*, joining the centres of the abutments, and a tangent to the curve at the middle point of the span. Hence

$CA = DB = \frac{1}{2}MN$, which may be laid off, and $A$ and $B$ are the true centres of the abutments, from which the foundations are staked out as before.

The distance $CE = DF$ to the points where the bridge-chord cuts the curve is $0.147\,CD$.

Should an abutment site on a curve be inaccessible, as when

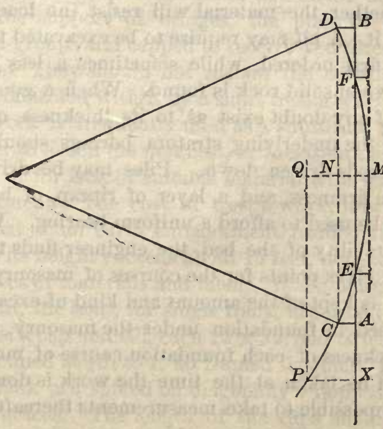


FIG. 96.

under water, from any transit point $P$ on the curve lay off $PX$ perpendicular to the tangent at $M$, observing that

$$PX = MQ - AC = R\,(vers\ PM - \tfrac{1}{2}\,vers\ CM)$$

and $$AX = PQ - \tfrac{1}{2}AB = R\,(sin\ PM - \tfrac{1}{2}CD)$$

The point $A$ may then be found by intersection, or by direct measurement with a steel tape or wire, driving a long stout stake to show the point above the water. Other points may then be approximately found, sufficient to begin operations.

In case of a bridge of several spans, the piers are laid out in the same manner, from a centre point and axis. If on a curve, each span has its own bridge-chord, but for convenience, the centre of a pier may be taken on the centre line during its construction, and the bridge-chord only found for the purpose of placing the bridge; the piers being long enough to allow of the shift.

**To locate the centres of piers,** a base line is required on one or both shores, and two transits are used to give the intersections by calculated angles. When practicable the spans should also be measured with a steel tape or wire.

**The bed of a pit** for any sort of structure should receive the closest scrutiny of the engineer, it being his duty to judge whether the material will resist the load to be imposed upon it. A pit may require to be excavated to a greater depth than first ordered, while sometimes a less depth will answer, as when solid rock is found. When a good material is reached, if any doubt exist as to its thickness, or as to the character of the underlying stratum, borings should be made or sounding rods driven down. Piles may be driven to gain the requisite firmness, and a layer of riprap, of beton, or of timber may be used to afford a uniform bearing. When satisfied of the stability of the bed, the engineer finds the original centres, and gives points for the courses of masonry. A complete record is kept of the amount and kind of excavation, the materials used in foundation under the masonry, and of the size and thickness of each foundation course of masonry; the notes should be taken at the time the work is done, it being generally impossible to take measurements thereafter.

**248. Cattle-guards** are shallow pits placed at right angles across the road at the fence lines to prevent the passage of cattle. They are either entirely open, in which case they should be at least 4 feet deep, or they are covered in part with wooden rails laid a few inches apart. The open guard is preferred. It is built like an open culvert except that no pavement is required. The stringers carrying the rails over any opening should be no longer than the span *plus* the thickness of the walls.

**249. Trestle Work.**—No wooden culverts should ever be used. If stone cannot be had at first, two trestle bents may be erected, leaving between them a space sufficient to contain the stone structure to be built when the material for it can be brought by rail. The bents may be backed by plank to retain the embankment, and the stringers are then notched down an inch on the caps to receive the pressure of the earth, and render the bents mutually sustaining. The sills are prevented from yielding to the pressure of the earth by being sunk in a trench, or by sheet piling. Should the span be too long, a central bent may be used, so as not to interfere with building the wall. Sometimes pile-bents may be used with greater advantage, the piles being driven in rows of four each, and capped to receive the stringers. In districts where suitable stone is entirely wanting, pile or trestle abutments and piers are used for the support of bridges, the piles or posts being arranged in groups and capped to receive the direct weight of the trusses. They should not sustain the embankment, but should be connected with it by a short trestle work.

Trestle work is frequently used as a substitute for embankment, either to lessen the first cost, or to hasten the completion of the line, or for lack of suitable material with which to form an embankment. The cost of trestle work, however, is not less than that of an earth embankment formed from borrow pits, unless its height exceeds about 15 feet, depending on the relative prices of materials and labor. When not exceeding 30 feet in height, the *bents*, for single track, are usually composed of two posts, a cap and sill, each 12 × 12, and two batter posts, 10 × 12, inclined at ¼th to 1, all framed together. Two lengths of 3-inch plank are spiked on diagonally on opposite sides of the bent as braces. The length of the caps should equal the width of the embankment; the posts should be 5 feet from centre to centre, and the batter posts 2 feet from the posts at the cap. The sill should extend about two feet beyond the foot of the batter post. A masonry foundation for the bent is preferable, though pile foundations are not uncommon, and some temporary structures are placed directly on a firm soil, supported only by mudsills laid crosswise under the sill. The spans, or distance between bents, may vary from 12 to 16 feet. The stringers should consist of 4 pieces, 2 under each rail, bolted together, with packing blocks to separate them 2 or 3 inches. Over each bent and at the centre of each span a piece of thick plank about 4 feet long should be placed on edge between the two pair of beams to preserve the proper distance between them, while rods pass through the beams and strain them up to the ends of the plank, to increase the stability of the beams and prevent their buckling under a load. The stringers should be able to carry safely the heaviest load without bracing against the posts. The bents, however, if high, must be braced against each other. The stringers should be continuous, the two pieces breaking joints with each other at the bents, to which they are firmly bolted. They may rest directly on the caps, or corbels may intervene. The spans on a curve should be shorter than on a tangent. The ties should be notched down to fit the stringers closely, and guard rails, either wood or iron, secured to them firmly. Unless the spans are very short, horizontal bracing should be employed consisting of 3-inch plank, extending from the centre of each span to the ends of the caps, which are notched down to receive the plank.

For trestles much higher than 30 feet **the cluster bent** is preferable, so termed because each vertical post is composed of a cluster of four pieces, $8 \times 8$, standing a little apart to allow the horizontal members to pass between them. The verticals are continuous, breaking joints, two and two, while the horizontals pass the posts and are bolted to them at the joints; the framing is accomplished entirely by packing blocks and bolts. The batter posts consist each of two pieces $8 \times 8$; the horizontals may be $4 \times 10$, and extend not only across the bent, but from one bent to another. Proper bracing is also used in every direction. When very high, a secondary pair of batter posts may be introduced in the lower part of the structure. The batter need not exceed $\frac{1}{8}$th to 1. In some instances two adjoining bents are strongly braced together, forming a tower or pier, and the piers placed from 50 to 100 feet apart, the roadway being carried on trussed bridges. The cluster bent admits of any piece being removed and a new one inserted when necessary.

**Iron trestles** are now adopted where a permanent structure is desired. Owing to the expansion of the metal by heat, the bents cannot be continuously connected with each other as in a wooden trestle; hence the pier form is resorted to, having spans varying from 30 to 150 feet, covered by trussed bridges, and the whole structure is more properly styled a viaduct.

**250. Tunnels.** Tunnels are adopted in certain cases to avoid excessive excavations, steep grades, high summits, and circuitous routes. Their disadvantages are the increased time and cost of their construction compared with an open line, and their lack of light and fresh air when in use. It is desirable that they should be on a tangent throughout, both for the admission of light and for convenience of alignment. Many tunnels, however, have been built with a curve at one or both ends.*

**The location** of a tunnel, other things being equal, should be such as to make not only the tunnel proper, but also its immediate approaches by open cut as short as possible; and the latter should be selected so as not to be subject to overflow, nor liable to land slides. The material to be encountered may frequently be determined with tolerable accuracy by a study of the geological formation in the vicinity, or by actual borings. The most favorable material for tunnelling is a homogeneous self-supporting rock, devoid of springs, which does not disintegrate on exposure to the atmosphere. The worst materials are saturated earth and quicksands. The presence of water in any material increases the cost considerably.

**The alignment** of a tunnel is made the subject of special survey, after the general location is decided, and this is more or less elaborate according to the length of tunnel. A permanent station is established at the highest point crossed by the tunnel tangent, from which, if possible, monuments are set in each direction at points beyond the ends of the tunnel. If there are two principal summits, stations on these will define the tangent, which may then be produced. The monuments established beyond the tunnel should be sufficiently distant to afford a perfect backsight from the ends of the tunnel, where other monuments are also established. The first quality of instruments only should be used, and these perfectly adjusted, and the observations should be repeated many times until it is certain that all perceptible errors are eliminated. Since the line of collimation will be frequently inclined to the horizon at a considerable angle, it is important that it should revolve in a vertical plane; and to secure this, a sensitive bubble tube should be attached to the horizontal axis, at right angles to the telescope of the transit. The distance may be obtained by triangulation, though direct measurement is to be preferred. A steel tape is convenient and accurate, providing that allowance be made for variations due to temperature, from an assumed standard. The rods described in § 43 may be used instead of

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* The Mont Cenis tunnel, requiring a curve at each end, was first opened on the tangent produced, giving a straight line through, and the curves were excavated subsequently.

plumb lines, the tape being held at right angles to them, and therefore horizontal. A plug should be driven for each rod to stand on, and a centre set to indicate the line and measurement.

As the excavation of the tunnel proceeds, the centre line is given at short intervals by points either on the floor or roof. Overhead points are generally preferred, from which short plumb lines may be hung, constantly indicating the line, with little danger of being disturbed. When a new transit point is required in the tunnel, it should be established directly under an overhead point, which serves as a check upon its permanence, and as a backsight when needed.

**Shafts** are sometimes opened to give access to several points of the tunnel at the same time, thus facilitating the work, though at an increased cost. They also serve for ventilation during the progress of the work, though they are worse than useless for this purpose afterward, except possibly in the case of a single shaft near the centre of the tunnel. Some of the longest tunnels have been formed without shafts, while many shorter ones have had several, which have generally been closed after the tunnel was completed. Shafts are either vertical, inclined, or nearly horizontal; in the latter case they are called adits. Inclined shafts should make an angle of at least 60° with the vertical. Vertical shafts may be either rectangular, round, or oval. Their dimensions vary, depending on their depth and the material encountered, between 8 and 25 feet. They are usually sunk on the centre line of the tunnel, though sometimes at one side. When over the tunnel the alignment below is obtained directly from two plumb lines of fine wire suspended on opposite sides of the shaft from points very carefully determined at the surface. The plummets are suspended in water to lessen their vibrations, and as soon as the transit can be set up at a sufficient distance to bring the lines into focus, it is shifted by trial into exact line with the mean of their oscillations, the latter being very limited. Permanent points may then be set, but should be repeatedly verified. As soon as the workings from a shaft communicate with those from either end, or from another shaft, the alignment thus found is tested, and revised if necessary. These operations require the greatest nicety of observation and delicacy of manipulation to obtain satisfactory results.

From plumb lines in the central shaft of the Hoosac tunnel, the line was produced three tenths of a mile, and met the line produced 2.1 miles from the west end with an error in offset of five sixteenths of an inch. In the Mont Cenis tunnel the lines met from opposite ends with "no appreciable" error in alignment, while the error in measurement was about 45 feet in a total length of 7.6 miles.

When **a curve** occurs in a tunnel it is usually near one end. The tunnel tangent is produced and established as before described, and a second tangent from some point on the curve outside the tunnel is produced to intersect it, the intersection being precisely determined and the angle measured with many repetitions. The tangent distances are then calculated, and the position of the tangent points corrected by precise measurements, and permanent monuments are established. As the tunnel advances, points may be set at short intervals on the curve in the usual manner; but at intervals of 100 feet the regular stations should be defined with finely centred monuments, using a 100-foot steel tape carefully supported in a horizontal position. When it is necessary to use a subchord, its exact length should be calculated as shown in § 107. When the curve has advanced so far as to render a new transit point necessary, this should be established at a full station. The subtangents from the two transit points should then be produced to intersect, and measured for equality with each other and with their calculated length. The distance from their intersection to the middle of the long chord should also be measured as a check on the deflections. When no perceptible errors remain, the curve may be produced as before until the *P. T.* is reached. It is evident that correct measure is indispensable to correct alignment on curves. Should obstacles on the surface necessitate triangulation, more than ordinary care must be exercised, and as many checks introduced as possible. The triangles should be so arranged that all of the angles and most of the sides may be measured.

**Test levels** are carried over the surface with great care, each turning point being made a permanent bench, and its elevation determined with a probable error not exceeding 0.005 foot. Levels may be carried down a shaft on a series of bolts or spikes about 12 feet apart in the same vertical line, the distances being measured by the same level-rod as that with which the benches are determined. The measures should be taken between two graduations of the rod, not using the end of the rod, which may be slightly worn. Fine horizontal lines on the heads of the bolts may be used to mark the exact distances. After the shaft reaches the level of the tunnel, the depth may be measured more directly with a steel tape, the entire length of which has been corrected at the given temperature, by comparison with the same rod.

If the **grade of a tunnel** is to be continuous, it should be assumed at something less than the maximum of the road, but not less than 0.10 per station, which is required for drainage. If a summit is to be made in the tunnel, the grade from the upper end should not exceed 0.10 per station. Grades are given in the tunnel from day to day, or as often as required by the progress of the work, the marks being made on the sides at some arbitrary distance above grade. Turning points should be taken on permanent benches.

**The least width** of a tunnel in the clear should be, for single track about 15 feet, and for double track 26 feet. **The least height** in the clear above the tie should be 18.5 feet for single track, and 16.5 feet at the outside rails for double track, allowing for tie and ballast; the roof at the centre of the section should be at least 20 feet above subgrade, and with a full centred arch 22 or 23 feet for double track. **The form** of section depends somewhat on the material traversed. In perfectly solid rock a nearly rectangular section may be used, the roof being slightly rounded. In dry clay, and stratified rock, a flat arch may be used, and in other cases a full-centred arch. The latter form is rather to be preferred on account of the better ventilation afforded. The sides are made vertical, battered or curved, as necessity or taste may dictate. In wet and infirm soil an invert floor may be required, otherwise it is made level transversely. When a lining is required the original section must of course be made large enough to allow for the masonry, and the temporary timber supports behind it. Hard burned brick is usually adopted for arching, being durable and easily handled. In loose rock the arching may be from 13 to 26 inches thick, in wet and yielding soil a thickness of from 26 to 39 inches may be necessary. The walls may be from 2½ to 6 feet thick.

In forming a tunnel, **a heading** or gallery of smaller cross section is first driven and afterwards enlarged to the full size required. In firm clay or loose rock which will temporarily support itself until the masonry can be put in, it is better to drive the heading along the floor (at subgrade) of the tunnel, the remaining material being then easily thrown down in sections as the arching is advanced. In solid rock, or wet earth, a top-heading (along the roof) is generally preferred. The dimensions of a heading driven by hand are usually 8 feet high by 8 or 10 feet wide, but in solid rock where drilling machinery is introduced, it is advantageous to make the heading as wide as the tunnel at once. By drilling holes into the face at points about five feet each side of the centre, and converging on the centre line at a depth of about ten feet, a triangular mass of rock may be blown out, and the space thus gained facilitates the blasting of the adjacent rock on either side. An advance of about 10 feet in each day of 24 working hours may thus be made, using nitroglycerine in some form as the explosive agent. Owing, however, to unavoidable delays from various causes, this rate of progress cannot always be maintained. At the Hoosac tunnel the greatest advance in one week was 50 feet; in one month 184 feet at one heading. At the Musconetcong tunnel a heading 8 × 22 feet in syenitic gneiss was advanced at the average rate of 137 feet per month for 6 months, the maximum being 144 feet —the enlargement of the tunnel to full size going on at the same time, a few hundred feet behind. At the St. Gothard tunnel the north heading 2.5 × 3 metres was advanced in mica gneiss, during the year 1875 at the average daily rate of 3.71 metres, with a maximum of about 4 metres, but the enlargement was not made. The south heading advanced at the rate of 2 metres a day, timbering being at times necessary.

In ordinary clay a heading may be driven at from 75 to 180 ft. per month, according to circumstances, where timbering is put in. The enlargement, including timbering and masonry, may be advanced at from 20 to 60 ft. per month. Small tunnels for water conduits are driven through dry clay at the rate of 10 ft. per day, the masonry following at once without timbering.

**The compressed air** used to drive the drilling machinery serves to supply ventilation also. When this is wanting or proves insufficient, exhaust fans are used. At Mont Cenis a horizontal *brattice* or partition was built in the tunnel, dividing it so as to secure a circulation of air. When foul gases are encountered, ventilation becomes a serious question, and in one instance an important work was abandoned for this cause.

**Cross sections** of the heading, and also of the tunnel en largement, should be measured at intervals of about 20 feet, as soon as opened, to see that the sides, roof, and floor are taken out to the prescribed lines, at the same time that the latter are exceeded as little as possible. In solid rock, since some material outside of the true section will necessarily be thrown down, leaving an irregular outline, it is well to take two cross sections at the same point, one following the projections and the other the recesses of the rock, from which an average section may be estimated. A daily, or at least a weekly, record of operations should be kept in tabular form, and the progress indicated by a profile and cross sections drawn on a sufficiently large scale to show details.

**The drainage** of a tunnel is best secured by a line of stoneware or cement pipe laid in a trench along each side, and covered with ballast or other loose material. The entire floor is thus made available for the use of the trackmen. When an invert is used, the drain is placed in the centre between tracks. If the amount of water is large, drain pipe may be laid behind the walls, and the back of the arch may be covered with asphaltum, or coal tar, to prevent a constant dripping on the track.

**251. Retracing the Line.**—As the grading progresses, in either excavation or embankment, the principal transit points are established on the road-bed from the points of reference, and the centre line is retraced, setting stakes at every 50 feet. Transit points on grade should be fixed upon stout, durable posts firmly set in the ground, and standing high enough to be easily reached after the ballast is laid. To recover the old line, any discrepancies in measurement must be left between the transit points where they occur, and not carried forward. In retracing a curve, if the transit is placed at the forward point, allowing the chain to advance *toward* it, slight differences in measurement will not affect the position of the curve. If any short or long stations have been introduced on the location, their position on the line must not be changed in retracing. The chain may be adjusted so that its measures will agree with the recorded distances between transit points. Offsets are made right and left from the new stakes to see that the road-bed is of the full width at all points. The levels are also carried over the grade, and any remaining cut or fill found necessary is marked on the back of the stakes, due allowance being made for the probable settlement of embankments.

**252.** As the work approaches completion the contractor goes over the line dressing it to grade and opening the side ditches if this has not been previously done.

Drain-tile should be laid at the bottom of these ditches and lightly covered with earth, particularly if the cut be wet. These not only prevent the water from reaching the ballast, but by keeping the foot of the slope comparatively dry prevent the earth from sliding down and filling up the cut. There is also a marked economy in their use, as the cost is trifling, and all further excavation of mud and water from the cut is generally obviated. Should any springs appear in the slope a branch line of smaller tile may be laid to meet it. If the slope is liable to be overflowed from the surface above, an open ditch should be dug a few feet beyond the slope stakes, leading the surface water to discharge elsewhere.

**253.** The road-bed being prepared, **ballast stakes** are driven at every half station, giving the width of the ballast at its base, while the tops of the stakes indicate the proper level of its upper surface, which is the under side of the tie. These stakes should be set so as to give the proper elevation to the outer rails on curves when the ballast is graded to them. The ballast should be about one foot deep before the ties are laid. Broken stone or a mixture of coarse and fine gravel is the best material, affording elasticity and good drainage. The side slopes of the ballast are made 1 to 1; its width at the under side of the tie should be one foot greater than the length of the tie.

**254. Track-laying.**—After the ballast has been laid and graded, the centre line is retraced upon it; short stakes are used, each of which is centred. On long tangents, one stake in every 200 feet is sufficient, on ordinary curves one in every 50 feet, and on very sharp curves one in every 25 feet. The ties are then spaced evenly according to the number prescribed per mile, or per rail length; but a tie should not be allowed to cover a transit point. Ties for the standard gauge are 8 or 9 feet long; they should be sawed off square at the ends and in uniform lengths for appearance sake when laid. Specifications usually call for ties having a thickness of 6 inches and a width of from 7 to 10 inches. The ends of the ties are aligned on one side of the road, though if cut into uniform lengths both ends will be equally well aligned. The rails are then laid on, and spiked to gauge. The first spikes are driven in the ties near a centre stake, the centre mark of the gauge bar being kept over the centre on the stake. Upon curves the rails must be sprung to the proper arc before they are laid (§ 199). *All* the ties required in a given distance should be laid before the rails are brought upon them. The practice of laying only joint and middle ties at first subjects the rails to the danger of bending from passing loads.

Owing to the **expansion of the rails** by heat, a space must be left at the rail-joints. The highest temperature of a rail in the summer sun is about 130° Fah. The expansion of iron or steel per 100° is .0007 per foot; or for a 30-foot rail .021 foot or .252 inch. Therefore when 30-foot rails are laid at a temperature near the freezing point, or 100° below the maximum, the space allowed must be at least a quarter of an inch. At 80° Fah. or 50° below the maximum, it need be only half as much. The space required is also proportional to the length of rail used. The exact space should be given, as less would result in the rails being forced up by expansion, while more than necessary space gives a rough road, and hastens the destruction of the rail.

Wherever **sidings** are required, the necessary frogs and long switch-ties should be provided in advance, so that they may be put in place at the time of laying the main track. For every road crossing at grade, heavy oak plank should be provided, and laid upon the ties as soon as the rails are spiked, so that the highway travel may not be impeded.

# CHAPTER X.

## Calculation of Earthwork.

**254.** The first step toward finding the cubical content of an excavation is to divide it into a number of prismoids by several cross sections.

**A prismoid** is a solid having plane parallel bases or ends, and bounded on the sides either by planes, or by such surfaces as may be generated by a right line moving continuously along the edges of the bases as directrices.

**The positions** of the cross sections must be so selected that the solid included between any two consecutive sections may be a prismoid as nearly as possible. Upon a tangent the road-bed and side-slopes are planes, so that the prismoidal character of a given solid depends upon the shape of the natural surface. When the natural surface is a plane, the sections are taken only at the regular stations, 100 feet apart; when it is curved, warped, irregular, or broken, the sections must be more numerous, so that the surface limited by any two shall be composed substantially of right-lined elements extending from one section to the other.

If two end sections of a prismoid are somewhat similar, we infer that the corresponding points are connected by right-lined elements, forming in each case the axis of a ridge or of a hollow. If one section has less breaks than the next, some of these ridges or hollows must vanish; and in order that the solid may be a prismoid, they must vanish in the section of least breaks; therefore a cross section must be taken on the ground through the point where each ridge or hollow vanishes, and the distance of that point from the centre line noted, so that it may be coupled with the proper point in the next section for exact calculation of content.

When ridges or hollows run diagonally across the line of road, cross sections must be taken where they are intersected not only by the centre line but also by the side slopes; that is, sections must be taken so that a side stake may stand on top of each ridge and at bottom of each hollow. In case the centre line intersects at right angles a retaining wall or other vertical surface, two cross sections are required at the same point, one at top and the other at base of wall, in order to furnish the data necessary to calculate the content each way from the vertical surface. (See Art. 235.)

Every thorough cut terminates in either side-hill cutting, a pyramid, or a wedge; the latter happens only when the contour of the natural surface is at right angles to the line of road. Sections should always be taken through the points where the edges of the road-bed meet the surface, as these are the points of separation between thorough and side hill-work. Such sections also serve to define terminal pyramids when they occur as is illustrated by Fig. 97. In side-hill work the foregoing

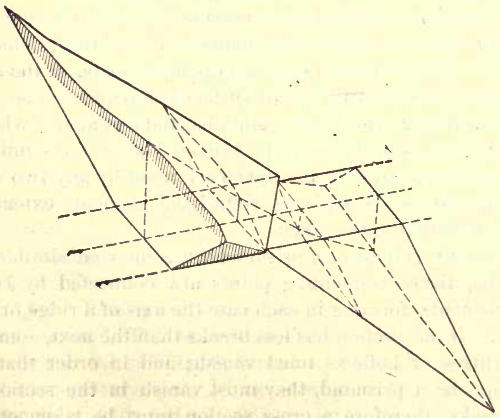

FIG. 97.

rules apply as well, but sections will generally be more numerous than in thorough cuts. The same rules apply also to embankment, but as grading is preferably paid for in excavation, the same precision in determining the quantities in embankment is not usually necessary.

## 255. Formulæ for Sectional Areas.

Let $b$ = base of section or width of road-bed,

" $s$ = slope ratio = $\frac{\text{horizontal}}{\text{vertical}}$.

" $d$ = depth at centre stake.

" $h, k$ = depths at side stakes.

" $m, n$ = horizontal distances from centre to side stakes.

*For ground level transversely*, the section is a parallelogram, and the area is evidently

$$A = bd + sd^2 \tag{342}$$

or directly from the field notes,

$$A = \tfrac{1}{2}(b + m + n)d \tag{343}$$

*For ground of uniform transverse slope between slope stakes*,

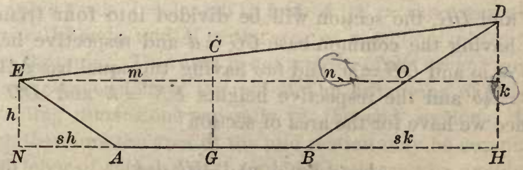

FIG. 98.

Fig. 98, the section consists of the parallelogram $ABOE$ and the triangle $EOD$. Hence

$$A = \tfrac{1}{2}(AB + EO)EN + \tfrac{1}{2}EO(DH - EN)$$

or

$$A = \tfrac{1}{2}(AB \,.\, EN + EO \,.\, DH)$$

also

$$\left.\begin{aligned} A &= \tfrac{1}{2}[bh + k(b + 2sh)] \\ A &= \tfrac{1}{2}[bk + h(b + 2sk)] \end{aligned}\right\} \tag{344}$$

From which also

and

$$\left.\begin{aligned} A &= \tfrac{1}{2}bh + mk \\ A &= \tfrac{1}{2}bk + nh \end{aligned}\right\} \tag{345}$$

These formulæ are independent of the centre depth. They are convenient for calculating the area of a plotted section having an irregular surface after the surface line has been averaged by stretching a silk thread over it. The points where the thread intersects the slope lines determine the values of $h$, $k$, $m$, and $n$ respectively.

*When the ground has uniform slopes transversely from the centre to the side stakes:* Fig. 99: If in the diagram we draw

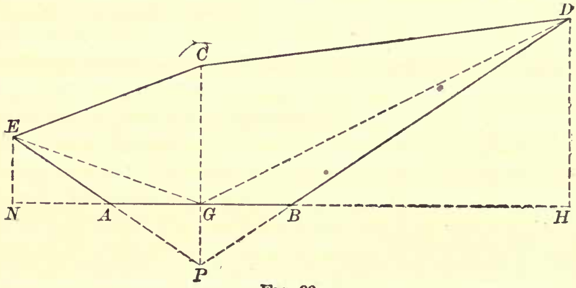


FIG. 99.

$EG$ and $DG$, the section will be divided into four triangles, *two* having the common base $CG = d$ and respective heights $GN = m$ and $GH = n$, and *two* having the equal bases $AG = GB = \frac{1}{2}b$ and the respective heights $EN = h$ and $DH = k$. Hence we have for the area of section

$$A = \tfrac{1}{2}d(m + n) + \tfrac{1}{4}b(h + k) \qquad (346)$$

*Otherwise*, if the slope lines are produced to meet below grade at $P$, then $GP = \frac{AG}{s} = \frac{b}{2s}$. The area of $CEPD$ is $\frac{1}{2}CP \times NH = \frac{1}{2}\left(d + \frac{b}{2s}\right)(m + n)$. The area of $ABP$ is $AG \times GP = \frac{b^2}{4s}$ Hence we have for the area of the section

$$A = \tfrac{1}{2}\left(d + \frac{b}{2s}\right)(m + n) - \frac{b^2}{4s} \qquad (347)$$

Both these formulæ are convenient, and as the values of the several letters can be substituted directly from the field notes, it is unnecessary to plot such sections.

*When the surface of the ground is irregular*, verticals are conceived to be drawn to the grade line through the slope stakes, and through each break in the surface line, giving a number of trapezoids, the areas of which are severally calculated, and from their sum is subtracted the area of the two triangles *ENA* and *DHB*. The remainder is the area of section required. This calculation may be made directly from the data furnished by the field notes without plotting; but if the ground has a number of small breaks, it is generally better to plot the sections and stretch an averaging line over them, finding the areas by eq. (345). Or two averaging lines may be employed extending from the centre stake, each way, when the area may be calculated by eq. (346) or (347).

**256. Prismoidal Formulæ for Solid Contents.**—The content of a prismoid may be exactly calculated by means of the Prismoidal Formula, which is

$$S = \frac{l}{6 \times 27}[A + 4M + A'] \qquad (348)$$

$S =$ cubic yards, $l =$ length in feet, $A$, $A' =$ the areas at the two parallel ends, and $M =$ the area of a section midway between the ends. This area is not a mean of the other two, but the linear dimensions of the mid-section are means of the corresponding dimensions severally of the end sections; from which therefore the area of the mid-section may be computed.

The labor of calculating the middle area may be avoided in many instances by substituting in the prismoidal formula, eq. (348), for $A$, $A'$, and $M$, their values as given in eq. (342) for ground level transversely:

$$A = bd + sd^2 \quad A' = bd' + sd'^2 \quad M = b\frac{d + d'}{2} + s\frac{d^2 + 2dd' + d'^2}{4}$$

$$\therefore \quad S = \frac{l}{6 \times 27}[2sd^2 + (3b + 2sd')d + (3b + 2sd')d'] \quad (349)$$

in which $S$ is expressed in terms of the end dimensions.

**257. Tables** of cubic yards may be constructed upon this formula which are very convenient in practice. The constant values in any one table are $l$ which is taken at 100, and $b$ and $s$ which are given values corresponding to the road-bed and slope ratio. The variables are $d$ and $d'$. The columns in the table will be headed by the successive values of $d'$, while each horizontal line will be headed by a value of $d$. For any one column therefore $d'$ is constant, and the only variable is $d$. Assuming any value for $d'$, the values of $S$ in that column may be computed, letting $d$ take a series of values differing by unity from zero upwards, and the corresponding values of $S$ will be placed in the column $d'$ opposite the several values of $d$.

But instead of solving the eq. (349) for each value of $S$ required, the process of filling the table may be much abbreviated by observing that since the equation is of the second degree with respect to the variable $d$, the second difference of the values of $S$ will be a constant and equal to *twice* the coefficient of $d^2$, or $\delta'' = \frac{4sl}{6 \times 27}$ Also the first term in the series of first differences of $S$ in the column $d'$ (*i.e.* between $d = 0$ and $d = 1$) is expressed by the *sum* of the coefficients of $d^2$ and $d$; or

$$\delta_0' = \frac{l}{6 \times 27} [3b + 2s(1 + d')] .$$

The first value of $S$ in any column $d'$ is found by solving eq. (349) after making $d = 0$; or,

$$S_0 = \frac{l}{6 \times 27} [(3b + 2sd')d']$$

Starting with these values we may fill any column $d'$ simply by successive additions. The values of $d'$ for the several columns should also differ by unity. The final value of $S$ in each column should be calculated by formula as a check; or since all the final quantities in the same line $d$ of the table form a series of which the second difference is $\delta''$, if on taking their differences this result is obtained, the quantities are proved to be correct.

*Example.*—Given a base of 18 feet and slopes $1\frac{1}{2}$ to 1, to fill the column of $d' = 6$ in a table of cubic yards for level cross sections. Here $l = 100$, $b = 18$, $s = \frac{3}{2}$, $d' = 6$. Hence $\delta'' = 3.7037+$, $\delta_0' = 46.2962+$, and $S_0 = 266.6666+$. It is not necessary to go beyond the fourth decimal place, since that figure will always be the same as the first decimal (a result due to dividing by 27), and may be corrected by it after every addition. The process is as follows:

| $d$ | $S$ | $\delta'$ | $\delta''$ |
|---|---|---|---|
| 0 | 266.6666 | | |
| | | 46.2962 | |
| 1 | 312.9629 | | 3.7037 |
| | | 50.0000 | |
| 2 | 362.9629 | | 3.7037 |
| | | 53.7037 | |
| 3 | 416.6666 | | 3.7037 |
| | | 57.4074 | |
| 4 | 474.0740 | | 3.7037 |
| | | 61.1111 | |
| 5 | 535.1851 | | 3.7037 |
| | | 64.8148 | |
| 6 | 600.0000 | | 3.7037 |
| | | 68.5185 | |
| 7 | 668.5185 | | 3.7037 |
| | | 72.2222 | |
| 8 | 740.7407 | | 3.7037 |
| | | 75.9259 | |
| | etc. | etc. | etc. |

In copying into the table, the quantities are taken to the nearest unit only, and the decimals are otherwise neglected.

The completed table furnishes values of $S$ corresponding to any values of $d$ and $d'$ in even feet. The correction for the decimal parts of the depths, when there are such, is made by adding to $S$ (found opposite the even feet) the product of the half sum of the decimals by the difference between $S$ as found and the next value of $S$ diagonally below to the right. These differences may for convenience be inserted originally in the table under each quantity in small figures.

If the length of the solid differs from 100 feet, multiply the corrected quantity by the length and divide by 100, since $S$ varies directly as $l$. Such tables are published in separate sheets for a variety of bases and slopes, so that usually one may be purchased to suit the case in hand.

**258.** These tables may be used to find quantities when the ground is not level transversely, by finding, first, the area of the actual sections, and second, the depths of level sections having equal areas, and then using the depths so found as the values of $d$ and $d'$ in the table of quantities. The depths of **equivalent level sections** are called equivalent depths. They may be calculated by the formula

$$d = -\frac{b}{2s} + \sqrt{\frac{A}{s} + \frac{b^2}{4s}} \qquad (350)$$

which is derived directly from eq. (342). The more convenient method, however, is to construct a table on eq. (342), giving to $d$ a series of values varying by one tenth of a foot from zero upward. The values of $b$ and $s$ in this table must agree with those of the road and of the table of cubic yards.

**259.** When the transverse slope is uniform between slope stakes **the equivalent depth** may be expressed **in terms of the centre depth and slope of surface** without reference to the area. Fig. 100.

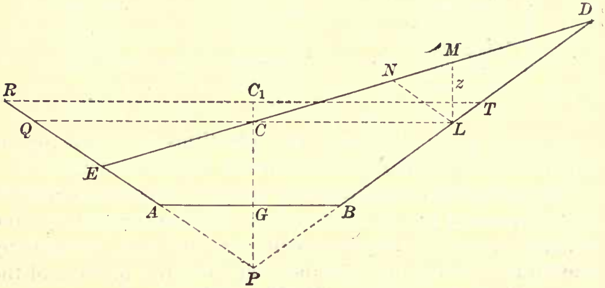


FIG. 100.

Let $EABD$ be the given section.

" $RABT$ be the equivalent level section.

Produce the side slopes to meet at $P$, and let $c = CP$ and $c_1 = C_1P$.

Through $C$ draw the horizontal line $QL$, and at $L$ erect the perpendicular $LM = z$, and draw $LN$ parallel to $PE$.

The area $RPT$ = area $EPD$; and $QEC = LNC$; hence area $EPLN = QPL = EPD - NLD$.

Since $NLD$ is similar to $EPD$, we have

$$EPD : NLD :: c^2 : z^2$$

or $$EPD - NLD : EPD :: c^2 - z^2 : c^2$$

Since $QPL$ and $RPT$ are similar,

$$QPL : RPT :: c^2 : c_1^2$$

$$\therefore \quad c^2 - z^2 : c^2 :: c^2 : c_1^2 \text{ or } c_1^2 = \frac{c^4}{c^2 - z^2}$$

Let $s'$ = slope ratio of surface $= \frac{CL}{ML} = \frac{cs}{z}$. Then $z^2 = \frac{c^2 s^2}{s'^2}$ which substituted gives

$$c_1 = \frac{cs'}{\sqrt{s'^2 - s^2}} \qquad (351)$$

If $d_1$ = the equivalent depth $C_1G$, then

$$d_1 = d + (c_1 - c)$$

A table may be prepared giving $(c_1 - c)$ for various inclinations of surface with given base and side slopes. It is then only necessary to add this correction to the centre depth to obtain the equivalent depth. Such tables of correction usually accompany the published tables of cubic yards. This method of obtaining quantities is particularly applicable to preliminary estimates, where the ground has not been cross-sectioned, and only the centre depth and transverse inclination is known.

**260.** The use of the earthwork tables described gives **correct results**;—

1st. When the surface of the prismoid is a plane, however much inclined; provided it does not intersect the road-bed within the limits of the prismoid.

2d. When with regular, or three-level end sections, generally similar to each other, the surface is regularly warped from one end to the other; provided that the side lines and centre line of the surface are straight, and that no two of them are inclined to grade in opposite directions.

3d. When the ridges or hollows of an undulating surface are parallel to the line of the road.

4th. When a surface of numerous irregularities may be averaged by planes or warped surfaces so as to comply with one of the preceding conditions.

But the method **fails** on undulating ground when the ridges or hollows run obliquely to the line of road, even though the sections may appear quite regular.

In general, the method of equivalent depths holds good when the mid-section of the equivalent level end sections equals in area the actual mid-section of the prismoid; otherwise it fails.

**261.** The content of a prismoid may be approximately obtained by the method of **mean areas,** the formula for which is

$$S = \frac{l}{2 \times 27} A + A' \qquad (352)$$

Although approximate, this method is much employed on account of its convenience. It is approved by statute to be used upon the public works of the State of New York.

If the values of $A$ and $A'$ derived from eq. (342) be substituted in eq. (352), and then eq. (349) be subtracted from it there remains

$$\frac{ls}{6 \times 27}(d - d')^2$$

which is the correction by which $S$ obtained by eq. (352) must be diminished to make it equal to $S$ obtained by eq. (349) when the ground is level transversely.

Again, for three-level sections, if the values of $A$, $A'$, and $M$ derived from eq. (347) be substituted in both eq. (348) and (352), and one subtracted from the other, there remains

$$\frac{l}{12 \times 27}[(d - d')(m + n - (m' + n'))]$$

which is the correction by which $S$ obtained by eq. (352) must be diminished to make it equal to $S$ obtained by eq. (349). Hence we may write at once, for three level-sections, the correct formula:

$$S = \frac{l}{2 \times 27}\left[A + A' - \frac{d - d'}{6}[m + n - (m' + n')]\right] \qquad (353)$$

This formula gives results identical with eq. (349), is applicable to the same cases, and gives correct results or fails to do so according to the conditions stated in the previous section.

**262.** When the conditions of the surface are such that eq. (349) or eq. (353) will not give correct results, **the area of the mid-section** may be derived from its calculated linear dimensions as stated in § 256. The contents of the prismoid are then given by eq. (348).

*Example* 1. (Fig. 101.)—Base 20. Slopes $1\frac{1}{2}$ : 1.

$$A'. + \frac{22}{8} + \frac{0}{8} \qquad + \frac{47.5}{25} \qquad \therefore A' = 443 \text{ sq. ft.}$$

$$A + \frac{34}{16} + \frac{0}{4} \qquad + \frac{16}{4} \qquad \therefore A = 200 \text{ sq. ft.}$$

$$\therefore M + \frac{28}{12} + \frac{11}{6} + \frac{0}{6} + \frac{8}{6} + \frac{31.75}{14.5} \therefore M = 244.75 \text{ sq. ft.}$$

If $l = 100$, eq. (348)

$$S = \frac{100}{6 \times 27}(443 + 967 + 200) = 1001 \text{ c. yds.}$$

Had this been calculated by eq. (349) or eq. (353) or by the

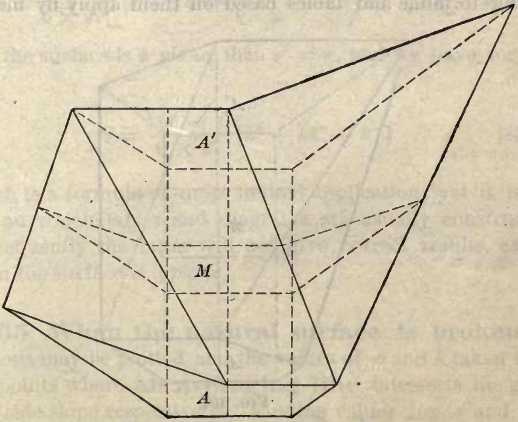


FIG. 101.

tables, the result would be 1167 c. yds., showing an error of 166 cubic yards in *excess*.

*Example* 2. (Fig. 102.)—Base 20. Slopes $1\frac{1}{2} : 1$.

$$A' + \frac{22}{8} + \frac{0}{8} + \frac{19}{6} \qquad 234 \text{ sq. f}$$

$$A + \frac{13}{2} + \frac{0}{4} + \frac{16}{4} \qquad 88 \text{ sq.}$$

$$\therefore M + \frac{17.5}{5} + \frac{11}{6} + \frac{0}{6} + \frac{8}{6} + \frac{17.5}{5} \qquad 164.5 \text{ sq.}$$

If $l = 100$, eq. (348)

$$S = \frac{100}{6 \times 27}[88 + 658 + 234] = 605 \text{ c. yds.}$$

Had this been calculated by eq. (349) or eq. (353) or by the tables, the result would be 584 c. yds., showing an error of 21 cubic yards in *deficit.*

**263.** At the termination of a cut or fill we have usually either **a wedge** or **a pyramid.** To a wedge the preceding formulæ and tables based on them apply by making

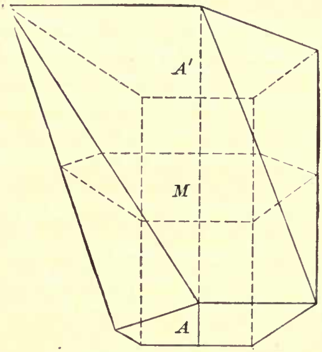


FIG. 102.

one end depth equal zero. In the case of a pyramid, the content is equal to the area of the section forming the base multiplied by one third the length of the solid. and divided by 27; or

$$S = \frac{lA}{3 \times 27} \qquad (354)$$

**264. Side-hill Work.**—When the natural surface has a regular transverse slope and intersects the road-bed, the cross section is reduced to a triangle. If $w$ = the intercepted portion of the road-bed, and $k$ = the side height, then $A = \frac{1}{2}wk$. Similarly $A' = \frac{1}{2}w'k'$ and $4M = \frac{1}{2}(w + w')(k + k')$, which substituted in eq. (348) give

$$S = \frac{l}{12 \times 27} [(2w + w')k + (2w' + w)k'] \qquad (355)$$

which is convenient for direct calculation from the field notes. It is not adapted to the construction of tables, since it contains four independent variables.

If the slope of the natural surface is given, let $s'$ be the surface slope ratio at one section, and $s''$ that at the other, and $s$ the ratio of the side slope. Then $w = k(s' - s)$ and $w' = k'(s'' - s)$, which substituted in eq. (355) give

$$S = \frac{l}{6 \times 27}\left[(s' - s)k^2 + \left(\frac{s'' + s'}{2} - s\right)kk' + (s'' - s)k'^2\right]$$

If the surface is a *plane*, then $s'' = s'$, and we have for this case

$$S = \frac{l(s' - s)}{6 \times 27}[k^2 + kk' + k'^2] \qquad (356)$$

which is a formula of quite limited application; yet it is the one on which tables and diagrams are usually constructed. Consequently the latter will not give correct results, except when the surface is a *plane*.

**265. When the natural surface is broken** the sections may be plotted, and the values of $w$ and $k$ taken from the points where **an averaging line** intersects the grade and side slope respectively. Finding values for $w'$ and $k'$ in the same way, the content may then be obtained by eq. (355) as before. The averaging line should not only cut off the same area as the original section, but should also have in each case a slope agreeing as nearly as possible with the general slope of the natural surface. The slope is determined simply by inspection of the diagram, but the area may be had precisely, for, taking $w$ from the averaging line, and knowing $A$, we may calculate $k$ by the formula $k = \frac{2A}{w}$; or $k$ may be taken from the plot and $w$ calculated.

**Otherwise,** the actual mid-section may be calculated and the cubic contents determined by the method illustrated in § 262.

**266. To express side-hill areas and cubic yards in terms of the centre depth, d, and transverse slope-ratio s'.** Fig. 103.

When $d = 0$, $A = \frac{1}{4}bk = \frac{b^2}{8(s' - s)}$

For any depth $d$, add to this area

$$s'd\left(k+\frac{x}{2}\right)=s'd\left(\frac{b}{2(s'-s)}+\frac{s'd}{2(s'-s)}\right)$$

and there results,

$$\left.\begin{aligned} A &= \frac{(\tfrac{1}{2}b+s'd)^2}{2(s'-s)} \\ S &= \frac{l(\tfrac{1}{2}b+s'd)^2}{2\times 27(s'-s)} \end{aligned}\right\} \qquad (357)$$

Observe that $d$ may be *plus* or *minus*, and that its limits are $d=\pm\frac{b}{2s'}$

Tables of cubic yards may be constructed on this formula, making $d$ and $s'$ the variables, which would be extremely con-

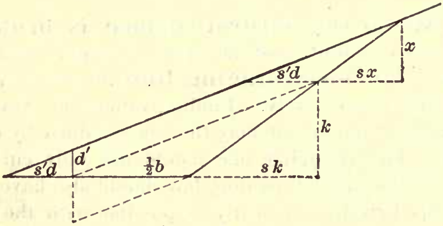


FIG. 108.

venient for making up estimates upon preliminary lines on which the profile of centre line and angle of transverse slope only are known. Since $s'$ is the cotangent of the slope angle the columns of the table may be headed by the angles in a series of degrees, while the corresponding values of $s'$ are used in the formula. The values of $d$ should vary by tenths of a foot. The results obtained by eq. (356) and eq. (357) will be identical for the same sections.

**267.** Several different systems of **diagrams** have been devised and published for determining quantities in earthwork by a sort of graphical method. These diagrams, which are substitutes for tables are preferred by some engineers. They are based on the same principles, and are constructed on modifications of the same formulæ.

**268. Correction of Earthwork for Curvature.**—The preceding calculations are based on the assumption that the centre line is straight, with cross sections at right angles to it. When an excavation is on a curve, the cross sections, being in radial planes, are inclined to each other, so that the condition of a prismoid is not exactly fulfilled. But by the property of Guldinus, if any plane area is made to revolve about an axis in the same plane, the volume of a solid generated by the area is equal to that of a prism having a base equal to the given area, and a height equal to the length of path described by the centre of gravity of the area. The path, being the arc of a circle, is proportional to the radius drawn to the centre of gravity. If therefore a cross section is symmetrical with respect to the centre line, the path of the centre of gravity is equal to the measured length of the centre line, and no correction for curvature is required.

But when the ground is inclined transversely, the centre of gravity is one side of the centre line, and its path, if we conceive it to sweep around the curve, from one end of a prismoid to the other, is longer or shorter than the distance measured on the centre line, according as the centre of gravity is outside or inside of the centre line curve.

Let $C =$ correction in cubic yards due to curvature.
" $S =$ cubic yards as obtained by prismoidal formula.
" $R =$ radius of centre line.
" $e =$ eccentricity of centre of gravity of section.
$=$ horizontal distance from centre line to centre of gravity.

We then have the proportion,

$$S \pm C : S :: R \pm e : R$$

$$C = \frac{Se}{R}$$

As the sections of a solid are seldom similar and equal, we shall usually have a different value of $e$ for every section, from which, however, a mean average value may be deduced, and used in the above formula. But it will be more convenient to correct the areas themselves for eccentricity before finding $S$, which will then require no correction. For the same result will ensue whether we multiply $S$ by $\frac{e}{R}$, or multiply one of the component factors of $S$ by the same ratio.

If then $c$ = correction of area in square feet due to eccentricity, we have at once

$$c = \frac{Ae}{R}$$

and the corrected area equals $A \pm c$ according as the cut is deeper on the outside or inside of the curve. Each area used in determining the solid contents should, on a curve, be first corrected in this manner.

*To find the value of e for any three-level section.* Fig. 104.

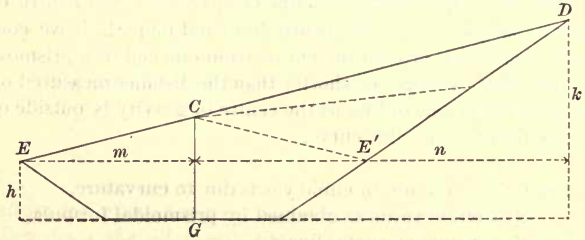


FIG. 104.

Find the areas either side of the centre line separately, calling them $H$ and $K$, and take their sum and difference. Using the same notation as in § 255, $H = \frac{1}{2}md + \frac{1}{4}bh$, $K = \frac{1}{2}nd + \frac{1}{4}bk$, and $H + K = A$.

$$K - H = \tfrac{1}{2}d\,(n - m) + \tfrac{1}{4}b\,(k - h)$$

In the figure draw $CE'$ equal to $CE$, and the triangle $CE'D$ will represent the area $(K - H)$. Bisect the side $E'D$, and draw a line from $C$ to the middle point. Then the centre of gravity of the triangle will be on this line at two thirds its length from $C$, and the horizontal distance of the centre of gravity from $C$ is $\frac{2}{3} \times \frac{1}{2}(m+n) = \frac{1}{3}(m+n)$. The centre of gravity of the remainder of the section is on the centre line $CG$, so that the value of $e$ is found from the proportion

$$e : \tfrac{1}{3}(n+m) :: K - H : A$$

$$\therefore \quad e = \frac{n+m}{3A}(K-H)$$

Hence $$c = \frac{Ae}{R} = \frac{n+m}{3R}\left[\tfrac{1}{2}d(n-m) + \tfrac{1}{2}b(k-h)\right] \qquad (358)$$

Sections which are more irregular may be plotted and reduced by averaging lines to three-level sections, in order that the formula may be applied. If the ground is so irregular as to require the computation of the middle section, the correction $c$ should be found and applied to this area ($M$) also before introducing it into the prismoidal formula. As the correction for curvature is always relatively small, it is usually ignored in practice for thorough cuts, except where deep cuttings with steep transverse slope occur on sharp curves.

**The correction** is of more importance relatively **in side-hill work** as the centre of gravity of the section is more remote from the centre line. Let the section be reduced

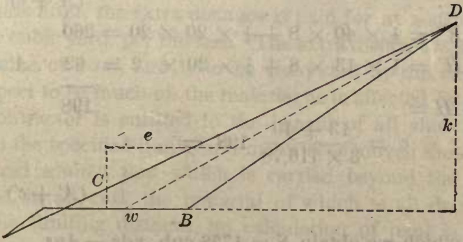


FIG. 105.

to a triangle by an averaging line (Fig. 105), and $w$ be the base of the triangle formed by the averaging line. The centre of gravity is at one third the horizontal distance from the middle point of $w$ to the side stake $D$, while the distance of this middle point from the centre stake $C$ is evidently $\frac{1}{2}b - \frac{1}{2}w$.

Hence $e = \frac{1}{2}b - \frac{1}{2}w + \frac{1}{3}[n - (\frac{1}{2}b - \frac{1}{2}w)]$

or $e = \frac{1}{3}(b + n - w)$

and $$c = \frac{Ac}{R} = \frac{b + n - w}{3R} \times \frac{wk}{2} \qquad (359)$$

The correction $c$ will be *plus* or *minus* as before explained. This formula applies to all side-hill triangular sections, whether there be cut or fill at the centre stake

*Example* 1.—Thorough cut; base 20; slopes $1\frac{1}{2} : 1$.

$l = 100$; 8° curve, left; $R = 716.78$

*Notes.* $A . + \frac{16}{4} + \frac{12}{0} + \frac{58}{32}$

$A' . + \frac{13}{2} + \frac{8}{0} + \frac{40}{20}$

Then $K = \frac{1}{2} \times 58 \times 12 + \frac{1}{4} \times 20 \times 32 = 508$

$H = \frac{1}{2} \times 16 \times 12 + \frac{1}{4} \times 20 \times 4 = 116 \therefore A = 624$

$K - H = 392$

Eq. (358) $c = \frac{16 + 58}{3 \times 716.78} \, 392 = 13.49$

$(A + c) \quad 637.49$

$K' = \frac{1}{2} \times 40 \times 8 + \frac{1}{4} \times 20 \times 20 = 260$

$H' = \frac{1}{2} \times 13 \times 8 + \frac{1}{4} \times 20 \times 2 = 62 \therefore A' = 322$

$K - H = 198$

$c' = \frac{13 + 40}{3 \times 716.78} \, 198 = 4.87$

$(A' + c') = 326.87$

From which we obtain $S = 1758$ cub. yds.—*Ans.*
Without correction we have 1726 " "

Showing a difference of 32 " "

Had the curve been to the *right* with same notes, $c$ would have been *minus*, and $S$ would $= 1694$.

*Example* 2.—Side-hill cut; base 20; slopes $1\frac{1}{2} : 1$

$l = 60$; 10° curve, right; $R = 573.69$

*Notes.*

$$\frac{6}{0} + \frac{0}{2.8} + \frac{40}{20}$$

$$-\frac{0}{0.8} + \frac{2}{0.0} + \frac{37}{18}$$

$$A = \tfrac{1}{2} \times 16 \times 20 = \qquad 160$$

Eq. (359) $$c = \frac{20 + 40 - 16}{3 \times 573.69}\, 160 = \qquad 3.58$$

$$(A - c) = 156.42$$

$$A' = \tfrac{1}{2} \times 8 \times 18 = \qquad 72$$

$$c' = \frac{20 + 37 - 8}{3 \times 573.69}\, 72 = \qquad 2.05$$

$$(A' - c) = \quad 69.95$$

Hence $S = 248$ cub. yds.

Without correction $S$ would $= 255$ " "

Difference 7 " "

**269. Haul.**—The cost of removing excavated material, when the distance does not exceed a certain specified limit, is included in the price per cubic yard of the material as measured in the cutting. But when the material must be carried beyond this limit, the extra distance is paid for at a stipulated price per cubic yard, per 100 feet. The extra distance is known by the name of *haul*, and is to be computed by the engineer with respect to so much of the material as is affected by it.

The contractor is entitled to the benefit of all short hauls (less than the specified limit), and material so moved should not be averaged against that which is carried beyond the limit. Therefore, in all cuts, the material of which is all deposited within the limiting distance, no calculation of haul is to be made.

On the other hand, the company is entitled, in cases of long haul, to free transportation for that *portion* of the cutting, no one yard of which is carried beyond the specified limit. Therefore, this portion is first to be determined in respect to its extent; and the number of cubic yards contained in it is to be deducted from the total content of the cutting, before estimating the haul upon the remainder. Find on the profile of the line two points, one in excavation, and the other in embankment, such, that while the distance between them equals the specified limit, the included quantities of excavation and embankment shall just balance. These points are easily found by trial, with the aid of the cross sections and calculated quantities, and become the starting points from which the haul of the remainder of the material is to be estimated.

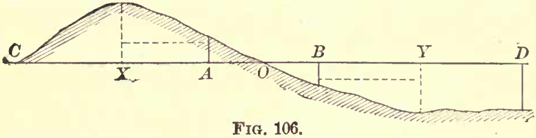


FIG. 106.

Fig. 106 represents a cut and fill in profile. The distance $AB$ is the limit of free haul. The materials taken from $AO$ just make the fill $OB$ and without charge for haul; but the haul of every cubic yard taken from $AC$, and carried to the fill $BD$, is subject to charge for the distance it is carried, less $AB$. It would be impossible to find the distance that each separate yard is carried, but we know from mechanics that the average distance for the entire number of yards is the distance between the centres of gravity of the cut $AC$, and of the fill $BD$ which is made from it. If, therefore, $X$ and $Y$ represent the centres of gravity, the actual average haul is the sum of the distances $(AX+BY)$, and this (expressed in stations) multiplied by the number of cubic yards in the cut $AC$, gives the product to which the price for haul applies.

But the product of $AX$ by the number of cubic yards in $AC$ is equal to the sum of the products obtained by multiplying the contents of each prismoid in $AC$ by the distance of its own centre of gravity from $A$. The distance of the centre of gravity of a prismoid from its mid-section is expressed by the formula

$$x = \frac{l^2 (A - A')}{12 \times 27\, S} \tag{360}$$

If we replace $S$ by its approximate value, $\frac{l(A + A')}{2 \times 27}$, which will produce no important error in this case, we have

$$x = \frac{l}{6} \cdot \frac{A - A'}{A + A'} \tag{361}$$

in which $A$ should always represent the more remote end area from the starting point $A$, fig. 106. Hence, $x$ may be + or −, and it must be applied, with its proper sign, to the distance of the mid-section from the starting point $A$, before multiplying by the contents $S$. Each partial product is thus obtained.

By a similar process with respect to the prismoids composing the mass $BD$, and using the point $B$ as the starting point, we obtain finally a sum of the products representing this portion of the haul.

If a cut is divided, and parts are carried in opposite directions, the calculation of each part terminates at the dividing line. If a portion of the material in $AC$ is wasted, it must be deducted, and the haul calculated only on the remainder.

The specified limit is sometimes made as low as 100 feet, sometimes as high as 1000 feet. A limit of about 300 feet, however is usually most convenient, as it includes the wheelbarrow work, and a large part of the carting, while it protects the contractor on such long hauls as may occur.

**270. The Final Estimate** is a complete statement in detail, of the amount of work done and materials provided, in the construction of the road, and is the basis of final settlement between the company and contractor. Its preparation should be begun as soon as possible after the work is in progress, and should be continued, as fast as the necessary data are accumulated, while the circumstances are still fresh in mind, and when any omissions in the field notes may be readily supplied. The content of each prismoid, the classification of its material, and the length of haul to which it is subject, should be matters of special record in a book provided for that purpose. These results having been carefully computed by exact methods form a standard of comparison for those approximate results which must be had from time to time during the progress of the work, and furnish a limit to the amounts of the monthly estimates. The same remark applies to all other items of labor and material. The notes and record of the final estimate should be particularly full and exact in respect to all such items as will be inaccessible to measurement at the completion of the work, such as foundation pits, foundation courses of masonry, culverts, and works under water.

**271. Monthly Estimates.**—On or before the last day of every month during the progress of construction, measurements are taken to determine the total amount of work done and material provided up to that date. The estimates based on these measurements are called Monthly Estimates. It is frequently necessary to take measurements for both monthly and final estimates at other times than the end of the month, as in the case of foundations which are not long accessible. With respect to each piece of work satisfactorily completed, the monthly estimate should be exact, and identical in amount with the final estimate. With respect, however, to items of work in progress at the time of measurement, the monthly estimate is only approximate, yet should be as precise as the nature of the case will allow; and the quantities stated should not be in excess of fair proportion of the total quantities given on the final estimate for the same piece of work.

**A special field book** is devoted to monthly estimate notes. Each page should be dated with the day on which the notes upon it were taken. The notes consist of measurements of all sorts, principally of cross sections partially excavated. These sections should be at the same points on the line as the original sections, so that comparisons may be made. Where-ever the excavation is finished to grade, it is only necessary to write "completed" opposite such stations, and the quantities may be taken from the final estimate or computed from the original notes. It is frequently necessary to retrace portions of the centre line in taking estimate notes, so that all the field instruments are required, but a party of three or four men is usually sufficient.

If the contractor has provided materials, such as stone, lumber, etc., which are not as yet put into any structure when the estimate is taken, these should be measured and entered under the head of **temporary allowance,** an arbitrary price being used somewhat below the actual value of the material as delivered. Such allowances should never be copied from one month's estimate to the next, but made anew on such material as may be found that seems to require it. But all *completed* items of contract work, and of extra work when ordered by the engineer, are necessarily copied from one monthly estimate to the next during the continuance of the contract.

**A blank form** is used by the resident engineer in report ing monthly estimates, on which a column is provided for each class of material and work required by the contract, while the several lines, headed by the numbers of the proper stations, are devoted to the different cuttings, structures, etc., in consecutive order as they occur on the line of road. The estimates are made out and reported separately for the several sections into which the line of road is divided for letting.

**These reports** are reviewed by the division engineer, and the footings copied upon another blank, which is the monthly estimate proper; the prices are attached to the items, and the amounts extended and summed up. This sum indicates approximately the total amount earned by the contractor up to date, from which is deducted a certain percentage (usually 15 per cent.), which is retained by the company until the completion of the contract. From the remainder is deducted the amount of previous payments, which leaves the amount due the contractor on the present estimate. A blank form of receipt is appended, to be signed by the contractor.

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## CHAPTER XI.

### Topographical Sketching.

**272.** Topographical sketches taken on preliminary surveys are usually of great value in projecting a line for location; they should be made therefore as accurate and complete as possible. In too many instances sketches are presented having a picturesque appearance, but conveying little information, if not tending to mislead the map-maker. The aim of the topographer should be to record the topographical features either side of the line with as much precision as those directly upon the line, without taking actual measurements, except in rare instances. The eye and the judgment must be usually depended on for distances and dimensions. The sketch of a tract extending to 400 feet each side of the line ought to be accurate enough to warrant its being copied literally upon the map. If a much wider range is required it may be advisable to use the plane-table; but an approximation to plane-table methods may be employed in ordinary sketching.

**273.** As **artificial features** are the most readily defined and located these should first receive attention in making a sketch. When recorded they form a skeleton upon which the natural features can be drawn with more precision than if the order were reversed. The point where each fence crosses the line and the angle between the two may be sketched exactly. The distance along the fence to any object may be estimated, and checked (in case of an oblique angle) by observing where a line from the object perpendicular to the centre line would intersect the latter. The book may be rested on any support, the centre-line of the page coinciding with the line of survey, and the direction of objects defined by a small ruler laid on the page. This operation being repeated from another point gives intersections which locate the several objects on the sketch. If the bearings are taken they may be plotted on the page as well as recorded, giving the same results. The eye may be trained to estimate distances correctly by observing the appearance of objects along the measured line, the distances to which are therefore known.

**274.** After the artificial objects the more distinct **natural features** are to be sketched, as streams, shores, margins of swamps, forests, etc., ravines, ridges, and bluffs, taking care that all these outlines intersect the features of the sketch already delineated at the proper points. The correct representation of **contours** is the most difficult part of sketching, since these lines are quite imaginary, yet for railroad maps they are usually as important as any others. It is desirable to know not only the locality of a hill or slope, but also its shape, steepness, and height. This information is best given by contour lines. A contour is the intersection of the surface of the ground by an imaginary level surface. When the surface is real, like that of a lake, the intersection is called a shore. If the water should rise a certain height a new shore would be defined, and rising double that height still another shore would result, each of which, on the subsidence of the water, would be a contour. A practiced eye is able to follow on the ground the course of a contour with all its windings; but in sketching them due allowance must be made for the foreshortening effect of distance. All contours on the same sketch should have the same vertical interval, so that by counting them the height of the hill may be known. The spaces on the sketch between contours vary as the cotangent of the slope angle, so that the width of the spaces indicates the degree of steepness. The contours nearest the topographer should generally be sketched first, although if there be a shore that is apt to be the best guide to the shape of the slopes. If the height of the hill is known and the upper contour located, the other contours can be spaced between with less difficulty, the proper number being ascertained by dividing the height by the assumed vertical interval. A special line of levels up an inclined ravine or sloping ridge to fix the contour points is often of the greatest service in obtaining correct results. Other random lines are sometimes run to locate the contours more definitely. These should be made to cross several contours rather than to trace a single one. Old preliminary lines which have proved useless in themselves often furnish by their profiles valuable information in respect to contours.

The use of hatchings should be avoided in the sketch-book, except to represent precipitous banks, or slight terraces, which would not be sufficiently defined by the contour system. Hatchings freely used consume too much time, and fail to give an accurate idea of either slope or height, while they obscure the page for the representation of other objects.

**275. The centre line** on the page is straight, and for sketching purposes the surveyed line on the ground is assumed to be so also. Slight deflections in the course of a preliminary line may be ignored in the sketch; but if a large angle occurs it is better to terminate the sketch with the course, and begin again, leaving a few blank lines between the two sketches. On a located line with curves, the sketch is continuous. The curved line in the field is represented by the straight line on the page, and the radial lines through the stations are represented by the parallel lines ruled across the page. All objects are sketched at the proper offset distance by scale from the centre line; but longitudinally the sketch is necessarily diminished outside of the curve, and magnified inside of the curve. Consequently topographical lines which are straight in fact appear curved in the sketch, concave to the centre line if inside the curve, and convex if outside of it. Such features are correctly sketched by means of offsets estimated or measured from each station of the curve on the radial lines. This kind of distortion creates no confusion if properly done, for in making the map, after drawing the curve and the radial lines, the same offsets will give the correct positions of the objects delineated. This method is preferable to drawing a curved line on the page to represent the centre line, as it is difficult to draw it correctly; it will cross the ruled lines obliquely, rendering them of no service for offsets or scale, and moreover is likely to run off the page altogether.

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## CHAPTER XII.

### ADJUSTMENT OF INSTRUMENTS.

Every adjustment consists of two processes: first *the test*, and second *the correction*. Inasmuch as the amount of correction is made by estimation, the test must always be repeated until no further lack of adjustment is observable.

**276.** THE TRANSIT.

**The level tubes should be parallel to the vernier plate.**

**Test:** Place the tubes in position over the levelling screws, and turn the latter till the bubbles are centred; revolve the plate 180°. The bubbles should remain centred; if they have retreated—

**Correction:** Bring them half way back to the centre by turning the adjusting screws which attach the tubes to the plate.

**The line of collimation should be perpendicular to the horizontal axis.**

**Test:** Clamp the limb, and by the tangent screws bring the intersection of the cross-hairs to cover a well-defined point about on a level with the telescope; plunge the telescope to look in the opposite direction, and note any point about on a level with the telescope and about equidistant with the first point, which the intersection of the cross-hairs now happens to cover. Now unclamp the limb and turn through 180°, and repeat the above operation, using the same *first* point as before.

The *third* point obtained should be identical with the *second;* if not—

**Correction :** Move the vertical cross-hair over *one fourth* of the apparent distance from the third to the second point, by turning the adjusting screws at the side of the telescope.

**The horizontal axis should be parallel to the vernier plate.**

**Test :** After completing the above adjustments level the limb, clamp it, and bring the intersection of the cross-hairs to cover some high point so that the telescope may be elevated to a large angle; depress the telescope and note some point on the ground now covered by the intersection of the cross-hairs. Now unclamp the limb, turn it through 180°, and repeat the above operation, using the same high point as before. The third point found should be identical with the second; if not—

**Correction :** Raise the end of the axis opposite the second point (or lower the other end) by a small amount, by turning the adjusting screws in the standard. The amount of motion required is only determined by repeated trials until the test is satisfied.

**The intersection of the cross-hairs should appear in the centre of the field of view.**

**Test :** Bring the cross-hairs into focus and direct the telescope toward the sky, or hold a sheet of blank paper in front of it. If the intersection appear eccentric—

**Correction :** Turn the screws (by pairs) which support the end of the eyepiece until the desired result is obtained.

If there be **a level on the telescope** it **should be parallel to the line of collimation.**

Drive two stakes equidistant from the instrument in exactly opposite directions, and having perfected the previous adjustments, level the plate carefully, clamp the telescope in about a horizontal position, and observe a rod placed on each stake. Have the stakes driven by trial until the rod reads alike on both. The heads of the stakes are then on a level. Remove the instrument beyond one stake, and set it up in line with the two, level the plate, and elevate or depress the telescope to a position which will again give equal readings on the stakes. The line of collimation is now level—

**Test:** While in this position the bubble of the attached level should stand centred; if not—

**Correction:** Bring the bubble to the centre by turning the nuts at one end of the tube, while the cross-hair continues to give equal readings.

## 277. THE Y LEVEL.

**The line of collimation should coincide with the axis of the telescope.**

**Test:** Clamp the spindle, and bring the intersection of the cross-hairs to cover a well-defined point by the tangent and levelling screws; revolve the telescope half over in the Ys, so that the level tube is on top. The intersection of the cross-hairs should still cover the point. If either hair has departed—

**Correction:** bring it half way back by means of the pair of adjusting screws at the extremities of the other hair.

**The attached level should be parallel to the axis of the telescope.**

**Test:** Bring the telescope over one pair of levelling screws, clamp the spindle, open the clips, and bring the bubble to the centre. Then gently remove the telescope from the Ys, and replace it end for end. If the Ys have not been disturbed, the bubble should return to the centre. If it does not—

**Correction:** bring the bubble half way back by turning the nuts at one end of the tube.

But as now the level tube and telescope may only lie in parallel planes, and yet not be parallel to each other—

**Test:** bring the bubble to the centre as before, and turn the telescope on its axis so as to bring the level tube out to one side. The bubble should remain centred. If it has departed—

**Correction:** bring it back to the centre by the adjusting screws at one end.

**The axis of the telescope should be at right angles to the spindle.**

**Test:** Having completed the above adjustments (and not before), fasten down the clips, unclamp the spindle, and bring the bubble to the centre over each pair of levelling screws in succession, then swing the telescope end for end on the spindle. The bubble should settle at the centre. If it do not—

**Correction:** bring it half way back by the large nuts at one end of the bar.

**278.** THE THEODOLITE.

This instrument being a combination of Transit and Level, its several adjustments are to be made according to the rules already given for those instruments.

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# CHAPTER XIII.

## EXPLANATION OF TABLES.

TABLE I.—Contains concise statements of such geometrical truths as are applicable to the various discussions in this volume. References are given to Davies' Geometry, in which the demonstrations of the propositions may be found.

TABLE II.—Contains all the formulæ necessary to the solution of any plane triangle; also, a select list of miscellaneous formulæ. A few formulæ with respect to the versed sine and external secant are new.

TABLE III.—Contains a complete list of formulæ expressing the relations between the radius, tangent, chord, versed sine, external secant, and central angle of a railway curve; also, the relations between the radius, degree of curve, length of curve, and central angle. The notation is identical with that used elsewhere in the book.

TABLE IV.—Contains the radius, and its logarithm, for every degree of curve to single minutes up to 10 degrees, and thence by larger intervals up to 50 degrees. With the radius is given also the perpendicular off-set, $t$, from the tangent to a point on the curve at the end of the first 100-foot chord from the tangent-point, and the middle ordinate, $m$, of a 100-foot chord. See eqs. (16, 34, 37, 40, and 305).

TABLE V.—Contains the corrections to be added to the tangents and externals of any railroad curve, as obtained by reference to Table VI., according to the degree of the given curve (found at head of columns), and its central angle, (found in the first column.) If the given degree of curve, or central angle, does not appear in the table, the exact value of the correction may be easily obtained by interpolation.

TABLE VI.—Contains the exact values of the tangents, T, and externals, E, to a 1 degree curve, for every 10 minutes of central angle, from 1° to 120° 50′. Approximate values of the tangent and external to any other degree of curve may be had by simply dividing the tabular values opposite the given central angle by the given degree of curve, expressed in degrees. These approximations may be made exact by adding the proper corrections taken from Table V. See eqs. (21) and (24).

TABLE VII.—Contains the value of Long Chords of from 2 to 12 stations, for every 10 minutes of degree of curve from 0° to 15°, and of a less number of stations for degrees of curve between 15° and 30°. As the chord of one station is always 100 feet, the column of the first station gives instead the length of arc subtended by the chord of 100 feet. See §§ 121, 122, 123, 124, 125.

TABLE VIII.—Contains the values of Middle Ordinates to long chords of from 2 to 12 stations, for every 10 minutes of degree of curve from 0° to 10°, and of from 2 to 6 stations for every curve from 10° to 20°, at 10-minute intervals. The table may be used, not only to fix the middle point of an arc, but also, in conjunction with the table of long chords, to locate intermediate stations. See §§ 121, 122, 123, 124, 125.

TABLE IX.—Contains the chords of a series of angles varying by half degrees up to 30° for radii varying by 100 feet up to 1000 feet. It shows, therefore, the linear opening between the extremities of two equal lines at any given number of hundred feet from their intersection, when the angle does not exceed 30°. For any distance exceeding 1000 we have only to add to the value found in that column, the value found in the column headed by the excess of distance over 1000 feet. *Conversely,* the table gives the angular deflection required between two equal lines, in order that at a given distance from the point of intersection they may be separated a given amount.

TABLE X.—1. Contains values of the ratio $u = \frac{i}{\triangle}$, according to the notation of § 147 for finding the angle $i$ (Fig. 34) between the radius $PO$ of the curve at any point $P$, and the tangent $PK$ to the valvoid arc $PX$ by the simple formula eq. (80) $i = u\triangle$. The table embraces lengths of curve from 300 to 2000 feet, and central angles from 10° to 120°.

When $\frac{L\triangle}{1000} = 60°$ $u = \frac{1}{3}$, and for hasty approximation this value of $u$ may be assumed in any case without consulting the table.

2. Contains values of the ratio $v = \frac{r}{L}$ for finding the radius of the valvoid arc at the point $P$ (Fig. 35) in terms of the length of curve $L = AP$ by the simple formula, eq. (82), $r = vL$.

3. Contains values of the length $l_{,}$ of a valvoid arc limited by two curves of equal length laid out from the same tangent and same $P.C.$, but whose central angles differ by 1°. The length $L$ of each curve is given in the first column, and the half sum of their central angles $\left(\frac{\triangle' + \triangle''}{2}\right)$ is given at the head of the other columns.

When the central angles of two curves of equal length differ by $x$ degrees the length $l$ of the valvoid arc joining their extremities is expressed by the simple formula, Fig. 36,

$$\text{eq. (86)} \qquad l = P'P'' = (\triangle' - \triangle'')l_{,}$$

in which $l_{,}$ is taken from the column headed by $\frac{\triangle' + \triangle''}{2}$ and opposite the given value of $L$; or $l_{,}$ is found by interpolation if necessary. See § 150 and example.

TABLE XI.—Contains the measurements necessary to lay down a turnout with frogs of given numbers or angles for both a standard and a three-foot gauge. The distance $BF$ is measured on the rail of the given track from the *heel* of the switch to the *point* of the frog, while $af$ is the chord of the centre line of the turnout between the same points. The radius $r$ applies to the centre line of the turnout. The distance $aF''$ is measured on the centre line of the straight track from the *heel* of the switch to the point of the middle frog. The length of switch $AD$ should conform to the tabular values unless the throw is to be different from that assumed in the table. See §§ 180, 181, 182.

TABLE XII.—Contains the middle ordinates of chords varying in length from 10 to 32 feet, and for degrees of curve varying from 1° to 50°. The use of the table is obvious. See § 199.

TABLE XIII.—Gives the proper difference in elevation of rails on curves of various degrees from 1° to 50° for velocities varying from 10 to 60 miles per hour. See § 201.

TABLE XIV.—Gives the rise of grades in feet per mile and their angle of inclination corresponding to a rise per station (100 feet) varying from 0.01 foot to 10 feet.

TABLE XV.—Contains values of the formula $(\log h - 1)$ 60384.3 in which $h$ = reading of the barometer in inches. The inches and tenths of the readings are in the left-hand column, while the hundredths are found at the top of the other columns. The *difference* of any two values corresponding to two readings taken simultaneously at any two stations is the difference in elevation in feet of those stations. But the difference in height so found is subject to a correction for temperature given in the next table. See § 10.

TABLE XVI.—Contains coefficients of correction for atmospheric temperature, by which the approximate heights obtained by Table XV. are to be multiplied for a correction of these heights, which correction is to be added or subtracted according as the coefficient given in the table is marked + or −. See § 11.

TABLE XVII.—Contains corrections in feet, required by the curvature of the earth and the refraction of the atmosphere, to be applied to the elevation of a distant object as obtained by a level or theodolite observation for distances ranging from 300 feet to 10 miles. See § 219.

TABLE XVIII.—Contains the coefficients for reducing the space on a vertical rod intercepted by the stadia hairs when the line of collimation is inclined to the horizon, to the space that would be intercepted were the line of collimation horizontal; *provided*, that the visual angle $\theta$ defined by the stadia hairs is such that $\tan \frac{1}{2}\theta = .005$ or $\theta = 0^\circ\ 34'\ 22''.63$, which is its customary value in surveying instruments. The angle of inclination $\alpha$ is taken at every 10 minutes through half a quadrant.

TABLE XIX.—Contains the logarithms of the coefficients given in Table XVIII.

TABLE XX.—Gives the lengths of circular arcs to a radius = 1.

To find the length of any arc expressed in degrees, minutes, and seconds, take from the table the lengths of the given number of degrees, minutes, and seconds respectively, and multiply their sum by the length of the radius. The product is the length of arc required.

TABLE XXI.—Contains the values of minutes and seconds expressed in decimals of a degree, for every 10 seconds of arc, and also for quarter minutes up to one degree.

TABLE XXII.—Contains the values of inches and fractions expressed in decimals of a foot for every 32d of an inch up to one foot.

TABLE XXIII.—Contains the squares, cubes, square roots, cube roots, and reciprocals of numbers from 1 to 1054. Its use may be greatly extended by observing that if any number is multiplied by $n$ its square is multiplied by $n^2$, its cube by $n^3$, and its reciprocal by $\frac{1}{n}$.

TABLE XXIV.—**The logarithm** of a number consists of two parts, a whole number called the *characteristic*, and a decimal called the *mantissa*. All numbers which consist of the same figures standing in the same order have the same mantissa, regardless of the position of the decimal point in the number, or of the number of ciphers which precede or follow the significant figures of the number. The value of the characteristic depends entirely on the position of the decimal point in the number. It is always one less than the number of figures in the number to the left of the decimal point. The value is therefore diminished by one every time the decimal point of the number is removed one place to the left, and *vice versa.* Thus

| *Number.* | *Logarithm.* |
|---|---|
| 13840. | 4.141136 |
| 1384.0 | 3.141136 |
| 138.40 | 2.141136 |
| 13.84 | 1.141136 |
| 1.384 | 0.141136 |
| .1384 | —1.141136 |
| .01384 | —2.141136 |
| .001384 | —3.141136 |
| etc. | etc. |

The mantissa is always positive even when the characteristic is negative. We may avoid the use of a negative characteristic by arbitrarily adding 10, which may be neglected at the close of the calculation. By this rule we have

| *Number.* | *Logarithm.* |
|---|---|
| 1.384 | 0.141136 |
| .1384 | 9.141136 |
| .01384 | 8.141136 |
| .001384 | 7.141136 |
| etc. | etc. |

No confusion need arise from this method in finding a number from its logarithm; for although the logarithm 6.141136 represents either the number 1,384,000, or the decimal .0001384, yet these are so diverse in their values that we can never be uncertain in a given problem which to adopt.

The table XXIV. contains the mantissas of logarithms, carried to six places of decimals, for numbers between 1 and 9999, inclusive. The first three figures of a number are given in the first column, the fourth at the top of the other columns. The first two figures of the mantissa are given only in the second column, but these are understood to apply to the remaining four figures in either column following, which are comprised between the same horizontal lines with the two.

If a number (after cutting off the ciphers at either end) consists of not more than four figures, the mantissa may be taken direct from the table; but by interpolation the logarithm of a number having six figures may be obtained. The last column contains the average difference of consecutive logarithms on the same line, but for a given case the difference needs to be verified by actual subtraction, at least so far as the last figure is concerned. The lower part of the page contains a complete list of differences, with their multiples divided by 10.

**To find the logarithm of a number having six figures:**—Take out the mantissa for the four superior places directly from the table, and find the difference between this mantissa and the next greater in the table. Add to the mantissa taken out the quantity found in the table of proportional parts, opposite the difference, and in the column headed by the fifth figure of the number; also add $\frac{1}{10}$ the quantity in the column headed by the sixth figure. The sum is the mantissa required, to which must be prefixed a decimal point and the proper characteristic.

*Example.*—Find the log of 23.4275.

| | |
|---|---|
| For 2342 mantissa is | 369587 |
| " diff. 185 col. 7 | 129.5 |
| " " " " 5 | 9.2 |
| *Ans.* For 23.4275 log is | 1.369726 |

The decimals of the corrections are added together to determine the nearest value of the sixth figure of the mantissa.

**To find the number corresponding to a given logarithm.**—If the given mantissa is not in the table find the one next less, and take out the four figures corresponding to it; divide the difference between the two mantissas by the tabular difference in that part of the table, and annex the figures of the quotient to the four figures already taken out. Finally, place the decimal point according to the rule for characteristics, prefixing or annexing ciphers if necessary. The division required is facilitated by the table of proportional parts, which furnishes by inspection the figures of the quotient.

*Example.*—Find the number of which the logarithm is 8.263927

| | | |
|---|---|---|
| | | 8.263927 |
| First 4 figures 1836 from | | 263873 |
| | Diff. | 54.0 |
| Tabular diff. = 236 | ∴ 5th fig. = 2 | 47.2 |
| | | 6.80 |
| | 6th fig. = 3 | 7.08 |

*Ans.* No. = .0183623 or 183,623,000.

The number derived from a six-place logarithm is not reliable beyond the sixth figure.

At the end of table XXIV. is a small table of logarithms of numbers from 1 to 100, with the characteristic prefixed, for easy reference when the given number does not exceed two digits. But the same mantissas may be found in the larger table.

TABLE XXV.—**The logarithmic sine, tangent, etc.** of an arc is the logarithm of the natural sine, tangent, etc. of the same arc, but with 10 added to the characteristic to avoid negatives. This table gives log sines, tangents, cosines, and cotangents for every minute of the quadrant. With the number of degrees at the left side of the page are to be read the minutes in the left-hand column; with the degrees on the right-hand side are to be read the minutes in the right-hand column. When the degrees appear at the top of the page the top headings must be observed, when at the bottom those at the bottom. Since the values found for arcs in the first quadrant are duplicated in the second, the degrees are given from 0° to 180°. The differences in the logarithms due to a change of one second in the arc are given in adjoining columns.

**To find the log. sin, cos, tan, or cot of a given arc.:** Take out from the proper column of the table the logarithm corresponding to the given number of degrees and minutes. If there be any seconds multiply them by the adjoining tabular difference, and apply their product as a correction to the logarithm already taken out. The correction is to be *added* if the logarithms of the table are increasing with the angle, or *subtracted* if they are decreasing as the angle increases. In the first quadrant the log sines and tangents increase, and the log. cosines and cotangents decrease as the angle increases.

*Example.*—Find the log sin of 9° 28′ 20″.

| | |
|---|---|
| Log sin of 9° 28′ is | 9.216097 |
| Add correction 20 × 12.62 | 252 |
| *Ans.* | 9.216349 |

*Example.*—Find the log cot of 9° 28′ 20″.

| | |
|---|---|
| Log cotan of 9° 28′ is | 10.777948 |
| Subtract correction 20 × 12.97 | 259 |
| *Ans.* | 10.777689 |

**To find the angle or arc corresponding to a given logarithmic sine, tangent, cosine, or cotangent.**—If the given logarithm is found in the proper column take out the degrees and minutes directly; if not, find the two consecutive logarithms between which the given logarithm would fall, and adopt that one which corresponds to the least number of minutes; which minutes take out with the degrees, and divide the difference between this logarithm and the given one by the adjoining tabular difference for a quotient, which will be the required number of seconds.

With logarithms to six places of decimals the quotient is not reliable beyond the tenth of a second.

*Example.*—9.383731 is the log tan of what angle?

| | | |
|---|---|---|
| Next *less* | 9.383682 gives | 13° 36′ |
| Diff. | 49.00 ÷ 9.20 = | 05″.3 |
| | *Ans.* | 13° 36′ 05″.3 |

*Example.*—9.249348 is the log cos of what angle?

| | | |
|---|---|---|
| Next *greater* | 583 gives | 79° 46′ |
| Diff. | 235 ÷ 11.67 = | 20″.1 |
| | *Ans.* | 79° 46′ 20″.1 |

The above rules do not apply to the first two pages of this table (except for the column headed cosine at top) because here the differences vary so rapidly that interpolation made by them in the usual way will not give exact results.

On the first two pages, the *first* column contains the number of seconds for every minute from 1′ to 2°; the minutes are given in the *second*, the log. sin. in the *third*, and in the *fourth* are the last three figures of a logarithm which is the difference between the log sin and the logarithm of the number of seconds in the first column. The first three figures and the characteristic of this logarithm are placed, once for all, at the head of the column.

**To find the log sin of an arc less than 2° given to seconds.**—Reduce the given arc to seconds, and take the logarithm of the number of seconds from the table of logarithms, and *add* to this the logarithm from the fourth column opposite the same number of seconds. The sum is the log sin required.

The logarithm in the fourth column may need a slight interpolation of the last figure, to make it correspond closely to the given number of seconds.

*Example.*—Find the log sin of 1° 39′ 14″.4.

| | | |
|---|---|---|
| 1° 39′ 14″.4 = 5954″.4 | log | 3.774838 |
| | add $(q - l)$ | 4.685515 |
| | *Ans.* log sin | 8.460353 |

Log tangents of small arcs are found in the same way, only taking the last four figures of $(q - l)$ from the *fifth* column.

*Example.*—Find the log tan of 0° 52′ 35″.

| | | |
|---|---|---|
| 52′ 35″ = (3120″ + 35″) = 3155″ | log | 3.498999 |
| | add $(q - l)$ | 4.685609 |
| | *Ans.* log tan | 8.184608 |

**To find the log cotangent of an angle less than 2° given to seconds.**—Take from the column headed $(q + l)$ the logarithm corresponding to the given angle, interpolating for the last figure if necessary, and from this *subtract* the logarithm of the number of seconds in the given angle.

*Example.*—Find the log cotan of 1° 44′ 22″.5.

| | | |
|---|---|---|
| | $q + l$ | 15.314292 |
| 6240″ + 22″.5 = 6262.5 | log | 3.796748 |
| | *Ans.* | 11.517544 |

These two pages may be used in the same way when the given angle lies between 88° and 92°, or between 178° and 180°; but if the number of degrees be found at the *bottom* of the page, the title of each column will be found there also; and if the number of degrees be found on the *right hand* side of the page, the number of minutes must be found in the right hand column, and since here the minutes increase upward, the number of seconds on the same line in the first column must be *diminished* by the odd seconds in the given angle to obtain the number whose logarithm is to be used with $(q \pm l)$ taken from the table.

*Example.*—Find the log cos of 88° 41′ 12″.5

| | | |
|---|---|---|
| | $(q - l)$ | 4.685537 |
| 4740″ − 12″.5 = 4727.5 | log | 3.674631 |
| | *Ans.* | 8.360168 |

*Example.*—Find the log tan of 90° 30′ 50″.

| | | |
|---|---|---|
| | $q+l$ | 15.314413 |
| 1800″ + 50″ = 1850″ | log | 3.267172 |
| | *Ans.* | 12.047241 |

**To find the arc corresponding to a given log sin, cos, tan, or cotan which falls within the limits of the first two pages of Table XXV.** Find in the proper column two consecutive logarithms between which the given logarithm falls. If the title of the given function is found at the top of that column read the degrees from the top of the page; if at the bottom read from the bottom.

Find the value of $(q-l)$ or $(q+l)$, as the case may require, corresponding to the given log (interpolating for the last figure if necessary). Then if $q$ = given log and $l$ = log of number of seconds, $n$, in the required arc, we have at once $l = q - (q-l)$ or $l = (q+l) - q$, whence $n$ is easily found.

Find in the first column two consecutive quantities between which the number $n$ falls, and if the degrees are read from the *left hand* side of the page, adopt the *less*, take out the minutes from the second column, and take for the seconds the difference between the quantity adopted and the number $n$. But if the degrees are read from the *right-hand* side of the page, adopt the *greater* quantity, take out the minutes on the same line from the right-hand column, and for the seconds take the difference between the number adopted and the number $n$.

*Example.*—11.734268 is the log cot of what arc?

| | | | |
|---|---|---|---|
| $q+l$ | | | 15.314376 |
| $q$ | | | 11.734268 |
| ∴ $n =$ | 3802″.8 | | 3.580108 |
| For 1° adopt | 3780. | giving 03′ | |
| Difference | 22″.8 | | |

*Ans.* 1° 03′ 22″.8 or 178° 56′ 37″.2.

*Example.*—8.201795 is the log cos of what arc?

| | | | |
|---|---|---|---|
| $q-l$ | | | 4.685556 |
| $q$ | | | 8.201795 |
| ∴ $n =$ | 3282″.8 | | 3.516239 |
| For 89° adopt | 3300. | giving 05′ | |
| Difference | 17″.2 | | |

*Ans.* 89° 05′ 17″.2 or 90° 54′ 42″.8.

TABLE XXVI.—Contains logarithmic versed sines and external secants for every minute of the quadrant, with the differences of the same corresponding to a change of 1 second in the arc or angle. Interpolation for seconds is made in the same manner as with log sines of the preceding table, except on the first two pages. For angles less than 4° the differences vary so rapidly that interpolation by direct proportion will not give exact values.

On the first two pages the column headed $q - 2l$ contains the difference between the log versed sine (or log ex secant) of an arc and *twice* the logarithm of the number of seconds in the same arc. The characteristic, and first three decimals (9.070) are common to all the logarithms in these columns up to 3° 19′ for log vers sines, where it changes to (9.069), as shown at the foot of the column; and up to 4° for log ex secants, where it changes to (9.071). At the point of change a cipher is replaced by the mark ✦ to call attention.

**To find the log vers sin, or log ex sec of an angle given to seconds.**—Reduce the angle to seconds, take the logarithm of this number, multiply it by 2, and add the product to the logarithm in the column $(q - 2l)$ found opposite the given angle. The log $(q - 2l)$ should be corrected by interpolation for the fractional part of a minute in the given angle.

*Example.*—What is the log ex secant of 2° 14′ 43″.7?

| | | |
|---|---|---|
| 2° 14′ 43″.7 = 8040″ + 43.7 = 8083″.7 | log | 3.907610 |
| | | 2 |
| | $2l$ | 7.815220 |
| | $(q - 2l)$ | 9.070398 |
| *Ans.* | ∴ $q$ | 6.885618 |

**To find the arc corresponding to a given log vers, or log ex sec.**—Find in the column of log vers, or log ex sec the two values between which the given log falls, and take out from the column $(q - 2l)$ the logarithm corresponding to the given log (interpolating for the value of the last figure if necessary). Subtract this from the given logarithm and divide by 2. The quotient is the logarithm of the number of seconds in the required arc.

*Example.*—7.344728 is the log vers of what arc?

| | | | |
|---|---|---|---|
| 3° 48′ + | | $q$ | 7.344728 |
| | | $(q-2l)$ | 9.069960 |
| | | | 2)8.274768 |
| | 13720″.9 | ∴ $l$ | 4.137384 |
| | 13680. | | |
| *Ans.* | 3° 48′ 40″.9 | | |

**To find the log ex sec of an arc greater than 88° given to seconds.**—Take from the column $(q+l)$ the logarithm corresponding to the given arc, interpolating for the fraction of a minute. From this subtract the logarithm of the number of seconds in the *complement* of the given arc.

*Example.*—What is the log ex sec of 88° 24′ 20″.5?

| | | |
|---|---|---|
| For 88° 24′ | $q+l$ | 15.302183 |
| Correction $129 \times \frac{20.5}{60} =$ | | 44 |
| | $q+l$ | 15.302227 |
| Comp. 88° 24′ 20″.5 = 5739″.5 | log | 3.758874 |
| | *Ans.* log ex sec | 11.543353 |

**To find the angle corresponding to a given log ex sec when the angle is greater than 88°.**—Find in the table the two consecutive log ex secants between which the given one falls, and then find by interpolation the value of the log $(q+l)$ corresponding to the given log ex sec and subtract the latter from it. The difference will be the logarithm of the number of seconds in the *complement* of the required angle, which is then easily found.

*Example.*—11.924368 is the log ex sec of what arc?

| | | | |
|---|---|---|---|
| Given log ex sec | 11.924368 | | |
| Next less | 11.918290 | $q+l$ | 15.309225 |
| Diff. | 6078 | | |
| Correction $= \frac{9352-9225}{29141-18290} \times 6078 =$ | | | 71 |
| | | $q+l$ | 15.309296 |
| Given log ex sec | | | 11.924368 |
| 0° 40′ 26″.2 = 2426″.2 | | ∴ log | 3.384928 |
| *Ans.* 89° 19′ 33″.8. | | | |

TABLE XXVII.—Contains natural sines and cosines, to five places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values in the table; positive for sines, negative for cosines.

TABLE XXVIII.—Contains natural tangents and cotangents to five places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values in the table; positive for tangents, negative for cotangents.

TABLE XXIX.—Contains natural versed sines and external secants to five places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values. They are positive in every case.

TABLE XXX.—Contains the number of cubic yards contained in prismoids of various side slopes, bases, and depths, as indicated by the title and the numbers in the first column. Each prismoid is supposed to have a uniform level cross section throughout. These tables are chiefly useful in making up preliminary estimates from the profile, or in other cases where only approximate results are required. For monthly and final estimates more elaborate tables are required, such as are described in § 257.

**To make an approximate estimate of quantities from a profile** by use of Table XXX.—Select the proper column for base and slopes, and if the outline of a cut on the profile is roughly a four-sided figure, stretch a fine silk thread over the surface line to average it, note the depth from thread to grade line midway of the cutting, and multiply the tabular number opposite this depth by the average length of the cutting in stations of 100 feet. (By average length is meant the half sum of the length of the grade line in the cutting and of so much of the surface line as is covered by the thread.) If the area of a cutting as seen on the profile is approximately triangular, stretch an averaging line over each incline, and note the depth from the intersection of these lines to grade, and multiply the tabular number opposite this depth by one-half the length of the cut measured on the grade line in stations. The resulting quantities will be slightly in excess if the ground is level transversely, but may be too small if the transverse slope is steep, and cutting on the centre line is small. In general they furnish a good approximation. Quantities in embankments may, of course, be found similarly. A cut or fill may be divided on the profile into several portions, and the contents of each portion found separately if preferred.

The content of a prismoid, level transversely, but having different end depths, may be found correctly by this table thus: add together the quantities opposite each end-depth and 4 times the quantity opposite the half sum of the depths; multiply the sum by the length in feet, and divide by 600.

TABLE XXXI.—Contains a variety of useful numbers and formulæ. The logarithms are here given to seven places of decimals.

# TABLES.

*The References are to Davies' Legendre, Revised Edition.*

| No. | REFERENCE. | HYPOTHESES. | CONSEQUENCES. |
|---|---|---|---|
| 1 | IV., XI. .......... | If a triangle is right angled, | The square on the hypothenuse is equal to the sum of the squares on the other two sides. |
| 2 | I., XI., Cor. 1.... | If a triangle is equilateral, | It is equiangular. |
| 3 | I., XI............ | If a triangle is isosceles, | The angles at the base are equal. |
| 4 | I., XI., Cor. 2.... | If a straight line from the vertex of an isosceles triangle bisects the base, | It bisects the vertical angle. And is perpendicular to the base. |
| 5 | I., XXV., Cor. 6.. | If one side of a triangle is produced, | The exterior angle is equal to the sum of the two interior and opposite angles. |
| 6 | IV., XX. ......... | If two triangles are mutually equiangular, | They are similar. And their corresponding sides are proportional. |
| 7 | I., XXVII........ | If the sides of a polygon are produced in the same order, | The sum of the exterior angles equals four right angles. |
| 8 | I., XXVI., Cor. 1. | If a figure is a quadrilateral, | The sum of the interior angles equals four right angles. |
| 9 | I., XXVIII.......<br>I., XXXI. | If a figure is a parallelogram, | The opposite sides are equal. The opposite angles are equal. It is bisected by its diagonal. And its diagonals bisect each other. |
| 10 | III., VII.......... | If three points are not in the same straight line, | A circle may be passed through them. |
| 11 | III., XVII........ | If two arcs are intercepted on the same circle, | They are proportional to the corresponding angles at the centre. |
| 12 | V., XIII., Cor. 2.. | If two arcs are similar, | They are proportional to their radii. |
| 13 | V., XIII.......... | If two areas are circles, | They are proportional to the squares on their radii. |
| 14 | III., VI.......... | If a radius is perpendicular to a chord, | It bisects the chord. And it bisects the arc subtended by the chord. |
| 15 | III., IX.......... | If a straight line is tangent to a circle, | It meets it in only one point. And it is perpendicular to the radius drawn to that point. |
| 16 | III., XIV., Cor...<br>I., XI.......... | If from a point without a circle tangents are drawn to touch the circle, | There are but two. They are equal. And they make equal angles with the chord joining the tangent points. |

*The References are to Davies' Legendre, Revised Edition.*

| No. | Reference. | Hypotheses. | Consequences. |
|---|---|---|---|
| 17 | III., X. | If two lines are parallel chords or a tangent and parallel chord, | They intercept equal arcs of a circle. |
| 18 | III., XVIII. | If an angle at the circumference of a circle is subtended by the same arc as an angle at the centre, | The angle at the circumference is equal to half the angle at the centre. |
| 19 | III., XVIII., Cor. 2 | If an angle is inscribed in a semicircle, | It is a right angle. |
| 20 | III., XXI. | If an angle is formed by a tangent and chord, | It is measured by one half of the intercepted arc. |
| 21 | IV., XXVIII., Cor. | If two chords intersect each other in a circle, | The rectangle of the segments of the one, equals the rectangle of the segments of the other. |
| 22 | IV., XXIII., Cor. 2 | And if one chord is a diameter, and the other perpendicular to it, | The rectangle of the segments of the diameter is equal to the square on half the other chord. And the half chord is a mean proportional between the segments of the diameter. |
| 23 | IV., XXIX., Cor. | If two secants meet without the circle, | The rectangles of each secant and its external segment are equal. |
| 24 | IV., XXX. | If a secant and tangent meet, | The rectangle of the secant and its external segment is equal to the square on the tangent. And the tangent is a mean proportional between the secant and its external segment. |
| 25 | IV., XIV. | If a straight line from the vertex of a triangle bisects its base, | The sum of the squares on the two sides is equal to twice the square of half the base increased by twice the square of the bisecting line. |
| 26 | IV., XII. | If a perpendicular be drawn from the vertex of a triangle to the base, | The square of a side opposite an acute angle is equal to the sum of the squares of the other side and the base, diminished by twice the rectangle of the base and the distance from the vertex of the acute angle to the foot of the perpendicular. |

## TRIGONOMETRIC FUNCTIONS.

Let $A$ (Fig. 107) = angle $BAC$ = arc $BF$, and let the radius $AF = AB = AH = 1$.

We then have

| | |
|---|---|
| sin $A$ | $= BC$ |
| cos $A$ | $= AC$ |
| tan $A$ | $= DF$ |
| cot $A$ | $= HG$ |
| sec $A$ | $= AD$ |
| cosec $A$ | $= AG$ |
| versin $A$ | $= CF = BE$ |
| covers $A$ | $= BK = HL$ |
| exsec $A$ | $= BD$ |
| coexsec $A$ | $= BG$ |
| chord $A$ | $= BF$ |
| chord 2 $A$ | $= BI = 2BC$ |

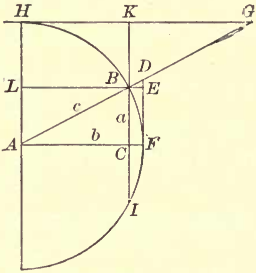


FIG. 107.

In the right-angled triangle $ABC$ (Fig. 107)

Let $AB = c$, $AC = b$, and $BC = a$.

We then have:

1. $\sin A = \frac{a}{c} = \cos B$
2. $\cos A = \frac{b}{c} = \sin B$
3. $\tan A = \frac{a}{b} = \cot B$
4. $\cot A = \frac{b}{a} = \tan B$
5. $\sec A = \frac{c}{b} = \operatorname{cosec} B$
6. $\operatorname{cosec} A = \frac{c}{a} = \sec B$
7. $\operatorname{vers} A = \frac{c-b}{c} = \operatorname{covers} B$
8. $\operatorname{exsec} A = \frac{c-b}{b} = \operatorname{coexsec} B$
9. $\operatorname{covers} A = \frac{c-a}{c} = \operatorname{versin} B$
10. $\operatorname{coexsec} A = \frac{c-a}{a} = \operatorname{exsec} B$
11. $a = c \sin A = b \tan A$
12. $b = c \cos A = a \cot A$
13. $c = \frac{a}{\sin A} = \frac{b}{\cos A}$
14. $a = c \cos B = b \cot B$
15. $b = c \sin B = a \tan B$
16. $c = \frac{a}{\cos B} = \frac{b}{\sin B}$
17. $a = \sqrt{(c+b)(c-b)}$
18. $b = \sqrt{(c+a)(c-a)}$
19. $c = \sqrt{a^2 + b^2}$
20. $C = 90° = A + B$
21. $\text{area} = \frac{ab}{2}$

## SOLUTION OF OBLIQUE TRIANGLES.

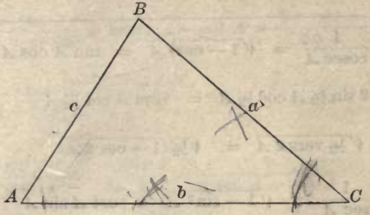


FIG. 108.

| | GIVEN. | SOUGHT. | FORMULÆ. |
|---|---|---|---|
| 22 | $A, B, a$ | $C, b, c$ | $C = 180° - (A + B)$, $b = \frac{a}{\sin A} . \sin B$, $c = \frac{a}{\sin A} \sin (A + B)$ |
| 23 | $A, a, b$ | $B, C, c$ | $\sin B = \frac{\sin A}{a} . b$, $C = 180° - (A + B)$, $c = \frac{a}{\sin A} . \sin C$. |
| 24 | $C, a, b$ | $\frac{1}{2}(A + B)$ | $\frac{1}{2}(A + B) = 90° - \frac{1}{2} C$ |
| 25 | | $\frac{1}{2}(A - B)$ | $\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$ |
| 26 | | $A, B$ | $A = \frac{1}{2}(A + B) + \frac{1}{2}(A - B)$, $B = \frac{1}{2}(A + B) - \frac{1}{2}(A - B)$ |
| 27 | | $c$ | $c = (a + b) \frac{\cos \frac{1}{2}(A + B)}{\cos \frac{1}{2}(A - B)} = (a - b) \frac{\sin \frac{1}{2}(A + B)}{\sin \frac{1}{2}(A - B)}$ |
| 28 | | area | $K = \frac{1}{2} a b \sin C$. |
| 29 | $a, b, c$ | $A$ | Let $s = \frac{1}{2}(a + b + c)$; $\sin \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}}$ |
| 30 | | | $\cos \frac{1}{2} A = \sqrt{\frac{s(s-a)}{bc}}$; $\tan \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$ |
| 31 | | | $\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$; $\text{vers } A = \frac{2(s-b)(s-c)}{bc}$ |
| 32 | | area | $K = \sqrt{s(s-a)(s-b)(s-c)}$ |
| 33 | $A, B, C, a$ | area | $K = \frac{a^2 \sin B . \sin C}{2 \sin A}$ |

| | GENERAL FORMULÆ. |
|---|---|
| 34 | $\sin A = \frac{1}{\operatorname{cosec} A} = \sqrt{1-\cos^2 A} = \tan A \cos A$ |
| 35 | $\sin A = 2 \sin \frac{1}{2} A \cos \frac{1}{2} A = \operatorname{vers} A \cot \frac{1}{2} A$ |
| 36 | $\sin A = \sqrt{\frac{1}{2} \operatorname{vers} 2A} = \sqrt{\frac{1}{2}(1-\cos 2A)}$ |
| 37 | $\cos A = \frac{1}{\sec A} = \sqrt{1-\sin^2 A} = \cot A \sin A$ |
| 38 | $\cos A = 1 - \operatorname{vers} A = 2\cos^2 \frac{1}{2} A - 1 = 1 - 2\sin^2 \frac{1}{2} A$ |
| 39 | $\cos A = \cos^2 \frac{1}{2} A - \sin^2 \frac{1}{2} A = \sqrt{\frac{1}{2} + \frac{1}{2}\cos 2A}$ |
| 40 | $\tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A} = \sqrt{\sec^2 A - 1}$ |
| 41 | $\tan A = \sqrt{\frac{1}{\cos^2 A} - 1} = \frac{\sqrt{1-\cos^2 A}}{\cos A} = \frac{\sin 2A}{1+\cos 2A}$ |
| 42 | $\tan A = \frac{1-\cos 2A}{\sin 2A} = \frac{\operatorname{vers} 2A}{\sin 2A} = \operatorname{exsec} A \cot \frac{1}{2} A$ |
| 43 | $\cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A} = \sqrt{\operatorname{cosec}^2 A - 1}$ |
| 44 | $\cot A = \frac{\sin 2A}{1-\cos 2A} = \frac{\sin 2A}{\operatorname{vers} 2A} = \frac{1+\cos 2A}{\sin 2A}$ |
| 45 | $\cot A = \frac{\tan \frac{1}{2} A}{\operatorname{exsec} A}$ |
| 46 | $\operatorname{vers} A = 1 - \cos A = \sin A \tan \frac{1}{2} A = 2\sin^2 \frac{1}{2} A$ |
| 47 | $\operatorname{vers} A = \operatorname{exsec} A \cos A$ |
| 48 | $\operatorname{exsec} A = \sec A - 1 = \tan A \tan \frac{1}{2} A = \frac{\operatorname{vers} A}{\cos A}$ |
| 49 | $\sin \frac{1}{2} A = \sqrt{\frac{1-\cos A}{2}} = \sqrt{\frac{\operatorname{vers} A}{2}}$ |
| 50 | $\sin 2A = 2 \sin A \cos A$ |
| 51 | $\cos \frac{1}{2} A = \sqrt{\frac{1+\cos A}{2}}$ |
| 52 | $\cos 2A = 2\cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2\sin^2 A$ |

## GENERAL FORMULÆ.

53. $\tan \tfrac{1}{2} A = \dfrac{\tan A}{1 + \sec A} = \operatorname{cosec} A - \cot A = \dfrac{1 - \cos A}{\sin A} = \sqrt{\dfrac{1 - \cos A}{1 + \cos A}}$

54. $\tan 2A = \dfrac{2 \tan A}{1 - \tan^2 A}$

55. $\cot. \tfrac{1}{2} A = \dfrac{\sin A}{\operatorname{vers} A} = \dfrac{1 + \cos A}{\sin A} = \dfrac{1}{\operatorname{cosec} A - \cot A}$

56. $\cot 2A = \dfrac{\cot^2 A - 1}{2 \cot A}$

57. $\operatorname{vers} \tfrac{1}{2} A = \dfrac{\tfrac{1}{2} \operatorname{vers} A}{1 + \sqrt{1 - \tfrac{1}{2} \operatorname{vers} A}} = \dfrac{1 - \cos A}{2 + \sqrt{2(1 + \cos A)}}$

58. $\operatorname{vers} 2A = 2 \sin^2 A = 2 \sin A \cos A \tan A$

59. $\operatorname{exsec} \tfrac{1}{2} A = \dfrac{1 - \cos A}{(1 + \cos A) + \sqrt{2(1 + \cos A)}}$

60. $\operatorname{exsec} 2A = \dfrac{2 \tan^2 A}{1 - \tan^2 A}$

61. $\sin (A \pm B) = \sin A . \cos B \pm \sin B . \cos A$

62. $\cos (A \pm B) = \cos A . \cos B \mp \sin A . \sin B$

63. $\sin A + \sin B = 2 \sin \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$

64. $\sin A - \sin B = 2 \cos \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$

65. $\cos A + \cos B = 2 \cos \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$

66. $\cos B - \cos A = 2 \sin \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$

67. $\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin (A + B) \sin (A - B)$

68. $\cos^2 A - \sin^2 B = \cos (A + B) \cos (A - B)$

69. $\tan A + \tan B = \dfrac{\sin (A + B)}{\cos A . \cos B}$

70. $\tan A - \tan B = \dfrac{\sin (A - B)}{\cos A . \cos B}$

## TABLE III.—CURVE FORMULÆ.

| | GIVEN. | SOUGHT. | FORMULÆ. |
|---|---|---|---|
| 1 | $D$ | $R$ | $R = \frac{50}{\sin \frac{1}{2} D}$ |
| 2 | $R$ | $D$ | $\sin \frac{1}{2} D = \frac{50}{R}$ |
| 3 | $\Delta$, $D$ | $L$ | $L = 100 \frac{\Delta}{D}$ |
| 4 | $D$, $L$ | $\Delta$ | $\Delta = \frac{DL}{100}$ |
| 5 | $\Delta$, $L$ | $D$ | $D = 100 \frac{\Delta}{L}$ |
| 6 | $R$, $\Delta$ | $T$ | $T = R \tan \frac{1}{2} \Delta$ |
| 7 | " | $C$ | $C = 2 R \sin \frac{1}{2} \Delta$ |
| 8 | " | $M$ | $M = R \operatorname{vers} \frac{1}{2} \Delta$ |
| 9 | " | $E$ | $E = R \operatorname{exsec} \frac{1}{2} \Delta$ |
| 10 | $T$, $\Delta$ | $R$ | $R = T \cot \frac{1}{2} \Delta$ |
| 11 | " | $E$ | $E = T \tan \frac{1}{4} \Delta$ |
| 12 | " | $C$ | $C = 2 T \cos \frac{1}{2} \Delta$ |
| 13 | " | $M$ | $M = T \cot \frac{1}{2} \Delta \, . \operatorname{vers} \frac{1}{2} \Delta$ |
| 14 | $E$, $\Delta$ | $R$ | $R = \frac{E}{\operatorname{exsec} \frac{1}{2} \Delta}$ |
| 15 | " | $T$ | $T = E \cot \frac{1}{4} \Delta$ |
| 16 | " | $C$ | $C = 2 E \frac{\sin \frac{1}{2} \Delta}{\operatorname{exsec} \frac{1}{2} \Delta}$ |
| 17 | " | $M$ | $M = E \cos \frac{1}{2} \Delta$ |
| 18 | $C$, $\Delta$ | $R$ | $R = \frac{C}{2 \sin \frac{1}{2} \Delta}$ |
| 19 | " | $M$ | $M = \frac{1}{2} C \tan \frac{1}{4} \Delta$ |
| 20 | " | $T$ | $T = \frac{C}{2 \cos \frac{1}{2} \Delta}$ |
| 21 | " | $E$ | $E = \frac{1}{2} C \frac{\operatorname{exsec} \frac{1}{2} \Delta}{\sin \frac{1}{2} \Delta}$ |
| 22 | $M$, $\Delta$ | $R$ | $R = \frac{M}{\operatorname{vers} \frac{1}{2} \Delta}$ |
| 23 | " | $C$ | $C = 2 M \cot \frac{1}{4} \Delta$ |
| 24 | " | $T$ | $T = M \frac{\tan \frac{1}{2} \Delta}{\operatorname{vers} \frac{1}{2} \Delta}$ |
| 25 | " | $E$ | $E = \frac{M}{\cos \frac{1}{2} \Delta}$ |

TABLE III.—CURVE FORMULÆ.

| | GIVEN. | SOUGHT. | FORMULÆ. |
|---|---|---|---|
| 26 | $R, T$ | $\Delta$ | $\tan \frac{1}{2} \Delta = \frac{T}{R}$ |
| 27 | " | " | $\sin \frac{1}{2} \Delta = \frac{T}{\sqrt{T^2 + R^2}}$ |
| 28 | $R, C$ | $\Delta$ | $\sin \frac{1}{2} \Delta = \frac{C}{2R}$ |
| 29 | " | " | $\cos \frac{1}{2} \Delta = \frac{1}{R}\sqrt{\left(R + \frac{C}{2}\right)\left(R - \frac{C}{2}\right)}$ |
| 30 | $R, M$ | $\Delta$ | $\text{vers} \frac{1}{2} \Delta = \frac{M}{R}$ |
| 31 | " | " | $\cos \frac{1}{2} \Delta = \frac{R - M}{R}$ |
| 32 | $R, E$ | $\Delta$ | $\text{exsec} \frac{1}{2} \Delta = \frac{E}{R}$ |
| 33 | " | " | $\cos \frac{1}{2} \Delta = \frac{R}{R + E}$ |
| 34 | $T, C$ | $\Delta$ | $\cos \frac{1}{2} \Delta = \frac{C}{2T}$ |
| 35 | " | " | $\tan \frac{1}{4} \Delta = \sqrt{\frac{2T - C}{2T + C}}$ |
| 36 | $T, E$ | $\Delta$ | $\tan \frac{1}{4} \Delta = \frac{E}{T}$ |
| 37 | " | " | $\cos \frac{1}{2} \Delta = \frac{T^2 - E^2}{T^2 + E^2}$ |
| 38 | $C, M$ | $\Delta$ | $\tan \frac{1}{4} \Delta = \frac{2M}{C}$ |
| 39 | " | " | $\cos \frac{1}{2} \Delta = \frac{C^2 - 4M^2}{C^2 + 4M^2}$ |
| 40 | $M, E$ | $\Delta$ | $\cos \frac{1}{2} \Delta = \frac{M}{E}$ |
| 41 | " | " | $\tan \frac{1}{4} \Delta = \sqrt{\frac{E - M}{E + M}}$ |
| 42 | $R, T$ | $C$ | $C = \frac{2TR}{\sqrt{T^2 + R^2}}$ |
| 43 | " | $M$ | $M = R - \frac{R^2}{\sqrt{T^2 + R^2}}$ |
| 44 | " | $E$ | $E = \sqrt{T^2 + R^2} - R$ |
| 45 | $R, C$ | $T$ | $T = \frac{CR}{2\sqrt{\left(R + \frac{C}{2}\right)\left(R - \frac{C}{2}\right)}}$ |
| 46 | " | $M$ | $M = R - \sqrt{(R + \frac{1}{2}C)(R - \frac{1}{2}C)}$ |
| 47 | " | $E$ | $E = \frac{R^2}{\sqrt{(R + \frac{1}{2}C)(R - \frac{1}{2}C)}} - R$ |

# TABLE III.—CURVE FORMULÆ.

| | GIVEN. | SOUGHT. | FORMULÆ. |
|---|---|---|---|
| 48 | $R, M$ | $T$ | $T = \frac{R\sqrt{M(2R-M)}}{R-M}$ |
| 49 | " | $C$ | $C = 2\sqrt{M(2R-M)}$ |
| 50 | " | $E$ | $E = \frac{RM}{R-M}$ |
| 51 | $R, E$ | $T$ | $T = \sqrt{E(2R+E)}$ |
| 52 | " | $C$ | $C = \frac{2R\sqrt{E(2R+E)}}{R+E}$ |
| 53 | " | $M$ | $M = \frac{RE}{R+E}$ |
| 54 | $T, C$ | $R$ | $R = \frac{CT}{\sqrt{(2T+C)(2T-C)}}$ |
| 55 | " | $M$ | $M = \frac{1}{2} C \sqrt{\frac{2T-C}{2T+C}}$ |
| 56 | " | $E$ | $E = T\sqrt{\frac{2T-C}{2T+C}}$ |
| 57 | $T, E$ | $R$ | $R = \frac{(T+E)(T-E)}{2E}$ |
| 58 | " | $C$ | $C = \frac{2T(T^2-E^2)}{T^2+E^2}$ |
| 59 | " | $M$ | $M = \frac{E(T^2-E^2)}{T^2+E^2}$ |
| 60 | $C, M$ | $R$ | $R = \frac{M^2+(\frac{1}{2}C)^2}{2M}$ |
| 61 | " | $T$ | $T = \frac{C(C^2+4M^2)}{2(C^2-4M^2)}$ |
| 62 | " | $E$ | $E = M\frac{C^2+4M^2}{C^2-4M^2}$ |
| 63 | $M, E$ | $R$ | $R = \frac{EM}{E-M}$ |
| 64 | " | $T$ | $T = E\sqrt{\frac{E+M}{E-M}}$ |
| 65 | " | $C$ | $C = 2M\sqrt{\frac{E+M}{E-M}}$ |
| 66 | $T, M$ | $R$ | $R^3 - R^2\frac{M^2+T^2}{2M} + RT^2 - \frac{1}{2}MT^2 = 0$ |
| 67 | " | $E$ | $E^3 + E^2M - ET^2 + MT^2 = 0$ |
| 68 | " | $C$ | $C^3 + 2TC^2 + 4M^2C - 8M^2T = 0$ |
| 69 | $C, E$ | $R$ | $R^3 + R^2\frac{4E^2-C^2}{8E} - R\frac{C^2}{4} - \frac{C^2E}{8} = 0$ |
| 70 | " | $T$ | $2T^3 - T^2C - 2TE^2 - CE^2 = 0$ |
| 71 | " | $M$ | $M^3 + M^2E + M\frac{C^2}{4} - \frac{C^2E}{4} = 0$ |

| Deg. D. | Radius. R. | Logarithm. log. R. | Tan. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| 0° 0′ | Infinite | Infinite | .000 | .000 | 1° 0′ | 5729.65 | 3.758128 | .873 | .218 |
| 1 | 343775. | 5.536274 | .015 | .004 | 1 | 5635.72 | .750950 | .887 | .222 |
| 2 | 171887. | 5.235244 | .029 | .007 | 2 | 5544.83 | .743888 | .902 | .225 |
| 3 | 114592. | 5.059153 | .044 | .011 | 3 | 5456.82 | .736939 | .916 | .229 |
| 4 | 85943.7 | 4.934214 | .058 | .015 | 4 | 5371.56 | .730100 | .931 | .233 |
| 5 | 68754.9 | .837304 | .073 | .018 | 5 | 5288.92 | .723367 | .945 | .236 |
| 6 | 57295.8 | .758123 | .087 | .022 | 6 | 5208.79 | .716737 | .960 | .240 |
| 7 | 49110.7 | .691176 | .102 | .025 | 7 | 5131.05 | .710206 | .974 | .244 |
| 8 | 42971.8 | .633184 | .116 | .029 | 8 | 5055.59 | .703772 | .989 | .247 |
| 9 | 38197.2 | .582031 | .131 | .033 | 9 | 4982.33 | .697432 | 1.004 | .251 |
| 10 | 34377.5 | 4.536274 | .145 | .036 | 10 | 4911.15 | 3.691183 | 1.018 | .255 |
| 11 | 31252.3 | 4.494881 | .160 | .040 | 11 | 4841.98 | 3.685023 | 1.033 | .258 |
| 12 | 28647.8 | .457093 | .175 | .044 | 12 | 4774.74 | .678949 | 1.047 | .262 |
| 13 | 26444.2 | .422331 | .189 | .047 | 13 | 4709.33 | .672959 | 1.062 | .265 |
| 14 | 24555.4 | .390146 | .204 | .051 | 14 | 4645.69 | .667051 | 1.076 | .269 |
| 15 | 22918.3 | .360183 | .218 | .055 | 15 | 4583.75 | .661221 | 1.091 | .273 |
| 16 | 21485.9 | .332154 | .233 | .658 | 16 | 4523.44 | .655469 | 1.105 | .276 |
| 17 | 20222.1 | .305825 | .247 | .062 | 17 | 4464.70 | .649792 | 1.120 | .280 |
| 18 | 19098.6 | .281002 | .262 | .065 | 18 | 4407.46 | .644189 | 1.134 | .284 |
| 19 | 18093.4 | .257521 | .276 | .069 | 19 | 4351.67 | .638656 | 1.149 | .287 |
| 20 | 17188.8 | 4.235244 | .291 | .073 | 20 | 4297.28 | 3.633194 | 1.164 | .291 |
| 21 | 16370.2 | 4.214055 | .305 | .076 | 21 | 4244.23 | 3.627799 | 1.178 | .295 |
| 22 | 15626.1 | .193852 | .320 | .080 | 22 | 4192.47 | .622470 | 1.193 | .298 |
| 23 | 14946.7 | .174547 | .335 | .084 | 23 | 4141.96 | .617206 | 1.207 | .302 |
| 24 | 14323.6 | .156064 | .349 | .087 | 24 | 4092.66 | .612005 | 1.222 | .305 |
| 25 | 13751.0 | .138335 | .364 | .091 | 25 | 4044.51 | .606866 | 1.236 | .309 |
| 26 | 13222.1 | .121302 | .378 | .095 | 26 | 3997.49 | .601787 | 1.251 | .313 |
| 27 | 12732.4 | .104911 | .393 | .098 | 27 | 3951.54 | .596766 | 1.265 | .316 |
| 28 | 12277.7 | .089117 | .407 | .102 | 28 | 3906.54 | .591803 | 1.280 | .320 |
| 29 | 11854.3 | .073877 | .422 | .105 | 29 | 3862.74 | .586896 | 1.294 | .324 |
| 30 | 11459.2 | 4.059154 | .436 | .109 | 30 | 3819.83 | 3.582044 | 1.309 | .327 |
| 31 | 11089.6 | 4.044914 | .451 | .113 | 31 | 3777.85 | 3.577245 | 1.324 | .331 |
| 32 | 10743.0 | .031125 | .465 | .116 | 32 | 3736.79 | .572499 | 1.338 | .335 |
| 33 | 10417.5 | .017762 | .480 | .120 | 33 | 3696.61 | .567804 | 1.353 | .338 |
| 34 | 10111.1 | 4.004797 | .495 | .124 | 34 | 3657.29 | .563160 | 1.367 | .342 |
| 35 | 9822.18 | 3.992208 | .509 | .127 | 35 | 3618.80 | .558564 | 1.382 | .345 |
| 36 | 9549.34 | .979973 | .524 | .131 | 36 | 3581.10 | .554017 | 1.396 | .349 |
| 37 | 9291.29 | .968074 | .538 | .135 | 37 | 3544.19 | .549517 | 1.411 | .353 |
| 38 | 9046.75 | .956493 | .553 | .138 | 38 | 3508.02 | .545063 | 1.425 | .356 |
| 39 | 8814.78 | .945212 | .567 | .142 | 39 | 3472.59 | .540654 | 1.440 | .360 |
| 40 | 8594.42 | 3.934216 | .582 | .145 | 40 | 3437.87 | 3.536289 | 1.454 | .364 |
| 41 | 8384.80 | 3.923493 | .596 | .149 | 41 | 3403.83 | 3.531968 | 1.469 | .367 |
| 42 | 8185.16 | .913027 | .611 | .153 | 42 | 3370.46 | .527690 | 1.483 | .371 |
| 43 | 7994.81 | .902808 | .625 | .156 | 43 | 3337.74 | .523453 | 1.498 | .375 |
| 44 | 7813.11 | .892824 | .640 | .160 | 44 | 3305.65 | .519257 | 1.513 | .378 |
| 45 | 7639.49 | .883065 | .654 | .164 | 45 | 3274.17 | .515101 | 1.527 | .382 |
| 46 | 7473.42 | .873519 | .669 | .167 | 46 | 3243.29 | .510985 | 1.542 | .385 |
| 47 | 7314.41 | .864179 | .684 | .171 | 47 | 3212.98 | .506908 | 1.556 | .389 |
| 48 | 7162.03 | .855036 | .698 | .174 | 48 | 3183.23 | .502868 | 1.571 | .393 |
| 49 | 7015.87 | .846082 | .713 | .178 | 49 | 3154.03 | .498866 | 1.585 | .396 |
| 50 | 6875.55 | 3.837308 | .727 | .182 | 50 | 3125.36 | 3.494900 | 1.600 | .400 |
| 51 | 6740.74 | 3.828708 | .742 | .185 | 51 | 3097.20 | 3.490970 | 1.614 | .404 |
| 52 | 6611.12 | .820275 | .756 | .189 | 52 | 3069.55 | .487075 | 1.629 | .407 |
| 53 | 6486.38 | .812002 | .771 | .193 | 53 | 3042.39 | .483215 | 1.643 | .411 |
| 54 | 6366.26 | .803885 | .785 | .196 | 54 | 3015.71 | .479389 | 1.658 | .414 |
| 55 | 6250.51 | .795916 | .800 | .200 | 55 | 2989.48 | .475596 | 1.673 | .418 |
| 56 | 6138.90 | .788091 | .814 | .204 | 56 | 2963.71 | .471836 | 1.687 | .422 |
| 57 | 6031.20 | .780404 | .829 | .207 | 57 | 2938.39 | .468109 | 1.702 | .425 |
| 58 | 5927.22 | .772851 | .844 | .211 | 58 | 2913.49 | .464413 | 1.716 | .429 |
| 59 | 5826.76 | .765427 | .858 | .215 | 59 | 2889.01 | .460749 | 1.731 | .433 |
| 60 | 5729.65 | 3.758128 | .873 | .218 | 60 | 2864.93 | 3.457115 | 1.745 | .436 |

| Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| 2° 0′ | 2864.93 | 3.457115 | 1.745 | .436 | 3° 0′ | 1910.08 | 3.281051 | 2.618 | .654 |
| 1 | 2841.26 | .453511 | 1.760 | .440 | 1 | 1899.53 | .278646 | 2.632 | .658 |
| 2 | 2817.97 | .449937 | 1.774 | .444 | 2 | 1889.09 | .276253 | 2.647 | .662 |
| 3 | 2795.06 | .446392 | 1.789 | .447 | 3 | 1878.77 | .273874 | 2.661 | .665 |
| 4 | 2772.53 | .442876 | 1.803 | .451 | 4 | 1868.56 | .271508 | 2.676 | .669 |
| 5 | 2750.35 | .439388 | 1.818 | .454 | 5 | 1858.47 | .269155 | 2.690 | .673 |
| 6 | 2728.52 | .435928 | 1.832 | .458 | 6 | 1848.48 | .266814 | 2.705 | .676 |
| 7 | 2707.04 | .432495 | 1.847 | .462 | 7 | 1838.59 | .264486 | 2.719 | .680 |
| 8 | 2685.89 | .429089 | 1.862 | .465 | 8 | 1828.82 | .262170 | 2.734 | .684 |
| 9 | 2665.08 | .425710 | 1.876 | .469 | 9 | 1819.14 | .259867 | 2.749 | .687 |
| 10 | 2644.58 | 3.422356 | 1.891 | .473 | 10 | 1809.57 | 3.257576 | 2.763 | .691 |
| 11 | 2624.39 | 3.419029 | 1.905 | .476 | 11 | 1800.10 | 3.255296 | 2.778 | .694 |
| 12 | 2604.51 | .415727 | 1.920 | .480 | 12 | 1790.73 | .253029 | 2.792 | .698 |
| 13 | 2584.93 | .412449 | 1.934 | .484 | 13 | 1781.45 | .250774 | 2.807 | .702 |
| 14 | 2565.65 | .409197 | 1.949 | .487 | 14 | 1772.27 | .248530 | 2.821 | .705 |
| 15 | 2546.64 | .405968 | 1.963 | .491 | 15 | 1763.18 | .246297 | 2.836 | .709 |
| 16 | 2527.92 | .402763 | 1.978 | .494 | 16 | 1754.19 | .244077 | 2.850 | .713 |
| 17 | 2509.47 | .399582 | 1.992 | .498 | 17 | 1745.26 | .241867 | 2.865 | .716 |
| 18 | 2491.29 | .396424 | 2.007 | .502 | 18 | 1736.48 | .239669 | 2.879 | .720 |
| 19 | 2473.37 | .393289 | 2.022 | .505 | 19 | 1727.75 | .237481 | 2.894 | .723 |
| 20 | 2455.70 | 3.390176 | 2.036 | .509 | 20 | 1719.12 | 3.235305 | 2.908 | .727 |
| 21 | 2438.29 | 3.387085 | 2.051 | .513 | 21 | 1710.56 | 3.233140 | 2.923 | .731 |
| 22 | 2421.12 | .384016 | 2.065 | .516 | 22 | 1702.10 | .230985 | 2.938 | .734 |
| 23 | 2404.19 | .380969 | 2.080 | .520 | 23 | 1693.72 | .228841 | 2.952 | .738 |
| 24 | 2387.50 | .377943 | 2.094 | .524 | 24 | 1685.42 | .226707 | 2.967 | .742 |
| 25 | 2371.04 | .374938 | 2.109 | .527 | 25 | 1677.20 | .224584 | 2.981 | .745 |
| 26 | 2354.80 | .371954 | 2.123 | .531 | 26 | 1669.06 | .222472 | 2.996 | .749 |
| 27 | 2338.78 | .368990 | 2.138 | .534 | 27 | 1661.00 | .220369 | 3.010 | .753 |
| 28 | 2322.98 | .366046 | 2.152 | .538 | 28 | 1653.01 | .218277 | 3.025 | .756 |
| 29 | 2307.39 | .363122 | 2.167 | .542 | 29 | 1645.11 | .216195 | 3.039 | .760 |
| 30 | 2292.01 | 3.360217 | 2.181 | .545 | 30 | 1637.28 | 3.214122 | 3.054 | .763 |
| 31 | 2276.84 | 3.357332 | 2.196 | .549 | 31 | 1629.52 | 3.212060 | 3.068 | .767 |
| 32 | 2261.86 | .354466 | 2.211 | .553 | 32 | 1621.84 | .210007 | 3.083 | .771 |
| 33 | 2247.08 | .351618 | 2.225 | .556 | 33 | 1614.22 | .207964 | 3.097 | .774 |
| 34 | 2232.49 | .348789 | 2.240 | .560 | 34 | 1606.68 | .205930 | 3.112 | .778 |
| 35 | 2218.09 | .345979 | 2.254 | .564 | 35 | 1599.21 | .203906 | 3.127 | .782 |
| 36 | 2203.87 | .343187 | 2.269 | .567 | 36 | 1591.81 | .201892 | 3.141 | .785 |
| 37 | 2189.84 | .340412 | 2.283 | .571 | 37 | 1584.48 | .199886 | 3.156 | .789 |
| 38 | 2175.98 | .337655 | 2.298 | .574 | 38 | 1577.21 | .197890 | 3.170 | .793 |
| 39 | 2162.30 | .334916 | 2.312 | .578 | 39 | 1570.01 | .195903 | 3.185 | .796 |
| 40 | 2148.79 | 3.332193 | 2.327 | .582 | 40 | 1562.88 | 3.193925 | 3.199 | .800 |
| 41 | 2135.44 | 3.329488 | 2.341 | .585 | 41 | 1555.81 | 3.191956 | 3.214 | .803 |
| 42 | 2122.26 | .326799 | 2.356 | .589 | 42 | 1548.80 | .189996 | 3.228 | .807 |
| 43 | 2109.24 | .324127 | 2.371 | .593 | 43 | 1541.86 | .188045 | 3.243 | .811 |
| 44 | 2096.39 | .321471 | 2.385 | .596 | 44 | 1534.98 | .186103 | 3.257 | .814 |
| 45 | 2083.68 | .318832 | 2.400 | .600 | 45 | 1528.16 | .184169 | 3.272 | .818 |
| 46 | 2071.13 | .316208 | 2.414 | .604 | 46 | 1521.40 | .182244 | 3.286 | .822 |
| 47 | 2058.73 | .313600 | 2.429 | .607 | 47 | 1514.70 | .180327 | 3.301 | .825 |
| 48 | 2046.48 | .311008 | 2.443 | .611 | 48 | 1508.06 | .178419 | 3.316 | .829 |
| 49 | 2034.37 | .308431 | 2.458 | .614 | 49 | 1501.48 | .176519 | 3.330 | .832 |
| 50 | 2022.41 | 3.305869 | 2.472 | .618 | 50 | 1494.95 | 3.174627 | 3.345 | .836 |
| 51 | 2010.59 | 3.303323 | 2.487 | .622 | 51 | 1488.48 | 3.172744 | 3.359 | .840 |
| 52 | 1998.90 | .300791 | 2.501 | .625 | 52 | 1482.07 | .170868 | 3.374 | .843 |
| 53 | 1987.35 | .298274 | 2.516 | .629 | 53 | 1475.71 | .169001 | 3.388 | .847 |
| 54 | 1975.93 | .295771 | 2.530 | .633 | 54 | 1469.41 | .167142 | 3.403 | .851 |
| 55 | 1964.64 | .293283 | 2.545 | .636 | 55 | 1463.16 | .165291 | 3.417 | .854 |
| 56 | 1953.48 | .290809 | 2.560 | .640 | 56 | 1456.96 | .163447 | 3.432 | .858 |
| 57 | 1942.44 | .288349 | 2.574 | .644 | 57 | 1450.81 | .161612 | 3.446 | .862 |
| 58 | 1931.53 | .285902 | 2.589 | .647 | 58 | 1444.72 | .159784 | 3.461 | .865 |
| 59 | 1920.75 | .283470 | 2.603 | .651 | 59 | 1438.68 | .157963 | 3.475 | .869 |
| 60 | 1910.08 | 3.281051 | 2.618 | .654 | 60 | 1432.69 | 3.156151 | 3.490 | .872 |

| Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| 4° 0′ | 1432.69 | 3.156151 | 3.490 | .872 | 5° 0′ | 1146.28 | 3.059290 | 4.362 | 1.091 |
| 1 | 1426.74 | .154346 | 3.505 | .876 | 1 | 1142.47 | .057846 | 4.376 | 1.094 |
| 2 | 1420.85 | .152548 | 3.519 | .880 | 2 | 1138.69 | .056407 | 4.391 | 1.098 |
| 3 | 1415.01 | .150758 | 3.534 | .883 | 3 | 1134.94 | .054972 | 4.405 | 1.102 |
| 4 | 1409.21 | .148975 | 3.548 | .887 | 4 | 1131.21 | .053542 | 4.420 | 1.105 |
| 5 | 1403.46 | .147200 | 3.563 | .891 | 5 | 1127.50 | .052116 | 4.435 | 1.109 |
| 6 | 1397.76 | .145431 | 3.577 | .894 | 6 | 1123.82 | .050696 | 4.449 | 1.11 |
| 7 | 1392.10 | .143670 | 3.592 | .898 | 7 | 1120.16 | .049280 | 4.464 | 1.11 |
| 8 | 1386.49 | .141916 | 3.606 | .902 | 8 | 1116.52 | .047868 | 4.478 | 1.12 |
| 9 | 1380.92 | .140170 | 3.621 | .905 | 9 | 1112.91 | .046462 | 4.493 | 1.12 |
| 10 | 1375.40 | 3.138430 | 3.635 | .909 | 10 | 1109.33 | 3.045059 | 4.507 | 1.127 |
| 11 | 1369.92 | 3.136697 | 3.650 | .912 | 11 | 1105.76 | 3.043662 | 4.522 | 1.131 |
| 12 | 1364.49 | .134971 | 3.664 | .916 | 12 | 1102.22 | .042268 | 4.536 | 1.134 |
| 13 | 1359.10 | .133251 | 3.679 | .920 | 13 | 1098.70 | .040880 | 4.551 | 1.138 |
| 14 | 1353.75 | .131539 | 3.693 | .923 | 14 | 1095.20 | .039495 | 4.565 | 1.142 |
| 15 | 1348.45 | .129833 | 3.708 | .927 | 15 | 1091.73 | .038115 | 4.580 | 1.146 |
| 16 | 1343.15 | .128134 | 3.723 | .931 | 16 | 1088.28 | .036740 | 4.594 | 1.149 |
| 17 | 1337.65 | .126442 | 3.736 | .934 | 17 | 1084.85 | .035368 | 4.609 | 1.153 |
| 18 | 1332.77 | .124756 | 3.752 | .938 | 18 | 1081.44 | .034002 | 4.623 | 1.157 |
| 19 | 1327.63 | .123077 | 3.766 | .942 | 19 | 1078.05 | .032639 | 4.638 | 1.160 |
| 20 | 1322.53 | 3.121404 | 3.781 | .945 | 20 | 1074.68 | 3.031281 | 4.653 | 1.164 |
| 21 | 1317.46 | 3.119738 | 3.795 | .949 | 21 | 1071.34 | 3.029927 | 4.667 | 1.168 |
| 22 | 1312.43 | .118078 | 3.810 | .952 | 22 | 1068.01 | .028577 | 4.682 | 1.171 |
| 23 | 1307.45 | .116424 | 3.824 | .956 | 23 | 1064.71 | .027231 | 4.696 | 1.175 |
| 24 | 1302.50 | .114777 | 3.839 | .960 | 24 | 1061.43 | .025890 | 4.711 | 1.179 |
| 25 | 1297.58 | .113136 | 3.853 | .963 | 25 | 1058.16 | .024552 | 4.725 | 1.182 |
| 26 | 1292.71 | .111501 | 3.868 | .967 | 26 | 1054.92 | .023219 | 4.740 | 1.186 |
| 27 | 1287.87 | .109872 | 3.882 | .971 | 27 | 1051.70 | .021890 | 4.754 | 1.190 |
| 28 | 1283.07 | .108249 | 3.897 | .974 | 28 | 1048.48 | .020565 | 4.769 | 1.193 |
| 29 | 1278.30 | .106632 | 3.911 | .978 | 29 | 1045.31 | .019244 | 4.783 | 1.197 |
| 30 | 1273.57 | 3.105022 | 3.926 | .982 | 30 | 1042.14 | 3.017927 | 4.798 | 1.200 |
| 31 | 1268.87 | 3.103417 | 3.941 | .985 | 31 | 1039.00 | 3.016614 | 4.812 | 1.204 |
| 32 | 1264.21 | .101818 | 3.955 | .989 | 32 | 1035.87 | .015305 | 4.827 | 1.208 |
| 33 | 1259.58 | .100225 | 3.970 | .993 | 33 | 1032.76 | .013999 | 4.841 | 1.211 |
| 34 | 1254.98 | .098638 | 3.984 | .996 | 34 | 1029.67 | .012698 | 4.856 | 1.215 |
| 35 | 1250.42 | .097057 | 3.999 | 1.000 | 35 | 1026.60 | .011401 | 4.870 | 1.218 |
| 36 | 1245.89 | .095481 | 4.013 | 1.003 | 36 | 1023.55 | .010107 | 4.885 | 1.222 |
| 37 | 1241.40 | .093912 | 4.028 | 1.007 | 37 | 1020.51 | .008818 | 4.900 | 1.226 |
| 38 | 1236.94 | .092347 | 4.042 | 1.011 | 38 | 1017.49 | .007532 | 4.914 | 1.229 |
| 39 | 1232.51 | .090789 | 4.057 | 1.014 | 39 | 1014.50 | .006250 | 4.929 | 1.233 |
| 40 | 1228.11 | 3.089236 | 4.071 | 1.018 | 40 | 1011.51 | 3.004972 | 4.943 | 1.237 |
| 41 | 1223.74 | 3.087689 | 4.086 | 1.022 | 41 | 1008.55 | 3.003698 | 4.958 | 1.240 |
| 42 | 1219.40 | .086147 | 4.100 | 1.025 | 42 | 1005.60 | .002427 | 4.972 | 1.244 |
| 43 | 1215.30 | .084610 | 4.115 | 1.029 | 43 | 1002.67 | 3.001160 | 4.987 | 1.247 |
| 44 | 1210.82 | .083079 | 4.129 | 1.032 | 44 | 999.762 | 2.999897 | 5.001 | 1.251 |
| 45 | 1206.57 | .081553 | 4.144 | 1.036 | 45 | 996.867 | .998637 | 5.016 | 1.255 |
| 46 | 1202.36 | .080033 | 4.159 | 1.040 | 46 | 993.988 | .997381 | 5.030 | 1.258 |
| 47 | 1198.17 | .078518 | 4.173 | 1.043 | 47 | 991.126 | .996129 | 5.045 | 1.262 |
| 48 | 1194.01 | .077008 | 4.188 | 1.047 | 48 | 988.280 | .994880 | 5.059 | 1.266 |
| 49 | 1189.88 | .075504 | 4.202 | 1.051 | 49 | 985.451 | .993635 | 5.074 | 1.269 |
| 50 | 1185.78 | 3.074005 | 4.217 | 1.054 | 50 | 982.638 | 2.992393 | 5.088 | 1.273 |
| 51 | 1181.71 | 3.072511 | 4.231 | 1.058 | 51 | 979.840 | 2.991155 | 5.103 | 1.277 |
| 52 | 1177.66 | .071022 | 4.246 | 1.062 | 52 | 977.060 | .989921 | 5.117 | 1.280 |
| 53 | 1173.65 | .069538 | 4.260 | 1.065 | 53 | 974.294 | .988690 | 5.132 | 1.284 |
| 54 | 1169.66 | .068059 | 4.275 | 1.069 | 54 | 971.544 | .987463 | 5.146 | 1.288 |
| 55 | 1165.70 | .066585 | 4.289 | 1.073 | 55 | 968.810 | .986238 | 5.161 | 1.291 |
| 56 | 1161.76 | .065116 | 4.304 | 1.076 | 56 | 966.091 | .985018 | 5.175 | 1.295 |
| 57 | 1157.85 | .063653 | 4.318 | 1.080 | 57 | 963.387 | .983801 | 5.190 | 1.298 |
| 58 | 1153.97 | .062194 | 4.333 | 1.083 | 58 | 960.698 | .982587 | 5.205 | 1.302 |
| 59 | 1150.11 | .060740 | 4.347 | 1.088 | 59 | 958.025 | .981377 | 5.219 | 1.306 |
| 60 | 1146.28 | 3.059290 | 4.362 | 1.091 | 60 | 955.366 | 2.980170 | 5.234 | 1.309 |

| Deg. D. | Radius. R. | Loga-rithm. log. R. | Tang. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Loga-rithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| 6° 0′ | 955.366 | 2.980170 | 5.234 | 1.309 | 7° 0′ | 819.020 | 2.913295 | 6.105 | 1.528 |
| 1 | 952.722 | .978966 | 5.248 | 1.313 | 1 | 817.077 | .912263 | 6.119 | 1.531 |
| 2 | 950.093 | .977766 | 5.263 | 1.317 | 2 | 815.144 | .911234 | 6.134 | 1.535 |
| 3 | 947.478 | .976569 | 5.277 | 1.320 | 3 | 813.238 | .910208 | 6.148 | 1.539 |
| 4 | 944.877 | .975375 | 5.292 | 1.324 | 4 | 811.303 | .909183 | 6.163 | 1.543 |
| 5 | 942.291 | .974185 | 5.306 | 1.327 | 5 | 809.397 | .908162 | 6.177 | 1.546 |
| 6 | 939.719 | .972998 | 5.321 | 1.331 | 6 | 807.499 | .907142 | 6.192 | 1.550 |
| 7 | 937.161 | .971814 | 5.335 | 1.335 | 7 | 805.611 | .906125 | 6.206 | 1.553 |
| 8 | 934.616 | .970633 | 5.350 | 1.338 | 8 | 803.731 | .905111 | 6.221 | 1.557 |
| 9 | 932.086 | .969456 | 5.364 | 1.342 | 9 | 801.860 | .904098 | 6.236 | 1.561 |
| 10 | 929.569 | 2.968282 | 5.379 | 1.346 | 10 | 799.997 | 2.903089 | 6.250 | 1.564 |
| 11 | 927.066 | 2.967111 | 5.393 | 1.349 | 11 | 798.144 | 2.902081 | 6.265 | 1.568 |
| 12 | 924.576 | .965943 | 5.408 | 1.353 | 12 | 796.299 | .901076 | 6.279 | 1.572 |
| 13 | 922.100 | .964778 | 5.422 | 1.356 | 13 | 794.462 | .900073 | 6.294 | 1.575 |
| 14 | 919.637 | .963616 | 5.437 | 1.360 | 14 | 792.634 | .899073 | 6.308 | 1.579 |
| 15 | 917.187 | .962458 | 5.451 | 1.364 | 15 | 790.814 | .898074 | 6.323 | 1.582 |
| 16 | 914.750 | .961303 | 5.466 | 1.368 | 16 | 789.003 | .897078 | 6.337 | 1.586 |
| 17 | 912.326 | .960150 | 5.480 | 1.371 | 17 | 787.210 | .896085 | 6.352 | 1.590 |
| 18 | 909.915 | .959001 | 5.495 | 1.375 | 18 | 785.405 | .895094 | 6.366 | 1.593 |
| 19 | 907.517 | .957855 | 5.510 | 1.378 | 19 | 783.618 | .894105 | 6.381 | 1.597 |
| 20 | 905.131 | 2.956711 | 5.524 | 1.382 | 20 | 781.840 | 2.893118 | 6.395 | 1.600 |
| 21 | 902.758 | 2.955571 | 5.539 | 1.386 | 21 | 780.069 | 2.892133 | 6.410 | 1.604 |
| 22 | 900.397 | .954434 | 5.553 | 1.389 | 22 | 778.307 | .891151 | 6.424 | 1.608 |
| 23 | 898.048 | .953300 | 5.568 | 1.393 | 23 | 776.552 | .890171 | 6.439 | 1.611 |
| 24 | 895.712 | .952168 | 5.582 | 1.397 | 24 | 774.806 | .889193 | 6.453 | 1.615 |
| 25 | 893.388 | .951040 | 5.597 | 1.400 | 25 | 773.067 | .888217 | 6.468 | 1.619 |
| 26 | 891.076 | .949915 | 5.611 | 1.404 | 26 | 771.336 | .887244 | 6.482 | 1.623 |
| 27 | 888.776 | .948792 | 5.626 | 1.407 | 27 | 769.613 | .886272 | 6.497 | 1.626 |
| 28 | 886.488 | .947673 | 5.640 | 1.411 | 28 | 767.897 | .885303 | 6.511 | 1.630 |
| 29 | 884.211 | .946556 | 5.655 | 1.415 | 29 | 766.190 | .884336 | 6.526 | 1.633 |
| 30 | 881.946 | 2.945442 | 5.669 | 1.418 | 30 | 764.489 | 2.883371 | 6.540 | 1.637 |
| 31 | 879.693 | 2.944331 | 5.684 | 1.422 | 31 | 762.797 | 2.882409 | 6.555 | 1.641 |
| 32 | 877.451 | .943223 | 5.698 | 1.426 | 32 | 761.112 | .881448 | 6.569 | 1.644 |
| 33 | 875.221 | .942118 | 5.713 | 1.429 | 33 | 759.434 | .880490 | 6.584 | 1.648 |
| 34 | 873.002 | .941015 | 5.727 | 1.433 | 34 | 757.764 | .879534 | 6.598 | 1.651 |
| 35 | 870.795 | .939916 | 5.742 | 1.437 | 35 | 756.101 | .878580 | 6.613 | 1.655 |
| 36 | 868.598 | .938819 | 5.756 | 1.440 | 36 | 754.445 | .877627 | 6.627 | 1.659 |
| 37 | 866.412 | .937725 | 5.771 | 1.444 | 37 | 752.796 | .876678 | 6.642 | 1.662 |
| 38 | 864.238 | .936633 | 5.785 | 1.447 | 38 | 751.155 | .875730 | 6.656 | 1.666 |
| 39 | 862.075 | .935545 | 5.800 | 1.451 | 39 | 749.521 | .874784 | 6.671 | 1.670 |
| 40 | 859.922 | 2.934459 | 5.814 | 1.455 | 40 | 747.894 | 2.873840 | 6.685 | 1.673 |
| 41 | 857.780 | 2.933376 | 5.829 | 1.458 | 41 | 746.274 | 2.872898 | 6.700 | 1.677 |
| 42 | 855.648 | .932295 | 5.844 | 1.462 | 42 | 744.661 | .871959 | 6.714 | 1.680 |
| 43 | 853.527 | .931218 | 5.858 | 1.466 | 43 | 743.055 | .871021 | 6.729 | 1.684 |
| 44 | 851.417 | .930142 | 5.873 | 1.469 | 44 | 741.456 | .870086 | 6.743 | 1.688 |
| 45 | 849.317 | .929070 | 5.887 | 1.473 | 45 | 739.864 | .869152 | 6.758 | 1.691 |
| 46 | 847.228 | .928000 | 5.902 | 1.476 | 46 | 738.279 | .868221 | 6.773 | 1.695 |
| 47 | 845.148 | .926933 | 5.916 | 1.480 | 47 | 736.701 | .867291 | 6.787 | 1.699 |
| 48 | 843.080 | .925869 | 5.931 | 1.484 | 48 | 735.129 | .866363 | 6.802 | 1.702 |
| 49 | 841.021 | .924807 | 5.945 | 1.487 | 49 | 733.564 | .865438 | 6.816 | 1.706 |
| 50 | 838.972 | 2.923747 | 5.960 | 1.491 | 50 | 732.005 | 2.864514 | 6.831 | 1.710 |
| 51 | 836.933 | 2.922691 | 5.974 | 1.495 | 51 | 730.454 | 2.863593 | 6.845 | 1.713 |
| 52 | 834.904 | .921637 | 5.989 | 1.498 | 52 | 728.909 | .862673 | 6.860 | 1.717 |
| 53 | 832.885 | .920585 | 6.003 | 1.502 | 53 | 727.370 | .861755 | 6.874 | 1.720 |
| 54 | 830.876 | .919536 | 6.018 | 1.505 | 54 | 725.838 | .860840 | 6.889 | 1.724 |
| 55 | 828.876 | .918489 | 6.032 | 1.510 | 55 | 724.312 | .859926 | 6.903 | 1.728 |
| 56 | 826.886 | .917446 | 6.047 | 1.513 | 56 | 722.793 | .859014 | 6.918 | 1.731 |
| 57 | 824.905 | .916404 | 6.061 | 1.517 | 57 | 721.280 | .858104 | 6.932 | 1.735 |
| 58 | 822.934 | .915365 | 6.076 | 1.520 | 58 | 719.774 | .857196 | 6.947 | 1.739 |
| 59 | 820.973 | .914329 | 6.090 | 1.524 | 59 | 718.273 | .856290 | 6.961 | 1.742 |
| 60 | 819.020 | 2.913295 | 6.105 | 1.528 | 60 | 716.779 | 2.855385 | 6.976 | 1.746 |

| Deg. D. | Radius. R. | Loga-rithm. log. R. | Tang. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Loga-rithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| 8° 0′ | 716.779 | 2.855385 | 6.976 | 1.746 | 9° 0′ | 637.275 | 2.804327 | 7.846 | 1.965 |
| 1 | 715.291 | .854483 | 6.990 | 1.749 | 1 | 636.099 | .803525 | 7.860 | 1.968 |
| 2 | 713.810 | .853583 | 7.005 | 1.753 | 2 | 634.928 | .802724 | 7.875 | 1.972 |
| 3 | 712.335 | .852684 | 7.019 | 1.756 | 3 | 633.761 | .801926 | 7.889 | 1.975 |
| 4 | 710.865 | .851787 | 7.034 | 1.761 | 4 | 632.599 | .801128 | 7.904 | 1.979 |
| 5 | 709.402 | .850892 | 7.048 | 1.764 | 5 | 631.440 | .800332 | 7.918 | 1.983 |
| 6 | 707.945 | .849999 | 7.063 | 1.768 | 6 | 630.286 | .799538 | 7.933 | 1.987 |
| 7 | 706.493 | .849108 | 7.077 | 1.771 | 7 | 629.136 | .798745 | 7.947 | 1.990 |
| 8 | 705.048 | .848219 | 7.092 | 1.775 | 8 | 627.991 | .797953 | 7.962 | 1.994 |
| 9 | 703.609 | .847331 | 7.106 | 1.778 | 9 | 626.849 | .797163 | 7.976 | 1.998 |
| 10 | 702.175 | 2.846445 | 7.121 | 1.782 | 10 | 625.712 | 2.796374 | 7.991 | 2.001 |
| 11 | 700.748 | 2.845562 | 7.135 | 1.786 | 11 | 624.579 | 2.795587 | 8.005 | 2.005 |
| 12 | 699.326 | .844679 | 7.150 | 1.790 | 12 | 623.450 | .794801 | 8.020 | 2.008 |
| 13 | 697.910 | .843799 | 7.164 | 1.793 | 13 | 622.325 | .794017 | 8.034 | 2.012 |
| 14 | 696.499 | .842921 | 7.179 | 1.797 | 14 | 621.203 | .793234 | 8.049 | 2.016 |
| 15 | 695.095 | .842044 | 7.193 | 1.801 | 15 | 620.087 | .792453 | 8.063 | 2.019 |
| 16 | 693.696 | .841169 | 7.208 | 1.804 | 16 | 618.974 | .791673 | 8.078 | 2.023 |
| 17 | 692.302 | .840296 | 7.222 | 1.807 | 17 | 617.865 | .790894 | 8.092 | 2.026 |
| 18 | 690.914 | .839424 | 7.237 | 1.811 | 18 | 616.760 | .790117 | 8.107 | 2.030 |
| 19 | 689.532 | .838555 | 7.251 | 1.815 | 19 | 615.660 | .789341 | 8.121 | 2.034 |
| 20 | 688.156 | 2.837687 | 7.266 | 1.819 | 20 | 614.563 | 2.788566 | 8.136 | 2.037 |
| 21 | 686.785 | 2.836821 | 7.280 | 1.822 | 21 | 613.470 | 2.787793 | 8.150 | 2.041 |
| 22 | 685.419 | .835956 | 7.295 | 1.826 | 22 | 612.380 | .787021 | 8.165 | 2.045 |
| 23 | 684.059 | .835093 | 7.309 | 1.829 | 23 | 611.295 | .786251 | 8.179 | 2.048 |
| 24 | 682.704 | .834232 | 7.324 | 1.833 | 24 | 610.214 | .785482 | 8.194 | 2.052 |
| 25 | 681.354 | .833373 | 7.338 | 1.837 | 25 | 609.136 | .784714 | 8.208 | 2.056 |
| 26 | 680.010 | .832515 | 7.353 | 1.840 | 26 | 608.062 | .783948 | 8.223 | 2.060 |
| 27 | 678.671 | .831660 | 7.367 | 1.844 | 27 | 606.992 | .783183 | 8.237 | 2.063 |
| 28 | 677.338 | .830805 | 7.382 | 1.848 | 28 | 605.926 | .782420 | 8.252 | 2.066 |
| 29 | 676.008 | .829953 | 7.396 | 1.851 | 29 | 604.864 | .781657 | 8.266 | 2.070 |
| 30 | 674.686 | 2.829102 | 7.411 | 1.855 | 30 | 603.805 | 2.780897 | 8.281 | 2.074 |
| 31 | 673.369 | 2.828253 | 7.425 | 1.858 | 31 | 602.750 | 2.780137 | 8.295 | 2.077 |
| 32 | 672.056 | .827405 | 7.440 | 1.862 | 32 | 601.698 | .779379 | 8.310 | 2.081 |
| 33 | 670.748 | .826560 | 7.454 | 1.866 | 33 | 600.651 | .778622 | 8.324 | 2.084 |
| 34 | 669.446 | .825715 | 7.469 | 1.869 | 34 | 599.607 | .777867 | 8.339 | 2.088 |
| 35 | 668.148 | .824873 | 7.483 | 1.873 | 35 | 598.567 | .777112 | 8.353 | 2.092 |
| 36 | 666.856 | .824032 | 7.598 | 1.877 | 36 | 597.530 | .776360 | 8.368 | 2.096 |
| 37 | 665.568 | .823193 | 7.512 | 1.880 | 37 | 596.497 | .775608 | 8.382 | 2.099 |
| 38 | 664.286 | .822355 | 7.527 | 1.884 | 38 | 595.467 | .774858 | 8.397 | 2.103 |
| 39 | 663.008 | .821519 | 7.541 | 1.887 | 39 | 594.441 | .774109 | 8.411 | 2.106 |
| 40 | 661.736 | 2.820685 | 7.556 | 1.892 | 40 | 593.419 | 2.773361 | 8.426 | 2.110 |
| 41 | 660.468 | 2.819852 | 7.570 | 1.895 | 41 | 592.400 | 2.772615 | 8.440 | 2.113 |
| 42 | 659.205 | .819021 | 7.585 | 1.899 | 42 | 591.384 | .771870 | 8.455 | 2.117 |
| 43 | 657.947 | .818191 | 7.599 | 1.903 | 43 | 590.372 | .771126 | 8.469 | 2.121 |
| 44 | 656.694 | .817363 | 7.614 | 1.906 | 44 | 589.364 | .770383 | 8.484 | 2.125 |
| 45 | 655.446 | .816537 | 7.628 | 1.910 | 45 | 588.359 | .769642 | 8.498 | 2.128 |
| 46 | 654.202 | .815712 | 7.643 | 1.914 | 46 | 587.357 | .768902 | 8.513 | 2.132 |
| 47 | 652.963 | .814889 | 7.657 | 1.918 | 47 | 586.359 | .768164 | 8.527 | 2.135 |
| 48 | 651.729 | .814067 | 7.672 | 1.921 | 48 | 585.364 | .767426 | 8.542 | 2.139 |
| 49 | 650.499 | .813247 | 7.686 | 1.924 | 49 | 584.373 | .766690 | 8.556 | 2.142 |
| 50 | 649.274 | 2.812428 | 7.701 | 1.928 | 50 | 583.385 | 2.765955 | 8.571 | 2.147 |
| 51 | 648.054 | 2.811611 | 7.715 | 1.932 | 51 | 582.400 | 2.765221 | 8.585 | 2.150 |
| 52 | 646.838 | .810796 | 7.730 | 1.935 | 52 | 581.419 | .764489 | 8.600 | 2.154 |
| 53 | 645.627 | .809982 | 7.744 | 1.939 | 53 | 580.441 | .763758 | 8.614 | 2.158 |
| 54 | 644.420 | .809169 | 7.759 | 1.943 | 54 | 579.466 | .763028 | 8.629 | 2.161 |
| 55 | 643.218 | .808358 | 7.773 | 1.946 | 55 | 578.494 | .762299 | 8.643 | 2.165 |
| 56 | 642.021 | .807549 | 7.788 | 1.950 | 56 | 577.526 | .761572 | 8.658 | 2.168 |
| 57 | 640.828 | .806741 | 7.802 | 1.953 | 57 | 576.561 | .760845 | 8.672 | 2.172 |
| 58 | 639.639 | .805935 | 7.817 | 1.957 | 58 | 575.599 | .760120 | 8.687 | 2.175 |
| 59 | 638.455 | .805130 | 7.831 | 1.961 | 59 | 574.641 | .759397 | 8.701 | 2.179 |
| 60 | 637.275 | 2.804327 | 7.846 | 1.965 | 60 | 573.686 | 2.758674 | 8.716 | 2.183 |

| Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| 10° 0′ | 573.686 | 2.758674 | 8.716 | 2.183 | 12° 0′ | 478.339 | 2.679735 | 10.453 | 2.620 |
| 2 | 571.784 | .757232 | 8.745 | 2.190 | 2 | 477.018 | .678535 | 10.482 | 2.628 |
| 4 | 569.896 | .755796 | 8.774 | 2.198 | 4 | 475.705 | .677338 | 10.511 | 2.635 |
| 6 | 568.020 | .754364 | 8.803 | 2.205 | 6 | 474.400 | .676145 | 10.540 | 2.642 |
| 8 | 566.156 | .752937 | 8.831 | 2.212 | 8 | 473.102 | .674954 | 10.569 | 2.650 |
| 10 | 564.305 | .751514 | 8.860 | 2.219 | 10 | 471.810 | .673767 | 10.597 | 2.657 |
| 12 | 562.466 | .750096 | 8.889 | 2.227 | 12 | 470.526 | .672584 | 10.626 | 2.664 |
| 14 | 560.638 | .748683 | 8.918 | 2.234 | 14 | 469.249 | .671403 | 10.655 | 2.671 |
| 16 | 558.823 | .747274 | 8.947 | 2.241 | 16 | 467.978 | .670226 | 10.684 | 2.679 |
| 18 | 557.019 | 2.745870 | 8.976 | 2.234 | 18 | 466.715 | 2.669052 | 10.713 | 2.686 |
| 20 | 555.227 | 2.744471 | 9.005 | 2.256 | 20 | 465.459 | 2.667881 | 10.742 | 2.693 |
| 22 | 553.447 | .743076 | 9.034 | 2.263 | 22 | 464.209 | .666713 | 10.771 | 2.701 |
| 24 | 551.678 | .741686 | 9.063 | 2.270 | 24 | 462.966 | .665549 | 10.800 | 2.708 |
| 26 | 549.920 | .740300 | 9.092 | 2.278 | 26 | 461.729 | .664387 | 10.829 | 2.715 |
| 28 | 548.174 | .738918 | 9.121 | 2.285 | 28 | 460.500 | .663229 | 10.858 | 2.722 |
| 30 | 546.438 | .737541 | 9.150 | 2.293 | 30 | 459.276 | .662074 | 10.887 | 2.730 |
| 32 | 544.714 | .736169 | 9.179 | 2.300 | 32 | 458.060 | .660922 | 10.916 | 2.737 |
| 34 | 543.001 | .734800 | 9.208 | 2.307 | 34 | 456.850 | .659773 | 10.945 | 2.744 |
| 36 | 541.298 | .733436 | 9.237 | 2.314 | 36 | 455.646 | .658628 | 10.973 | 2.752 |
| 38 | 539.606 | 2.732077 | 9.266 | 2.321 | 38 | 454.449 | 2.657485 | 11.002 | 2.759 |
| 40 | 537.924 | 2.730721 | 9.295 | 2.329 | 40 | 453.259 | 2.656345 | 11.031 | 2.766 |
| 42 | 536.253 | .729370 | 9.324 | 2.336 | 42 | 452.073 | .655208 | 11.060 | 2.774 |
| 44 | 534.593 | .728023 | 9.353 | 2.343 | 44 | 450.894 | .654075 | 11.089 | 2.781 |
| 46 | 532.943 | .726681 | 9.382 | 2.351 | 46 | 449.722 | .652944 | 11.118 | 2.788 |
| 48 | 531.303 | .725342 | 9.411 | 2.358 | 48 | 448.556 | .651816 | 11.147 | 2.795 |
| 50 | 529.673 | .724008 | 9.440 | 2.365 | 50 | 447.395 | .650691 | 11.176 | 2.803 |
| 52 | 528.053 | .722677 | 9.469 | 2.372 | 52 | 446.241 | .649570 | 11.205 | 2.810 |
| 54 | 526.443 | .721351 | 9.498 | 2.380 | 54 | 445.093 | .648451 | 11.234 | 2.817 |
| 56 | 524.843 | .720029 | 9.527 | 2.387 | 56 | 443.951 | .647335 | 11.263 | 2.825 |
| 58 | 523.252 | 2.718711 | 9.556 | 2.394 | 58 | 442.814 | 2.646221 | 11.291 | 2.832 |
| 11° 0′ | 521.671 | 2.717397 | 9.585 | 2.402 | 13° 0′ | 441.684 | 2.645111 | 11.320 | 2.839 |
| 2 | 520.100 | .716087 | 9.614 | 2.409 | 2 | 440.559 | .644004 | 11.349 | 2.846 |
| 4 | 518.539 | .714781 | 9.642 | 2.416 | 4 | 439.440 | .642899 | 11.378 | 2.854 |
| 6 | 516.986 | .713479 | 9.671 | 2.423 | 6 | 438.326 | .641798 | 11.407 | 2.861 |
| 8 | 515.443 | .712181 | 9.700 | 2.431 | 8 | 437.219 | .640699 | 11.436 | 2.868 |
| 10 | 513.909 | .710887 | 9.729 | 2.438 | 10 | 436.117 | .639603 | 11.465 | 2.876 |
| 12 | 512.385 | .709596 | 9.758 | 2.445 | 12 | 435.020 | .638510 | 11.494 | 2.883 |
| 14 | 510.869 | .708310 | 9.787 | 2.453 | 14 | 433.929 | .637419 | 11.523 | 2.890 |
| 16 | 509.363 | .707027 | 9.816 | 2.460 | 16 | 432.844 | .636331 | 11.552 | 2.898 |
| 18 | 507.865 | 2.705748 | 9.845 | 2.467 | 18 | 431.764 | 2.635246 | 11.580 | 2.905 |
| 20 | 506.376 | 2.704473 | 9.874 | 2.475 | 20 | 430.690 | 2.634164 | 11.609 | 2.912 |
| 22 | 504.896 | .703202 | 9.903 | 2.482 | 22 | 429.620 | .633085 | 11.638 | 2.919 |
| 24 | 503.425 | .701934 | 9.932 | 2.489 | 24 | 428.557 | .632008 | 11.667 | 2.927 |
| 26 | 501.962 | .700671 | 9.961 | 2.496 | 26 | 427.498 | .630934 | 11.696 | 2.934 |
| 28 | 500.507 | .699410 | 9.990 | 2.504 | 28 | 426.445 | .629863 | 11.725 | 2.941 |
| 30 | 499.061 | .698154 | 10.019 | 2.511 | 30 | 425.396 | .628794 | 11.754 | 2.949 |
| 32 | 497.624 | .696901 | 10.048 | 2.518 | 32 | 424.354 | .627728 | 11.783 | 2.956 |
| 34 | 496.195 | .695652 | 10.077 | 2.526 | 34 | 423.316 | .626665 | 11.812 | 2.963 |
| 36 | 494.774 | .694407 | 10.106 | 2.533 | 36 | 422.283 | .625604 | 11.840 | 2.971 |
| 38 | 493.361 | 2.693165 | 10.135 | 2.540 | 38 | 421.256 | 2.624546 | 11.869 | 2.978 |
| 40 | 491.956 | 2.691926 | 10.164 | 2.547 | 40 | 420.233 | 2.623490 | 11.898 | 2.985 |
| 42 | 490.559 | .690692 | 10.192 | 2.555 | 42 | 419.215 | .622437 | 11.927 | 2.992 |
| 44 | 489.171 | .689460 | 10.221 | 2.562 | 44 | 418.203 | .621387 | 11.956 | 3.000 |
| 46 | 487.790 | .688233 | 10.250 | 2.569 | 46 | 417.195 | .620339 | 11.985 | 3.007 |
| 48 | 486.417 | .687008 | 10.279 | 2.577 | 48 | 416.192 | .619294 | 12.014 | 3.014 |
| 50 | 485.051 | .685788 | 10.308 | 2.584 | 50 | 415.194 | .618251 | 12.043 | 3.022 |
| 52 | 483.694 | .684570 | 10.337 | 2.591 | 52 | 414.201 | .617211 | 12.071 | 3.029 |
| 54 | 482.344 | .683357 | 10.366 | 2.598 | 54 | 413.212 | .616173 | 12.100 | 3.036 |
| 56 | 481.001 | .682146 | 10.395 | 2.606 | 56 | 412.229 | .615138 | 12.129 | 3.044 |
| 58 | 479.666 | .680939 | 10.424 | 2.613 | 58 | 411.250 | .614106 | 12.158 | 3.051 |
| 60 | 478.339 | 2.679735 | 10.453 | 2.620 | 60 | 410.275 | 2.613075 | 12.187 | 3.058 |

| Deg. D. | Radius. R. | Loga-rithm. log. R. | Tan. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Loga-rithm. log. R. | Tan. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| **14°** 0′ | 410.275 | 2.613075 | 12.187 | 3.058 | **16°** 0′ | 359.265 | 2.555415 | 13.917 | 3.496 |
| 2 | 409.306 | .612048 | 12.216 | 3.065 | 2 | 358.523 | .554517 | 13.946 | 3.504 |
| 4 | 408.341 | .611023 | 12.245 | 3.073 | 4 | 357.784 | .553621 | 13.975 | 3.511 |
| 6 | 407.380 | .610000 | 12.274 | 3.080 | 6 | 357.048 | .552727 | 14.004 | 3.518 |
| 8 | 406.424 | .608980 | 12.302 | 3.087 | 8 | 356.315 | .551834 | 14.033 | 3.526 |
| 10 | 405.473 | .607962 | 12.331 | 3.095 | 10 | 355.585 | .550944 | 14.061 | 3.533 |
| 12 | 404.526 | .606946 | 12.360 | 3.102 | 12 | 354.859 | .550055 | 14.090 | 3.540 |
| 14 | 403.583 | .605933 | 12.389 | 3.109 | 14 | 354.135 | .549169 | 14.119 | 3.547 |
| 16 | 402.645 | .604923 | 12.418 | 3.117 | 16 | 353.414 | .548284 | 14.148 | 3.555 |
| 18 | 401.712 | .603914 | 12.447 | 3.124 | 18 | 352.696 | .547401 | 14.177 | 3.562 |
| 20 | 400.782 | 2.602908 | 12.476 | 3.131 | 20 | 351.981 | 2.546519 | 14.205 | 3.569 |
| 22 | 399.857 | .601905 | 12.504 | 3.138 | 22 | 351.269 | .545640 | 14.234 | 3.577 |
| 24 | 398.937 | .600904 | 12.533 | 3.146 | 24 | 350.560 | .544762 | 14.263 | 3.584 |
| 26 | 398.020 | .599905 | 12.562 | 3.153 | 26 | 349.854 | .543887 | 14.292 | 3.591 |
| 28 | 397.108 | .598908 | 12.591 | 3.160 | 28 | 349.150 | .543013 | 14.320 | 3.599 |
| 30 | 396.200 | .597914 | 12.620 | 3.168 | 30 | 348.450 | .542140 | 14.349 | 3.606 |
| 32 | 395.296 | .596922 | 12.649 | 3.175 | 32 | 347.752 | .541270 | 14.378 | 3.613 |
| 34 | 394.396 | .595933 | 12.678 | 3.182 | 34 | 347.057 | .540401 | 14.407 | 3.621 |
| 36 | 393.501 | .594945 | 12.706 | 3.190 | 36 | 346.365 | .539535 | 14.436 | 3.628 |
| 38 | 392.609 | .593960 | 12.735 | 3.197 | 38 | 345.676 | .538670 | 14.464 | 3.635 |
| 40 | 391.722 | 2.592978 | 12.764 | 3.204 | 40 | 344.990 | 2.537806 | 14.493 | 3.643 |
| 42 | 390.838 | .591997 | 12.793 | 3.211 | 42 | 344.306 | .536945 | 14.522 | 3.650 |
| 44 | 389.959 | .591019 | 12.822 | 3.219 | 44 | 343.625 | .536085 | 14.551 | 3.657 |
| 46 | 389.084 | .590043 | 12.851 | 3.226 | 46 | 342.947 | .535227 | 14.580 | 3.664 |
| 48 | 388.212 | .589069 | 12.880 | 3.233 | 48 | 342.271 | .534370 | 14.608 | 3.672 |
| 50 | 387.345 | .588097 | 12.908 | 3.241 | 50 | 341.598 | .533516 | 14.637 | 3.679 |
| 52 | 386.481 | .587128 | 12.937 | 3.248 | 52 | 340.928 | .532663 | 14.666 | 3.686 |
| 54 | 385.621 | .586161 | 12.966 | 3.255 | 54 | 340.260 | .531811 | 14.695 | 3.694 |
| 56 | 384.765 | .585196 | 12.995 | 3.263 | 56 | 339.595 | .530962 | 14.723 | 3.701 |
| 58 | 383.913 | .584233 | 13.024 | 3.270 | 58 | 338.933 | .530114 | 14.752 | 3.708 |
| **15°** 0 | 383.065 | 2.583272 | 13.053 | 3.277 | **17°** 0 | 338.273 | 2.529268 | 14.781 | 3.716 |
| 2 | 382.220 | .582314 | 13.081 | 3.284 | 2 | 337.616 | .528424 | 14.810 | 3.723 |
| 4 | 381.380 | .581358 | 13.110 | 3.292 | 4 | 336.962 | .527581 | 14.838 | 3.730 |
| 6 | 380.543 | .580403 | 13.139 | 3.299 | 6 | 336.310 | .526740 | 14.867 | 3.738 |
| 8 | 379.709 | .579451 | 13.168 | 3.306 | 8 | 335.660 | .525900 | 14.896 | 3.745 |
| 10 | 378.880 | .578501 | 13.197 | 3.314 | 10 | 335.013 | .525062 | 14.925 | 3.752 |
| 12 | 378.054 | .577553 | 13.226 | 3.321 | 12 | 334.369 | .524226 | 14.954 | 3.760 |
| 14 | 377.231 | .576608 | 13.254 | 3.328 | 14 | 333.727 | .523392 | 14.982 | 3.767 |
| 16 | 376.412 | .575664 | 13.283 | 3.336 | 16 | 333.088 | .522559 | 15.011 | 3.774 |
| 18 | 375.597 | .574722 | 13.312 | 3.343 | 18 | 332.451 | .521728 | 15.040 | 3.781 |
| 20 | 374.786 | 2.573783 | 13.341 | 3.350 | 20 | 331.816 | 2.520898 | 15.069 | 3.789 |
| 22 | 373.977 | .572845 | 13.370 | 3.358 | 22 | 331.184 | .520070 | 15.097 | 3.796 |
| 24 | 373.173 | .571910 | 13.399 | 3.365 | 24 | 330.555 | .519244 | 15.126 | 3.803 |
| 26 | 372.372 | .570977 | 13.427 | 3.372 | 26 | 329.928 | .518419 | 15.155 | 3.811 |
| 28 | 371.574 | .570045 | 13.456 | 3.379 | 28 | 329.303 | .517596 | 15.184 | 3.818 |
| 30 | 370.780 | .569116 | 13.485 | 3.387 | 30 | 328.689 | .516774 | 15.212 | 3.825 |
| 32 | 369.989 | .568189 | 13.514 | 3.394 | 32 | 328.061 | .515954 | 15.241 | 3.833 |
| 34 | 369.202 | .567264 | 13.543 | 3.401 | 34 | 327.443 | .515136 | 15.270 | 3.840 |
| 36 | 368.418 | .566340 | 13.572 | 3.409 | 36 | 326.828 | .514319 | 15.299 | 3.847 |
| 38 | 367.637 | .565419 | 13.600 | 3.416 | 38 | 326.215 | .513504 | 15.327 | 3.855 |
| 40 | 366.859 | 2.564500 | 13.629 | 3.423 | 40 | 325.604 | 2.512690 | 15.356 | 3.862 |
| 42 | 366.085 | .563582 | 13.658 | 3.431 | 42 | 324.996 | .511878 | 15.385 | 3.869 |
| 44 | 365.315 | .562667 | 13.687 | 3.438 | 44 | 324.390 | .511067 | 15.414 | 3.877 |
| 46 | 364.547 | .561754 | 13.716 | 3.445 | 46 | 323.786 | .510258 | 15.442 | 3.884 |
| 48 | 363.783 | .560843 | 13.744 | 3.452 | 48 | 323.184 | .509451 | 15.471 | 3.891 |
| 50 | 363.022 | .559933 | 13.773 | 3.460 | 50 | 322.585 | .508645 | 15.500 | 3.899 |
| 52 | 362.264 | .559026 | 13.802 | 3.467 | 52 | 321.989 | .507840 | 15.529 | 3.906 |
| 54 | 361.510 | .558120 | 13.831 | 3.474 | 54 | 321.394 | .507037 | 15.557 | 3.913 |
| 56 | 360.758 | .557216 | 13.860 | 3.482 | 56 | 320.801 | .506236 | 15.586 | 3.920 |
| 58 | 360.010 | .556315 | 13.889 | 3.489 | 58 | 320.211 | .505436 | 15.615 | 3.928 |
| 60 | 359.265 | 2.555415 | 13.917 | 3.496 | 60 | 319.623 | 2.504638 | 15.643 | 3.935 |

| Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|
| 18° 0′ | 319.623 | 2.504638 | 15.643 | 3.935 |
| 2 | 319.037 | .503841 | 15.672 | 3.942 |
| 4 | 318.453 | .503045 | 15.701 | 3.950 |
| 6 | 317.871 | .502251 | 15.730 | 3.957 |
| 8 | 317.292 | .501459 | 15.758 | 3.964 |
| 10 | 316.715 | .500668 | 15.787 | 3.972 |
| 12 | 316.139 | .499879 | 15.816 | 3.979 |
| 14 | 315.566 | .499091 | 15.845 | 3.986 |
| 16 | 314.993 | .498304 | 15.873 | 3.994 |
| 18 | 314.426 | .497519 | 15.902 | 4.001 |
| 20 | 313.860 | 2.496736 | 15.931 | 4.008 |
| 22 | 313.295 | .495953 | 15.959 | 4.016 |
| 24 | 312.732 | .495173 | 15.988 | 4.023 |
| 26 | 312.172 | .494393 | 16.017 | 4.030 |
| 28 | 311.613 | .493616 | 16.046 | 4.038 |
| 30 | 311.056 | .492839 | 16.074 | 4.045 |
| 32 | 310.502 | .492064 | 16.103 | 4.052 |
| 34 | 309.949 | .491291 | 16.132 | 4.060 |
| 36 | 309.399 | .490518 | 16.160 | 4.067 |
| 38 | 308.850 | .489748 | 16.189 | 4.074 |
| 40 | 308.303 | 2.488978 | 16.218 | 4.081 |
| 42 | 307.759 | .488210 | 16.246 | 4.089 |
| 44 | 307.216 | .487444 | 16.275 | 4.096 |
| 46 | 306.675 | .486679 | 16.304 | 4.103 |
| 48 | 306.136 | .485915 | 16.333 | 4.111 |
| 50 | 305.599 | .485152 | 16.361 | 4.118 |
| 52 | 305.064 | .484391 | 16.390 | 4.125 |
| 54 | 304.531 | .483632 | 16.419 | 4.133 |
| 56 | 304.000 | .482873 | 16.447 | 4.140 |
| 58 | 303.470 | .482116 | 16.476 | 4.147 |
| 19° 0′ | 302.943 | 2.481361 | 16.505 | 4.155 |
| 2 | 302.417 | .480607 | 16.533 | 4.162 |
| 4 | 301.893 | .479854 | 16.562 | 4.169 |
| 6 | 301.371 | .479102 | 16.591 | 4.177 |
| 8 | 300.851 | .478352 | 16.620 | 4.184 |
| 10 | 300.333 | .477603 | 16.648 | 4.191 |
| 12 | 299.816 | .476855 | 16.677 | 4.199 |
| 14 | 299.302 | .476109 | 16.706 | 4.206 |
| 16 | 298.789 | .475364 | 16.734 | 4.213 |
| 18 | 298.278 | .474621 | 16.763 | 4.221 |
| 20 | 297.768 | 2.473878 | 16.792 | 4.228 |
| 22 | 297.260 | .473137 | 16.820 | 4.235 |
| 24 | 296.755 | .472398 | 16.849 | 4.243 |
| 26 | 296.250 | .471659 | 16.878 | 4.250 |
| 28 | 295.748 | .470922 | 16.906 | 4.257 |
| 30 | 295.247 | .470186 | 16.935 | 4.265 |
| 32 | 294.748 | .469452 | 16.964 | 4.272 |
| 34 | 294.251 | .468718 | 16.992 | 4.279 |
| 36 | 293.756 | .467986 | 17.021 | 4.287 |
| 38 | 293.262 | .467256 | 17.050 | 4.294 |
| 40 | 292.770 | 2.466526 | 17.078 | 4.301 |
| 42 | 292.279 | .465798 | 17.107 | 4.308 |
| 44 | 291.790 | .465071 | 17.136 | 4.316 |
| 46 | 291.303 | .464345 | 17.164 | 4.323 |
| 48 | 290.818 | .463621 | 17.193 | 4.330 |
| 50 | 290.334 | .462897 | 17.222 | 4.338 |
| 52 | 289.851 | .462175 | 17.250 | 4.345 |
| 54 | 289.371 | .461455 | 17.279 | 4.352 |
| 56 | 288.892 | .460735 | 17.308 | 4.360 |
| 58 | 288.414 | .460017 | 17.336 | 4.367 |
| 60 | 287.939 | 2.459300 | 17.365 | 4.374 |

| Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|
| 20° 0′ | 287.939 | 2.459300 | 17.365 | 4.374 |
| 10 | 285.583 | .455733 | 17.508 | 4.411 |
| 20 | 283.267 | .452195 | 17.651 | 4.448 |
| 30 | 280.988 | .448688 | 17.794 | 4.484 |
| 40 | 278.746 | .445209 | 17.937 | 4.521 |
| 50 | 276.541 | .441759 | 18.081 | 4.558 |
| 21° 0′ | 274.370 | 2.438337 | 18.224 | 4.594 |
| 10 | 272.234 | .434943 | 18.367 | 4.631 |
| 20 | 270.132 | .431576 | 18.509 | 4.668 |
| 30 | 268.062 | .428235 | 18.652 | 4.704 |
| 40 | 266.024 | .424921 | 18.795 | 4.741 |
| 50 | 264.018 | .421633 | 18.938 | 4.778 |
| 22° 0′ | 262.042 | 2.418371 | 19.081 | 4.814 |
| 10 | 260.098 | .415134 | 19.224 | 4.851 |
| 20 | 258.180 | .411922 | 19.366 | 4.888 |
| 30 | 256.292 | .408734 | 19.509 | 4.925 |
| 40 | 254.431 | .405571 | 19.652 | 4.961 |
| 50 | 252.599 | .402431 | 19.794 | 4.998 |
| 23° 0′ | 250.793 | 2.399315 | 19.937 | 5.035 |
| 10 | 249.013 | .396222 | 20.079 | 5.071 |
| 20 | 247.258 | .393151 | 20.222 | 5.108 |
| 30 | 245.529 | .390103 | 20.364 | 5.145 |
| 40 | 243.825 | .387077 | 20.507 | 5.182 |
| 50 | 242.144 | .384074 | 20.649 | 5.218 |
| 24° 0′ | 240.487 | 2.381091 | 20.791 | 5.255 |
| 10 | 238.853 | .378130 | 20.933 | 5.292 |
| 20 | 237.241 | .375190 | 21.076 | 5.329 |
| 30 | 235.652 | .372270 | 21.218 | 5.366 |
| 40 | 234.084 | .369371 | 21.360 | 5.402 |
| 50 | 232.537 | .366492 | 21.502 | 5.439 |
| 25° 0′ | 231.011 | 2.363633 | 21.644 | 5.476 |
| 10 | 229.506 | .360794 | 21.786 | 5.513 |
| 20 | 228.020 | .357974 | 21.928 | 5.549 |
| 30 | 226.555 | .355173 | 22.070 | 5.586 |
| 40 | 225.108 | .352391 | 22.212 | 5.623 |
| 50 | 223.680 | .349627 | 22.353 | 5.660 |
| 26° 0′ | 222.271 | 2.346882 | 22.495 | 5.697 |
| 10 | 220.879 | .344155 | 22.637 | 5.734 |
| 20 | 219.506 | .341446 | 22.778 | 5.770 |
| 30 | 218.150 | .338755 | 22.920 | 5.807 |
| 40 | 216.811 | .336081 | 23.062 | 5.844 |
| 50 | 215.489 | .333424 | 23.203 | 5.881 |
| 27° 0′ | 214.183 | 2.330785 | 23.345 | 5.918 |
| 10 | 212.893 | .328162 | 23.486 | 5.955 |
| 20 | 211.620 | .325556 | 23.627 | 5.992 |
| 30 | 210.362 | .322967 | 23.769 | 6.029 |
| 40 | 209.119 | .320393 | 23.910 | 6.065 |
| 50 | 207.891 | .317836 | 24.051 | 6.102 |
| 28° 0′ | 206.678 | 2.315295 | 24.192 | 6.139 |
| 10 | 205.480 | .312769 | 24.333 | 6.176 |
| 20 | 204.296 | .310259 | 24.474 | 6.213 |
| 30 | 203.125 | .307764 | 24.615 | 6.250 |
| 40 | 201.969 | .305285 | 24.756 | 6.287 |
| 50 | 200.826 | .302820 | 24.897 | 6.324 |
| 29° 0′ | 199.696 | 2.300370 | 25.038 | 6.360 |
| 10 | 198.580 | .297935 | 25.179 | 6.398 |
| 20 | 197.476 | .295515 | 25.320 | 6.435 |
| 30 | 196.385 | .293108 | 25.460 | 6.472 |
| 40 | 195.306 | .290716 | 25.601 | 6.509 |
| 50 | 194.240 | .288338 | 25.741 | 6.545 |
| 30° 0′ | 193.185 | 2.285974 | 25.882 | 6.583 |

| Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. | Deg. D. | Radius. R. | Logarithm. log. R. | Tang. Off. t. | Mid. Ord. m. |
|---|---|---|---|---|---|---|---|---|---|
| **30° 20′** | 191.111 | 2.281286 | 26.163 | 6.657 | **38°30′** | 151.657 | 2.180863 | 32.969 | 8.479 |
| 40 | 189.083 | .276652 | 26.443 | 6.731 | **39° 0′** | 149.787 | .175475 | 33.381 | 8.592 |
| **31° 0′** | 187.099 | .272071 | 26.724 | 6.805 | 30 | 147.965 | .170160 | 33.792 | 8.704 |
| 20 | 185.158 | .267541 | 27.004 | 6.879 | **40° 0′** | 146.190 | .164918 | 34.202 | 8.816 |
| 40 | 183.258 | .263062 | 27.284 | 6.958 | 30 | 144.460 | .159747 | 34.612 | 8.929 |
| **32° 0′** | 181.398 | .258632 | 27.564 | 7.027 | **41° 0′** | 142.773 | .154645 | 35.021 | 9.041 |
| 20 | 179.577 | .254250 | 27.843 | 7.101 | 30 | 141.127 | .149610 | 35.429 | 9.154 |
| 40 | 177.794 | .249916 | 28.123 | 7.175 | **42° 0′** | 139.521 | .144641 | 35.837 | 9.267 |
| **33° 0′** | 176.047 | .245628 | 28.402 | 7.250 | 30 | 137.955 | .139736 | 36.244 | 9.380 |
| 20 | 174.336 | .241386 | 28.680 | 7.324 | **43° 0′** | 136.425 | .134895 | 36.650 | 9.493 |
| 40 | 172.659 | .237188 | 28.959 | 7.398 | 30 | 134.932 | .130114 | 37.056 | 9.606 |
| **34° 0′** | 171.015 | 2.233035 | 29.237 | 7.473 | **44° 0′** | 133.473 | 2.125395 | 37.461 | 9.719 |
| 20 | 169.404 | .228924 | 29.515 | 7.547 | 30 | 132.049 | .120734 | 37.865 | 9.832 |
| 40 | 167.825 | .224855 | 29.793 | 7.621 | **45° 0′** | 130.656 | .116130 | 38.268 | 9.946 |
| **35° 0′** | 166.275 | .220828 | 30.071 | 7.696 | 30 | 129.296 | .111584 | 38.671 | 10.059 |
| 20 | 164.756 | .216842 | 30.348 | 7.770 | **46° 0′** | 127.965 | .107092 | 39.073 | 10.173 |
| 40 | 163.266 | .212895 | 30.625 | 7.845 | 30 | 126.664 | .102655 | 39.474 | 10.286 |
| **36° 0′** | 161.803 | .208988 | 30.902 | 7.919 | **47° 0′** | 125.392 | .098270 | 39.875 | 10.400 |
| 20 | 160.368 | .205119 | 31.178 | 7.994 | 30 | 124.148 | .093938 | 40.275 | 10.516 |
| 40 | 158.960 | .201288 | 31.454 | 8 068 | **48° 0′** | 122.930 | .089657 | 40.674 | 10.628 |
| **37° 0′** | 157.577 | .197494 | 31.730 | 8.143 | 30 | 121.738 | .085425 | 41.072 | 10.742 |
| 20 | 156.220 | .193736 | 32.006 | 8.218 | **49° 0′** | 120.571 | .081243 | 41.469 | 10.856 |
| 40 | 154.887 | .190014 | 32.282 | 8.292 | 30 | 119.429 | .077109 | 41.866 | 10.970 |
| **38° 0′** | 153.578 | 2.186328 | 32.557 | 8.367 | **50° 0′** | 118.310 | 2.073022 | 42.262 | 11.085 |

## TABLE V.—CORRECTIONS FOR TANGENTS AND EXTERNALS.

| Ang Δ | For Tangents, add | | | | | | Ang Δ | For Externals, add | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5° Cur. | 10° Cur. | 15° Cur. | 20° Cur. | 25° Cur. | 30° Cur. | | 5° Cur. | 10° Cur. | 15° Cur. | 20° Cur. | 25° Cur. | 30° Cur. |
| 10° | .03 | .06 | .09 | .13 | .16 | .19 | 10° | 001 | .003 | .004 | .006 | .007 | .008 |
| 20 | .06 | .13 | .19 | .26 | .32 | .39 | 20 | .006 | .011 | .017 | .022 | .028 | .034 |
| 30 | .10 | .19 | .29 | .39 | .49 | .59 | 30 | .013 | .025 | .038 | .051 | .065 | .078 |
| 40 | .13 | .26 | .40 | .53 | .67 | .80 | 40 | .023 | .046 | .070 | .093 | .117 | .141 |
| 50 | .17 | .34 | .51 | .68 | .85 | 1 02 | 50 | .037 | .075 | .116 | .151 | .189 | .227 |
| 60 | .21 | .42 | .63 | .84 | 1.05 | 1.27 | 60 | .056 | .112 | .168 | .225 | .283 | .340 |
| 70 | .25 | .51 | .76 | 1.02 | 1.28 | 1.54 | 70 | .080 | .159 | .240 | .321 | .403 | .485 |
| 80 | .30 | .61 | .91 | 1.22 | 1.53 | 1.84 | 80 | .110 | .220 | .332 | .445 | .558 | .671 |
| 90 | .36 | .72 | 1.09 | 1.45 | 1.83 | 2.20 | 90 | .149 | .299 | .450 | .603 | .756 | .910 |
| 100 | .43 | .86 | 1.30 | 1.74 | 2 18 | 2.62 | 100 | .200 | .401 | .604 | .809 | 1.015 | 1.221 |
| 110 | .51 | 1.03 | 1.56 | 2 08 | 2.61 | 3.14 | 110 | .268 | .536 | .806 | 1.082 | 1.355 | 1.633 |
| 120 | .62 | 1.25 | 1.93 | 2.52 | 3 16 | 3.81 | 120 | .360 | .721 | 1.086 | 1.456 | 1.825 | 2.197 |

# TABLE VI.—TANGENTS AND EXTERNALS TO A 1° CURVE.

| Angle. Δ | Tan-gent. T. | Exter-nal. E. | Angle. Δ | Tan-gent. T. | Exter-nal. E. | Angle. Δ | Tan-gent. T. | Exter-nal. E. |
|---|---|---|---|---|---|---|---|---|
| 1° | 50.00 | .218 | 11 | 551.70 | 26.500 | 21° | 1061.9 | 97.577 |
| 10 | 58.34 | .297 | 10′ | 560.11 | 27.313 | 10′ | 1070.6 | 99.155 |
| 20 | 66.67 | .388 | 20 | 568.53 | 28.137 | 20 | 1079.2 | 100.75 |
| 30 | 75.01 | .491 | 30 | 576.95 | 28.974 | 30 | 1087.8 | 102.35 |
| 40 | 83.34 | .606 | 40 | 585.36 | 29.824 | 40 | 1096.4 | 103.97 |
| 50 | 91.68 | .733 | 50 | 593.79 | 30.686 | 50 | 1105.1 | 105.60 |
| 2 | 100.01 | .873 | 12 | 602.21 | 31.561 | 22 | 1113.7 | 107.24 |
| 10 | 108.35 | 1.024 | 10 | 610.64 | 32.447 | 10 | 1122.4 | 108.90 |
| 20 | 116.68 | 1.188 | 20 | 619.07 | 33.347 | 20 | 1131.0 | 110.57 |
| 30 | 125.02 | 1.364 | 30 | 627.50 | 34.259 | 30 | 1139.7 | 112.25 |
| 40 | 133.36 | 1.552 | 40 | 635.93 | 35.183 | 40 | 1148.4 | 113.95 |
| 50 | 141.70 | 1.752 | 50 | 644.37 | 36.120 | 50 | 1157.0 | 115.66 |
| 3 | 150.04 | 1.964 | 13 | 652.81 | 37.070 | 23 | 1165.7 | 117.38 |
| 10 | 158.38 | 2.188 | 10 | 661.25 | 38.031 | 10 | 1174.4 | 119.12 |
| 20 | 166.72 | 2.425 | 20 | 669.70 | 39.006 | 20 | 1183.1 | 120.87 |
| 30 | 175.06 | 2.674 | 30 | 678.15 | 39.993 | 30 | 1191.8 | 122.63 |
| 40 | 183.40 | 2.934 | 40 | 686.60 | 40.992 | 40 | 1200.5 | 124.41 |
| 50 | 191.74 | 3.207 | 50 | 695.06 | 42.004 | 50 | 1209.2 | 126.20 |
| 4 | 200.08 | 3.492 | 14 | 703.51 | 43.029 | 24 | 1217.9 | 128.00 |
| 10 | 208.43 | 3.790 | 10 | 711.97 | 44.066 | 10 | 1226.6 | 129.82 |
| 20 | 216.77 | 4.099 | 20 | 720.44 | 45.116 | 20 | 1235.3 | 131.65 |
| 30 | 225.12 | 4.421 | 30 | 728.90 | 46.178 | 30 | 1244.0 | 133.50 |
| 40 | 233.47 | 4.755 | 40 | 737.37 | 47.253 | 40 | 1252.8 | 135.35 |
| 50 | 241.81 | 5.100 | 50 | 745.85 | 48.341 | 50 | 1261.5 | 137.23 |
| 5 | 250.16 | 5.459 | 15 | 754.32 | 49.441 | 25 | 1270.2 | 139.11 |
| 10 | 258.51 | 5.829 | 10 | 762.80 | 50.554 | 10 | 1279.0 | 141.01 |
| 20 | 266.86 | 6.211 | 20 | 771.29 | 51.679 | 20 | 1287.7 | 142.93 |
| 30 | 275.21 | 6.606 | 30 | 779.77 | 52.818 | 30 | 1296.5 | 144.85 |
| 40 | 283.57 | 7.013 | 40 | 788.26 | 53.969 | 40 | 1305.3 | 146.79 |
| 50 | 291.92 | 7.432 | 50 | 796.75 | 55.132 | 50 | 1314.0 | 148.75 |
| 6 | 300.28 | 7.863 | 16 | 805.25 | 56.309 | 26 | 1322.8 | 150.71 |
| 10 | 308.64 | 8.307 | 10 | 813.75 | 57.498 | 10 | 1331.6 | 152.69 |
| 20 | 316.99 | 8.762 | 20 | 822.25 | 58.699 | 20 | 1340.4 | 154.69 |
| 30 | 325.35 | 9.230 | 30 | 830.76 | 59.914 | 30 | 1349.2 | 156.70 |
| 40 | 333.71 | 9.710 | 40 | 839.27 | 61.141 | 40 | 1358.0 | 158.72 |
| 50 | 342.08 | 10.202 | 50 | 847.78 | 62.381 | 50 | 1366.8 | 160.76 |
| 7 | 350.44 | 10.707 | 17 | 856.30 | 63.634 | 27 | 1375.6 | 162.81 |
| 10 | 358.81 | 11.224 | 10 | 864.82 | 64.900 | 10 | 1384.4 | 164.86 |
| 20 | 367.17 | 11.753 | 20 | 873.35 | 66.178 | 20 | 1393.2 | 166.95 |
| 30 | 375.54 | 12.294 | 30 | 881.88 | 67.470 | 30 | 1402.0 | 169.04 |
| 40 | 383.91 | 12.847 | 40 | 890.41 | 68.774 | 40 | 1410.9 | 171.15 |
| 50 | 392.28 | 13.413 | 50 | 898.95 | 70.091 | 50 | 1419.7 | 173.27 |
| 8 | 400.66 | 13.991 | 18 | 907.49 | 71.421 | 28 | 1428.6 | 175.41 |
| 10 | 409.03 | 14.582 | 10 | 916.03 | 72.764 | 10 | 1437.4 | 177.55 |
| 20 | 417.41 | 15.184 | 20 | 924.58 | 74.119 | 20 | 1446.3 | 179.72 |
| 30 | 425.79 | 15.799 | 30 | 933.13 | 75.488 | 30 | 1455.1 | 181.89 |
| 40 | 434.17 | 16.426 | 40 | 941.69 | 76.869 | 40 | 1464.0 | 184.08 |
| 50 | 442.55 | 17.065 | 50 | 950.25 | 78.264 | 50 | 1472.9 | 186.29 |
| 9 | 450.93 | 17.717 | 19 | 958.81 | 79.671 | 29 | 1481.8 | 188.51 |
| 10 | 459.32 | 18.381 | 10 | 967.38 | 81.092 | 10 | 1490.7 | 190.74 |
| 20 | 467.71 | 19.058 | 20 | 975.96 | 82.525 | 20 | 1499.6 | 192.99 |
| 30 | 476.10 | 19.746 | 30 | 984.53 | 83.972 | 30 | 1508.5 | 195.25 |
| 40 | 484.49 | 20.447 | 40 | 993.12 | 85.431 | 40 | 1517.4 | 197.53 |
| 50 | 492.88 | 21.161 | 50 | 1001.7 | 86.904 | 50 | 1526.3 | 199.82 |
| 10 | 501.28 | 21.887 | 20 | 1010.3 | 88.389 | 30 | 1535.3 | 202.12 |
| 10 | 509.68 | 22.624 | 10 | 1018.9 | 89.888 | 10 | 1544.2 | 204.44 |
| 20 | 518.08 | 23.375 | 20 | 1027.5 | 91.399 | 20 | 1553.1 | 206.77 |
| 30 | 526.48 | 24.138 | 30 | 1036.1 | 92.924 | 30 | 1562.1 | 209.12 |
| 40 | 534.89 | 24.918 | 40 | 1044.7 | 94.462 | 40 | 1571.0 | 211.48 |
| 50 | 543.29 | 25.700 | 50 | 1053.3 | 96.013 | 50 | 1580.0 | 213.86 |

| Angle. Δ | Tangent. T. | External. E. | Angle. Δ | Tangent. T. | External. E. | Angle. Δ | Tangent. T. | External. E. |
|---|---|---|---|---|---|---|---|---|
| **31°** | 1589.0 | 216.25 | **41°** | 2142.2 | 387.38 | **51°** | 2732.9 | 618.39 |
| 10 | 1598.0 | 218.66 | 10′ | 2151.7 | 390.71 | 10′ | 2743.1 | 622.81 |
| 20 | 1606.9 | 221.08 | 20 | 2161.2 | 394.06 | 20 | 2753.4 | 627.24 |
| 30 | 1615.9 | 223.51 | 30 | 2170.8 | 397.43 | 30 | 2763.7 | 631.69 |
| 40 | 1624.9 | 225.96 | 40 | 2180.3 | 400.82 | 40 | 2773.9 | 636.17 |
| 50 | 1633.9 | 228.42 | 50 | 2189.9 | 404.22 | 50 | 2784.2 | 640.66 |
| **32** | 1643.0 | 230.90 | **42** | 2199.4 | 407.64 | **52** | 2794.5 | 645.17 |
| 10 | 1652.0 | 233.39 | 10 | 2209.0 | 411.07 | 10 | 2804.9 | 649.70 |
| 20 | 1661.0 | 235.90 | 20 | 2218.6 | 414.52 | 20 | 2815.2 | 654.25 |
| 30 | 1670.0 | 238.43 | 30 | 2228.1 | 417.99 | 30 | 2825.6 | 658.83 |
| 40 | 1679.1 | 240.96 | 40 | 2237.7 | 421.48 | 40 | 2835.9 | 663.42 |
| 50 | 1688.1 | 243.52 | 50 | 2247.3 | 424.98 | 50 | 2846.3 | 668.03 |
| **33** | 1697.2 | 246.08 | **43** | 2257.0 | 428.50 | **53** | 2856.7 | 672.66 |
| 10 | 1706.3 | 248.66 | 10 | 2266.6 | 432.04 | 10 | 2867.1 | 677.32 |
| 20 | 1715.3 | 251.26 | 20 | 2276.2 | 435.59 | 20 | 2877.5 | 681.99 |
| 30 | 1724.4 | 253.87 | 30 | 2285.9 | 439.16 | 30 | 2888.0 | 686.68 |
| 40 | 1733.5 | 256.50 | 40 | 2295.6 | 442.75 | 40 | 2898.4 | 691.40 |
| 50 | 1742.6 | 259.14 | 50 | 2305.2 | 446.35 | 50 | 2908.9 | 696.13 |
| **34** | 1751.7 | 261.80 | **44** | 2314.9 | 449.98 | **54** | 2919.4 | 700.89 |
| 10 | 1760.8 | 264.47 | 10 | 2324.6 | 453.62 | 10 | 2929.9 | 705.66 |
| 20 | 1770.0 | 267.16 | 20 | 2334.3 | 457.27 | 20 | 2940.4 | 710.46 |
| 30 | 1779.1 | 269.86 | 30 | 2344.1 | 460.95 | 30 | 2951.0 | 715.28 |
| 40 | 1788.2 | 272.58 | 40 | 2353.8 | 464.64 | 40 | 2961.5 | 720.11 |
| 50 | 1797.4 | 275.31 | 50 | 2363.5 | 468.35 | 50 | 2972.1 | 724.97 |
| **35** | 1806.6 | 278.05 | **45** | 2373.3 | 472.08 | **55** | 2982.7 | 729.85 |
| 10 | 1815.7 | 280.82 | 10 | 2383.1 | 475.82 | 10 | 2993.3 | 734.76 |
| 20 | 1824.9 | 283.60 | 20 | 2392.8 | 479.59 | 20 | 3003.9 | 739.68 |
| 30 | 1834.1 | 286.39 | 30 | 2402.6 | 483.37 | 30 | 3014.5 | 744.62 |
| 40 | 1843.3 | 289.20 | 40 | 2412.4 | 487.17 | 40 | 3025.2 | 749.59 |
| 50 | 1852.5 | 292.02 | 50 | 2422.3 | 490.98 | 50 | 3035.8 | 754.57 |
| **36** | 1861.7 | 294.86 | **46** | 2432.1 | 494.82 | **56** | 3046.5 | 759.58 |
| 10 | 1870.9 | 297.72 | 10 | 2441.9 | 498.67 | 10 | 3057.2 | 764.61 |
| 20 | 1880.1 | 300.59 | 20 | 2451.8 | 502.54 | 20 | 3067.9 | 769.66 |
| 30 | 1889.4 | 303.47 | 30 | 2461.7 | 506.42 | 30 | 3078.7 | 774.73 |
| 40 | 1898.6 | 306.37 | 40 | 2471.5 | 510.33 | 40 | 3089.4 | 779.83 |
| 50 | 1907.9 | 309.29 | 50 | 2481.4 | 514.25 | 50 | 3100.2 | 784.94 |
| **37** | 1917.1 | 312.22 | **47** | 2491.3 | 518.20 | **57** | 3110.9 | 790.08 |
| 10 | 1926.4 | 315.17 | 10 | 2501.2 | 522.16 | 10 | 3121.7 | 795.24 |
| 20 | 1935.7 | 318.13 | 20 | 2511.2 | 526.13 | 20 | 3132.6 | 800.42 |
| 30 | 1945.0 | 321.11 | 30 | 2521.1 | 530.13 | 30 | 3143.4 | 805.62 |
| 40 | 1954.3 | 324.11 | 40 | 2531.1 | 534.15 | 40 | 3154.2 | 810.85 |
| 50 | 1963.6 | 327.12 | 50 | 2541.0 | 538.18 | 50 | 3165.1 | 816.10 |
| **38** | 1972.9 | 330.15 | **48** | 2551.0 | 542.23 | **58** | 3176.0 | 821.37 |
| 10 | 1982.2 | 333.19 | 10 | 2561.0 | 546.30 | 10 | 3186.9 | 826.66 |
| 20 | 1991.5 | 336.25 | 20 | 2571.0 | 550.39 | 20 | 3197.8 | 831.98 |
| 30 | 2000.9 | 339.32 | 30 | 2581.0 | 554.50 | 30 | 3208.8 | 837.31 |
| 40 | 2010.2 | 342.41 | 40 | 2591.1 | 558.63 | 40 | 3219.7 | 842.67 |
| 50 | 2019.6 | 345.52 | 50 | 2601.1 | 562.77 | 50 | 3230.7 | 848.06 |
| **39** | 2029.0 | 348.64 | **49** | 2611.2 | 566.94 | **59** | 3241.7 | 853.46 |
| 10 | 2038.4 | 351.78 | 10 | 2621.2 | 571.12 | 10 | 3252.7 | 858.89 |
| 20 | 2047.8 | 354.94 | 20 | 2631.3 | 575.32 | 20 | 3263.7 | 864.34 |
| 30 | 2057.2 | 358.11 | 30 | 2641.4 | 579.54 | 30 | 3274.8 | 869.82 |
| 40 | 2066.6 | 361.29 | 40 | 2651.5 | 583.78 | 40 | 3285.8 | 875.32 |
| 50 | 2076.0 | 364.50 | 50 | 2661.6 | 588.04 | 50 | 3296.9 | 880.84 |
| **40** | 2085.4 | 367.72 | **50** | 2671.8 | 592.32 | **60** | 3308.0 | 886.38 |
| 10 | 2094.9 | 370.95 | 10 | 2681.9 | 596.62 | 10 | 3319.1 | 891.95 |
| 20 | 2104.3 | 374.20 | 20 | 2692.1 | 600.93 | 20 | 3330.3 | 897.54 |
| 30 | 2113.8 | 377.47 | 30 | 2702.3 | 605.27 | 30 | 3341.4 | 903.15 |
| 40 | 2123.3 | 380.76 | 40 | 2712.5 | 609.62 | 40 | 3352.6 | 908.79 |
| 50 | 2132.7 | 384.06 | 50 | 2722.7 | 614.00 | 50 | 3363.8 | 914.45 |

## TABLE VI.—TANGENTS AND EXTERNALS TO A 1° CURVE.

| Angle. Δ | Tangent. T. | External. E. | Angle. Δ | Tangent. T. | External. E. | Angle. Δ | Tangent. T. | External. E. |
|---|---|---|---|---|---|---|---|---|
| **61°** | 3375.0 | 920.14 | **71°** | 4086.9 | 1308.2 | **81°** | 4893.6 | 1805.3 |
| 10′ | 3386.3 | 925.85 | 10′ | 4099.5 | 1315.6 | 10′ | 4908.0 | 1814.7 |
| 20 | 3397.5 | 931.58 | 20 | 4112.1 | 1322.9 | 20 | 4922.5 | 1824.1 |
| 30 | 3408.8 | 937.34 | 30 | 4124.8 | 1330.3 | 30 | 4937.0 | 1833.6 |
| 40 | 3420.1 | 943.12 | 40 | 4137.4 | 1337.7 | 40 | 4951.5 | 1843.1 |
| 50 | 3431.4 | 948.92 | 50 | 4150.1 | 1345.1 | 50 | 4966.1 | 1852.6 |
| **62** | 3442.7 | 954.75 | **72** | 4162.8 | 1352.6 | **82** | 4980.7 | 1862.2 |
| 10 | 3454.1 | 960.60 | 10 | 4175.6 | 1360.1 | 10 | 4995.4 | 1871.8 |
| 20 | 3465.4 | 966.48 | 20 | 4188.5 | 1367.6 | 20 | 5010.0 | 1881.5 |
| 30 | 3476.8 | 972.38 | 30 | 4201.2 | 1375.2 | 30 | 5024.8 | 1891.2 |
| 40 | 3488.3 | 978.31 | 40 | 4214.0 | 1382.8 | 40 | 5039.5 | 1900.9 |
| 50 | 3499.7 | 984.27 | 50 | 4226.8 | 1390.4 | 50 | 5054.3 | 1910.7 |
| **63** | 3511.1 | 990.24 | **73** | 4239.7 | 1398.0 | **83** | 5069.2 | 1920.5 |
| 10 | 3522.6 | 996.24 | 10 | 4252.6 | 1405.7 | 10 | 5084.0 | 1930.4 |
| 20 | 3534.1 | 1002.3 | 20 | 4265.6 | 1413.5 | 20 | 5099.0 | 1940.3 |
| 30 | 3545.6 | 1008.3 | 30 | 4278.5 | 1421.2 | 30 | 5113.9 | 1950.3 |
| 40 | 3557.2 | 1014.4 | 40 | 4291.5 | 1429.0 | 40 | 5128.9 | 1960.2 |
| 50 | 3568.7 | 1020.5 | 50 | 4304.6 | 1436.8 | 50 | 5143.9 | 1970.3 |
| **64** | 3580.3 | 1026.6 | **74** | 4317.6 | 1444.6 | **84** | 5159.0 | 1980.4 |
| 10 | 3591.9 | 1032.8 | 10 | 4330.7 | 1452.5 | 10 | 5174.1 | 1990.5 |
| 20 | 3603.5 | 1039.0 | 20 | 4343.8 | 1460.4 | 20 | 5189.3 | 2000.6 |
| 30 | 3615.1 | 1045.2 | 30 | 4356.9 | 1468.4 | 30 | 5204.4 | 2010.8 |
| 40 | 3626.8 | 1051.4 | 40 | 4370.1 | 1476.4 | 40 | 5219.7 | 2021.1 |
| 50 | 3638.5 | 1057.7 | 50 | 4383.3 | 1484.4 | 50 | 5234.9 | 2031.4 |
| **65** | 3650.2 | 1063.9 | **75** | 4396.5 | 1492.4 | **85** | 5250.3 | 2041.7 |
| 10 | 3661.9 | 1070.2 | 10 | 4409.8 | 1500.5 | 10 | 5265.6 | 2052.1 |
| 20 | 3673.7 | 1076.6 | 20 | 4423.1 | 1508.6 | 20 | 5281.0 | 2062.5 |
| 30 | 3685.4 | 1082.9 | 30 | 4436.4 | 1516.7 | 30 | 5296.4 | 2073.0 |
| 40 | 3697.2 | 1089.3 | 40 | 4449.7 | 1524.9 | 40 | 5311.9 | 2083.5 |
| 50 | 3709.0 | 1095.7 | 50 | 4463.1 | 1533.1 | 50 | 5327.4 | 2094.1 |
| **66** | 3720.9 | 1102.2 | **76** | 4476.5 | 1541.4 | **86** | 5343.0 | 2104.7 |
| 10 | 3732.7 | 1108.6 | 10 | 4489.9 | 1549.7 | 10 | 5358.6 | 2115.3 |
| 20 | 3744.6 | 1115.1 | 20 | 4503.4 | 1558.0 | 20 | 5374.2 | 2126.0 |
| 30 | 3756.5 | 1121.7 | 30 | 4516.9 | 1566.3 | 30 | 5389.9 | 2136.7 |
| 40 | 3768.5 | 1128.2 | 40 | 4530.4 | 1574.7 | 40 | 5405.6 | 2147.5 |
| 50 | 3780.4 | 1134.8 | 50 | 4544.0 | 1583.1 | 50 | 5421.4 | 2158.4 |
| **67** | 3792.4 | 1141.4 | **77** | 4557.6 | 1591.6 | **87** | 5437.2 | 2169.2 |
| 10 | 3804.4 | 1148.0 | 10 | 4571.2 | 1600.1 | 10 | 5453.1 | 2180.2 |
| 20 | 3816.4 | 1154.7 | 20 | 4584.8 | 1608.6 | 20 | 5469.0 | 2191.1 |
| 30 | 3828.4 | 1161.3 | 30 | 4598.5 | 1617.1 | 30 | 5484.9 | 2202.2 |
| 40 | 3840.5 | 1168.1 | 40 | 4612.2 | 1625.7 | 40 | 5500.9 | 2213.2 |
| 50 | 3852.6 | 1174.8 | 50 | 4626.0 | 1634.4 | 50 | 5517.0 | 2224.3 |
| **68** | 3864.7 | 1181.6 | **78** | 4639.8 | 1643.0 | **88** | 5533.1 | 2235.5 |
| 10 | 3876.8 | 1188.4 | 10 | 4653.6 | 1651.7 | 10 | 5549.2 | 2246.7 |
| 20 | 3889.0 | 1195.2 | 20 | 4667.4 | 1660.5 | 20 | 5565.4 | 2258.0 |
| 30 | 3901.2 | 1202.0 | 30 | 4681.3 | 1669.2 | 30 | 5581.6 | 2269.3 |
| 40 | 3913.4 | 1208.9 | 40 | 4695.2 | 1678.1 | 40 | 5597.8 | 2280.6 |
| 50 | 3925.6 | 1215.8 | 50 | 4709.2 | 1686.9 | 50 | 5614.2 | 2292.0 |
| **69** | 3937.9 | 1222.7 | **79** | 4723.2 | 1695.8 | **89** | 5630.5 | 2303.5 |
| 10 | 3950.2 | 1229.7 | 10 | 4737.2 | 1704.7 | 10 | 5646.9 | 2315.0 |
| 20 | 3962.5 | 1236.7 | 20 | 4751.2 | 1713.7 | 20 | 5663.4 | 2326.6 |
| 30 | 3974.8 | 1243.7 | 30 | 4765.3 | 1722.7 | 30 | 5679.9 | 2338.2 |
| 40 | 3987.2 | 1250.8 | 40 | 4779.4 | 1731.7 | 40 | 5696.4 | 2349.8 |
| 50 | 3999.5 | 1257.9 | 50 | 4793.6 | 1740.8 | 50 | 5713.0 | 2361.5 |
| **70** | 4011.9 | 1265.0 | **80** | 4807.7 | 1749.9 | **90** | 5729.7 | 2373.3 |
| 10 | 4024.4 | 1272.1 | 10 | 4822.0 | 1759.0 | 10 | 5746.3 | 2385.1 |
| 20 | 4036.8 | 1279.3 | 20 | 4836.2 | 1768.2 | 20 | 5763.1 | 2397.0 |
| 30 | 4049.3 | 1286.5 | 30 | 4850.5 | 1777.4 | 30 | 5779.9 | 2408.9 |
| 40 | 4061.8 | 1293.6 | 40 | 4864.8 | 1786.7 | 40 | 5796.7 | 2420.9 |
| 50 | 4074.4 | 1300.9 | 50 | 4879.2 | 1796.0 | 50 | 5813.6 | 2432.9 |

| Angle. Δ | Tangent. T. | External. E. | Angle. Δ | Tangent. T. | External. E. | Angle. Δ | Tangent. T. | External E. |
|---|---|---|---|---|---|---|---|---|
| **91°** | 5830.5 | 2444.9 | **101°** | 6950.6 | 3278.1 | **111°** | 8336.7 | 4386.1 |
| 10′ | 5847.5 | 2457.1 | 10′ | 6971.3 | 3294.1 | 10′ | 8362.7 | 4407.6 |
| 20 | 5864.6 | 2469.3 | 20 | 6992.0 | 3310.1 | 20 | 8388.9 | 4429.2 |
| 30 | 5881.7 | 2481.5 | 30 | 7012.7 | 3326.1 | 30 | 8415.1 | 4450.9 |
| 40 | 5898.8 | 2493.8 | 40 | 7033.6 | 3342.3 | 40 | 8441.5 | 4472.7 |
| 50 | 5916.0 | 2506.1 | 50 | 7054.5 | 3358.5 | 50 | 8468.0 | 4494.6 |
| **92** | 5933.2 | 2518.5 | **102** | 7075.5 | 3374.9 | **112** | 8494.6 | 4516.6 |
| 10 | 5950.5 | 2531.0 | 10 | 7096.6 | 3391.2 | 10 | 8521.3 | 4538.8 |
| 20 | 5967.9 | 2543.5 | 20 | 7117.8 | 3407.7 | 20 | 8548.1 | 4561.1 |
| 30 | 5985.3 | 2556.0 | 30 | 7139.0 | 3424.3 | 30 | 8575.0 | 4583.4 |
| 40 | 6002.7 | 2568.6 | 40 | 7160.3 | 3440.9 | 40 | 8602.1 | 4606.0 |
| 50 | 6020.2 | 2581.3 | 50 | 7181.7 | 3457.6 | 50 | 8629.3 | 4628.6 |
| **93** | 6037.8 | 2594.0 | **103** | 7203.2 | 3474.4 | **113** | 8656.6 | 4651.3 |
| 10 | 6055.4 | 2606.8 | 10 | 7224.7 | 3491.3 | 10 | 8684.0 | 4674.2 |
| 20 | 6073.1 | 2619.7 | 20 | 7246.3 | 3508.2 | 20 | 8711.5 | 4697.2 |
| 30 | 6090.8 | 2632.6 | 30 | 7268.0 | 3525.2 | 30 | 8739.2 | 4720.3 |
| 40 | 6108.6 | 2645.5 | 40 | 7289.8 | 3542.4 | 40 | 8767.0 | 4743.6 |
| 50 | 6126.4 | 2658.5 | 50 | 7311.7 | 3559.6 | 50 | 8794.9 | 4766.9 |
| **94** | 6144.3 | 2671.6 | **104** | 7333.6 | 3576.8 | **114** | 8822.9 | 4790.4 |
| 10 | 6162.2 | 2684.7 | 10 | 7355.6 | 3594.2 | 10 | 8851.0 | 4814.1 |
| 20 | 6180.2 | 2697.9 | 20 | 7377.8 | 3611.7 | 20 | 8879.3 | 4837.8 |
| 30 | 6198.3 | 2711.2 | 30 | 7399.9 | 3629.2 | 30 | 8907.7 | 4861.7 |
| 40 | 6216.4 | 2724.5 | 40 | 7422.2 | 3646.8 | 40 | 8936.3 | 4885.7 |
| 50 | 6234.6 | 2737.9 | 50 | 7444.6 | 3664.5 | 50 | 8965 0 | 4909.9 |
| **95** | 6252.8 | 2751.3 | **105** | 7467.0 | 3682.3 | **115** | 8993.8 | 4934.1 |
| 10 | 6271.1 | 2764.8 | 10 | 7489.6 | 3700.2 | 10 | 9022.7 | 4958.6 |
| 20 | 6289.4 | 2778.3 | 20 | 7512.2 | 3718.2 | 20 | 9051.7 | 4983.1 |
| 30 | 6307.9 | 2792.0 | 30 | 7534.9 | 3736.2 | 30 | 9080.9 | 5007.8 |
| 40 | 6326.3 | 2805.6 | 40 | 7557.7 | 3754.4 | 40 | 9110.3 | 5032.6 |
| 50 | 6344.8 | 2819.4 | 50 | 7580.5 | 3772.6 | 50 | 9139.8 | 5057.6 |
| **96** | 6363.4 | 2833.2 | **106** | 7603.5 | 3791.0 | **116** | 9169.4 | 5082.7 |
| 10 | 6382.1 | 2847.0 | 10 | 7626.6 | 3809.4 | 10 | 9199.1 | 5107.9 |
| 20 | 6400.8 | 2861.0 | 20 | 7649.7 | 3827.9 | 20 | 9229.0 | 5133.3 |
| 30 | 6419.5 | 2875.0 | 30 | 7672.9 | 3846.5 | 30 | 9259.0 | 5158.8 |
| 40 | 6438.4 | 2889.0 | 40 | 7696.3 | 3865.2 | 40 | 9289.2 | 5184.5 |
| 50 | 6457.3 | 2903.1 | 50 | 7719.7 | 3884.0 | 50 | 9319.5 | 5210.3 |
| **97** | 6476.2 | 2917.3 | **107** | 7743.2 | 3902.9 | **117** | 9349.9 | 5236.2 |
| 10 | 6495.2 | 2931.6 | 10 | 7766.8 | 3921.9 | 10 | 9380.5 | 5262.3 |
| 20 | 6514.3 | 2945.9 | 20 | 7790.5 | 3940.9 | 20 | 9411.3 | 5288.6 |
| 30 | 6533.4 | 2960.3 | 30 | 7814.3 | 3960.1 | 30 | 9442.2 | 5315.0 |
| 40 | 6552.6 | 2974.7 | 40 | 7838.1 | 3979.4 | 40 | 9473.2 | 5341.5 |
| 50 | 6571.9 | 2989.2 | 50 | 7862.1 | 3998.7 | 50 | 9504.4 | 5368.2 |
| **98** | 6591.2 | 3003.8 | **108** | 7886.2 | 4018.2 | **118** | 9535.7 | 5395.1 |
| 10 | 6610.6 | 3018.4 | 10 | 7910.4 | 4037 8 | 10 | 9567.2 | 5422.1 |
| 20 | 6630.1 | 3033.1 | 20 | 7934.6 | 4057.4 | 20 | 9598.9 | 5449.2 |
| 30 | 6649.6 | 3047.9 | 30 | 7959.0 | 4077.2 | 30 | 9630.7 | 5476.5 |
| 40 | 6669.2 | 3062.8 | 40 | 7983.5 | 4097.1 | 40 | 9662.6 | 5504.0 |
| 50 | 6688.8 | 3077.7 | 50 | 8008.0 | 4117.0 | 50 | 9694.7 | 5531.7 |
| **99** | 6708.6 | 3092.7 | **109** | 8032.7 | 4137.1 | **119** | 9727.0 | 5559.4 |
| 10 | 6728.4 | 3107.7 | 10 | 8057.4 | 4157.3 | 10 | 9759.4 | 5587.4 |
| 20 | 6748.2 | 3122.9 | 20 | 8082.3 | 4177.5 | 20 | 9792.0 | 5615.5 |
| 30 | 6768.1 | 3138.1 | 30 | 8107.3 | 4197.9 | 30 | 9824.8 | 5643.8 |
| 40 | 6788.1 | 3153.3 | 40 | 8132.3 | 4218.4 | 40 | 9857.7 | 5672.3 |
| 50 | 6808.2 | 3168.7 | 50 | 8157.5 | 4239.0 | 50 | 9890.8 | 5700.9 |
| **100** | 6828.3 | 3184.1 | **110** | 8182.8 | 4259.7 | **120** | 9924.0 | 5729.7 |
| 10 | 6848.5 | 3199.6 | 10 | 8208.2 | 4280.5 | 10 | 9957.5 | 5758.6 |
| 20 | 6868.8 | 3215.1 | 20 | 8233.7 | 4301.4 | 20 | 9991.0 | 5787.7 |
| 30 | 6889.2 | 3230.8 | 30 | 8259.3 | 4322.4 | 30 | 10025.0 | 5817.0 |
| 40 | 6909.6 | 3246.5 | 40 | 8285.0 | 4343.6 | 40 | 10059.0 | 5846.5 |
| 50 | 6930.1 | 3262.3 | 50 | 8310.8 | 4364.8 | 50 | 10093.0 | 5876.1 |

TABLE VII.—LONG CHORDS.

| Degree of Curve. | Actual Arc, One Station. | LONG CHORDS. | | | | |
|---|---|---|---|---|---|---|
| | | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
| 0° 10′ | 100.000 | 200.000 | 299.999 | 399.998 | 499.996 | 599.993 |
| 20 | .000 | 199.999 | 299.997 | 399.992 | 499.983 | 599.970 |
| 30 | .000 | 199.998 | 299.992 | 399.981 | 499.962 | 599.933 |
| 40 | .001 | 199.997 | 299.986 | 399.966 | 499.932 | 599.882 |
| 50 | .001 | 199.995 | 299.979 | 399.947 | 499.894 | 599.815 |
| 1 | 100.001 | 199.992 | 299.970 | 399.924 | 499.848 | 599.733 |
| 10 | .002 | 199.990 | 299.959 | 399.896 | 499.793 | 599.637 |
| 20 | .002 | 199.986 | 299.946 | 399.865 | 499.729 | 599.526 |
| 30 | .003 | 199.983 | 299.932 | 399.829 | 499.657 | 599.401 |
| 40 | .003 | 199.979 | 299.915 | 399.789 | 499.577 | 599.260 |
| 50 | .004 | 199.974 | 299.898 | 399.744 | 499.488 | 599.105 |
| 2 | 100.005 | 199.970 | 299.878 | 399.695 | 499.391 | 598.934 |
| 10 | .006 | 199.964 | 299.857 | 399.643 | 499.285 | 598.756 |
| 20 | .007 | 199.959 | 299.834 | 399.586 | 499.171 | 598.550 |
| 30 | .008 | 199.952 | 299.810 | 399.524 | 499.049 | 598.336 |
| 40 | .009 | 199.946 | 299.783 | 399.459 | 498.918 | 598.106 |
| 50 | .010 | 199.939 | 299.756 | 399.389 | 498.778 | 597.862 |
| 3 | 100.011 | 199.931 | 299.726 | 399.315 | 498.630 | 597.604 |
| 10 | .013 | 199.924 | 299.695 | 399.237 | 498.474 | 597.331 |
| 20 | .014 | 199.915 | 299.662 | 399.154 | 498.309 | 597.043 |
| 30 | .015 | 199.907 | 299.627 | 399.068 | 498.136 | 596.740 |
| 40 | .017 | 199.898 | 299.591 | 398.977 | 497.955 | 596.423 |
| 50 | .019 | 199.888 | 299.553 | 398.882 | 497.765 | 596.091 |
| 4 | 100.020 | 199.878 | 299.513 | 398.782 | 497.566 | 595.744 |
| 10 | .022 | 199.868 | 299.471 | 398.679 | 497.360 | 595.383 |
| 20 | .024 | 199.857 | 299.428 | 398.571 | 497.145 | 595.007 |
| 30 | .026 | 199.846 | 299.383 | 398.459 | 496.921 | 594.617 |
| 40 | .028 | 199.834 | 299.337 | 398.343 | 496.689 | 594.212 |
| 50 | .030 | 199.822 | 299.289 | 398.223 | 496.449 | 593.792 |
| 5 | 100.032 | 199.810 | 299.239 | 398.099 | 496.201 | 593.358 |
| 10 | .034 | 199.797 | 299.187 | 397.970 | 495.944 | 592.909 |
| 20 | .036 | 199.783 | 299.134 | 397.837 | 495.678 | 592.446 |
| 30 | .038 | 199.770 | 299.079 | 397.700 | 495.405 | 591.968 |
| 40 | .041 | 199.756 | 299.023 | 397.559 | 495.123 | 591.476 |
| 50 | .043 | 199.741 | 298.964 | 397.413 | 494.832 | 590.970 |
| 6 | 100.046 | 199.726 | 298.904 | 397.264 | 494.534 | 590.449 |
| 10 | .048 | 199.710 | 298.843 | 397.110 | 494.227 | 589.913 |
| 20 | .051 | 199.695 | 298.779 | 396.952 | 493.912 | 589.364 |
| 30 | .054 | 199.678 | 298.714 | 396.790 | 493.588 | 588.800 |
| 40 | .056 | 199.662 | 298.648 | 396.623 | 493.257 | 588.221 |
| 50 | .059 | 199.644 | 298.579 | 396.453 | 492.917 | 587.628 |
| 7 | 100.062 | 199.627 | 298.509 | 396.278 | 492.568 | 587.021 |
| 10 | .065 | 199.609 | 298.438 | 396.099 | 492.212 | 586.400 |
| 20 | .068 | 199.591 | 298.364 | 395.916 | 491.847 | 585.765 |
| 30 | .071 | 199.572 | 298.289 | 395.729 | 491.474 | 585.115 |
| 40 | .075 | 199.553 | 298.212 | 395.538 | 491.093 | 584.451 |
| 50 | .078 | 199.533 | 298.134 | 395.342 | 490.704 | 583.773 |
| 8 | 100.081 | 199.513 | 298.054 | 395.142 | 490.306 | 583.081 |
| 10 | .085 | 199.492 | 297.972 | 394.938 | 489.900 | 582.375 |
| 20 | .088 | 199.471 | 297.888 | 394.731 | 489.486 | 581.654 |
| 30 | .092 | 199.450 | 297.803 | 394.518 | 489.064 | 580.920 |
| 40 | .095 | 199.428 | 297.716 | 394.302 | 488.634 | 580.172 |
| 50 | .099 | 199.406 | 297.628 | 394.082 | 488.196 | 579.409 |
| 9 | 100.103 | 199.383 | 297.538 | 393.857 | 487.749 | 578.633 |
| 10 | .107 | 199.360 | 297.446 | 393.629 | 487.294 | 577.843 |
| 20 | .111 | 199.337 | 297.352 | 393.396 | 486.832 | 577.039 |
| 30 | .115 | 199.313 | 297.257 | 393.159 | 486.361 | 576.222 |
| 40 | .119 | 199.289 | 297.160 | 392.918 | 485.882 | 575.390 |
| 50 | .123 | 199.264 | 297.062 | 392.673 | 485.395 | 574.545 |
| 10 | 100.127 | 199.239 | 296.962 | 392.424 | 484.900 | 573.686 |

# TABLE VII.—LONG CHORDS.

| Degree of Curve. | Long Chords. 7 Stations. | 8 Stations. | 9 Stations. | 10 Stations. | 11 Stations. | 12 Stations. |
|---|---|---|---|---|---|---|
| 0° 10 | 699.988 | 799.982 | 899.974 | 999.965 | 1099.95 | 1199.94 |
| 20 | 699.953 | 799.929 | 899.899 | 999.860 | 1099.81 | 1199.76 |
| 30 | 699.893 | 799.840 | 899.772 | 999.686 | 1099.58 | 1199.46 |
| 40 | 699.810 | 799.716 | 899.594 | 999.442 | 1099.25 | 1199.03 |
| 50 | 699.704 | 799.556 | 899.365 | 999.128 | 1098.84 | 1198.49 |
| 1 | 699.574 | 799.360 | 899.086 | 998.744 | 1098.33 | 1197.82 |
| 10 | 699.420 | 799.130 | 898.757 | 998.290 | 1097.72 | 1197.04 |
| 20 | 699.242 | 798.863 | 898.376 | 997.768 | 1097.02 | 1196.13 |
| 30 | 699.041 | 798.562 | 897.945 | 997.175 | 1096.23 | 1195.11 |
| 40 | 698.816 | 798.224 | 897.464 | 996.513 | 1095.35 | 1193.96 |
| 50 | 698.567 | 797.852 | 896.931 | 995.782 | 1094.38 | 1192.69 |
| 2 | 698.295 | 797.444 | 896.349 | 994.981 | 1093.31 | 1191.31 |
| 10 | 698.000 | 797 000 | 895.716 | 994.112 | 1092.15 | 1189.80 |
| 20 | 697.680 | 796.522 | 895.033 | 993.173 | 1090.90 | 1188.18 |
| 30 | 697.338 | 796.008 | 894.299 | 992.165 | 1089.56 | 1186.43 |
| 40 | 696.971 | 795.459 | 893.515 | 991.088 | 1088.12 | 1184.57 |
| 50 | 696.581 | 794.874 | 892.681 | 989.943 | 1086.60 | 1182.59 |
| 3 | 696.168 | 794.255 | 891.798 | 988.729 | 1084.98 | 1180.49 |
| 10 | 695.731 | 793.600 | 890.864 | 987.447 | 1083.28 | 1178.28 |
| 20 | 695.271 | 792.911 | 889.880 | 986.096 | 1081.48 | 1175.94 |
| 30 | 694.787 | 792.186 | 888.846 | 984.677 | 1079.59 | 1173.49 |
| 40 | 694.280 | 791.427 | 887.763 | 983.190 | 1077.61 | 1170.93 |
| 50 | 693.750 | 790.632 | 886.630 | 981.636 | 1075.54 | 1168.25 |
| 4 | 693.196 | 789.803 | 885.448 | 980.014 | 1073.38 | 1165.45 |
| 10 | 692.619 | 788.939 | 884.217 | 978.325 | 1071.14 | 1162.54 |
| 20 | 692.018 | 788.040 | 882.936 | 976.569 | 1068.81 | 1159.51 |
| 30 | 691.395 | 787.108 | 881.606 | 974.746 | 1066.38 | 1156.37 |
| 40 | 690.748 | 786.140 | 880.228 | 972.856 | 1063.87 | 1153.12 |
| 50 | 690.079 | 785.138 | 878.800 | 970.900 | 1061.27 | 1149.76 |
| 5 | 689.386 | 784.101 | 877.324 | 968.877 | 1058.59 | 1146.28 |
| 10 | 688.670 | 783.030 | 875.800 | 966.788 | 1055.81 | 1142.69 |
| 20 | 687.930 | 781.925 | 874.227 | 964.634 | 1052.95 | 1138.99 |
| 30 | 687.169 | 780.786 | 872.605 | 962.415 | 1050.01 | 1135.18 |
| 40 | 686.384 | 779.612 | 870.936 | 960.130 | 1046.97 | 1131.26 |
| 50 | 685.576 | 778.406 | 869.219 | 957.780 | 1043.86 | 1127.24 |
| 6 | 684.745 | 777.165 | 867.454 | 955.366 | 1040.66 | 1123.10 |
| 10 | 683.892 | 775.890 | 865.642 | 952.888 | 1037.37 | 1118.86 |
| 20 | 683.016 | 774.582 | 863.782 | 950.345 | 1034.01 | 1114.51 |
| 30 | 682.117 | 773.240 | 861.875 | 947.739 | 1030.55 | 1110.05 |
| 40 | 681.195 | 771.864 | 859.922 | 945.069 | 1027.02 | 1105.49 |
| 50 | 680.251 | 770.455 | 857.921 | 942.337 | 1023.40 | 1100.83 |
| 7 | 679.285 | 769.014 | 855.874 | 939.542 | 1019.70 | 1096.06 |
| 10 | 678.296 | 767.539 | 853.780 | 936.684 | 1015.93 | 1091.19 |
| 20 | 677.284 | 766.030 | 851.640 | 933.764 | 1012.07 | 1086.22 |
| 30 | 676.250 | 764.490 | 849.455 | 930.783 | 1008.13 | 1081.15 |
| 40 | 675.194 | 762.916 | 847.224 | 927.741 | 1004.11 | 1075.98 |
| 50 | 674.116 | 761.309 | 844.947 | 924.638 | 1000.01 | 1070.71 |
| 8 | 673.015 | 759.670 | 842.625 | 921.474 | 995.834 | 1065.34 |
| 10 | 671.892 | 757.999 | 840.258 | 918.250 | 991.580 | 1059.88 |
| 20 | 670.748 | 756.295 | 837.845 | 914.966 | 987.250 | 1054.32 |
| 30 | 669.581 | 754.560 | 835.389 | 911.623 | 982.844 | 1048.66 |
| 40 | 668.393 | 752.792 | 832.888 | 908.221 | 978.362 | 1042.91 |
| 50 | 667.182 | 750.993 | 830.342 | 904.761 | 973.806 | 1037.06 |
| 9 | 665.950 | 749.161 | 827.754 | 901.242 | 969.175 | 1031.13 |
| 10 | 664.697 | 747.299 | 825.121 | 897.667 | 964.471 | 1025.11 |
| 20 | 663.421 | 745.404 | 822.445 | 894.033 | 959.694 | 1018.99 |
| 30 | 662.124 | 743.479 | 819.726 | 890.343 | 954.844 | 1012.79 |
| 40 | 660.806 | 741.522 | 816.965 | 886.597 | 949.924 | 1006.49 |
| 50 | 659.466 | 739.535 | 814.160 | 882.795 | 944.933 | 1000.12 |
| 10 | 658.105 | 737.516 | 811.314 | 878.938 | 939.871 | 993.653 |

## TABLE VII.—LONG CHORDS.

| Degree of Curve. | Actual Arc, One Station. | Long Chords. 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
|---|---|---|---|---|---|---|
| 10° 10′ | 100.131 | 199.213 | 296.860 | 392.171 | 484.397 | 572.813 |
| 20 | .136 | 199.187 | 296.756 | 391.914 | 483.886 | 571.926 |
| 30 | .140 | 199.161 | 296.651 | 391.652 | 483.367 | 571.027 |
| 40 | .145 | 199.134 | 296.544 | 391.387 | 482.840 | 570.113 |
| 50 | .149 | 199.107 | 296.436 | 391.117 | 482.305 | 569.186 |
| 11 | 100.154 | 199.079 | 296.325 | 390.843 | 481.762 | 568.245 |
| 10 | .158 | 199.051 | 296.214 | 390.565 | 481.211 | 567.292 |
| 20 | .163 | 199.023 | 296.100 | 390.284 | 480.653 | 566.324 |
| 30 | .168 | 198.994 | 295.985 | 389.998 | 480.086 | 565.343 |
| 40 | .173 | 198.964 | 295.868 | 389.708 | 479.511 | 564.349 |
| 50 | .178 | 198.935 | 295.750 | 389.414 | 478.929 | 563.341 |
| 12 | 100.183 | 198.904 | 295.629 | 389.116 | 478.338 | 562.321 |
| 10 | .188 | 198.874 | 295.508 | 388.814 | 477.740 | 561.287 |
| 20 | .193 | 198.843 | 295.384 | 388.508 | 477.135 | 560.240 |
| 30 | .199 | 198.811 | 295.259 | 388.197 | 476.521 | 559.180 |
| 40 | .204 | 198.779 | 295.132 | 387.883 | 475.899 | 558.107 |
| 50 | .209 | 198.747 | 295.004 | 387.565 | 475.270 | 557.020 |
| 13 | 100.215 | 198.714 | 294.874 | 387.243 | 474.633 | 555.921 |
| 10 | .220 | 198.681 | 294.742 | 386.916 | 473.988 | 554.809 |
| 20 | .226 | 198.648 | 294.609 | 386.586 | 473.336 | 553.684 |
| 30 | .232 | 198.614 | 294.474 | 386.252 | 472.675 | 552.546 |
| 40 | .237 | 198.579 | 294.337 | 385.914 | 472.007 | 551.395 |
| 50 | .243 | 198.544 | 294.199 | 385.572 | 471.332 | 550.232 |
| 14 | 100.249 | 198.509 | 294.059 | 385.225 | 470.649 | 549.056 |
| 10 | .255 | 198.474 | 293.918 | 384.875 | 469.958 | 547.867 |
| 20 | .261 | 198.437 | 293.774 | 384.521 | 469.260 | 546.666 |
| 30 | .267 | 198.401 | 293.629 | 384.163 | 468.554 | 545.452 |
| 40 | .274 | 198.364 | 293.483 | 383.801 | 467.840 | 544.226 |
| 50 | .280 | 198.327 | 293.335 | 383.435 | 467.119 | 542.987 |
| 15 | 100.286 | 198.289 | 293.185 | 383.065 | 466.390 | 541.736 |
| 10 | .292 | 198.251 | 293.034 | 382.691 | 465.654 | 540.472 |
| 20 | .299 | 198.212 | 292.881 | 382.313 | 464.911 | 539.196 |
| 30 | .306 | 198.173 | 292.726 | 381.931 | 464.160 | 537.908 |
| 40 | .312 | 198.134 | 292.570 | 381.546 | 463.401 | 536.608 |
| 50 | .319 | 198.094 | 292.412 | 381.156 | 462.635 | 535.296 |
| 16 | 100.326 | 198.054 | 292.252 | 380.763 | 461.862 | 533.972 |
| 10 | .333 | 198.013 | 292.091 | 380.365 | 461.081 | 532.635 |
| 20 | .339 | 197.972 | 291.928 | 379.964 | 460.293 | 531.287 |
| 30 | .346 | 197.930 | 291.764 | 379.559 | 459.498 | 529.927 |
| 40 | .353 | 197.888 | 291.598 | 379.150 | 458.695 | 528.555 |
| 50 | .361 | 197.846 | 291.430 | 378.737 | 457.886 | 527.171 |
| 17 | 100.368 | 197.803 | 291.261 | 378.320 | 457.069 | 525.776 |
| 10 | .375 | 197.760 | 291.090 | 377.900 | 456.244 | 524.369 |
| 20 | .382 | 197.716 | 290.918 | 377.475 | 455.413 | 522.950 |
| 30 | .390 | 197.672 | 290.743 | 377.047 | 454.574 | 521.519 |
| 40 | .397 | 197.628 | 290.568 | 376.615 | 453.728 | 520.078 |
| 50 | .405 | 197.583 | 290.390 | 376.179 | 452.875 | 518.625 |
| 18 | 100.412 | 197.538 | 290.211 | 375.739 | 452.015 | 517.160 |
| 10 | .420 | 197.492 | 290.031 | 375.295 | 451.147 | 515.685 |
| 20 | .428 | 197.446 | 289.849 | 374.848 | 450.373 | 514.198 |
| 30 | .436 | 197.399 | 289.665 | 374.397 | 449.392 | 512.699 |
| 40 | .444 | 197.352 | 289.479 | 373.942 | 448.504 | 511.190 |
| 50 | .452 | 197.305 | 289.292 | 373.483 | 447.608 | 509.670 |
| 19 | 100.460 | 197.256 | 289.104 | 373.021 | 446.706 | 508.139 |
| 10 | .468 | 197.209 | 288.913 | 372.554 | 445.797 | 506.597 |
| 20 | .476 | 197.160 | 288.722 | 372.084 | 444.881 | 505.043 |
| 30 | .484 | 197.111 | 288.528 | 371.610 | 443.957 | 503.479 |
| 40 | .493 | 197.062 | 288.333 | 371.133 | 443.028 | 501.905 |
| 50 | .501 | 197.012 | 288.137 | 370.652 | 442.091 | 500.320 |
| 20 | 100.510 | 196.962 | 287.939 | 370.167 | 441.147 | 498.724 |

| Degree of Curve. | | Long Chords. 7 Stations. | 8 Stations. | 9 Stations. | 10 Stations. | 11 Stations. | 12 Stations. |
|---|---|---|---|---|---|---|---|
| 10° | 10 | 656.723 | 735.467 | 808.426 | 875.025 | 934.741 | 987.105 |
| | 20 | 655.320 | 733.387 | 805.495 | 871.058 | 929.542 | 980.473 |
| | 30 | 653.895 | 731.277 | 802.524 | 867.038 | 924.276 | 973.760 |
| | 40 | 652.450 | 729.137 | 799.512 | 862.963 | 918.943 | 966.967 |
| | 50 | 650.983 | 726.967 | 796.458 | 858.836 | 913.544 | 960.093 |
| 11 | | 649.496 | 724.767 | 793.364 | 854.656 | 908.080 | 953.141 |
| | 10 | 647.989 | 722.537 | 790.230 | 850.425 | 902.550 | 946.112 |
| | 20 | 646.460 | 720.278 | 787.056 | 846.140 | 896.957 | 939.007 |
| | 30 | 644.911 | 717.990 | 783.843 | 841.808 | 891.303 | 931.828 |
| | 40 | 643.342 | 715.672 | 780.590 | 837.424 | 885.586 | 924.575 |
| | 50 | 641.752 | 713.325 | 777.298 | 832.990 | 879.807 | 917.250 |
| 12 | | 640.142 | 710.950 | 773.968 | 828.507 | 873.968 | 909.854 |
| | 10 | 638.512 | 708.546 | 770.600 | 823.974 | 868.070 | 902.389 |
| | 20 | 636.862 | 706.113 | 767.193 | 819.394 | 862.113 | 894.855 |
| | 30 | 635.191 | 703.653 | 763.749 | 814.766 | 856.099 | 887.254 |
| | 40 | 633.501 | 701.164 | 760.268 | 810.092 | 850.028 | 879.588 |
| | 50 | 631.792 | 698.647 | 756.749 | 805.370 | 843.900 | 871.857 |
| 13 | | 630.062 | 696.103 | 753.194 | 800.602 | 837.718 | 864.063 |
| | 10 | 628.313 | 693.531 | 749.603 | 795.790 | 831.482 | 856.208 |
| | 20 | 626.544 | 690.932 | 745.976 | 790.932 | 825.192 | 848.293 |
| | 30 | 624.756 | 688.306 | 742.313 | 786.030 | 818.850 | 840.318 |
| | 40 | 622.949 | 685.653 | 738.616 | 781.085 | 812.457 | 832.286 |
| | 50 | 621.123 | 682.974 | 734.883 | 776.096 | 806.013 | 824.198 |
| 14 | | 619.278 | 680.268 | 731.116 | 771.066 | 799.520 | 816.056 |
| | 10 | 617.413 | 677.535 | 727.315 | 765.993 | 792.979 | 807.860 |
| | 20 | 615.530 | 674.777 | 723.480 | 760.879 | 786.389 | 799.612 |
| | 30 | 613.628 | 671.993 | 719.612 | 755.725 | 779.753 | 791.313 |
| | 40 | 611.708 | 669.183 | 715.711 | 750.531 | 773.072 | 782.966 |
| | 50 | 609.769 | 666.348 | 711.777 | 745.297 | 766.345 | 774.571 |
| 15 | | 607.812 | 663.488 | 707.811 | 740.024 | 759.575 | 766.130 |
| | 10 | 605.836 | 660.603 | 703.814 | 734.714 | 752.763 | |
| | 20 | 603.842 | 657.693 | 699.785 | 729.366 | 745.908 | |
| | 30 | 601.831 | 654.758 | 695.725 | 723.982 | 739.014 | |
| | 40 | 599.801 | 651.799 | 691.634 | 718.561 | 732.078 | |
| | 50 | 597.753 | 648.817 | 687.513 | 713.105 | 725.104 | |
| 16 | | 595.688 | 645.810 | 683.362 | 707.614 | 718.092 | |
| | 10 | 593.605 | 642.780 | 679.182 | 702.088 | 711.043 | |
| | 20 | 591.505 | 639.727 | 674.973 | 696.529 | 703.959 | |
| | 30 | 589.388 | 636.650 | 670.735 | 690.938 | | |
| | 40 | 587.253 | 633.550 | 666.469 | 685.314 | | |
| | 50 | 585.101 | 630.428 | 662.175 | 679.659 | | |
| 17 | | 582.933 | 627.283 | 657.854 | 673.972 | | |
| | 10 | 580.747 | 624.117 | 653.506 | 668.256 | | |
| | 20 | 578.545 | 620.928 | 649.131 | 662.510 | | |
| | 30 | 576.326 | 617.717 | 644.730 | 656.735 | | |
| | 40 | 574.091 | 614.485 | 640.304 | 650.933 | | |
| | 50 | 571.839 | 611.232 | 635.852 | 645.103 | | |
| 18 | | 569.571 | 607.958 | 631.375 | 639.245 | | |
| | 10 | 567.287 | 604.664 | 626.874 | | | |
| | 20 | 564.988 | 601.349 | 622.349 | | | |
| | 30 | 562.673 | 598.013 | 617.801 | | | |
| | 40 | 560.342 | 594.658 | 613.229 | | | |
| | 50 | 557.996 | 591.283 | 608.635 | | | |
| 19 | | 555.634 | 587.888 | 604.018 | | | |
| | 10 | 553.257 | 584.475 | 599.379 | | | |
| | 20 | 550.864 | 581.042 | 594.720 | | | |
| | 30 | 548.457 | 577.591 | 590.039 | | | |
| | 40 | 546.035 | 574.121 | 585.339 | | | |
| | 50 | 543.599 | 570.634 | 580.618 | | | |
| 20 | | 541.147 | 567.128 | 575.877 | | | |

TABLE VII.—LONG CHORDS.

| Degree of Curve. | Actual Arc, One Station. | Long Chords. 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
|---|---|---|---|---|---|---|
| 21° | 100.562 | 196.651 | 286.716 | 367.179 | 435.345 | 488.931 |
| 22 | 100.617 | 196.325 | 285.437 | 364.060 | 429.305 | 478.775 |
| 23 | 100.675 | 195.985 | 284.101 | 360.810 | 423.033 | 468.270 |
| 24 | 100.735 | 195.630 | 282.709 | 357.433 | 416.535 | 457.433 |
| 25 | 100.798 | 195.259 | 281.262 | 353.930 | 409.819 | 446.280 |
| 26 | 100.863 | 194.874 | 279.759 | 350.303 | 402.891 | 434.827 |
| 27 | 100.931 | 194.474 | 278.201 | 346.555 | 395.758 | 423.092 |
| 28 | 101.002 | 194.059 | 276.589 | 342.688 | 388.428 | 411.092 |
| 29 | 101.075 | 193.630 | 274.924 | 338.704 | 380.908 | 398.846 |
| 30 | 101.152 | 193.185 | 273.205 | 334.607 | 373.205 | 386.370 |
| 31° | 101.230 | 192.726 | 271.433 | 330.397 | 365.328 | 373.685 |
| 32 | 101.312 | 192.252 | 269.610 | 326.078 | 357.284 | 360.808 |
| 33 | 101.396 | 191.764 | 267.734 | 321.654 | 349.081 | 347.759 |
| 34 | 101.482 | 191.261 | 265.808 | 317.125 | 340.729 | 334.556 |
| 35 | 101.572 | 190.743 | 263.830 | 312.496 | 332.234 | 321.220 |
| 36 | 101.664 | 190.211 | 261.803 | 307.768 | 323.607 | 307.768 |
| 37 | 101.759 | 189.665 | 259.727 | 302.946 | 314.855 | 294.222 |
| 38 | 101.857 | 189.104 | 257.602 | 298.032 | 305.987 | 280.600 |
| 39 | 101.957 | 188.528 | 255.429 | 293.028 | 297.012 | 266.923 |
| 40 | 102.060 | 187.939 | 253.209 | 287.938 | 287.939 | 253.209 |
| 41° | 102.166 | 187.334 | 250.942 | 282.766 | 278.777 | 239.478 |
| 42 | 102.275 | 186.716 | 248.629 | 277.514 | 269.535 | 225.750 |
| 43 | 102.386 | 186.084 | 246.271 | 272.186 | 260.222 | 212.045 |
| 44 | 102.500 | 185.437 | 243.868 | 266.784 | 250.848 | 198.380 |
| 45 | 102.617 | 184.776 | 241.421 | 261.313 | 241.421 | 184.776 |
| 46 | 102.737 | 184.101 | 238.932 | 255.775 | 231.952 | 171.251 |
| 47 | 102.860 | 183.412 | 236.400 | 250.173 | 222.448 | 157.824 |
| 48 | 102.985 | 182.709 | 233.826 | 244.512 | 212.920 | 144.512 |
| 49 | 103.114 | 181.992 | 231.212 | 238.795 | 203.377 | 131.335 |
| 50° | 103.245 | 181.262 | 228.558 | 233.025 | 193.828 | 118.310 |

| D | 50 | 25 | 20 | 10 | D | 50 | 25 | 20 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 3° | .004 | .003 | .002 | .001 | 27° | .349 | .218 | .179 | .092 |
| 4 | .008 | .005 | .004 | .002 | 28 | .376 | .235 | .192 | .099 |
| 5 | .012 | .008 | .006 | .003 | 29 | .403 | .252 | .206 | .106 |
| 6 | .017 | .011 | .009 | .005 | 30° | .431 | .270 | .221 | .114 |
| 7 | .023 | .015 | .012 | .006 | 31 | .461 | .288 | .236 | .122 |
| 8 | .030 | .019 | .016 | .008 | 32 | .491 | .307 | .252 | .130 |
| 9 | .039 | .024 | .020 | .010 | 33 | .523 | .327 | .268 | .138 |
| 10° | .048 | .030 | .024 | .013 | 34 | .555 | .347 | .285 | .147 |
| 11 | .058 | .036 | .030 | .015 | 35 | .589 | .368 | .302 | .156 |
| 12 | .069 | .043 | .035 | .018 | 36 | .623 | .390 | .320 | .165 |
| 13 | .081 | .050 | .041 | .021 | 37 | .659 | .412 | .338 | .174 |
| 14 | .093 | .058 | .048 | .025 | 38 | .695 | .435 | .356 | .184 |
| 15 | .107 | .067 | .055 | .028 | 39 | .733 | .458 | .376 | .194 |
| 16 | .122 | .076 | .063 | .032 | 40° | .771 | .483 | .396 | .204 |
| 17 | .138 | .086 | .071 | .036 | 41 | .811 | .507 | .416 | .214 |
| 18 | .155 | .097 | .079 | .041 | 42 | .851 | .533 | .437 | .225 |
| 19 | .172 | .108 | .088 | .045 | 43 | .893 | .559 | .458 | .236 |
| 20° | .191 | .119 | .098 | .050 | 44 | .936 | .586 | .480 | .248 |
| 21 | .211 | .132 | .108 | .056 | 45 | .980 | .613 | .502 | .259 |
| 22 | .231 | .144 | .118 | .061 | 46 | 1.024 | .641 | .525 | .271 |
| 23 | .253 | .158 | .130 | .067 | 47 | 1.070 | .670 | .549 | .283 |
| 24 | .275 | .172 | .141 | .073 | 48 | 1.117 | .699 | .573 | .296 |
| 25 | .299 | .187 | .153 | .079 | 49 | 1.165 | .729 | .598 | .308 |
| 26° | .323 | .202 | .166 | .085 | 50° | 1.214 | .760 | .623 | .321 |

## TABLE VIII.—MIDDLE ORDINATES.

| Degree of Curve. | 1 Station. | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
|---|---|---|---|---|---|---|
| 21° | 4.594 | 18.224 | 40.431 | 70.473 | 107.344 | 149.809 |
| 22 | 4.814 | 19.081 | 42.275 | 73.545 | 111.741 | 155.460 |
| 23 | 5.035 | 19.937 | 44.108 | 76.577 | 116.042 | 160.917 |
| 24 | 5.255 | 20.791 | 45.929 | 79.570 | 120.243 | 166.172 |
| 25 | 5.476 | 21.644 | 47.738 | 82.520 | 124.342 | 171.221 |
| 26 | 5.697 | 22.495 | 49.534 | 85.427 | 128.335 | 176.058 |
| 27 | 5.918 | 23.345 | 51.317 | 88.289 | 132.219 | 180.677 |
| 28 | 6.139 | 24.192 | 53.086 | 91.105 | 135.990 | 185.075 |
| 29 | 6.360 | 25.038 | 54.842 | 93.873 | 139.647 | 189.245 |
| 30 | 6.583 | 25.882 | 56.583 | 96.593 | 143.185 | 193.185 |
| 31° | 6.805 | 26.724 | 58.309 | 99.261 | 146.603 | |
| 32 | 7.027 | 27.564 | 60.019 | 101.878 | 149.898 | |
| 33 | 7.250 | 28.402 | 61.714 | 104.442 | 153.068 | |
| 34 | 7.473 | 29.237 | 63.392 | 106.952 | 156.110 | |
| 35 | 7.696 | 30.071 | 65.053 | 109.406 | 159.023 | |
| 36 | 7.919 | 30.902 | 66.698 | 111.803 | 161.803 | |
| 37 | 8.143 | 31.730 | 68.325 | 114.143 | | |
| 38 | 8.367 | 32.557 | 69.933 | 116.424 | | |
| 39 | 8.592 | 33.381 | 71.524 | 118.645 | | |
| 40 | 8.816 | 34.202 | 73.095 | 120.805 | | |
| 41° | 9.041 | 35.021 | 74.647 | 122.902 | | |
| 42 | 9.267 | 35.837 | 76.180 | 124.937 | | |
| 43 | 9.493 | 36.650 | 77.693 | 126.909 | | |
| 44 | 9.719 | 37.461 | 79.185 | 128.815 | | |
| 45 | 9.946 | 38.268 | 80.656 | 130.656 | | |
| 46 | 10.173 | 39.073 | 82.107 | | | |
| 47 | 10.400 | 39.875 | 83.535 | | | |
| 48 | 10.628 | 40.674 | 84.942 | | | |
| 49 | 10.856 | 41.469 | 86.327 | | | |
| 50° | 11.085 | 42.262 | 87.689 | | | |

TABLE VIII.—MIDDLE ORDINATES.

| Degree of Curve. | 1 Station. | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
|---|---|---|---|---|---|---|
| 0° 10′ | .036 | .145 | .327 | .582 | .909 | 1.309 |
| 20 | .073 | .291 | .654 | 1.164 | 1.818 | 2.618 |
| 30 | .109 | .436 | .982 | 1.745 | 2.727 | 3.926 |
| 40 | .145 | .582 | 1.309 | 2.327 | 3.636 | 5.235 |
| 50 | .182 | .727 | 1.636 | 2.909 | 4.545 | 6.544 |
| 1 | .218 | .873 | 1.963 | 3.490 | 5.453 | 7.852 |
| 10 | .255 | 1.018 | 2.291 | 4.072 | 6.362 | 9.160 |
| 20 | .291 | 1.164 | 2.618 | 4.654 | 7.270 | 10.468 |
| 30 | .327 | 1.309 | 2.945 | 5.235 | 8.179 | 11.775 |
| 40 | .364 | 1.454 | 3.272 | 5.816 | 9.087 | 13.082 |
| 50 | .400 | 1.600 | 3.599 | 6.398 | 9.994 | 14.389 |
| 2 | .436 | 1.745 | 3.926 | 6.979 | 10.902 | 15.694 |
| 10 | .473 | 1.891 | 4.253 | 7.560 | 11.809 | 17.000 |
| 20 | .509 | 2.036 | 4.580 | 8.141 | 12.716 | 18.304 |
| 30 | .545 | 2.181 | 4.907 | 8.722 | 13.623 | 19.608 |
| 40 | .582 | 2.327 | 5.234 | 9.303 | 14.529 | 20.912 |
| 50 | .618 | 2.472 | 5.561 | 9.883 | 15.435 | 22.214 |
| 3 | .654 | 2.618 | 5.888 | 10.464 | 16.341 | 23.516 |
| 10 | .691 | 2.763 | 6.215 | 11.044 | 17.246 | 24.817 |
| 20 | .727 | 2.908 | 6.542 | 11.624 | 18.151 | 26.117 |
| 30 | .763 | 3.054 | 6.868 | 12.204 | 19.055 | 27.416 |
| 40 | .800 | 3.199 | 7.195 | 12.784 | 19.959 | 28.714 |
| 50 | .836 | 3.345 | 7.522 | 13.363 | 20.863 | 30.012 |
| 4 | .872 | 3.490 | 7.848 | 13.943 | 21.766 | 31.308 |
| 10 | .909 | 3.635 | 8.175 | 14.522 | 22.668 | 32.603 |
| 20 | .945 | 3.781 | 8.501 | 15.101 | 23.570 | 33.896 |
| 30 | .982 | 3.926 | 8.828 | 15.680 | 24.471 | 35.189 |
| 40 | 1.018 | 4.071 | 9.154 | 16.258 | 25.372 | 36.480 |
| 50 | 1.054 | 4.217 | 9.480 | 16.837 | 26.272 | 37.770 |
| 5 | 1.091 | 4.362 | 9.807 | 17.415 | 27.171 | 39.059 |
| 10 | 1.127 | 4.507 | 10.133 | 17.992 | 28.070 | 40.346 |
| 20 | 1.164 | 4.653 | 10.459 | 18.570 | 28.968 | 41.631 |
| 30 | 1.200 | 4.798 | 10.785 | 19.147 | 29.866 | 42.916 |
| 40 | 1.237 | 4.943 | 11.111 | 19.724 | 30.762 | 44.198 |
| 50 | 1.273 | 5.088 | 11.436 | 20.301 | 31.658 | 45.479 |
| 6 | 1.309 | 5.234 | 11.762 | 20.877 | 32.553 | 46.759 |
| 10 | 1.346 | 5.379 | 12.088 | 21.453 | 33.448 | 48.037 |
| 20 | 1.382 | 5.524 | 12.413 | 22.029 | 34.341 | 49.313 |
| 30 | 1.418 | 5.669 | 12.739 | 22.604 | 35.234 | 50.587 |
| 40 | 1.455 | 5.814 | 13.064 | 23.179 | 36.126 | 51.860 |
| 50 | 1.491 | 5.960 | 13.389 | 23.754 | 37.017 | 53.130 |
| 7 | 1.528 | 6.105 | 13.715 | 24.328 | 37.907 | 54.399 |
| 10 | 1.564 | 6.250 | 14.040 | 24.902 | 38.796 | 55.666 |
| 20 | 1.600 | 6.395 | 14.365 | 25.476 | 39.684 | 56.931 |
| 30 | 1.637 | 6.540 | 14.689 | 26.049 | 40.571 | 58.193 |
| 40 | 1.673 | 6.685 | 15.014 | 26.622 | 41.458 | 59.454 |
| 50 | 1.710 | 6.831 | 15.339 | 27.195 | 42.343 | 60.712 |
| 8 | 1.746 | 6.976 | 15.663 | 27.767 | 43.227 | 61.969 |
| 10 | 1.782 | 7.121 | 15.988 | 28.338 | 44.110 | 63.223 |
| 20 | 1.819 | 7.266 | 16.312 | 28.910 | 44.992 | 64.475 |
| 30 | 1.855 | 7.411 | 16.636 | 29.481 | 45.873 | 65.724 |
| 40 | 1.892 | 7.556 | 16.960 | 30.051 | 46.753 | 66.972 |
| 50 | 1.928 | 7.701 | 17.284 | 30.621 | 47.632 | 68.216 |
| 9 | 1.965 | 7.846 | 17.608 | 31.190 | 48.510 | 69.459 |
| 10 | 2.001 | 7.991 | 17.932 | 31.759 | 49.386 | 70.699 |
| 20 | 2.037 | 8.136 | 18.255 | 32.328 | 50.261 | 71.936 |
| 30 | 2.074 | 8.281 | 18.578 | 32.896 | 51.135 | 73.171 |
| 40 | 2.110 | 8.426 | 18.902 | 33.464 | 52.008 | 74 403 |
| 50 | 2.147 | 8.571 | 19.225 | 34.031 | 52.880 | 75.632 |
| 10 | 2.183 | 8.716 | 19.548 | 34.597 | 53.750 | 76.859 |

# TABLE VIII.—MIDDLE ORDINATES.

| Degree of Curve. | 7 Stations. | 8 Stations. | 9 Stations. | 10 Stations. | 11 Stations. | 12 Stations. |
|---|---|---|---|---|---|---|
| 0° 10′ | 1.782 | 2.327 | 2.945 | 3.636 | 4.400 | 5.236 |
| 20 | 3.563 | 4.654 | 5.890 | 7.272 | 8.799 | 10.471 |
| 30 | 5.345 | 6.981 | 8.835 | 10.907 | 13.197 | 15.704 |
| 40 | 7.126 | 9.307 | 11.778 | 14.540 | 17.593 | 20.936 |
| 50 | 8.907 | 11.632 | 14.721 | 18.173 | 21.987 | 26.164 |
| 1 | 10.687 | 13.957 | 17.663 | 21.803 | 26.378 | 31.388 |
| 10 | 12.467 | 16.281 | 20.603 | 25.431 | 30.766 | 36.607 |
| 20 | 14.246 | 18.604 | 23.541 | 29.057 | 35.150 | 41.821 |
| 30 | 16.024 | 20.925 | 26.477 | 32.679 | 39.530 | 47.028 |
| 40 | 17.802 | 23.246 | 29.411 | 36.298 | 43.905 | 52.229 |
| 50 | 19.579 | 25.564 | 32.343 | 39.914 | 48.274 | 57.422 |
| 2 | 21.355 | 27.881 | 35.272 | 43.525 | 52.637 | 62.606 |
| 10 | 23.130 | 30.197 | 38.198 | 47.131 | 56.993 | 67.780 |
| 20 | 24.903 | 32.510 | 41.121 | 50.733 | 61.343 | 72.945 |
| 30 | 26.676 | 34.821 | 44.040 | 54.330 | 65.684 | 78.098 |
| 40 | 28.447 | 37.130 | 46.956 | 57.921 | 70.018 | 83.240 |
| 50 | 30.216 | 39.436 | 49.868 | 61.506 | 74.342 | 88.370 |
| 3 | 31.984 | 41.740 | 52.776 | 65.084 | 78.657 | 93.486 |
| 10 | 33.751 | 44.041 | 55.679 | 68.656 | 82.963 | 98.588 |
| 20 | 35.516 | 46.339 | 58.577 | 72.221 | 87.258 | 103.675 |
| 30 | 37.279 | 48.634 | 61.471 | 75.778 | 91.542 | 108.747 |
| 40 | 39.040 | 50.926 | 64.360 | 79.328 | 95.814 | 113.803 |
| 50 | 40.800 | 53.215 | 67.243 | 82.869 | 100.075 | 118.841 |
| 4 | 42.557 | 55.500 | 70.121 | 86.402 | 104.323 | 123.862 |
| 10 | 44.312 | 57.781 | 72.992 | 89.925 | 108.558 | 128.864 |
| 20 | 46.065 | 60.059 | 75.858 | 93.440 | 112.779 | 133.847 |
| 30 | 47.816 | 62.333 | 78.717 | 96.945 | 116.986 | 138.810 |
| 40 | 49.564 | 64.602 | 81.570 | 100.439 | 121.178 | 143.753 |
| 50 | 51.310 | 66.868 | 84.416 | 103.924 | 125.356 | 148.674 |
| 5 | 53.053 | 69.129 | 87.255 | 107.397 | 129.517 | 153.572 |
| 10 | 54.794 | 71.386 | 90.087 | 110.860 | 133.663 | 158.448 |
| 20 | 56.532 | 73.638 | 92.911 | 114.311 | 137.791 | 163.300 |
| 30 | 58.267 | 75.885 | 95.728 | 117.751 | 141.903 | 168.128 |
| 40 | 59.999 | 78.127 | 98.536 | 121.178 | 145.997 | 172.931 |
| 50 | 61.729 | 80.364 | 101.337 | 124.593 | 150.072 | 177.708 |
| 6 | 63.455 | 82.596 | 104.129 | 127.995 | 154.129 | 182.459 |
| 10 | 65.178 | 84.822 | 106.912 | 131.384 | 158.166 | 187.182 |
| 20 | 66.898 | 87.043 | 109.686 | 134.759 | 162.184 | 191.878 |
| 30 | 68.615 | 89.258 | 112.452 | 138.120 | 166.182 | 196.545 |
| 40 | 70.328 | 91.468 | 115.208 | 141.468 | 170.159 | 201.183 |
| 50 | 72.037 | 93.671 | 117.954 | 144.800 | 174.114 | 205.792 |
| 7 | 73.744 | 95.868 | 120.691 | 148.118 | 178.048 | 210.370 |
| 10 | 75.446 | 98.059 | 123.417 | 151.421 | 181.960 | 214.916 |
| 20 | 77.145 | 100.244 | 126.134 | 154.708 | 185.850 | 219.431 |
| 30 | 78.840 | 102.422 | 128.840 | 157.979 | 189.716 | 223.914 |
| 40 | 80.531 | 104.594 | 131.535 | 161.234 | 193.559 | 228.363 |
| 50 | 82.218 | 106.758 | 134.219 | 164.473 | 197.377 | 232.779 |
| 8 | 83.901 | 108.916 | 136.893 | 167.695 | 201.171 | 237.160 |
| 10 | 85.580 | 111.067 | 139.555 | 170.899 | 204.941 | 241.507 |
| 20 | 87.254 | 113.210 | 142.205 | 174.086 | 208.685 | 245.818 |
| 30 | 88.924 | 115.346 | 144.844 | 177.255 | 212.403 | 250.093 |
| 40 | 90.590 | 117.475 | 147.470 | 180.407 | 216.095 | 254.331 |
| 50 | 92.252 | 119.596 | 150.085 | 183.539 | 219.760 | 258.531 |
| 9 | 93.909 | 121.709 | 152.687 | 186.653 | 223.398 | 262.694 |
| 10 | 95.561 | 123.814 | 155.277 | 189.748 | 227.008 | 266.818 |
| 20 | 97.208 | 125.911 | 157.854 | 192.824 | 230.591 | 270.904 |
| 30 | 98.851 | 128.000 | 160.417 | 195.880 | 234.145 | 274.949 |
| 40 | 100.489 | 130.081 | 162.968 | 198.916 | 237.670 | 278.955 |
| 50 | 102.122 | 132.153 | 165.505 | 201.932 | 241.167 | 282.919 |
| 10 | 103.750 | 134.217 | 168.029 | 204.928 | 244.633 | 286.843 |

TABLE VIII.—MIDDLE ORDINATES.

| Degree of Curve. | | 1 Station. | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
|---|---|---|---|---|---|---|---|
| 10° | 10′ | 2.219 | 8.860 | 19.870 | 35.164 | 54.619 | 78.083 |
| | 20 | 2.256 | 9.005 | 20.193 | 35.729 | 55.486 | 79.305 |
| | 30 | 2.293 | 9.150 | 20.516 | 36.294 | 56.353 | 80.523 |
| | 40 | 2.329 | 9.295 | 20.838 | 36.859 | 57.218 | 81.739 |
| | 50 | 2.365 | 9.440 | 21.160 | 37.423 | 58.081 | 82.951 |
| 11 | | 2.402 | 9.585 | 21.483 | 37.986 | 58.943 | 84.161 |
| | 10 | 2.438 | 9.729 | 21.804 | 38.549 | 59.804 | 85.368 |
| | 20 | 2.475 | 9.874 | 22.126 | 39.111 | 60.663 | 86.571 |
| | 30 | 2.511 | 10.019 | 22.448 | 39.673 | 61.521 | 87.772 |
| | 40 | 2.547 | 10.164 | 22.769 | 40.234 | 62.377 | 88.969 |
| | 50 | 2.584 | 10.308 | 23.090 | 40.795 | 63.232 | 90.164 |
| 12 | | 2.620 | 10.453 | 23.412 | 41.355 | 64.085 | 91.355 |
| | 10 | 2.657 | 10.597 | 23.732 | 41.914 | 64.937 | 92.542 |
| | 20 | 2.693 | 10.742 | 24.053 | 42.473 | 65.787 | 93.727 |
| | 30 | 2.730 | 10.887 | 24.374 | 43.031 | 66.636 | 94.908 |
| | 40 | 2.766 | 11.031 | 24.694 | 43.588 | 67.482 | 96.086 |
| | 50 | 2.803 | 11.176 | 25.014 | 44.145 | 68.328 | 97.260 |
| 13 | | 2.839 | 11.320 | 25.334 | 44.701 | 69.171 | 98.431 |
| | 10 | 2.876 | 11.465 | 25.654 | 45.256 | 70.012 | 99.598 |
| | 20 | 2.912 | 11.609 | 25.974 | 45.811 | 70.854 | 100.762 |
| | 30 | 2.949 | 11.754 | 26.293 | 46.365 | 71.692 | 101.922 |
| | 40 | 2.985 | 11.898 | 26.612 | 46.919 | 72.529 | 103.079 |
| | 50 | 3.022 | 12.043 | 26.931 | 47.472 | 73.364 | 104.232 |
| 14 | | 3.058 | 12.187 | 27.250 | 48.024 | 74.197 | 105.381 |
| | 10 | 3.095 | 12.331 | 27.569 | 48.575 | 75.029 | 106.527 |
| | 20 | 3.131 | 12.476 | 27.887 | 49.126 | 75.859 | 107.669 |
| | 30 | 3.168 | 12.620 | 28.206 | 49.676 | 76.687 | 108.807 |
| | 40 | 3.204 | 12.764 | 28.524 | 50.225 | 77.513 | 109.941 |
| | 50 | 3.241 | 12.908 | 28.841 | 50.773 | 78.337 | 111.071 |
| 15 | | 3.277 | 13.053 | 29.159 | 51.321 | 79.159 | 112.197 |
| | 10 | 3.314 | 13.197 | 29.476 | 51.868 | 79.979 | 113.319 |
| | 20 | 3.350 | 13.341 | 29.794 | 52.414 | 80.798 | 114.438 |
| | 30 | 3.387 | 13.485 | 30.111 | 52.959 | 81.614 | 115.552 |
| | 40 | 3.423 | 13.629 | 30.427 | 53.504 | 82.429 | 116.662 |
| | 50 | 3.460 | 13.773 | 30.744 | 54.048 | 83.241 | 117.768 |
| 16 | | 3.496 | 13.917 | 31.060 | 54.591 | 84.052 | 118.870 |
| | 10 | 3.533 | 14.061 | 31.376 | 55.133 | 84.861 | 119.967 |
| | 20 | 3.569 | 14.205 | 31.692 | 55.675 | 85.667 | 121.061 |
| | 30 | 3.606 | 14.349 | 32.008 | 56.215 | 86.471 | 122.150 |
| | 40 | 3.643 | 14.493 | 32.323 | 56.755 | 87.274 | 123.235 |
| | 50 | 3.679 | 14.637 | 32.638 | 57.294 | 88.074 | 124.315 |
| 17 | | 3.716 | 14.781 | 32.953 | 57.832 | 88.872 | 125.391 |
| | 10 | 3.752 | 14.925 | 33.267 | 58.369 | 89.668 | 126.463 |
| | 20 | 3.789 | 15.069 | 33.582 | 58.906 | 90.462 | 127.530 |
| | 30 | 3.825 | 15.212 | 33.896 | 59.441 | 91.254 | 128.593 |
| | 40 | 3.862 | 15.356 | 34.210 | 59.976 | 92.043 | 129.651 |
| | 50 | 3.899 | 15.500 | 34.523 | 60.510 | 92.830 | 130.704 |
| 18 | | 3.935 | 15.643 | 34.837 | 61.042 | 93.616 | 131.753 |
| | 10 | 3.972 | 15.787 | 35.150 | 61.574 | 94.398 | 132.797 |
| | 20 | 4.008 | 15.931 | 35.463 | 62.106 | 95.179 | 133.837 |
| | 30 | 4.045 | 16.074 | 35.775 | 62.636 | 95.957 | 134.872 |
| | 40 | 4.081 | 16.218 | 36.088 | 63.165 | 96.733 | 135.902 |
| | 50 | 4.118 | 16.361 | 36.400 | 63.693 | 97.506 | 136.928 |
| 19 | | 4.155 | 16.505 | 36.712 | 64.221 | 98.278 | 137.948 |
| | 10 | 4.191 | 16.648 | 37.023 | 64.747 | 99.047 | 138.964 |
| | 20 | 4.228 | 16.792 | 37.334 | 65.273 | 99.813 | 139.975 |
| | 30 | 4.265 | 16.935 | 37.645 | 65.797 | 100.577 | 140.981 |
| | 40 | 4.301 | 17.078 | 37.956 | 66.321 | 101.339 | 141.982 |
| | 50 | 4.338 | 17.222 | 38.266 | 66.843 | 102.098 | 142.978 |
| 20 | | 4.374 | 17.365 | 38.576 | 67.365 | 102.855 | 143.969 |

## TABLE IX.—LINEAR DEFLECTION TABLE.

| Deflection. | 100. | 200. | 300. | 400. | 500. | 600. | 700. | 800. | 900. | 1000. |
|---|---|---|---|---|---|---|---|---|---|---|
| 30′ | 0.87 | 1.75 | 2.62 | 3.49 | 4.36 | 5.24 | 6.11 | 6.98 | 7.85 | 8.73 |
| 1° | 1.75 | 3.49 | 5.24 | 6.98 | 8.73 | 10.47 | 12.22 | 13.96 | 15.71 | 17.45 |
| 30 | 2.62 | 5.24 | 7.85 | 10.47 | 13.09 | 15.71 | 18.33 | 20.94 | 23.56 | 26.18 |
| 2 | 3.49 | 6.98 | 10.47 | 13.96 | 17.45 | 20.94 | 24.43 | 27.92 | 31.41 | 34.90 |
| 30 | 4.36 | 8.72 | 13.09 | 17.45 | 21.81 | 26.18 | 30.54 | 34.90 | 39.27 | 43.63 |
| 3 | 5.24 | 10.47 | 15.71 | 20.94 | 26.18 | 31.41 | 36.65 | 41.88 | 47.12 | 52.35 |
| 30 | 6.11 | 12.22 | 18.32 | 24.43 | 30.54 | 36.65 | 42.75 | 48.86 | 54.97 | 61.08 |
| 4 | 6.98 | 13.96 | 20.94 | 27.92 | 34.90 | 41.88 | 48.86 | 55.84 | 66.82 | 69.80 |
| 30 | 7.85 | 15.70 | 23.56 | 31.41 | 39.26 | 47.11 | 54.96 | 62.82 | 70.67 | 78.52 |
| 5 | 8.73 | 17.45 | 26.17 | 34.89 | 43.62 | 52.34 | 61.07 | 69.79 | 78.51 | 87.24 |
| 30 | 9.60 | 19.19 | 28.79 | 38.38 | 47.98 | 57.57 | 67.17 | 76.76 | 86.36 | 95.96 |
| 6 | 10.47 | 20.93 | 31.40 | 41.87 | 52.34 | 62.80 | 73.27 | 83.74 | 94.20 | 104.67 |
| 30 | 11.34 | 22.68 | 34.02 | 45.35 | 56.67 | 68.03 | 79.37 | 90.71 | 102.05 | 113.39 |
| 7 | 12.21 | 24.42 | 36.63 | 48.84 | 61.05 | 73.26 | 85.47 | 97.68 | 109.89 | 122.10 |
| 30 | 13.08 | 26.16 | 39.24 | 52.32 | 65.40 | 78.48 | 91.56 | 104.64 | 117.73 | 130.81 |
| 8 | 13.95 | 27.90 | 41.85 | 55.80 | 69.76 | 83.71 | 97.66 | 111.61 | 125.56 | 139.51 |
| 30 | 14.82 | 29.64 | 44.47 | 59.29 | 74.11 | 88.93 | 103.75 | 118.57 | 133.40 | 148.22 |
| 9 | 15.69 | 31.38 | 47.08 | 62.77 | 78.46 | 94.15 | 109.84 | 125.53 | 141.23 | 156.92 |
| 30 | 16.56 | 33.12 | 49.68 | 66.25 | 82.81 | 99.37 | 115.93 | 132.49 | 149.05 | 165.62 |
| 10 | 17.43 | 34.86 | 52.29 | 69.72 | 87.16 | 104.59 | 122.02 | 139.45 | 156.88 | 174.31 |
| 30 | 18.30 | 36.60 | 54.90 | 73.20 | 91.50 | 109.80 | 128.10 | 146.40 | 164.70 | 183.00 |
| 11 | 19.17 | 38.34 | 57.51 | 76.68 | 95.85 | 115.01 | 134.18 | 153.35 | 172.52 | 191.69 |
| 30 | 20.04 | 40.08 | 60.11 | 80.15 | 100.19 | 120.23 | 140.26 | 160.30 | 180.34 | 200.38 |
| 12 | 20.91 | 41.81 | 62.72 | 83.62 | 104.53 | 125.43 | 146.34 | 167.25 | 188.15 | 209.06 |
| 30 | 21.77 | 43.55 | 65.32 | 87.09 | 108.87 | 130.64 | 152.41 | 174.19 | 195.96 | 217.73 |
| 13 | 22.64 | 45.28 | 67.92 | 90.56 | 113.20 | 135.84 | 158.48 | 181.13 | 203.77 | 226.41 |
| 30 | 23.51 | 47.01 | 70.52 | 94.03 | 117.54 | 141.04 | 164.55 | 188.06 | 211.57 | 235.07 |
| 14 | 24.37 | 48.75 | 73.12 | 97.50 | 121.87 | 146.24 | 170.62 | 194.99 | 219.36 | 243.74 |
| 30 | 25.24 | 50.48 | 75.72 | 100.96 | 126.20 | 151.44 | 176.68 | 201.92 | 227.16 | 252.40 |
| 15 | 26.11 | 52.21 | 78.32 | 104.42 | 130.53 | 156.63 | 182.74 | 208.84 | 234.95 | 261.05 |
| 30 | 26.97 | 53.94 | 80.91 | 107.88 | 134.85 | 161.82 | 188.79 | 215.76 | 242.73 | 269.70 |
| 16 | 27.83 | 55.67 | 83.50 | 111.34 | 139.17 | 167.01 | 194.84 | 222.68 | 250.51 | 278.35 |
| 30 | 28.70 | 57.40 | 86.10 | 114.79 | 143.49 | 172.19 | 200.89 | 229.59 | 258.29 | 286.99 |
| 17 | 29.56 | 59.12 | 88.69 | 118.25 | 147.81 | 177.37 | 206.93 | 236.50 | 266.06 | 295.62 |
| 30 | 30.42 | 60.85 | 91.27 | 121.70 | 152.12 | 182.55 | 212.97 | 243.40 | 273.82 | 304.25 |
| 18 | 31.29 | 62.57 | 93.86 | 125.15 | 156.43 | 187.72 | 219.01 | 250.30 | 281.58 | 312.87 |
| 30 | 32.15 | 64.30 | 96.45 | 128.59 | 160.74 | 192.89 | 225.04 | 257.19 | 289.34 | 321.49 |
| 19 | 33.01 | 66.02 | 99.03 | 132.04 | 165.05 | 198.06 | 231.07 | 264.08 | 297.08 | 330.09 |
| 30 | 33.87 | 67.74 | 101.61 | 135.48 | 169.35 | 203.22 | 237.09 | 270.96 | 304.83 | 338.70 |
| 20 | 34.73 | 69.46 | 104.19 | 138.92 | 173.65 | 208.38 | 243.11 | 277.84 | 312.57 | 347.30 |
| 30 | 35.59 | 71.18 | 106.77 | 142.35 | 177.94 | 213.53 | 249.12 | 284.71 | 320.30 | 355.89 |
| 21 | 36.45 | 72.89 | 109.34 | 145.79 | 182.24 | 218.68 | 255.13 | 291.58 | 328.02 | 364.47 |
| 30 | 37.30 | 74.61 | 111.91 | 149.22 | 186.52 | 223.83 | 261.13 | 298.44 | 335.74 | 373.05 |
| 22 | 38.16 | 76.32 | 114.49 | 152.65 | 190.81 | 228.97 | 267.13 | 305.29 | 343.46 | 381.62 |
| 30 | 39.02 | 78.04 | 117.05 | 156.07 | 195.09 | 234.11 | 273.13 | 312.14 | 351.16 | 390.18 |
| 23 | 39.87 | 79.75 | 119.62 | 159.49 | 199.37 | 239.24 | 279.12 | 318.99 | 358.86 | 398.74 |
| 30 | 40.73 | 81.46 | 122.19 | 162.91 | 203.64 | 244.37 | 285.10 | 325.83 | 366.56 | 407.28 |
| 24 | 41.58 | 83.16 | 124.75 | 166.33 | 207.91 | 249.49 | 291.08 | 332.66 | 374.24 | 415.82 |
| 30 | 42.44 | 84.87 | 127.31 | 169.74 | 212.18 | 254.61 | 297.05 | 339.48 | 381.92 | 424.36 |
| 25 | 43.29 | 86.58 | 129.86 | 173.15 | 216.44 | 259.73 | 303.02 | 364.30 | 389.59 | 432.88 |
| 30 | 44.14 | 88.28 | 132.42 | 176.56 | 220.70 | 264.84 | 308.98 | 353.12 | 397.26 | 441.39 |
| 26 | 44.99 | 89.98 | 134.97 | 179.96 | 224.95 | 269.94 | 314.93 | 359.92 | 404.91 | 449.90 |
| 30 | 45.84 | 91.68 | 137.52 | 183.36 | 229.20 | 275.04 | 320.88 | 366.72 | 412.56 | 458.40 |
| 27 | 46.69 | 93.38 | 140.07 | 186.76 | 233.45 | 280.14 | 326.82 | 373.51 | 420.20 | 466.89 |
| 30 | 47.54 | 95.07 | 142.61 | 190.15 | 237.69 | 285.22 | 332.76 | 380.30 | 427.83 | 475.37 |
| 28 | 48.38 | 96.77 | 145.15 | 193.54 | 241.92 | 290.31 | 338.69 | 387.08 | 435.46 | 483.84 |
| 30 | 49.23 | 98.46 | 147.69 | 196.92 | 246.15 | 295.38 | 344.62 | 393.85 | 443.08 | 492.31 |
| 29 | 50.08 | 100.15 | 150.23 | 200.30 | 250.38 | 300.46 | 350.53 | 400.16 | 450.68 | 500.76 |
| 30 | 50.92 | 101.84 | 152.76 | 203.68 | 254.60 | 305.52 | 356.44 | 407.36 | 458.28 | 509.20 |
| 30 | 51.76 | 103.53 | 155.29 | 207.06 | 258.82 | 310.59 | 362.35 | 414.11 | 465.87 | 517.64 |

# TABLE X.—COEFFICIENTS FOR VALVOID ARCS

## I.—Ratio of $u = \frac{i}{\Delta}$.

| L | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° | 100° | 110° | 120° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | .3518 | .3516 | .3514 | .3510 | .3506 | .3500 | .3493 | .3485 | .3476 | .3466 | .3455 | .3444 |
| 400 | .3437 | .3436 | .3433 | .3430 | .3426 | .3421 | .3415 | .3408 | .3399 | .3390 | .3380 | .3368 |
| 500 | .3400 | .3398 | .3396 | .3393 | .3389 | .3383 | .3379 | .3372 | .3364 | .3356 | .3345 | .3335 |
| 600 | .3379 | .3378 | .3376 | .3373 | .3369 | .3365 | .3359 | .3353 | .3345 | .3337 | .3327 | .3317 |
| 700 | .3367 | .3366 | .3364 | .3361 | .3357 | .3353 | .3347 | .3341 | .3334 | .3326 | .3316 | .3306 |
| 800 | .3359 | .3358 | .3356 | .3353 | .3349 | .3345 | .3340 | .3333 | .3326 | .3318 | .3309 | .3299 |
| 900 | .3353 | .3352 | .3350 | .3348 | .3344 | .3340 | .3334 | .3328 | .3321 | .3313 | .3304 | .3294 |
| 1000 | .3350 | .3348 | .3346 | .2344 | .3340 | .3336 | .3331 | .3324 | .3317 | .3310 | .3301 | .3291 |
| 1200 | .3345 | .3343 | .3341 | .3339 | .3336 | .3331 | .3326 | .3320 | .3313 | .3305 | .3296 | .3286 |
| 1500 | .3340 | .3339 | .3337 | .3335 | .3331 | .3327 | .3322 | .3316 | .3309 | .3301 | .3292 | .3283 |
| 2000 | .3337 | .3336 | .2333 | .3331 | .3328 | .3324 | .3319 | .3313 | .3306 | .3298 | .3289 | .3280 |

## II.—Ratio of $v = \frac{r}{L}$.

| L | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° | 100° | 110° | 120° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | .7706 | .7683 | .7643 | .7588 | .7518 | .7432 | .7332 | .7218 | .7090 | .6949 | .6795 | .6630 |
| 400 | .7611 | .7588 | .7549 | .7495 | .7425 | .7341 | .7243 | .7130 | .7004 | .6865 | .6714 | 6551 |
| 500 | .7568 | .7545 | .7506 | .7452 | .7384 | .7300 | .7202 | .7091 | .6966 | .6828 | .6678 | .6516 |
| 600 | .7545 | .7522 | .7483 | .7430 | .7361 | .7278 | .7181 | .7070 | .6946 | .6808 | .6659 | 6498 |
| 700 | .7531 | .7508 | .7469 | .7416 | .7348 | .7265 | .7168 | .7057 | .6933 | .6797 | .6648 | 6487 |
| 800 | .7522 | .7499 | .7461 | .7407 | .7339 | .7257 | .7160 | .7049 | .6926 | .6789 | .6640 | .6480 |
| 900 | .7516 | .7492 | .7454 | .7401 | .7333 | .7251 | .7154 | .7044 | .6920 | .6784 | .6635 | .6475 |
| 1000 | .7512 | .7489 | .7450 | .7397 | .7329 | .7247 | .7150 | .7040 | .6917 | .6780 | .6632 | .6472 |
| 1200 | .7505 | .7483 | .7444 | .7391 | .7324 | .7241 | .7145 | .7035 | .6912 | .6775 | .6627 | .6468 |
| 1500 | .7501 | .7478 | .7440 | .7387 | .7319 | .7237 | .7141 | .7031 | .6908 | .6772 | .6624 | .6464 |
| 2000 | .7497 | .7474 | .7436 | .7383 | .7316 | .7234 | .7137 | .7028 | .6904 | .6769 | .6621 | .6461 |

## III.—Ratio of $l_{,} = \frac{l}{\Delta' - \Delta''}$ = Length of Valvoid Arc corresponding to a Change of One Degree in the Angle $\Delta$.

| L | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° | 100° | 110° | 120° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 2.62 | 2.61 | 2.60 | 2.59 | 2.57 | 2.55 | 2.52 | 2.49 | 2.46 | 2.42 | 2.38 | 2.34 |
| 400 | 3.49 | 3.48 | 3.46 | 3.44 | 3.42 | 3.38 | 3.35 | 3.30 | 3.25 | 3.20 | 3.14 | 3.08 |
| 500 | 4.36 | 4.35 | 4.33 | 4.30 | 4.26 | 4.22 | 4.17 | 4.11 | 4.05 | 3.98 | 3.90 | 3.81 |
| 600 | 5.23 | 5.22 | 5.19 | 5.16 | 5.11 | 5.06 | 4.99 | 4.92 | 4.84 | 4.75 | 4.65 | 4.55 |
| 700 | 6.10 | 6.09 | 6.06 | 6.02 | 5.96 | 5.90 | 5.83 | 5.74 | 5.65 | 5.54 | 5.43 | 5.31 |
| 800 | 6.97 | 6.95 | 6.92 | 6.87 | 6.82 | 6.74 | 6.66 | 6.56 | 6.45 | 6.33 | 6.20 | 6.06 |
| 900 | 7.85 | 7.82 | 7.79 | 7.73 | 7.67 | 7.59 | 7.49 | 7.38 | 7.26 | 7.13 | 6.98 | 6.82 |
| 1000 | 8.72 | 8.69 | 8.65 | 8.59 | 8.52 | 8.43 | 8.32 | 8.20 | 8.07 | 7.92 | 7.75 | 7.58 |
| 1100 | 9.59 | 9.56 | 9.52 | 9.45 | 9.37 | 9.27 | 9.16 | 9.02 | 8.87 | 8.71 | 8.53 | 8.34 |
| 1200 | 10.46 | 10.43 | 10.38 | 10.31 | 10.22 | 10.11 | 9.99 | 9.84 | 9.68 | 9.50 | 9.31 | 9.09 |
| 1300 | 11.33 | 11.30 | 11.25 | 11.17 | 11.07 | 10.96 | 10.82 | 10.66 | 10.49 | 10.29 | 10.08 | 9.85 |
| 1400 | 12.21 | 12.17 | 12.11 | 12.03 | 11.93 | 11.80 | 11.65 | 11.48 | 11.29 | 11.08 | 10.86 | 10.61 |
| 1500 | 13.08 | 13.04 | 12.98 | 12.89 | 12.78 | 12.64 | 12.48 | 12.30 | 12.10 | 11.88 | 11.63 | 11.37 |
| 1600 | 13.95 | 13.91 | 13.84 | 13.75 | 13.63 | 13.49 | 13.32 | 13.12 | 12.91 | 12.67 | 12.41 | 12.13 |
| 1700 | 14.82 | 14.78 | 14.71 | 14.61 | 14.48 | 14.33 | 14.15 | 13.94 | 13.71 | 13.46 | 13.18 | 12.88 |
| 1800 | 15.69 | 15.65 | 15.57 | 15.47 | 15.33 | 15.17 | 14.98 | 14.76 | 14.52 | 14.25 | 13.96 | 13.64 |
| 1900 | 16.57 | 16.52 | 16.44 | 16.33 | 16.19 | 16.01 | 15.81 | 15.58 | 15.33 | 15.04 | 14.73 | 14.40 |
| 2000 | 17.44 | 17.39 | 17.30 | 17.19 | 17.04 | 16.86 | 16.65 | 16.40 | 16.13 | 15.83 | 15.51 | 15.16 |

# TABLE XI.—TURNOUTS AND SWITCHES FROM A STRAIGHT TRACK. §§ 180, 181, 182.

GAUGE, 4 FEET 8½ INCHES = 4.708. THROW, 5 INCHES = 0.417.

| No. *n.* | Angle *F.* | Dist. *BF.* | Chord *af.* | Switch *AD.* | Radius *r.* | Log'thm. *log. r.* | Degree of Curve. |
|---|---|---|---|---|---|---|---|
| 4 | 14° 15′ 00″ | 37.664 | 37.373 | 11.209 | 150.656 | 2.177986 | 38° 45′ 57″ |
| 4½ | 12 40 49 | 42.372 | 42.113 | 12.610 | 190.674 | 2.280292 | 30 24 09 |
| 5 | 11 25 16 | 47.080 | 46.846 | 14.012 | 235.400 | 2.371806 | 24 31 36 |
| 5½ | 10 23 20 | 51.788 | 51.575 | 15.413 | 284.834 | 2.454592 | 20 13 13 |
| 6 | 9 31 39 | 56.496 | 56.301 | 16.814 | 338.976 | 2.530169 | 16 57 52 |
| 6½ | 8 47 51 | 61.204 | 61.024 | 18.215 | 397.826 | 2.599693 | 14 26 25 |
| 7 | 8 10 16 | 65.912 | 65.744 | 19.616 | 461.384 | 2.664063 | 12 26 34 |
| 7½ | 7 37 41 | 70.620 | 70.464 | 21.017 | 529.650 | 2.723989 | 10 50 02 |
| 8 | 7 09 10 | 75.328 | 75.181 | 22.418 | 602.624 | 2.780046 | 9 31 07 |
| 8½ | 6 43 59 | 80.036 | 79.898 | 23.820 | 680.306 | 2.832704 | 8 25 47 |
| 9 | 6 21 35 | 84.744 | 84.613 | 25.221 | 762.696 | 2.882352 | 7 31 04 |
| 9½ | 6 01 32 | 89.452 | 89.328 | 26.622 | 849.794 | 2.929314 | 6 44 46 |
| 10 | 5 43 29 | 94.160 | 94.043 | 28.023 | 941.600 | 2.973866 | 6 05 16 |
| 10½ | 5 27 09 | 98.868 | 93.756 | 29.424 | 1038.114 | 3.016245 | 5 31 17 |
| 11 | 5 12 18 | 103.576 | 103.469 | 30.825 | 1139.336 | 3.056652 | 5 01 50 |
| 11½ | 4 58 45 | 108.284 | 108.182 | 32.227 | 1245.266 | 3.095262 | 4 36 08 |
| 12 | 4 46 19 | 112.992 | 112.894 | 33.628 | 1355.904 | 3.132229 | 4 13 36 |

GAUGE, 3 FEET. THROW, 4 INCHES = 0.333.

| No. *n.* | Angle *F.* | Dist. *BF.* | Chord *af.* | Switch *AD.* | Radius *r.* | Log'thm. *log. r.* | Degree of Curve. |
|---|---|---|---|---|---|---|---|
| 4 | 14° 15′ 00″ | 24 | 23.815 | 8 | 96.0 | 1.982271 | 62° 46′ 34″ |
| 4½ | 12 40 49 | 27 | 26.835 | 9 | 121.5 | 2.084576 | 48 36 04 |
| 5 | 11 25 16 | 30 | 29.851 | 10 | 150.0 | 2.176091 | 38 56 33 |
| 5½ | 10 23 20 | 33 | 32.865 | 11 | 181.5 | 2.258877 | 31 58 55 |
| 6 | 9 31 39 | 36 | 35.876 | 12 | 216.0 | 2.334454 | 26 46 07 |
| 6½ | 8 47 51 | 39 | 38.885 | 13 | 253.5 | 2.403978 | 22 45 04 |
| 7 | 8 10 16 | 42 | 41.893 | 14 | 294.0 | 2.468347 | 19 35 01 |
| 7½ | 7 37 41 | 45 | 44.900 | 15 | 337.5 | 2.528274 | 17 02 21 |
| 8 | 7 09 10 | 48 | 47.906 | 16 | 384.0 | 2.584331 | 14 57 48 |
| 8½ | 6 43 59 | 51 | 50.912 | 17 | 433.5 | 2.636989 | 13 14 47 |
| 9 | 6 21 35 | 54 | 53.917 | 18 | 486.0 | 2.686636 | 11 48 37 |
| 9½ | 6 01 32 | 57 | 56.921 | 19 | 541.5 | 2.733598 | 10 35 46 |
| 10 | 5 43 29 | 60 | 59.925 | 20 | 600.0 | 2.778151 | 9 33 38 |
| 10½ | 5 27 09 | 63 | 62.929 | 21 | 661.5 | 2.820530 | 8 40 12 |
| 11 | 5 12 18 | 66 | 65.932 | 22 | 726.0 | 2.860937 | 7 53 54 |
| 11½ | 4 58 45 | 69 | 68.935 | 23 | 793.5 | 2.899547 | 7 13 32 |
| 12 | 4 46 19 | 72 | 71.938 | 24 | 864.0 | 2.936514 | 6 38 06 |

ANGLE AND DISTANCE OF MIDDLE FROG, *F″*

| No. *n.* | No. *n″.* | Angle *F″.* | Gauge 4, 8½. Dist. *aF″.* | Gauge 3. Dist. *aF″.* | No. *n.* | No. *n″.* | Angle *F″.* | Gauge 4, 8½. Dist. *aF″.* | Gauge 3. Dist. *aF″.* |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 2.817 | 20° 07′ 36″ | 26.736 | 17.037 | 8 | 5.651 | 10° 06′ 44″ | 53.317 | 33.974 |
| 4½ | 3.172 | 17 54 52 | 30.054 | 19.151 | 8½ | 6.005 | 9 31 08 | 56.643 | 36.094 |
| 5 | 3.527 | 16 08 19 | 33.374 | 21.266 | 9 | 6.359 | 8 59 30 | 59.969 | 38.213 |
| 5½ | 3.881 | 14 40 58 | 36.695 | 23.383 | 9½ | 6.713 | 8 31 10 | 63.296 | 40.333 |
| 6 | 4.235 | 13 27 57 | 40.018 | 25.500 | 10 | 7.067 | 8 05 40 | 66.623 | 42.453 |
| 6½ | 4.589 | 12 26 07 | 43.342 | 27.618 | 10½ | 7.420 | 7 42 35 | 69.950 | 44.573 |
| 7 | 4.943 | 11 33 04 | 46.666 | 29.736 | 11 | 7.774 | 7 21 36 | 73.277 | 46.693 |
| 7½ | 5.297 | 10 47 02 | 49.991 | 31 855 | 11½ | 8.128 | 7 02 26 | 76.605 | 48.813 |
| 8 | 5.651 | 10 06 44 | 53.317 | 33.974 | 12 | 8.482 | 6 44 51 | 79.932 | 50.934 |

| D | Length of Rail-Chord. 32 | 30 | 28 | 26 | 24 | 22 | 20 | 18 | 16 | 14 | 12 | 10 | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1° | .022 | .020 | .017 | .015 | .013 | .011 | .009 | .007 | .006 | .004 | .003 | .002 | 1° |
| 2 | .045 | .039 | .034 | .030 | .025 | .021 | .017 | .014 | .011 | .009 | .006 | .004 | 2 |
| 3 | .067 | .059 | .051 | .044 | .038 | .032 | .026 | .021 | .017 | .013 | .009 | .007 | 3 |
| 4 | .089 | .079 | .068 | .059 | .050 | .042 | .035 | .028 | .022 | .017 | .013 | .009 | 4 |
| 5 | .112 | .098 | .086 | .074 | .063 | .053 | .044 | .035 | .028 | .021 | .016 | .011 | 5 |
| 6 | .134 | .118 | .103 | .088 | .075 | .063 | .052 | .042 | .034 | .026 | .019 | .013 | 6 |
| 7 | .156 | .137 | .120 | .103 | .088 | .074 | .061 | .049 | .039 | .030 | .022 | .015 | 7 |
| 8 | .179 | .157 | .137 | .118 | .100 | .084 | .070 | .057 | .045 | .034 | .025 | .017 | 8 |
| 9 | .201 | .177 | .154 | .133 | .113 | .095 | .078 | .064 | .050 | .038 | .028 | .020 | 9 |
| 10 | .223 | .196 | .171 | .147 | .126 | .105 | .087 | .071 | .056 | .043 | .031 | .022 | 10 |
| 11 | .245 | .216 | .188 | .162 | .138 | .116 | .096 | .078 | .061 | .047 | .035 | .024 | 11 |
| 12 | .268 | .235 | .205 | .177 | .151 | .127 | .105 | .085 | .067 | .051 | .038 | .026 | 12 |
| 14 | .312 | .274 | .238 | .206 | .175 | .147 | .122 | .099 | .078 | .060 | .044 | .030 | 14 |
| 16 | .356 | .313 | .273 | .235 | .200 | .168 | .139 | .113 | .089 | .068 | .050 | .035 | 16 |
| 18 | .400 | .352 | .307 | .264 | .225 | .189 | .156 | .127 | .100 | .077 | .056 | .039 | 18 |
| 20 | .445 | .391 | .340 | .293 | .250 | .210 | .174 | .141 | .111 | .085 | .063 | .043 | 20 |
| 24 | .531 | .467 | .407 | .351 | .299 | .251 | .207 | .168 | .133 | .102 | .075 | .052 | 24 |
| 28 | .618 | .543 | .473 | .408 | .347 | .292 | .241 | .195 | .154 | .118 | .087 | .060 | 28 |
| 32 | .705 | .619 | .539 | .465 | .396 | .333 | .275 | .223 | .176 | .135 | .099 | .069 | 32 |
| 36 | .791 | .696 | .606 | .522 | .445 | .373 | .309 | .250 | .197 | .151 | .111 | .077 | 36 |
| 40 | .878 | .772 | .672 | .579 | .493 | .414 | .342 | .277 | .219 | .168 | .123 | .086 | 40 |
| 45 | .983 | .863 | .752 | .648 | .552 | .463 | .383 | .305 | .245 | .188 | .137 | .096 | 45 |
| 50 | 1.087 | .955 | .831 | .716 | .610 | .512 | .423 | .343 | .271 | .207 | .152 | .106 | 50 |

## TABLE XIII.—DIFFERENCE IN ELEVATION OF RAILS ON CURVES. § 201.

| D | Velocity in Miles per Hour. 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 | D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .006 | .013 | .023 | .036 | .051 | .070 | .091 | .116 | .143 | .206 | 1 |
| 2 | .011 | .026 | .046 | .071 | .103 | .140 | .183 | .231 | .285 | .410 | 2 |
| 3 | .017 | .039 | .069 | .107 | .154 | .210 | .274 | .346 | .427 | .612 | 3 |
| 4 | .023 | .051 | .091 | .143 | .206 | .280 | .365 | .461 | .568 | .811 | 4 |
| 5 | .029 | .064 | .114 | .179 | .257 | .349 | .455 | .574 | .707 | 1.006 | 5 |
| 6 | .034 | .077 | .137 | .214 | .308 | .418 | .545 | .687 | .844 | 1.196 | 6 |
| 7 | .040 | .090 | .160 | .250 | .359 | .487 | .634 | .798 | .979 | | |
| 8 | .046 | .103 | .183 | .285 | .410 | .556 | .723 | .908 | 1.112 | | |
| 9 | .051 | .116 | .206 | .320 | .460 | .624 | .811 | 1.017 | | | |
| 10 | .057 | .129 | .228 | .356 | .511 | .692 | .898 | 1.124 | | | |
| 11 | .063 | .142 | .251 | .391 | .561 | .760 | .984 | | | | |
| 12 | .069 | .154 | .274 | .427 | .611 | .826 | 1.069 | | | | |
| 14 | .080 | .180 | .319 | .497 | .711 | .959 | | | | | |
| 16 | .091 | .206 | .365 | .567 | .809 | 1.088 | | | | | |
| 18 | .102 | .231 | .410 | .637 | .906 | | | | | | |
| 20 | .114 | .256 | .455 | .707 | 1.002 | | | | | | |
| 25 | .141 | .318 | .563 | .775 | | | | | | | |
| 30 | .168 | .880 | .672 | .844 | | | | | | | |
| 35 | .195 | .441 | .778 | | | | | | | | |
| 40 | .222 | .501 | .881 | | | | | | | | |
| 50 | .276 | .618 | | | | | | | | | |

## TABLE XIV.—GRADES AND GRADE ANGLES.

| Feet per Station. | Feet per Mile. | Inclination. | Feet per Station. | Feet per Mile. | Inclination. | Feet per Station. | Feet per Mile. | Inclination. |
|---|---|---|---|---|---|---|---|---|
| | | ° ′ ″ | | | ° ′ ″ | | | ° ′ |
| .01 | .528 | 21 | .51 | 26.928 | 17 32 | 1.01 | 53.328 | 34 43 |
| .02 | 1.056 | 41 | .52 | 27.456 | 17 53 | 1.02 | 53.856 | 35 04 |
| .03 | 1.584 | 1 02 | .53 | 27.984 | 18 13 | 1.03 | 54.384 | 35 24 |
| .04 | 2.112 | 1 23 | .54 | 28.512 | 18 34 | 1.04 | 54.912 | 35 45 |
| .05 | 2.640 | 1 43 | .55 | 29.040 | 18 54 | 1.05 | 55.440 | 36 05 |
| .06 | 3.168 | 2 04 | .56 | 29.568 | 19 15 | 1.06 | 55.968 | 36 26 |
| .07 | 3.696 | 2 24 | .57 | 30.096 | 19 36 | 1.07 | 56.496 | 36 47 |
| .08 | 4.224 | 2 45 | .58 | 30.624 | 19 56 | 1.08 | 57.024 | 37 08 |
| .09 | 4.752 | 3 06 | .59 | 31.152 | 20 17 | 1.09 | 57.552 | 37 28 |
| .10 | 5.280 | 3 26 | .60 | 31.680 | 20 38 | 1.10 | 58.080 | 37 49 |
| .11 | 5.808 | 3 47 | .61 | 32.208 | 20 58 | 1.11 | 58.608 | 38 09 |
| .12 | 6.336 | 4 08 | .62 | 32.736 | 21 19 | 1.12 | 59.136 | 38 30 |
| .13 | 6.864 | 4 28 | .63 | 33.264 | 21 39 | 1.13 | 59.664 | 38 51 |
| .14 | 7.392 | 4 49 | .64 | 33.792 | 22 00 | 1.14 | 60.192 | 39 11 |
| .15 | 7.920 | 5 09 | .65 | 34.320 | 22 21 | 1.15 | 60.720 | 39 32 |
| .16 | 8.448 | 5 30 | .66 | 34.848 | 22 41 | 1.16 | 61.248 | 39 53 |
| .17 | 8.976 | 5 51 | .67 | 35.376 | 23 02 | 1.17 | 61.776 | 40 13 |
| .18 | 9.504 | 6 11 | .68 | 35.904 | 23 23 | 1.18 | 62.304 | 40 34 |
| .19 | 10.032 | 6 32 | .69 | 36.432 | 23 43 | 1.19 | 62.832 | 40 54 |
| .20 | 10.560 | 6 53 | .70 | 36.960 | 24 04 | 1.20 | 63.360 | 41 15 |
| .21 | 11.088 | 7 13 | .71 | 37.488 | 24 24 | 1.21 | 63.888 | 41 35 |
| .22 | 11.616 | 7 34 | .72 | 38.016 | 24 45 | 1.22 | 64.416 | 41 56 |
| .23 | 12.144 | 7 54 | .73 | 38.544 | 25 06 | 1.23 | 64.944 | 42 17 |
| .24 | 12.672 | 8 15 | .74 | 39.072 | 25 26 | 1.24 | 65.472 | 42 38 |
| .25 | 13.200 | 8 36 | .75 | 39.600 | 25 47 | 1.25 | 66.000 | 42 58 |
| .26 | 13.728 | 8 56 | .76 | 40.128 | 26 08 | 1.26 | 66.528 | 43 19 |
| .27 | 14.256 | 9 17 | .77 | 40.656 | 26 28 | 1.27 | 67.056 | 43 39 |
| .28 | 14.784 | 9 38 | .78 | 41.184 | 26 49 | 1.28 | 67.584 | 44 00 |
| .29 | 15.312 | 9 58 | .79 | 41.712 | 27 09 | 1.29 | 68.112 | 44 21 |
| .30 | 15.840 | 10 19 | .80 | 42.240 | 27 30 | 1.30 | 68.640 | 44 41 |
| .31 | 16.368 | 10 39 | .81 | 42.768 | 27 51 | 1.31 | 69.168 | 45 02 |
| .32 | 16.896 | 11 00 | .82 | 43.296 | 28 11 | 1.32 | 69.696 | 45 23 |
| .33 | 17.424 | 11 21 | .83 | 43.824 | 28 32 | 1.33 | 70.224 | 45 43 |
| .34 | 17.952 | 11 41 | .84 | 44.352 | 28 53 | 1.34 | 70.752 | 46 04 |
| .35 | 18.480 | 12 02 | .85 | 44.880 | 29 13 | 1.35 | 71.280 | 46 24 |
| .36 | 19.008 | 12 23 | .86 | 45.408 | 29 34 | 1.36 | 71.808 | 46 45 |
| .37 | 19.536 | 12 43 | .87 | 45.936 | 29 54 | 1.37 | 72.336 | 47 06 |
| .38 | 20.064 | 13 04 | .88 | 46.464 | 30 15 | 1.38 | 72.864 | 47 26 |
| .39 | 20.592 | 13 24 | .89 | 46.992 | 30 36 | 1.39 | 73.392 | 47 47 |
| .40 | 21.120 | 13 45 | .90 | 47.520 | 30 57 | 1.40 | 73.920 | 48 08 |
| .41 | 21.648 | 14 06 | .91 | 48.048 | 31 17 | 1.41 | 74.448 | 48 28 |
| .42 | 22.176 | 14 26 | .92 | 48.576 | 31 38 | 1.42 | 74.976 | 48 49 |
| .43 | 22.704 | 14 47 | .93 | 49.104 | 31 58 | 1.43 | 75.504 | 49 09 |
| .44 | 23.232 | 15 08 | .94 | 49.632 | 32 19 | 1.44 | 76.032 | 49 30 |
| .45 | 23.760 | 15 28 | .95 | 50.160 | 32 39 | 1.45 | 76.560 | 49 51 |
| .46 | 24.288 | 15 49 | .96 | 50.688 | 33 00 | 1.46 | 77.088 | 50 11 |
| .47 | 24.816 | 16 09 | .97 | 51.216 | 33 21 | 1.47 | 77.616 | 50 32 |
| .48 | 25.344 | 16 30 | .98 | 51.744 | 33 41 | 1.48 | 78.144 | 50 52 |
| .49 | 25.872 | 16 51 | .99 | 52.272 | 34 02 | 1.49 | 78.672 | 51 13 |
| .50 | 26.400 | 17 11 | 1.00 | 52.800 | 34 23 | 1.50 | 79.200 | 51 34 |

TABLE XIV.—GRADES AND GRADE ANGLES.

| Feet per Station. | Feet per Mile. | Inclination. | Feet per Station. | Feet per Mile. | Inclination. | Feet per Station. | Feet per Mile. | Inclination. |
|---|---|---|---|---|---|---|---|---|
| | | ° ′ ″ | | | ° ′ ″ | | | ° ′ ″ |
| 1.51 | 79.728 | 51 54 | 2.05 | 108.240 | 1 10 28 | 5.10 | 269.280 | 2 55 10 |
| 1.52 | 80.256 | 52 15 | 2.10 | 110.880 | 1 12 11 | 5.20 | 274.560 | 2 58 36 |
| 1.53 | 80.784 | 52 36 | 2.15 | 113.520 | 1 13 54 | 5.30 | 279.840 | 3 02 09 |
| 1.54 | 81.312 | 52 56 | 2.20 | 116.160 | 1 15 37 | 5.40 | 285.120 | 3 05 27 |
| 1.55 | 81.840 | 53 17 | 2.25 | 118.800 | 1 17 20 | 5.50 | 290.400 | 3 08 53 |
| 1.56 | 82.368 | 53 37 | 2.30 | 121.440 | 1 19 03 | 5.60 | 295.680 | 3 12 19 |
| 1.57 | 82.896 | 53 58 | 2.35 | 124.080 | 1 20 46 | 5.70 | 300.960 | 3 15 44 |
| 1.58 | 83.424 | 54 19 | 2.40 | 126.720 | 1 22 29 | 5.80 | 306.240 | 3 19 10 |
| 1.59 | 83.952 | 54.39 | 2.45 | 129.360 | 1 24 12 | 5.90 | 311.520 | 3 22 36 |
| 1.60 | 84.480 | 55 00 | 2.50 | 132.000 | 1 25 56 | 6.00 | 316.800 | 3 26 01 |
| 1.61 | 85.008 | 55 21 | 2.55 | 134.640 | 1 27 39 | 6.10 | 322.080 | 3 29 27 |
| 1.62 | 85.536 | 55 41 | 2.60 | 137.280 | 1 29 22 | 6.20 | 327.360 | 3 32 52 |
| 1.63 | 86.064 | 56 02 | 2.65 | 139.920 | 1 31 05 | 6.30 | 332.640 | 3 36 18 |
| 1.64 | 86.592 | 56 22 | 2.70 | 142.560 | 1 32 48 | 6.40 | 337.920 | 3 39 43 |
| 1.65 | 87.120 | 56 43 | 2.75 | 145.200 | 1 34 31 | 6.50 | 343.200 | 3 43 08 |
| 1.66 | 87.648 | 57 04 | 2.80 | 147.840 | 1 36 14 | 6.60 | 348.480 | 3 46 34 |
| 1.67 | 88.176 | 57 24 | 2.85 | 150.480 | 1 37 57 | 6.70 | 353.760 | 3 49 59 |
| 1.68 | 88.704 | 57 45 | 2.90 | 153.120 | 1 39 40 | 6.80 | 359.040 | 3 53 24 |
| 1.69 | 89.232 | 58 06 | 2.95 | 155.760 | 1 41 23 | 6.90 | 364.320 | 3 56 50 |
| 1.70 | 89.760 | 58 26 | 3.00 | 158.400 | 1 43 06 | 7.00 | 369.600 | 4 00 15 |
| 1.71 | 90.288 | 58 47 | 3.05 | 161.040 | 1 44 49 | 7.10 | 374.880 | 4 03 40 |
| 1.72 | 90.816 | 59 07 | 3.10 | 163.680 | 1 46 32 | 7.20 | 380.160 | 4 07 06 |
| 1.73 | 91.344 | 59 28 | 3.15 | 166.320 | 1 48 15 | 7.30 | 385.440 | 4 10 31 |
| 1.74 | 91.872 | 59 49 | 3.20 | 168.960 | 1 49 58 | 7.40 | 390.720 | 4 13 56 |
| 1.75 | 92.400 | 1 00 09 | 3.25 | 171.600 | 1 51 41 | 7.50 | 396.000 | 4 17 21 |
| 1.76 | 92.928 | 1 00 30 | 3.30 | 174.240 | 1 53 24 | 7.60 | 401.280 | 4 20 46 |
| 1.77 | 93.456 | 1 00 51 | 3.35 | 176.880 | 1 55 07 | 7.70 | 406.560 | 4 24 11 |
| 1.78 | 93.984 | 1 01 11 | 3.40 | 179.520 | 1 56 50 | 7.80 | 411.840 | 4 27 36 |
| 1.79 | 94.512 | 1 01 32 | 3.45 | 182.160 | 1 58 33 | 7.90 | 417.120 | 4 31 01 |
| 1.80 | 95.040 | 1 01 52 | 3.50 | 184.800 | 2 00 16 | 8.00 | 422.400 | 4 34 26 |
| 1.81 | 95.568 | 1 02 13 | 3.55 | 187.440 | 2 01 59 | 8.10 | 427.680 | 4 37 51 |
| 1.82 | 96.096 | 1 02 34 | 3.60 | 190.080 | 2 03 42 | 8.20 | 432.960 | 4 41 16 |
| 1.83 | 96.624 | 1 02 54 | 3.65 | 192.720 | 2 05 25 | 8.30 | 438.240 | 4 44 41 |
| 1.84 | 97.152 | 1 03 15 | 3.70 | 195.360 | 2 07 08 | 8.40 | 443.520 | 4 48 06 |
| 1.85 | 97.680 | 1 03 35 | 3.75 | 198.000 | 2 08 51 | 8.50 | 448.800 | 4 51 30 |
| 1.86 | 98.208 | 1 03 56 | 3.80 | 200.640 | 2 10 34 | 8.60 | 454.080 | 4 54 55 |
| 1.87 | 98.736 | 1 04 17 | 3.85 | 203.280 | 2 12 17 | 8.70 | 459.360 | 4 58 20 |
| 1.88 | 99.264 | 1 04 37 | 3.90 | 205.920 | 2 14 00 | 8.80 | 464.640 | 5 01 44 |
| 1.89 | 99.792 | 1 04 58 | 3.95 | 208.560 | 2 15 43 | 8.90 | 469.920 | 5 05 10 |
| 1.90 | 100.320 | 1 05 19 | 4.00 | 211.200 | 2 17 26 | 9.00 | 475.200 | 5 08 34 |
| 1.91 | 100.848 | 1 05 39 | 4.10 | 216.480 | 2 20 52 | 9.10 | 480.480 | 5 11 59 |
| 1.92 | 101.376 | 1 06 00 | 4.20 | 221.760 | 2 24 18 | 9.20 | 485.760 | 5 15 23 |
| 1.93 | 101.904 | 1 06 20 | 4.30 | 227.040 | 2 27 44 | 9.30 | 491.040 | 5 18 48 |
| 1.94 | 102.432 | 1 06 41 | 4.40 | 232.320 | 2 31 10 | 9.40 | 496.320 | 5 22 12 |
| 1.95 | 102.960 | 1 07 02 | 4.50 | 237.600 | 2 34 36 | 9 50 | 501.600 | 5 25 37 |
| 1.96 | 103.488 | 1 07 22 | 4.60 | 242.880 | 2 38 01 | 9.60 | 506.880 | 5 29 01 |
| 1.97 | 104.016 | 1 07 43 | 4.70 | 248.160 | 2 41 27 | 9.70 | 512.160 | 5 32 25 |
| 1.98 | 104.544 | 1 08 04 | 4.80 | 253.440 | 2 44 53 | 9.80 | 517.440 | 5 35 50 |
| 1.99 | 105.072 | 1 08 24 | 4.90 | 258.720 | 2 48 19 | 9.90 | 522.720 | 5 39 14 |
| 2.00 | 105.600 | 1 08 45 | 5.00 | 264.000 | 2 51 45 | 10.00 | 528.000 | 5 42 38 |

# TABLE XV.—FOR OBTAINING BAROMETRIC HEIGHTS IN FEET.

| Barometer. Inches $= h$. | 0.00 | 0.02 | 0.04 | 0 06 | 0.08 | Diff. per .002 in. |
|---|---|---|---|---|---|---|
| **19°**.0 | 16832 | 16860 | 16888 | 16915 | 16943 | 2.8 |
| .1 | 16970 | 16997 | 17025 | 17052 | 17080 | 2.8 |
| .2 | 17107 | 17134 | 17162 | 17189 | 17216 | 2.7 |
| .3 | 17243 | 17270 | 17298 | 17325 | 17352 | 2.7 |
| .4 | 17379 | 17406 | 17433 | 17460 | 17487 | 2.7 |
| .5 | 17514 | 17540 | 17567 | 17594 | 17621 | 2.7 |
| .6 | 17648 | 17674 | 17701 | 17728 | 17755 | 2.7 |
| .7 | 17781 | 17808 | 17834 | 17861 | 17887 | 2.7 |
| .8 | 17914 | 17940 | 17967 | 17993 | 18020 | 2.7 |
| .9 | 18046 | 18072 | 18099 | 18125 | 18151 | 2.6 |
| **20°**.0 | 18178 | 18204 | 18230 | 18256 | 18282 | 2.6 |
| .1 | 18308 | 18334 | 18360 | 18386 | 18413 | 2.6 |
| .2 | 18438 | 18464 | 18490 | 18516 | 18542 | 2.6 |
| .3 | 18568 | 18594 | 18620 | 18645 | 18671 | 2.6 |
| .4 | 18697 | 18723 | 18748 | 18774 | 18799 | 2.6 |
| .5 | 18825 | 18851 | 18876 | 18902 | 18927 | 2.6 |
| .6 | 18953 | 18978 | 19004 | 19029 | 19054 | 2.5 |
| .7 | 19080 | 19105 | 19130 | 19156 | 19181 | 2.5 |
| .8 | 19206 | 19231 | 19256 | 19282 | 19307 | 2.5 |
| .9 | 19332 | 19357 | 19382 | 19407 | 19432 | 2.5 |
| **21°**.0 | 19457 | 19482 | 19507 | 19532 | 19557 | 2.5 |
| .1 | 19582 | 19606 | 19631 | 19656 | 19681 | 2.5 |
| .2 | 19706 | 19730 | 19755 | 19780 | 19804 | 2.5 |
| .3 | 19829 | 19854 | 19878 | 19903 | 19927 | 2.5 |
| .4 | 19952 | 19976 | 20001 | 20025 | 20050 | 2.5 |
| .5 | 20074 | 20098 | 20123 | 20147 | 20172 | 2.5 |
| .6 | 20196 | 20220 | 20244 | 20269 | 20293 | 2.4 |
| .7 | 20317 | 20341 | 20365 | 20389 | 20413 | 2.4 |
| .8 | 20438 | 20462 | 20486 | 20510 | 20534 | 2,4 |
| .9 | 20558 | 20581 | 20605 | 20629 | 20653 | 2.4 |
| **22°**.0 | 20677 | 20701 | 20725 | 20748 | 20772 | 2.4 |
| .1 | 20796 | 20820 | 20843 | 20867 | 20891 | 2.4 |
| .2 | 20914 | 20938 | 20962 | 20985 | 21009 | 2.4 |
| .3 | 21032 | 21056 | 21079 | 21103 | 21126 | 2.4 |
| .4 | 21150 | 21173 | 21196 | 21220 | 21243 | 2.3 |
| .5 | 21266 | 21290 | 21313 | 21336 | 21359 | 2.3 |
| .6 | 21383 | 21406 | 21429 | 21452 | 21475 | 2.3 |
| .7 | 21498 | 21522 | 21545 | 21568 | 21591 | 2.3 |
| .8 | 21614 | 21637 | 21660 | 21683 | 21706 | 2.3 |
| .9 | 21728 | 21751 | 21774 | 21797 | 21820 | 2.3 |
| **23°**.0 | 21843 | 21866 | 21888 | 21911 | 21934 | 2.3 |
| .1 | 21957 | 21979 | 22002 | 22025 | 22047 | 2.3 |
| .2 | 22070 | 22092 | 22115 | 22138 | 22160 | 2.3 |
| .3 | 22183 | 22205 | 22228 | 22250 | 22272 | 2.2 |
| .4 | 22295 | 22317 | 22340 | 22362 | 22384 | 2.2 |
| .5 | 22407 | 22429 | 22451 | 22474 | 22496 | 2.2 |
| .6 | 22518 | 22540 | 22562 | 22585 | 22607 | 2.2 |
| .7 | 22629 | 22651 | 22673 | 22695 | 22717 | 2.2 |
| .8 | 22739 | 22761 | 22783 | 22805 | 22827 | 2.2 |
| .9 | 22849 | 22871 | 22893 | 22915 | 22937 | 2.2 |
| **24°**.0 | 22959 | 22981 | 23003 | 23024 | 23046 | 2.2 |
| .1 | 23068 | 23090 | 23111 | 23133 | 23155 | 2.2 |
| .2 | 23176 | 23198 | 23220 | 23241 | 23263 | 2.2 |
| .3 | 23285 | 23306 | 23328 | 23349 | 23371 | 2.2 |
| .4 | 23392 | 23414 | 23435 | 23457 | 23478 | 2.2 |
| .5 | 23500 | 23521 | 23542 | 23564 | 23585 | 2.1 |
| .6 | 23606 | 23628 | 23649 | 23670 | 23692 | 2.1 |
| .7 | 23713 | 23734 | 23755 | 23776 | 23798 | 2.1 |
| .8 | 23819 | 23840 | 23861 | 23882 | 23903 | 2.1 |
| .9 | 23924 | 23945 | 23966 | 23987 | 24008 | 2 1 |

TABLE XV.—FOR OBTAINING BAROMETRIC HEIGHTS IN FEET.

| Barometer. Inches = $h$. | 0.00 | 0.02 | 0.04 | 0.06 | 0.08 | Diff. per .002 in. |
|---|---|---|---|---|---|---|
| **25°**.0 | 24029 | 24050 | 24071 | 24092 | 24113 | 2.1 |
| .1 | 24134 | 24155 | 24176 | 24197 | 24217 | 2.1 |
| .2 | 24238 | 24259 | 24280 | 24301 | 24321 | 2.1 |
| .3 | 24342 | 24363 | 24384 | 24404 | 24425 | 2.1 |
| .4 | 24446 | 24466 | 24487 | 24508 | 24528 | 2.1 |
| .5 | 24549 | 24569 | 24590 | 24610 | 24631 | 2.1 |
| .6 | 24651 | 24672 | 24692 | 24713 | 24733 | 2.0 |
| .7 | 24754 | 24774 | 24794 | 24815 | 24835 | 2.0 |
| .8 | 24855 | 24876 | 24896 | 24916 | 24937 | 2.0 |
| .9 | 24957 | 24977 | 24997 | 25018 | 25038 | 2.0 |
| **26°**.0 | 25058 | 25078 | 25098 | 25118 | 25138 | 2.0 |
| .1 | 25159 | 25179 | 25199 | 25219 | 25239 | 2.0 |
| .2 | 25259 | 25279 | 25299 | 25319 | 25339 | 2.0 |
| .3 | 25359 | 25379 | 25399 | 25419 | 25438 | 2.0 |
| .4 | 25458 | 25478 | 25498 | 25518 | 25538 | 2.0 |
| .5 | 25557 | 25577 | 25597 | 25617 | 25637 | 2.0 |
| .6 | 25656 | 25676 | 25696 | 25715 | 25735 | 2.0 |
| .7 | 25755 | 25774 | 25794 | 25813 | 25833 | 2.0 |
| .8 | 25853 | 25872 | 25892 | 25911 | 25931 | 2.0 |
| .9 | 25950 | 25970 | 25989 | 26009 | 26028 | 2.0 |
| **27°**.0 | 26048 | 26067 | 26086 | 26106 | 26125 | 1.9 |
| .1 | 26145 | 26164 | 26183 | 26203 | 26222 | 1.9 |
| .2 | 26241 | 26260 | 26280 | 26299 | 26318 | 1.9 |
| .3 | 26337 | 26357 | 26376 | 26395 | 26414 | 1.9 |
| .4 | 26433 | 26452 | 26472 | 26491 | 26510 | 1.9 |
| .5 | 26529 | 26548 | 26567 | 26586 | 26605 | 1.9 |
| .6 | 26624 | 26643 | 26662 | 26681 | 26700 | 1.9 |
| .7 | 26719 | 26738 | 26757 | 26776 | 26795 | 1.9 |
| .8 | 26813 | 26832 | 26851 | 26870 | 26889 | 1.9 |
| .9 | 26908 | 26926 | 26945 | 26964 | 26983 | 1.9 |
| **28°**.0 | 27001 | 27020 | 27039 | 27058 | 27076 | 1.9 |
| .1 | 27095 | 27114 | 27132 | 27151 | 27169 | 1.9 |
| .2 | 27188 | 27207 | 27225 | 27244 | 27262 | 1.9 |
| .3 | 27281 | 27299 | 27318 | 27336 | 27355 | 1.8 |
| .4 | 27373 | 27392 | 27410 | 27429 | 27447 | 1.8 |
| .5 | 27466 | 27484 | 27502 | 27521 | 27539 | 1.8 |
| .6 | 27557 | 27576 | 27594 | 27612 | 27631 | 1.8 |
| .7 | 27649 | 27667 | 27685 | 27704 | 27722 | 1.8 |
| .8 | 27740 | 27758 | 27777 | 27795 | 27813 | 1.8 |
| .9 | 27831 | 27849 | 27867 | 27885 | 27904 | 1.8 |
| **29°**.0 | 27922 | 27940 | 27958 | 27976 | 27994 | 1.8 |
| .1 | 28012 | 28030 | 28048 | 28066 | 28084 | 1.8 |
| .2 | 28102 | 28120 | 28138 | 28156 | 28174 | 1.8 |
| .3 | 28192 | 28209 | 28227 | 28245 | 28263 | 1.8 |
| .4 | 28281 | 28299 | 28317 | 28334 | 28352 | 1.8 |
| .5 | 28370 | 28388 | 28405 | 28423 | 28441 | 1.8 |
| .6 | 28459 | 28476 | 28494 | 28512 | 28529 | 1.8 |
| .7 | 28547 | 28565 | 28582 | 28600 | 28618 | 1.8 |
| .8 | 28635 | 28653 | 28670 | 28688 | 28706 | 1.8 |
| .9 | 28723 | 28741 | 28758 | 28776 | 28793 | 1.8 |
| **30°**.0 | 28811 | 28828 | 28846 | 28863 | 28881 | 1.8 |
| .1 | 28898 | 28915 | 28933 | 28950 | 28968 | 1.8 |
| .2 | 28985 | 29002 | 29020 | 29037 | 29054 | 1.7 |
| .3 | 29072 | 29089 | 29106 | 29124 | 29141 | 1.7 |
| .4 | 29158 | 29175 | 29192 | 29210 | 29227 | 1.7 |
| .5 | 29244 | 29261 | 29278 | 29296 | 29313 | 1.7 |
| .6 | 29330 | 29347 | 29364 | 29381 | 29398 | 1.7 |
| .7 | 29416 | 29433 | 29450 | 29467 | 29484 | 1.7 |
| .8 | 29501 | 29518 | 29535 | 29552 | 29569 | 1.7 |
| .9 | 29586 | 29603 | 29620 | 29637 | 29654 | 1.7 |

## TABLE XVI.—COEFFICIENT OF CORRECTION FOR TEMPERATURE.

| $t + t'$ | $\frac{t+t'-64°}{900}$ | $t + t'$ | $\frac{t+t'-64°}{900}$ | $t + t'$ | $\frac{t+t'-64°}{900}$ | $\iota + t'$ | $\frac{t+t'-64°}{900}$ |
|---|---|---|---|---|---|---|---|
| 20° | .0489 | 65° | + .0011 | 110° | + .0511 | 155° | .1011 |
| 21 | − .0478 | 66 | .0022 | 111 | .0522 | 156 | .1022 |
| 22 | .0467 | 67 | .0033 | 112 | .0533 | 157 | .1033 |
| 23 | .0456 | 68 | .0044 | 113 | .0544 | 158 | .1044 |
| 24 | .0444 | 69 | .0056 | 114 | .0556 | 159 | .1056 |
| 25 | .0433 | 70 | .0067 | 115 | .0567 | 160 | .1067 |
| 26 | .0422 | 71 | .0078 | 116 | .0578 | 161 | .1078 |
| 27 | .0411 | 72 | .0089 | 117 | .0589 | 162 | .1089 |
| 28 | .0400 | 73 | .0100 | 118 | .0600 | 163 | .1100 |
| 29 | .0389 | 74 | .0111 | 119 | .0611 | 164 | .1111 |
| 30 | .0378 | 75 | .0122 | 120 | + .0622 | 165 | .1122 |
| 31 | − .0367 | 76 | + .0133 | 121 | .0633 | 166 | + .1133 |
| 32 | .0356 | 77 | .0144 | 122 | .0644 | 167 | .1144 |
| 33 | .0344 | 78 | .0156 | 123 | .0656 | 168 | .1156 |
| 34 | .0333 | 79 | .0167 | 124 | .0667 | 169 | .1167 |
| 35 | .0322 | 80 | .0178 | 125 | .0678 | 170 | .1178 |
| 36 | .0311 | 81 | .0189 | 126 | .0689 | 171 | .1189 |
| 37 | .0300 | 82 | .0200 | 127 | .0700 | 172 | .1200 |
| 38 | .0289 | 83 | .0211 | 128 | .0711 | 173 | .1211 |
| 39 | .0278 | 84 | .0222 | 129 | .0722 | 174 | .1222 |
| 40 | .0267 | 85 | .0233 | 130 | + .0733 | 175 | .1233 |
| 41 | − .0256 | 86 | + .0244 | 131 | .0744 | 176 | + .1244 |
| 42 | .0244 | 87 | .0256 | 132 | .0756 | 177 | .1256 |
| 43 | .0233 | 88 | .0267 | 133 | .0767 | 178 | .1267 |
| 44 | .0222 | 89 | .0278 | 134 | .0778 | 179 | .1278 |
| 45 | .0211 | 90 | .0289 | 135 | .0789 | 180 | .1289 |
| 46 | .0200 | 91 | .0300 | 136 | .0800 | 181 | .1300 |
| 47 | .0189 | 92 | .0311 | 137 | .0811 | 182 | .1311 |
| 48 | .0178 | 93 | .0322 | 138 | .0822 | 183 | .1322 |
| 49 | .0167 | 94 | .0333 | 139 | .0833 | 184 | .1333 |
| 50 | − .0156 | 95 | .0344 | 140 | + .0844 | 185 | .1344 |
| 51 | .0144 | 96 | + .0356 | 141 | .0856 | 186 | + .1356 |
| 52 | .0133 | 97 | .0367 | 142 | .0867 | 187 | .1367 |
| 53 | .0122 | 98 | .0378 | 143 | .0878 | 188 | .1378 |
| 54 | .0111 | 99 | .0389 | 144 | .0889 | 189 | .1389 |
| 55 | .0100 | 100 | .0400 | 145 | .0900 | 190 | .1400 |
| 56 | .0089 | 101 | .0411 | 146 | .0911 | 191 | .1411 |
| 57 | .0078 | 102 | .0422 | 147 | .0922 | 192 | .1422 |
| 58 | .0067 | 103 | .0433 | 148 | .0933 | 193 | .1433 |
| 59 | .0056 | 104 | .0444 | 149 | .0944 | 194 | .1444 |
| 60 | .0044 | 105 | .0456 | 150 | + .0956 | 195 | .1456 |
| 61 | − .0033 | 106 | + .0467 | 151 | .0967 | 196 | + .1467 |
| 62 | .0022 | 107 | .0478 | 152 | .0978 | 197 | .1478 |
| 63 | .0011 | 108 | .0489 | 153 | .0989 | 198 | .1489 |
| 64 | .0000 | 109 | .0500 | 154 | .1000 | 199 | .1500 |

## TABLE XVII.—CORRECTION FOR EARTH'S CURVATURE AND REFRACTION. § 119.

| $L^0$ | $H^0$ | $L^0$ | $H^0$ | $L^0$ | $H^0$ | $L^0$ | $H^0$ | $L^0$ | $H^0$ | Miles | $H^0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | .002 | 1300 | .035 | 2300 | .108 | 3300 | .223 | 4300 | .379 | 1 | .571 |
| 400 | .003 | 1400 | .040 | 2400 | 118 | 3400 | .237 | 4400 | .397 | 2 | 2.285 |
| 500 | .005 | 1500 | .046 | 2500 | .128 | 3500 | .251 | 4500 | .415 | 3 | 5.142 |
| 600 | .007 | 1600 | .052 | 2600 | .139 | 3600 | .266 | 4600 | .434 | 4 | 9.141 |
| 700 | .010 | 1700 | .059 | 2700 | .149 | 3700 | .281 | 4700 | .453 | 5 | 14.282 |
| 800 | .013 | 1800 | .066 | 2800 | .161 | 3800 | .296 | 4800 | .472 | 6 | 20.567 |
| 900 | .017 | 1900 | .074 | 2900 | .172 | 3900 | .312 | 4900 | .492 | 7 | 27.994 |
| 1000 | 020 | 2000 | 082 | 3000 | .184 | 4000 | .328 | 5000 | .512 | 8 | 36.563 |
| 1100 | .025 | 2100 | .090 | 3100 | .197 | 4100 | .345 | 5100 | .533 | 9 | 46.275 |
| 1200 | .030 | 2200 | .099 | 3200 | .210 | 4200 | .362 | 5200 | .554 | 10 | 57.130 |

## TABLE XVIII.—COEFFICIENT FOR REDUCING INCLINED STADIA MEASUREMENTS TO THE HORIZONTAL. § 224.

| α | 0′ | 10′ | 20′ | 30′ | 40′ | 50′ |
|---|---|---|---|---|---|---|
| 0° | 1.000000 | .999992 | .999967 | .999924 | .999865 | .999789 |
| 1 | .999696 | .999586 | .999459 | .999315 | .999154 | .998977 |
| 2 | .998782 | .998571 | .998343 | .998098 | .997836 | .997557 |
| 3 | .997261 | .996949 | .996619 | .996273 | .995910 | .995531 |
| 4 | .995134 | .994721 | .994291 | .993844 | .993381 | .992901 |
| 5 | .992404 | .991891 | .991360 | .990814 | .990250 | .989670 |
| 6 | .989074 | .988461 | .987831 | .987185 | .986522 | .985843 |
| 7 | .985148 | .984436 | .983708 | .982963 | .982202 | .981424 |
| 8 | .980631 | .979821 | .978995 | .978152 | .977[illegible]94 | .976419 |
| 9 | .975528 | .974621 | .973698 | .972759 | .9[illegible]1804 | .970833 |
| 10 | .969846 | .968843 | .967824 | .966790 | .[illegible]5739 | .964673 |
| 11° | .963591 | .962494 | .961380 | .960252 | 959107 | .957948 |
| 12 | .956772 | .955581 | .954375 | .953153 | .951916 | .950664 |
| 13 | .949396 | .948113 | .946815 | .945502 | .944174 | .942831 |
| 14 | .941473 | .940100 | .938711 | .937309 | .935891 | .934459 |
| 15 | .933011 | .931550 | .930073 | .928582 | .927077 | .925557 |
| 16 | .924022 | .922474 | .920911 | .919334 | .917742 | .916137 |
| 17 | .914517 | .912883 | .911236 | .909574 | .907899 | .906209 |
| 18 | .904507 | .902790 | .901060 | .899316 | .897558 | .895787 |
| 19 | .894003 | .892206 | .890395 | .888571 | .886733 | .884883 |
| 20 | .883020 | .881143 | .879254 | .877352 | .875437 | .873510 |
| 21° | .871569 | .869617 | .867652 | .865674 | .863684 | .861681 |
| 22 | .859667 | .857640 | .855601 | .853550 | .851487 | .849412 |
| 23 | .847326 | .845227 | .843117 | .840996 | .838862 | .836718 |
| 24 | .834561 | .832394 | .830215 | .828025 | .825825 | .823613 |
| 25 | .821390 | .819156 | .816911 | .814656 | .812390 | .810113 |
| 26 | .807826 | .805529 | .803221 | .800903 | .798575 | .796236 |
| 27 | .793888 | .791529 | .789161 | .786783 | .784396 | .781998 |
| 28 | .779591 | .777175 | .774749 | .772314 | .769870 | .767416 |
| 29 | .764954 | .762483 | .760002 | .757513 | .755015 | .752509 |
| 30 | .749994 | .747471 | .744939 | .742399 | .739850 | .737294 |
| 31° | .734729 | .732157 | .729577 | .726989 | .724393 | 721790 |
| 32 | .719179 | .716561 | .713935 | .711302 | .708662 | .706015 |
| 33 | .703361 | .700700 | .698033 | .695358 | .692677 | .689990 |
| 34 | .687296 | .684595 | .681889 | .679176 | .676457 | .673733 |
| 35 | .671002 | .668266 | .665524 | .662776 | .660023 | .657264 |
| 36 | .654500 | .651731 | .648957 | .646177 | .643393 | .640604 |
| 37 | .637810 | .635011 | .632208 | .629401 | .626588 | .623772 |
| 38 | .620952 | .618127 | .615299 | .612466 | .609630 | .606790 |
| 39 | .603946 | .601099 | .598248 | .595395 | .592537 | .589677 |
| 40 | .586814 | .583948 | .581079 | .578207 | .575332 | .572455 |
| 41° | .569576 | .566694 | .563810 | .560924 | .558036 | .555145 |
| 42 | .552253 | .549359 | .546464 | .543567 | .540668 | .537768 |
| 43 | .534867 | .531964 | .529061 | .526156 | .523251 | .520345 |
| 44 | .517438 | .514530 | .511622 | .508714 | .505805 | .502897 |
| 45 | .499988 | .497079 | .494170 | .491261 | .488353 | .485445 |

TABLE XIX. — LOGARITHM OF COEFFICIENT FOR REDUCING INCLINED STADIA MEASUREMENTS TO THE HORIZONTAL. § 224.

| α | 0′ | 10′ | 20′ | 30′ | 40′ | 50′ |
|---|---|---|---|---|---|---|
| 0° | 0.000000 | 9.999996 | 9.999985 | 9.999967 | 9.999941 | 9.999908 |
| 1 | 9.999868 | .999820 | .999765 | .999702 | .999633 | .999555 |
| 2 | .999471 | .999379 | .999280 | .999173 | .999059 | .998938 |
| 3 | .998809 | .998673 | .998529 | .998379 | .998220 | .998055 |
| 4 | .997882 | .997701 | .997514 | .997318 | .997116 | .996906 |
| 5 | .996689 | .996464 | .996232 | .995992 | .995745 | .995491 |
| 6° | 9.995229 | 9.994959 | 9.994683 | 9.994399 | 9.994107 | 9.993808 |
| 7 | .993501 | .993187 | .992866 | .992537 | .992201 | .991857 |
| 8 | .991506 | .991147 | .990780 | .990406 | .990025 | .989636 |
| 9 | .989240 | .988836 | .988424 | .988005 | .987579 | .987144 |
| 10 | .986703 | .986253 | .985797 | .985332 | .984860 | .984380 |
| 11° | 9.983893 | 9.983398 | 9.982895 | 9.982385 | 9.981867 | 9.981342 |
| 12 | .980808 | .980268 | .979719 | .979163 | .978599 | .978027 |
| 13 | .977447 | .976860 | .976265 | .975663 | .975052 | .974434 |
| 14 | .973808 | .973174 | .972532 | .971883 | .971225 | .970560 |
| 15 | .969887 | .969206 | .968517 | .967820 | .967116 | .966403 |
| 16° | 9.965683 | 9.964954 | 9.964218 | 9.963473 | 9.962721 | 9.961960 |
| 17 | .961192 | .960415 | .959631 | .958838 | .958037 | .957229 |
| 18 | .956412 | .955587 | .954753 | .953912 | .953063 | .952205 |
| 19 | .951339 | .950465 | .949583 | .948692 | .947793 | .946886 |
| 20 | .945970 | .945047 | .944114 | .943174 | .942225 | .941268 |
| 21° | 9.940302 | 9.939328 | 9.938345 | 9.937354 | 9.936355 | 9.935347 |
| 22 | .934330 | .933305 | .932271 | .931229 | .930178 | .929119 |
| 23 | .928050 | .926974 | .925888 | .924794 | .923691 | .922579 |
| 24 | .921458 | .920329 | .919191 | .918044 | .916888 | .915723 |
| 25 | .914549 | .913366 | .912175 | .910974 | .909764 | .908546 |
| 26° | 9.907318 | 9.906081 | 9.904835 | 9.903580 | 9.902316 | 9.901042 |
| 27 | .899759 | .898467 | .897166 | .895855 | .894535 | .893206 |
| 28 | .891867 | .890519 | .889161 | .887794 | .886417 | .885031 |
| 29 | .883635 | .882230 | .880815 | .879390 | .877956 | .876512 |
| 30 | .875058 | .873594 | .872121 | .870637 | .869144 | .867641 |
| 31° | 9.866127 | 9.864604 | 9.863071 | 9.861528 | 9.859974 | 9.858411 |
| 32 | .856837 | .855253 | .853659 | .852054 | .850439 | .848814 |
| 33 | .847178 | .845532 | .843876 | .842209 | .840531 | .838843 |
| 34 | .837144 | .835434 | .833714 | .831982 | .830240 | .828488 |
| 35 | .826724 | .824949 | .823163 | .821367 | .819559 | .817740 |
| 36° | 9.815910 | 9.814068 | 9.812216 | 9.810352 | 9.808476 | 9.806589 |
| 37 | .804691 | .802781 | .800860 | .798927 | .796982 | .795026 |
| 38 | .793058 | .791078 | .789086 | .787082 | .785066 | .783038 |
| 39 | .780998 | .778946 | .776882 | .774805 | .772716 | .770614 |
| 40 | .768500 | .766374 | .764235 | .762083 | .759919 | .757742 |
| 41° | 9.755552 | 9.753349 | 9.751133 | 9.748904 | 9.746662 | 9.744407 |
| 42 | .742138 | .739857 | .737561 | .735253 | .732931 | .730595 |
| 43 | .728246 | .725883 | .723506 | .721115 | .718710 | .716291 |
| 44 | .713858 | .711411 | .708950 | .706474 | .703983 | .701479 |
| 45 | 9.698959 | 9.696425 | 9.693876 | 9.691313 | 9.688734 | 9.686140 |

TABLE XX.—LENGTHS OF CIRCULAR ARCS; RADIUS = 1.

| Sec. | Length. | Min. | Length. | Deg. | Length. | Deg. | Length. |
|---|---|---|---|---|---|---|---|
| 1 | .0000048 | 1 | .0002909 | 1 | .0174533 | 61 | 1.0646508 |
| 2 | .0000097 | 2 | .0005818 | 2 | .0349066 | 62 | 1.0821041 |
| 3 | .0000145 | 3 | .0008727 | 3 | .0523599 | 63 | 1.0995574 |
| 4 | .0000194 | 4 | .0011636 | 4 | .0698132 | 64 | 1.1170107 |
| 5 | .0000242 | 5 | .0014544 | 5 | .0872665 | 65 | 1.1344640 |
| 6 | .0000291 | 6 | .0017453 | 6 | .1047198 | 66 | 1.1519173 |
| 7 | .0000339 | 7 | .0020362 | 7 | .1221730 | 67 | 1.1693706 |
| 8 | .0000388 | 8 | .0023271 | 8 | .1396263 | 68 | 1.1868239 |
| 9 | .0000436 | 9 | .0026180 | 9 | .1570796 | 69 | 1.2042772 |
| 10 | .0000485 | 10 | .0029089 | 10 | .1745329 | 70 | 1.2217305 |
| 11 | .0000533 | 11 | .0031998 | 11 | .1919862 | 71 | 1.2391838 |
| 12 | .0000582 | 12 | .0034907 | 12 | .2094395 | 72 | 1.2566371 |
| 13 | .0000630 | 13 | .0037815 | 13 | .2268928 | 73 | 1.2740904 |
| 14 | .0000679 | 14 | .0040724 | 14 | .2443461 | 74 | 1.2915436 |
| 15 | .0000727 | 15 | .0043633 | 15 | .2617994 | 75 | 1.3089969 |
| 16 | .0000776 | 16 | .0046542 | 16 | .2792527 | 76 | 1.3264502 |
| 17 | .0000824 | 17 | .0049451 | 17 | .2967060 | 77 | 1.3439035 |
| 18 | .0000873 | 18 | .0052360 | 18 | .3141593 | 78 | 1.3613568 |
| 19 | .0000921 | 19 | .0055269 | 19 | .3316126 | 79 | 1.3788101 |
| 20 | .0000970 | 20 | .0058178 | 20 | .3490659 | 80 | 1.3962634 |
| 21 | .0001018 | 21 | .0061087 | 21 | .3665191 | 81 | 1.4137167 |
| 22 | .0001067 | 22 | .0063995 | 22 | .3839724 | 82 | 1.4311700 |
| 23 | .0001115 | 23 | .0066904 | 23 | .4014257 | 83 | 1.4486233 |
| 24 | .0001164 | 24 | .0069813 | 24 | .4188790 | 84 | 1.4660766 |
| 25 | .0001212 | 25 | .0072722 | 25 | .4363323 | 85 | 1.4835299 |
| 26 | .0001261 | 26 | .0075631 | 26 | .4537856 | 86 | 1.5009832 |
| 27 | .0001309 | 27 | .0078540 | 27 | .4712389 | 87 | 1.5184364 |
| 28 | .0001357 | 28 | .0081449 | 28 | .4886922 | 88 | 1.5358897 |
| 29 | .0001406 | 29 | .0084358 | 29 | .5061455 | 89 | 1.5533430 |
| 30 | .0001454 | 30 | .0087266 | 30 | .5235988 | 90 | 1.5707963 |
| 31 | .0001503 | 31 | .0090175 | 31 | .5410521 | 91 | 1.5882496 |
| 32 | .0001551 | 32 | .0093084 | 32 | .5585054 | 92 | 1.6057029 |
| 33 | .0001600 | 33 | .0095993 | 33 | .5759587 | 93 | 1.6231562 |
| 34 | .0001648 | 34 | .0098902 | 34 | .5934119 | 94 | 1.6406095 |
| 35 | .0001697 | 35 | .0101811 | 35 | .6108652 | 95 | 1.6580628 |
| 36 | .0001745 | 36 | .0104720 | 36 | .6283185 | 96 | 1.6755161 |
| 37 | .0001794 | 37 | .0107629 | 37 | .6457718 | 97 | 1.6929694 |
| 38 | .0001842 | 38 | .0110538 | 38 | .6632251 | 98 | 1.7104227 |
| 39 | .0001891 | 39 | .0113446 | 39 | .6806784 | 99 | 1.7278760 |
| 40 | .0001939 | 40 | .0116355 | 40 | .6981317 | 100 | 1.7453293 |
| 41 | .0001988 | 41 | .0119264 | 41 | .7155850 | 101 | 1.7627825 |
| 42 | .0002036 | 42 | .0122173 | 42 | .7330383 | 102 | 1.7802358 |
| 43 | .0002085 | 43 | .0125082 | 43 | .7504916 | 103 | 1.7976891 |
| 44 | .0002133 | 44 | .0127991 | 44 | .7679449 | 104 | 1.8151424 |
| 45 | .0002182 | 45 | .0130900 | 45 | .7853982 | 105 | 1.8325957 |
| 46 | .0002230 | 46 | .0133809 | 46 | .8028515 | 106 | 1.8500490 |
| 47 | .0002279 | 47 | .0136717 | 47 | .8203047 | 107 | 1.8675023 |
| 48 | .0002327 | 48 | .0139626 | 48 | .8377580 | 108 | 1.8849556 |
| 49 | .0002376 | 49 | .0142535 | 49 | .8552113 | 109 | 1.9024089 |
| 50 | .0002424 | 50 | .0145444 | 50 | .8726646 | 110 | 1.9198622 |
| 51 | .0002473 | 51 | .0148353 | 51 | .8901179 | 111 | 1.9373155 |
| 52 | .0002521 | 52 | .0151262 | 52 | .9075712 | 112 | 1.9547688 |
| 53 | .0002570 | 53 | .0154171 | 53 | .9250245 | 113 | 1.9722221 |
| 54 | .0002618 | 54 | .0157080 | 54 | .9424778 | 114 | 1.9896753 |
| 55 | .0002666 | 55 | .0159989 | 55 | .9599311 | 115 | 2.0071286 |
| 56 | .0002715 | 56 | .0162897 | 56 | .9773844 | 116 | 2.0245819 |
| 57 | .0002763 | 57 | .0165806 | 57 | .9948377 | 117 | 2.0420352 |
| 58 | .0002812 | 58 | .0168715 | 58 | 1.0122910 | 118 | 2.0594885 |
| 59 | .0002860 | 59 | .0171624 | 59 | 1.0297443 | 119 | 2.0769418 |
| 60 | .0002909 | 60 | .0174533 | 60 | 1.0471976 | 120 | 2.0943951 |

## TABLE XXI.—MINUTES IN DECIMALS OF A DEGREE.

| ′ | 0″ | 10″ | 15″ | 20″ | 30″ | 40″ | 45″ | 50″ | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .00000 | 00278 | .00417 | .00556 | .00833 | .01111 | .01250 | .01389 | 0 |
| 1 | .01667 | .01944 | .02083 | .02222 | .02500 | .02778 | .02917 | .03055 | 1 |
| 2 | .03333 | .03611 | .03750 | .03889 | .04167 | .04444 | .04583 | .04722 | 2 |
| 3 | .05000 | .05278 | .05417 | .05556 | .05833 | .06111 | .06250 | .06389 | 3 |
| 4 | .06667 | .06944 | .07083 | .07222 | .07500 | .07778 | .07917 | .08056 | 4 |
| 5 | .08333 | .08611 | .08750 | .08889 | .09167 | .09444 | .09583 | .09722 | 5 |
| 6 | .10000 | .10278 | .10417 | .10556 | .10833 | .11111 | .11250 | .11389 | 6 |
| 7 | .11667 | .11944 | .12083 | .12222 | .12500 | .12778 | .12917 | .13056 | 7 |
| 8 | .13333 | .13611 | .13750 | .13889 | .14167 | .14444 | .14583 | .14722 | 8 |
| 9 | .15000 | .15278 | .15417 | .15556 | .15833 | .16111 | .16250 | .16389 | 9 |
| 10 | .16667 | .16944 | .17083 | .17222 | .17500 | .17778 | .17917 | .18056 | 10 |
| 11 | .18333 | .18611 | .18750 | .18889 | .19167 | 19444 | .19583 | .19722 | 11 |
| 12 | .20000 | .20278 | .20417 | .20556 | .20833 | .21111 | .21250 | .21389 | 12 |
| 13 | .21667 | .21944 | .22083 | .22222 | .22500 | .22778 | .22917 | .23056 | 13 |
| 14 | .23333 | .23611 | .23750 | .23889 | .24167 | .24444 | .24583 | .24722 | 14 |
| 15 | .25000 | .25278 | .25417 | .25556 | .25833 | .26111 | .26250 | .26389 | 15 |
| 16 | .26667 | .26944 | .27083 | .27222 | .27500 | .27778 | .27917 | .28056 | 16 |
| 17 | .28333 | .28611 | .28750 | .28889 | .29167 | .29444 | .29583 | .29722 | 17 |
| 18 | .30000 | .30278 | .30417 | .30556 | .30833 | .31111 | .31250 | .31389 | 18 |
| 19 | .31667 | .31944 | .32083 | .32222 | .32500 | .32778 | .32917 | .33056 | 19 |
| 20 | .33333 | .33611 | .33750 | .33889 | .34167 | .34444 | .34583 | .34722 | 20 |
| 21 | .35000 | .35278 | .35417 | .35556 | .35833 | .36111 | .36250 | .36389 | 21 |
| 22 | .36667 | .36944 | .37083 | .37222 | .37500 | .37778 | .37917 | .38056 | 22 |
| 23 | .38333 | .38611 | .38750 | .38889 | .39167 | .39444 | .39583 | .39722 | 23 |
| 24 | .40000 | .40278 | .40417 | .40556 | .40833 | .41111 | .41250 | .41389 | 24 |
| 25 | .41667 | .41944 | .42083 | .42222 | .42500 | .42778 | .42917 | .43056 | 25 |
| 26 | .43333 | .43611 | .43750 | .43889 | .44167 | .44444 | .44583 | .44722 | 26 |
| 27 | .45000 | .45278 | .45417 | .45556 | .45833 | .46111 | .46250 | .46389 | 27 |
| 28 | .46667 | .46944 | .47083 | .47222 | .47500 | .47778 | .47917 | .48056 | 28 |
| 29 | .48333 | .48611 | .48750 | .48889 | .49167 | .49444 | .49583 | .49722 | 29 |
| 30 | .50000 | .50278 | .50417 | .50556 | .50833 | .51111 | .51250 | .51389 | 30 |
| 31 | .51667 | .51944 | .52083 | .52222 | .52500 | .52778 | .52917 | .53056 | 31 |
| 32 | .53333 | .53611 | .53750 | .53889 | .54167 | .54444 | .54583 | .54722 | 32 |
| 33 | .55000 | .55278 | .55417 | .55556 | .55833 | .56111 | .56250 | .56389 | 33 |
| 34 | .56667 | .56944 | .57083 | .57222 | .57500 | .57778 | .57917 | .58056 | 34 |
| 35 | .58333 | .58611 | .58750 | .58889 | .59167 | .59444 | .59583 | .59722 | 35 |
| 36 | .60000 | .60278 | .60417 | .60556 | .60833 | .61111 | .61250 | .61389 | 36 |
| 37 | .61667 | .61944 | .62083 | .62222 | .62500 | .62778 | .62917 | .63056 | 37 |
| 38 | .63333 | .63611 | .63750 | .63889 | .64167 | .64444 | .64583 | .64722 | 38 |
| 39 | .65000 | .65278 | .65417 | .65556 | .65833 | .66111 | .66250 | .66389 | 39 |
| 40 | .66667 | .66944 | .67083 | .67222 | .67500 | .67778 | .67917 | .68056 | 40 |
| 41 | .68333 | .68611 | .68750 | .68889 | .69167 | .69444 | .69583 | .69722 | 41 |
| 42 | .70000 | .70278 | .70417 | .70556 | .70833 | .71111 | .71250 | .71389 | 42 |
| 43 | .71667 | .71944 | .72083 | .72222 | .72500 | .72778 | .72917 | .73056 | 43 |
| 44 | .73333 | .73611 | .73750 | .73889 | .74167 | .74444 | .74583 | .74722 | 44 |
| 45 | .75000 | .75278 | .75417 | .75556 | .75833 | .76111 | .76250 | .76389 | 45 |
| 46 | .76667 | .76944 | .77083 | .77222 | .77500 | .77778 | .77917 | .78056 | 46 |
| 47 | .78333 | .78611 | .78750 | .78889 | .79167 | .79444 | .79583 | .79722 | 47 |
| 48 | .80000 | .80278 | .80417 | .80556 | .80833 | .81111 | .81250 | .81389 | 48 |
| 49 | .81667 | .81944 | .82083 | .82222 | .82500 | .82778 | .82917 | .83056 | 49 |
| 50 | .83333 | .83611 | .83750 | .83889 | .84167 | .84444 | .84583 | .84722 | 50 |
| 51 | .85000 | .85278 | .85417 | .85556 | .85833 | 86111 | .86250 | .86389 | 51 |
| 52 | .86667 | .86944 | .87083 | .87222 | .87500 | .87778 | .87917 | .88056 | 52 |
| 53 | .88333 | .88611 | .88750 | .88889 | .89167 | .89444 | .89583 | .89722 | 53 |
| 54 | .90000 | .90278 | .90417 | .90556 | .90833 | .91111 | .91250 | .91389 | 54 |
| 55 | .91667 | .91944 | .92083 | .92222 | .92500 | .92778 | .92917 | .93056 | 55 |
| 56 | .93333 | .93611 | .93750 | .93889 | .94167 | .94444 | .94583 | .94722 | 56 |
| 57 | .95000 | .95278 | .95417 | .95556 | .95833 | .96111 | .96250 | .96389 | 57 |
| 58 | .96667 | .96944 | .97083 | .97222 | .97500 | .97778 | .97917 | .98056 | 58 |
| 59 | .98333 | .98611 | .98750 | .98889 | .99167 | .99444 | .99583 | .99722 | 59 |
| ′ | 0″ | 10″ | 15″ | 20″ | 30″ | 40″ | 45″ | 50″ | ′ |

## TABLE XXII.—INCHES IN DECIMALS OF A FOOT.

| In. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | In. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Foot | .0833 | .1667 | .2500 | .3333 | .4167 | .5000 | .5833 | .6667 | .7500 | .8333 | .9167 | 0 |
| 1-32 | .0026 | .0859 | .1693 | .2526 | .3359 | .4193 | .5026 | .5859 | .6693 | .7526 | .8359 | .9193 | 1-32 |
| 1-16 | .0052 | .0885 | .1719 | .2552 | .3385 | .4219 | .5052 | .5885 | .6719 | .7552 | .8385 | .9219 | 1-16 |
| 3-32 | .0078 | .0911 | .1745 | .2578 | .3411 | .4245 | .5078 | .5911 | .6745 | .7578 | .8411 | .9245 | 3-32 |
| 1-8 | .0104 | .0938 | .1771 | .2604 | .3438 | .4271 | .5104 | .5938 | .6771 | .7604 | .8438 | .9271 | 1-8 |
| 5-32 | .0130 | .0964 | .1797 | .2630 | .3464 | .4297 | .5130 | .5964 | .6797 | .7630 | .8464 | .9297 | 5-32 |
| 3-16 | .0156 | .0990 | .1823 | .2656 | .3490 | .4323 | .5156 | .5990 | .6823 | .7656 | .8490 | .9323 | 3-16 |
| 7-32 | .0182 | .1016 | .1849 | .2682 | .3516 | .4349 | .5182 | .6016 | .6849 | .7682 | .8516 | .9349 | 7-32 |
| 1-4 | .0208 | .1042 | .1875 | .2708 | .3542 | .4375 | .5208 | .6042 | .6875 | .7708 | .8542 | .9375 | 1-4 |
| 9-32 | .0234 | .1068 | .1901 | .2734 | .3568 | .4401 | .5234 | .6068 | .6901 | .7734 | .8568 | .9401 | 9-32 |
| 5-16 | .0260 | .1094 | .1927 | .2760 | .3594 | .4427 | .5260 | .6094 | .6927 | .7760 | .8594 | .9427 | 5-16 |
| 11-32 | .0286 | .1120 | .1953 | .2786 | .3620 | .4453 | .5286 | .6120 | .6953 | .7786 | .8620 | .9453 | 11-32 |
| 3-8 | .0313 | .1146 | .1979 | .2813 | .3646 | .4479 | .5313 | .6146 | .6979 | .7813 | .8646 | .9479 | 3-8 |
| 13-32 | .0339 | .1172 | .2005 | .2839 | .3672 | .4505 | .5339 | .6172 | .7005 | .7839 | .8672 | .9505 | 13-32 |
| 7-16 | .0365 | .1198 | .2031 | .2865 | .3698 | .4531 | .5365 | .6198 | .7031 | .7865 | .8698 | .9531 | 7-16 |
| 15-32 | .0391 | .1224 | .2057 | .2891 | .3724 | .4557 | .5391 | .6224 | .7057 | .7891 | .8724 | .9557 | 15-32 |
| 1-2 | .0417 | .1250 | .2083 | .2917 | .3750 | .4583 | .5417 | .6250 | .7083 | .7917 | .8750 | .9583 | 1-2 |
| 17-32 | .0443 | .1276 | .2109 | .2943 | .3776 | .4609 | .5443 | .6276 | .7109 | .7943 | .8776 | .9609 | 17-32 |
| 9-16 | .0469 | .1302 | .2135 | .2969 | .3802 | .4635 | .5469 | .6302 | .7135 | .7969 | .8802 | .9635 | 9-16 |
| 19-32 | .0495 | .1328 | .2161 | .2995 | .3828 | .4661 | .5495 | .6328 | .7161 | .7995 | .8828 | .9661 | 19-32 |
| 5-8 | .0521 | .1354 | .2188 | .3021 | .3854 | .4688 | .5521 | .6354 | .7188 | .8021 | .8854 | .9688 | 5-8 |
| 21-32 | .0547 | .1380 | .2214 | .3047 | .3880 | .4714 | .5547 | .6380 | .7214 | .8047 | .8880 | .9714 | 21-32 |
| 11-16 | .0573 | .1406 | .2240 | .3073 | .3906 | .4740 | .5573 | .6406 | .7240 | .8073 | .8906 | .9740 | 11-16 |
| 23-32 | .0599 | .1432 | .2266 | .3099 | .3932 | .4766 | .5599 | .6432 | .7266 | .8099 | .8932 | .9766 | 23-32 |
| 3-4 | .0625 | .1458 | .2292 | .3125 | .3958 | .4792 | .5625 | .6458 | .7292 | .8125 | .8958 | .9792 | 3-4 |
| 25-32 | .0651 | .1484 | .2318 | .3151 | .3984 | .4818 | .5651 | .6484 | .7318 | .8151 | .8984 | .9818 | 25-32 |
| 13-16 | .0677 | .1510 | .2344 | .3177 | .4010 | .4844 | .5677 | .6510 | .7344 | .8177 | .9010 | .9844 | 13-16 |
| 27-32 | .0703 | .1536 | .2370 | .3203 | .4036 | .4870 | .5703 | .6536 | .7370 | .8203 | .9036 | .9870 | 27-32 |
| 7-8 | .0729 | .1563 | .2396 | .3229 | .4063 | .4896 | .5729 | .6563 | .7396 | .8229 | .9063 | .9896 | 7-8 |
| 29-32 | .0755 | .1589 | .2422 | .3255 | .4089 | .4922 | .5755 | .6589 | .7422 | .8255 | .9089 | .9922 | 29-32 |
| 15-16 | .0781 | .1615 | .2448 | .3281 | .4115 | .4948 | .5781 | .6615 | .7448 | .8281 | .9115 | .9948 | 15-16 |
| 31-32 | .0807 | .1641 | .2474 | .3307 | .4141 | .4974 | .5807 | .6641 | .7474 | .8307 | .9141 | .9974 | 31-32 |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1.0000000 | 1.0000000 | 1.000000000 |
| 2 | 4 | 8 | 1.4142136 | 1.2599210 | .500000000 |
| 3 | 9 | 27 | 1.7320508 | 1.4422496 | .333333333 |
| 4 | 16 | 64 | 2.0000000 | 1.5874011 | .250000000 |
| 5 | 25 | 125 | 2.2360680 | 1.7099759 | .200000000 |
| 6 | 36 | 216 | 2 4494897 | 1.8171206 | .166666667 |
| 7 | 49 | 343 | 2.6457513 | 1.9129312 | .142857143 |
| 8 | 64 | 512 | 2.8284271 | 2.0000000 | .125000000 |
| 9 | 81 | 729 | 3.0000000 | 2.0800837 | .111111111 |
| 10 | 100 | 1000 | 3.1622777 | 2.1544347 | .100000000 |
| 11 | 121 | 1331 | 3.3166248 | 2.2239801 | .090909091 |
| 12 | 144 | 1728 | 3.4641016 | 2.2894286 | .083333333 |
| 13 | 169 | 2197 | 3.6055513 | 2.3513347 | .076923077 |
| 14 | 196 | 2744 | 3.7416574 | 2.4101422 | .071428571 |
| 15 | 225 | 3375 | 3.8729833 | 2.4662121 | .066666667 |
| 16 | 256 | 4096 | 4.0000000 | 2.5198421 | .062500000 |
| 17 | 289 | 4913 | 4.1231056 | 2.5712816 | .058823529 |
| 18 | 324 | 5832 | 4.2426407 | 2.6207414 | .055555556 |
| 19 | 361 | 6859 | 4.3588989 | 2.6684016 | .052631579 |
| 20 | 400 | 8000 | 4.4721360 | 2.7144177 | .050000000 |
| 21 | 441 | 9261 | 4.5825757 | 2.7589243 | .047619048 |
| 22 | 484 | 10648 | 4.6904158 | 2.8020393 | .045454545 |
| 23 | 529 | 12167 | 4.7958315 | 2.8438670 | .043478261 |
| 24 | 576 | 13824 | 4.8989795 | 2.8844991 | .041666667 |
| 25 | 625 | 15625 | 5.0000000 | 2.9240177 | .040000000 |
| 26 | 676 | 17576 | 5.0990195 | 2.9624960 | .038461538 |
| 27 | 729 | 19683 | 5.1961524 | 3.0000000 | .037037037 |
| 28 | 784 | 21952 | 5.2915026 | 3.0365889 | .035714286 |
| 29 | 841 | 24389 | 5.3851648 | 3.0723168 | .034482759 |
| 30 | 900 | 27000 | 5.4772256 | 3.1072325 | .033333333 |
| 31 | 961 | 29791 | 5.5677644 | 3.1413806 | .032258065 |
| 32 | 1024 | 32768 | 5.6568542 | 3.1748021 | .031250000 |
| 33 | 1089 | 35937 | 5.7445626 | 3.2075343 | .030303030 |
| 34 | 1156 | 39304 | 5.8309519 | 3.2396118 | .029411765 |
| 35 | 1225 | 42875 | 5.9160798 | 3.2710663 | .028571429 |
| 36 | 1296 | 46656 | 6.0000000 | 3.3019272 | .027777778 |
| 37 | 1369 | 50653 | 6.0827625 | 3.3322218 | .027027027 |
| 38 | 1444 | 54872 | 6.1644140 | 3.3619754 | .026315789 |
| 39 | 1521 | 59319 | 6.2449980 | 3.3912114 | .025641026 |
| 40 | 1600 | 64000 | 6.3245553 | 3.4199519 | .025000000 |
| 41 | 1681 | 68921 | 6.4031242 | 3.4482172 | .024390244 |
| 42 | 1764 | 74088 | 6.4807407 | 3.4760266 | .023809524 |
| 43 | 1849 | 79507 | 6.5574385 | 3.5033981 | .023255814 |
| 44 | 1936 | 85184 | 6.6332496 | 3.5303483 | .022727273 |
| 45 | 2025 | 91125 | 6.7082039 | 3.5568933 | .022222222 |
| 46 | 2116 | 97336 | 6.7823300 | 3.5830479 | .021739130 |
| 47 | 2209 | 103823 | 6.8556546 | 3.6088261 | .021276600 |
| 48 | 2304 | 110592 | 6.9282032 | 3.6342411 | .020833333 |
| 49 | 2401 | 117649 | 7.0000000 | 3.6593057 | .020408163 |
| 50 | 2500 | 125000 | 7.0710678 | 3.6840314 | .020000000 |
| 51 | 2601 | 132651 | 7.1414284 | 3.7084298 | .019607843 |
| 52 | 2704 | 140608 | 7.2111026 | 3.7325111 | .019230769 |
| 53 | 2809 | 148877 | 7.2801099 | 3.7562858 | .018867925 |
| 54 | 2916 | 157464 | 7.3484692 | 3.7797631 | .018518519 |
| 55 | 3025 | 166375 | 7.4161985 | 3.8029525 | .018181818 |
| 56 | 3136 | 175616 | 7.4833148 | 3.8258624 | .017857143 |
| 57 | 3249 | 185193 | 7.5498344 | 3.8485011 | .017543860 |
| 58 | 3364 | 195112 | 7.6157731 | 3.8708766 | .017241379 |
| 59 | 3481 | 205379 | 7.6811457 | 3.8929965 | .016949153 |
| 60 | 3600 | 216000 | 7.7459667 | 3.9148676 | .016666667 |
| 61 | 3721 | 226981 | 7.8102497 | 3.9364972 | .016393443 |
| 62 | 3844 | 238328 | 7.8740079 | 3.9578915 | .016129032 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 63 | 3969 | 250047 | 7.9372539 | 3.9790571 | .015873016 |
| 64 | 4096 | 262144 | 8.0000000 | 4.0000000 | .015625000 |
| 65 | 4225 | 274625 | 8.0622577 | 4.0207256 | .015384615 |
| 66 | 4356 | 287496 | 8.1240384 | 4.0412401 | .015151515 |
| 67 | 4489 | 300763 | 8.1853528 | 4.0615480 | .014925373 |
| 68 | 4624 | 314432 | 8.2462113 | 4.0816551 | .014705882 |
| 69 | 4761 | 328509 | 8.3066239 | 4.1015661 | .014492754 |
| 70 | 4900 | 343000 | 8.3666003 | 4.1212853 | .014285714 |
| 71 | 5041 | 357911 | 8.4261498 | 4.1408178 | .014084507 |
| 72 | 5184 | 373248 | 8.4852814 | 4.1601676 | .013888889 |
| 73 | 5329 | 389017 | 8.5440037 | 4.1793390 | .013698630 |
| 74 | 5476 | 405224 | 8.6023253 | 4.1983364 | .013513514 |
| 75 | 5625 | 421875 | 8.6602540 | 4.2171633 | .013333333 |
| 76 | 5776 | 438976 | 8.7177979 | 4.2358236 | .013157895 |
| 77 | 5929 | 456533 | 8.7749644 | 4.2543210 | .012987013 |
| 78 | 6084 | 474552 | 8.8317609 | 4.2726586 | .012820513 |
| 79 | 6241 | 493039 | 8.8881944 | 4.2908404 | .012658228 |
| 80 | 6400 | 512000 | 8.9442719 | 4.3088695 | .012500000 |
| 81 | 6561 | 531441 | 9.0000000 | 4.3267487 | .012345679 |
| 82 | 6724 | 551368 | 9.0553851 | 4.3444815 | .012195122 |
| 83 | 6889 | 571787 | 9.1104336 | 4.3620707 | .012048193 |
| 84 | 7056 | 592704 | 9.1651514 | 4.3795191 | .011904762 |
| 85 | 7225 | 614125 | 9.2195445 | 4.3968296 | .011764706 |
| 86 | 7396 | 636056 | 9.2736185 | 4.4140049 | .011627907 |
| 87 | 7569 | 658503 | 9.3273791 | 4.4310476 | .011494253 |
| 88 | 7744 | 681472 | 9.3808315 | 4.4479602 | .011363636 |
| 89 | 7921 | 704969 | 9.4339811 | 4.4647451 | .011235955 |
| 90 | 8100 | 729000 | 9.4868330 | 4.4814047 | .011111111 |
| 91 | 8281 | 753571 | 9.5393920 | 4.4979414 | .010989011 |
| 92 | 8464 | 778688 | 9.5916630 | 4.5143574 | .010869565 |
| 93 | 8649 | 804357 | 9.6436508 | 4.5306549 | .010752688 |
| 94 | 8836 | 830584 | 9.6953597 | 4.5468359 | .010638298 |
| 95 | 9025 | 857375 | 9.7467943 | 4.5629026 | .010526316 |
| 96 | 9216 | 884736 | 9.7979590 | 4.5788570 | .010416667 |
| 97 | 9409 | 912673 | 9.8488578 | 4.5947009 | .010309278 |
| 98 | 9604 | 941192 | 9.8994949 | 4.6104363 | .010204082 |
| 99 | 9801 | 970299 | 9.9498744 | 4.6260650 | .010101010 |
| 100 | 10000 | 1000000 | 10.0000000 | 4.6415888 | .010000000 |
| 101 | 10201 | 1030301 | 10.0498756 | 4.6570095 | .009900990 |
| 102 | 10404 | 1061208 | 10.0995049 | 4.6723287 | .009803922 |
| 103 | 10609 | 1092727 | 10.1488916 | 4.6875482 | .009708738 |
| 104 | 10816 | 1124864 | 10.1980390 | 4.7026694 | .009615385 |
| 105 | 11025 | 1157625 | 10.2469508 | 4.7176940 | .009523810 |
| 106 | 11236 | 1191016 | 10.2956301 | 4.7326235 | .009433962 |
| 107 | 11449 | 1225043 | 10.3440804 | 4.7474594 | .009345794 |
| 108 | 11664 | 1259712 | 10.3923048 | 4.7622032 | .009259259 |
| 109 | 11881 | 1295029 | 10.4403065 | 4.7768562 | .009174312 |
| 110 | 12100 | 1331000 | 10.4880885 | 4.7914199 | .009090909 |
| 111 | 12321 | 1367631 | 10.5356538 | 4.8058955 | .009009009 |
| 112 | 12544 | 1404928 | 10.5830052 | 4.8202845 | .008928571 |
| 113 | 12769 | 1442897 | 10.6301458 | 4.8345881 | .008849558 |
| 114 | 12996 | 1481544 | 10.6770783 | 4.8488076 | .008771930 |
| 115 | 13225 | 1520875 | 10.7238053 | 4.8629442 | .008695652 |
| 116 | 13456 | 1560896 | 10.7703296 | 4.8769990 | .008620690 |
| 117 | 13689 | 1601613 | 10.8166538 | 4.8909732 | .008547009 |
| 118 | 13924 | 1643032 | 10.8627805 | 4.9048681 | .008474576 |
| 119 | 14161 | 1685159 | 10.9087121 | 4.9186847 | .008403361 |
| 120 | 14400 | 1728000 | 10.9544512 | 4.9324242 | .008333333 |
| 121 | 14641 | 1771561 | 11.0000000 | 4.9460874 | .008264463 |
| 122 | 14884 | 1815848 | 11.0453610 | 4.9596757 | .008196721 |
| 123 | 15129 | 1860867 | 11.0905365 | 4.9731898 | .008130081 |
| 124 | 15376 | 1906624 | 11.1355287 | 4.9866310 | .008064516 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 125 | 15625 | 1953125 | 11.1803399 | 5.0000000 | .008000000 |
| 126 | 15876 | 2000376 | 11.2249722 | 5.0132979 | .007936508 |
| 127 | 16129 | 2048383 | 11.2694277 | 5.0265257 | .007874016 |
| 128 | 16384 | 2097152 | 11.3137085 | 5.0396842 | .007812500 |
| 129 | 16641 | 2146689 | 11.3578167 | 5.0527743 | .007751938 |
| 130 | 16900 | 2197000 | 11.4017543 | 5.0657970 | .007692308 |
| 131 | 17161 | 2248091 | 11.4455231 | 5.0787531 | .007633588 |
| 132 | 17424 | 2299968 | 11.4891253 | 5.0916434 | .007575758 |
| 133 | 17689 | 2352637 | 11.5325626 | 5.1044687 | .007518797 |
| 134 | 17956 | 2406104 | 11.5758369 | 5.1172299 | .007462687 |
| 135 | 18225 | 2460375 | 11.6189500 | 5.1299278 | .007407407 |
| 136 | 18496 | 2515456 | 11.6619038 | 5.1425632 | .007352941 |
| 137 | 18769 | 2571353 | 11.7046999 | 5.1551367 | .007299270 |
| 138 | 19044 | 2628072 | 11.7473401 | 5.1676493 | .007246377 |
| 139 | 19321 | 2685619 | 11.7898261 | 5.1801015 | .007194245 |
| 140 | 19600 | 2744000 | 11.8321596 | 5.1924941 | .007142857 |
| 141 | 19881 | 2803221 | 11.8743421 | 5.2048279 | .007092199 |
| 142 | 20164 | 2863288 | 11.9163753 | 5.2171034 | .007042254 |
| 143 | 20449 | 2924207 | 11.9582607 | 5.2293215 | .006993007 |
| 144 | 20736 | 2985984 | 12.0000000 | 5.2414828 | .006944444 |
| 145 | 21025 | 3048625 | 12.0415946 | 5.2535879 | .006896552 |
| 146 | 21316 | 3112136 | 12.0830460 | 5.2656374 | .006849315 |
| 147 | 21609 | 3176523 | 12.1243557 | 5.2776321 | .006802721 |
| 148 | 21904 | 3241792 | 12.1655251 | 5.2895725 | .006756757 |
| 149 | 22201 | 3307949 | 12.2065556 | 5.3014592 | .006711409 |
| 150 | 22500 | 3375000 | 12.2474487 | 5.3132928 | .006666667 |
| 151 | 22801 | 3442951 | 12.2882057 | 5.3250740 | .006622517 |
| 152 | 23104 | 3511808 | 12.3288280 | 5.3368033 | .006578947 |
| 153 | 23409 | 3581577 | 12.3693169 | 5.3484812 | .006535948 |
| 154 | 23716 | 3652264 | 12.4096736 | 5.3601084 | .006493506 |
| 155 | 24025 | 3723875 | 12.4498996 | 5.3716854 | .006451613 |
| 156 | 24336 | 3796416 | 12.4899960 | 5.3832126 | .006410256 |
| 157 | 24649 | 3869893 | 12.5299641 | 5 3946907 | .006369427 |
| 158 | 24964 | 3944312 | 12.5698051 | 5.4061202 | .006329114 |
| 159 | 25281 | 4019679 | 12.6095202 | 5.4175015 | .006289308 |
| 160 | 25600 | 4096000 | 12.6491106 | 5.4288352 | .006250000 |
| 161 | 25921 | 4173281 | 12.6885775 | 5.4401218 | .006211180 |
| 162 | 26244 | 4251528 | 12.7279221 | 5.4513618 | .006172840 |
| 163 | 26569 | 4330747 | 12.7671453 | 5.4625556 | .006134969 |
| 164 | 26896 | 4410944 | 12.8062485 | 5.4737037 | .006097561 |
| 165 | 27225 | 4492125 | 12.8452326 | 5.4848066 | .006060606 |
| 166 | 27556 | 4574296 | 12.8840987 | 5.4958647 | .006024096 |
| 167 | 27889 | 4657463 | 12.9228480 | 5.5068784 | .005988024 |
| 168 | 28224 | 4741632 | 12.9614814 | 5.5178484 | .005952381 |
| 169 | 28561 | 4826809 | 13.0000000 | 5.5287748 | .005917160 |
| 170 | 28900 | 4913000 | 13.0384048 | 5.5396583 | .005882353 |
| 171 | 29241 | 5000211 | 13.0766968 | 5.5504991 | .005847953 |
| 172 | 29584 | 5088448 | 13.1148770 | 5.5612978 | .005813953 |
| 173 | 29929 | 5177717 | 13.1529464 | 5.5720546 | .005780347 |
| 174 | 30276 | 5268024 | 13.1909060 | 5.5827702 | .005747126 |
| 175 | 30625 | 5359375 | 13.2287566 | 5.5934447 | .005714286 |
| 176 | 30976 | 5451776 | 13.2664992 | 5.6040787 | .005681818 |
| 177 | 31329 | 5545233 | 13.3041347 | 5.6146724 | .005649718 |
| 178 | 31684 | 5639752 | 13.3416641 | 5.6252263 | .005617978 |
| 179 | 32041 | 5735339 | 13.3790882 | 5.6357408 | .005586592 |
| 180 | 32400 | 5832000 | 13.4164079 | 5.6462162 | .005555556 |
| 181 | 32761 | 5929741 | 13.4536240 | 5.6566528 | .005524862 |
| 182 | 33124 | 6028568 | 13.4907376 | 5.6670511 | .005494505 |
| 183 | 33489 | 6128487 | 13.5277493 | 5.6774114 | .005464481 |
| 184 | 33856 | 6229504 | 13.5646600 | 5.6877340 | .005434783 |
| 185 | 34225 | 6331625 | 13.6014705 | 5.6980192 | .005405405 |
| 186 | 34596 | 6434856 | 13.6381817 | 5.7082675 | .005376344 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 187 | 34969 | 6539203 | 13.6747943 | 5.7184791 | .005347594 |
| 188 | 35344 | 6644672 | 13.7113092 | 5.7286543 | .005319149 |
| 189 | 35721 | 6751269 | 13.7477271 | 5.7387936 | .005291005 |
| 190 | 36100 | 6859000 | 13.7840488 | 5.7488971 | .005263158 |
| 191 | 36481 | 6967871 | 13.8202750 | 5.7589652 | .005235602 |
| 192 | 36864 | 7077888 | 13.8564065 | 5.7689982 | .005208333 |
| 193 | 37249 | 7189057 | 13.8924440 | 5.7789966 | .005181347 |
| 194 | 37636 | 7301384 | 13.9283883 | 5.7889604 | .005154639 |
| 195 | 38025 | 7414875 | 13.9642400 | 5.7988900 | .005128205 |
| 196 | 38416 | 7529536 | 14.0000000 | 5.8087857 | .005102041 |
| 197 | 38809 | 7645373 | 14.0356688 | 5.8186479 | .005076142 |
| 198 | 39204 | 7762392 | 14.0712473 | 5.8284767 | .005050505 |
| 199 | 39601 | 7880599 | 14.1067360 | 5.8382725 | .005025126 |
| 200 | 40000 | 8000000 | 14.1421356 | 5.8480355 | .005000000 |
| 201 | 40401 | 8120601 | 14.1774469 | 5.8577660 | .004975124 |
| 202 | 40804 | 8242408 | 14.2126704 | 5.8674643 | .004950495 |
| 203 | 41209 | 8365427 | 14.2478068 | 5.8771307 | .004926108 |
| 204 | 41616 | 8489664 | 14.2828569 | 5.8867653 | .004901961 |
| 205 | 42025 | 8615125 | 14.3178211 | 5.8963685 | .004878049 |
| 206 | 42436 | 8741816 | 14.3527001 | 5.9059406 | .004854369 |
| 207 | 42849 | 8869743 | 14.3874946 | 5.9154817 | .004830918 |
| 208 | 43264 | 8998912 | 14.4222051 | 5.9249921 | .004807692 |
| 209 | 43681 | 9129329 | 14.4568323 | 5.9344721 | .004784689 |
| 210 | 44100 | 9261000 | 14.4913767 | 5.9439220 | .004761905 |
| 211 | 44521 | 9393931 | 14.5258390 | 5.9533418 | .004739336 |
| 212 | 44944 | 9528128 | 14.5602198 | 5.9627320 | .004716981 |
| 213 | 45369 | 9663597 | 14.5945195 | 5.9720926 | .004694836 |
| 214 | 45796 | 9800344 | 14.6287388 | 5.9814240 | .004672897 |
| 215 | 46225 | 9938375 | 14.6628783 | 5.9907264 | .004651163 |
| 216 | 46656 | 10077696 | 14.6969385 | 6.0000000 | .004629630 |
| 217 | 47089 | 10218313 | 14.7309199 | 6.0092450 | .004608295 |
| 218 | 47524 | 10360232 | 14.7648231 | 6.0184617 | .004587156 |
| 219 | 47961 | 10503459 | 14.7986486 | 6.0276502 | .004566210 |
| 220 | 48400 | 10648000 | 14.8323970 | 6.0368107 | .004545455 |
| 221 | 48841 | 10793861 | 14.8660687 | 6.0459435 | .004524887 |
| 222 | 49284 | 10941048 | 14.8996644 | 6.0550489 | .004504505 |
| 223 | 49729 | 11089567 | 14.9331845 | 6.0641270 | .004484305 |
| 224 | 50176 | 11239424 | 14.9666295 | 6.0731779 | .004464286 |
| 225 | 50625 | 11390625 | 15.0000000 | 6.0822020 | .004444444 |
| 226 | 51076 | 11543176 | 15.0332964 | 6.0911994 | .004424779 |
| 227 | 51529 | 11697083 | 15.0665192 | 6.1001702 | .004405286 |
| 228 | 51984 | 11852352 | 15.0996689 | 6.1091147 | .004385965 |
| 229 | 52441 | 12008989 | 15.1327460 | 6.1180332 | .004366812 |
| 230 | 52900 | 12167000 | 15.1657509 | 6.1269257 | .004347826 |
| 231 | 53361 | 12326391 | 15.1986842 | 6.1357924 | .004329004 |
| 232 | 53824 | 12487168 | 15.2315462 | 6.1446337 | .004310345 |
| 233 | 54289 | 12649337 | 15.2643375 | 6.1534495 | .004291845 |
| 234 | 54756 | 12812904 | 15.2970585 | 6.1622401 | .004273504 |
| 235 | 55225 | 12977875 | 15.3297097 | 6.1710058 | .004255319 |
| 236 | 55696 | 13144256 | 15.3622915 | 6.1797466 | .004237288 |
| 237 | 56169 | 13312053 | 15.3948043 | 6.1884628 | .004219409 |
| 238 | 56644 | 13481272 | 15.4272486 | 6.1971544 | .004201681 |
| 239 | 57121 | 13651919 | 15.4596248 | 6.2058218 | .004184100 |
| 240 | 57600 | 13824000 | 15.4919334 | 6.2144650 | .004166667 |
| 241 | 58081 | 13997521 | 15.5241747 | 6.2230843 | .004149378 |
| 242 | 58564 | 14172488 | 15.5563492 | 6.2316797 | .004132231 |
| 243 | 59049 | 14348907 | 15.5884573 | 6.2402515 | .004115226 |
| 244 | 59536 | 14526784 | 15.6204994 | 6.2487998 | .004098361 |
| 245 | 60025 | 14706125 | 15.6524758 | 6.2573248 | .004081633 |
| 246 | 60516 | 14886936 | 15.6843871 | 6.2658266 | .004065041 |
| 247 | 61009 | 15069223 | 15.7162336 | 6.2743054 | .004048583 |
| 248 | 61504 | 15252992 | 15.7480157 | 6.2827613 | .004032258 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 249 | 62001 | 15438249 | 15.7797338 | 6.2911946 | .004016064 |
| 250 | 62500 | 15625000 | 15.8113883 | 6.2996053 | .004000000 |
| 251 | 63001 | 15813251 | 15.8429795 | 6.3079935 | .003984064 |
| 252 | 63504 | 16003008 | 15.8745079 | 6.3163596 | .003968254 |
| 253 | 64009 | 16194277 | 15.9059737 | 6.3247035 | .003952569 |
| 254 | 64516 | 16387064 | 15.9373775 | 6.3330256 | .003937008 |
| 255 | 65025 | 16581375 | 15.9687194 | 6.3413257 | .003921569 |
| 256 | 65536 | 16777216 | 16.0000000 | 6.3496042 | .003906250 |
| 257 | 66049 | 16974593 | 16.0312195 | 6.3578611 | .003891051 |
| 258 | 66564 | 17173512 | 16.0623784 | 6.3660968 | .003875969 |
| 259 | 67081 | 17373979 | 16.0934769 | 6.3743111 | .003861004 |
| 260 | 67600 | 17576000 | 16.1245155 | 6.3825043 | .003846154 |
| 261 | 68121 | 17779581 | 16.1554944 | 6.3906765 | .003831418 |
| 262 | 68644 | 17984728 | 16.1864141 | 6.3988279 | .003816794 |
| 263 | 69169 | 18191447 | 16.2172747 | 6.4069585 | .003802281 |
| 264 | 69696 | 18399744 | 16.2480768 | 6.4150687 | .003787879 |
| 265 | 70225 | 18609625 | 16.2788206 | 6.4231583 | .003773585 |
| 266 | 70756 | 18821096 | 16.3095064 | 6.4312276 | .003759398 |
| 267 | 71289 | 19034163 | 16.3401346 | 6.4392767 | .003745318 |
| 268 | 71824 | 19248832 | 16.3707055 | 6.4473057 | .003731343 |
| 269 | 72361 | 19465109 | 16.4012195 | 6.4553148 | .003717472 |
| 270 | 72900 | 19683000 | 16.4316767 | 6.4633041 | .003703704 |
| 271 | 73441 | 19902511 | 16.4620776 | 6.4712736 | .003690037 |
| 272 | 73984 | 20123648 | 16.4924225 | 6.4792236 | .003676471 |
| 273 | 74529 | 20346417 | 16.5227116 | 6.4871541 | .003663004 |
| 274 | 75076 | 20570824 | 16.5529454 | 6.4950653 | .003649635 |
| 275 | 75625 | 20796875 | 16.5831240 | 6.5029572 | .003636364 |
| 276 | 76176 | 21024576 | 16.6132477 | 6.5108300 | .003623188 |
| 277 | 76729 | 21253933 | 16.6433170 | 6.5186839 | .003610108 |
| 278 | 77284 | 21484952 | 16.6733320 | 6.5265189 | .003597122 |
| 279 | 77841 | 21717639 | 16.7032931 | 6.5343351 | .003584229 |
| 280 | 78400 | 21952000 | 16.7332005 | 6.5421326 | .003571429 |
| 281 | 78961 | 22188041 | 16.7630546 | 6.5499116 | .003558719 |
| 282 | 79524 | 22425768 | 16.7928556 | 6.5576722 | .003546099 |
| 283 | 80089 | 22665187 | 16.8226038 | 6.5654144 | .003533569 |
| 284 | 80656 | 22906304 | 16.8522995 | 6.5731385 | .003521127 |
| 285 | 81225 | 23149125 | 16.8819430 | 6.5808443 | .003508772 |
| 286 | 81796 | 23393656 | 16.9115345 | 6.5885323 | .003496503 |
| 287 | 82369 | 23639903 | 16.9410743 | 6.5962023 | .003484321 |
| 288 | 82944 | 23887872 | 16.9705627 | 6.6038545 | .003472222 |
| 289 | 83521 | 24137569 | 17.0000000 | 6.6114890 | .003460208 |
| 290 | 84100 | 24389000 | 17.0293864 | 6.6191060 | .003448276 |
| 291 | 84681 | 24642171 | 17.0587221 | 6.6267054 | .003436426 |
| 292 | 85264 | 24897088 | 17.0880075 | 6.6342874 | .003424658 |
| 293 | 85849 | 25153757 | 17.1172428 | 6.6418522 | .003412969 |
| 294 | 86436 | 25412184 | 17.1464282 | 6.6493998 | .003401361 |
| 295 | 87025 | 25672375 | 17.1755640 | 6.6569302 | .003389831 |
| 296 | 87616 | 25934336 | 17.2046505 | 6.6644437 | .003378378 |
| 297 | 88209 | 26198073 | 17.2336879 | 6.6719403 | .003367003 |
| 298 | 88804 | 26463592 | 17.2626765 | 6.6794200 | .003355705 |
| 299 | 89401 | 26730899 | 17.2916165 | 6.6868831 | .003344482 |
| 300 | 90000 | 27000000 | 17.3205081 | 6.6943295 | .003333333 |
| 301 | 90601 | 27270901 | 17.3493516 | 6.7017593 | .003322259 |
| 302 | 91204 | 27543608 | 17.3781472 | 6.7091729 | .003311258 |
| 303 | 91809 | 27818127 | 17.4068952 | 6.7165700 | .003300330 |
| 304 | 92416 | 28094464 | 17.4355958 | 6.7239508 | .003289474 |
| 305 | 93025 | 28372625 | 17.4642492 | 6.7313155 | .003278689 |
| 306 | 93636 | 28652616 | 17.4928557 | 6.7386641 | .003267974 |
| 307 | 94249 | 28934443 | 17.5214155 | 6.7459967 | .003257329 |
| 308 | 94864 | 29218112 | 17.5499288 | 6.7533134 | .003246753 |
| 309 | 95481 | 29503629 | 17.5783958 | 6.7606143 | .003236246 |
| 310 | 96100 | 29791000 | 17.6068169 | 6.7678995 | .003225806 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 311 | 96721 | 30080231 | 17.6351921 | 6.7751690 | .003215434 |
| 312 | 97344 | 30371328 | 17.6635217 | 6.7824229 | .003205128 |
| 313 | 97969 | 30664297 | 17.6918060 | 6.7896613 | .003194888 |
| 314 | 98596 | 30959144 | 17.7200451 | 6.7968844 | .003184713 |
| 315 | 99225 | 31255875 | 17.7482393 | 6.8040921 | .003174603 |
| 316 | 99856 | 31554496 | 17.7763888 | 6.8112847 | .003164557 |
| 317 | 100489 | 31855013 | 17.8044938 | 6.8184620 | .003154574 |
| 318 | 101124 | 32157432 | 17.8325545 | 6.8256242 | .003144654 |
| 319 | 101761 | 32461759 | 17.8605711 | 6.8327714 | .003134796 |
| 320 | 102400 | 32768000 | 17.8885438 | 6.8399037 | .003125000 |
| 321 | 103041 | 33076161 | 17.9164729 | 6.8470213 | .003115265 |
| 322 | 103684 | 33386248 | 17.9443584 | 6.8541240 | .003105590 |
| 323 | 104329 | 33698267 | 17.9722008 | 6.8612120 | .003095975 |
| 324 | 104976 | 34012224 | 18.0000000 | 6.8682855 | .003086420 |
| 325 | 105625 | 34328125 | 18.0277564 | 6.8753443 | .003076923 |
| 326 | 106276 | 34645976 | 18.0554701 | 6.8823888 | .003067485 |
| 327 | 106929 | 34965783 | 18.0831413 | 6.8894188 | .003058104 |
| 328 | 107584 | 35287552 | 18.1107703 | 6.8964345 | .003048780 |
| 329 | 108241 | 35611289 | 18.1383571 | 6.9034359 | .003039514 |
| 330 | 108900 | 35937000 | 18.1659021 | 6.9104232 | .003030303 |
| 331 | 109561 | 36264691 | 18.1934054 | 6.9173964 | .003021148 |
| 332 | 110224 | 36594368 | 18.2208672 | 6.9243556 | .003012048 |
| 333 | 110889 | 36926037 | 18.2482876 | 6.9313008 | .003003003 |
| 334 | 111556 | 37259704 | 18.2756669 | 6.9382321 | .002994012 |
| 335 | 112225 | 37595375 | 18.3030052 | 6.9451496 | .002985075 |
| 336 | 112896 | 37933056 | 18.3303028 | 6.9520533 | .002976190 |
| 337 | 113569 | 38272753 | 18.3575598 | 6.9589434 | .002967359 |
| 338 | 114244 | 38614472 | 18.3847763 | 6.9658198 | .002958580 |
| 339 | 114921 | 38958219 | 18.4119526 | 6.9726826 | .002949853 |
| 340 | 115600 | 39304000 | 18.4390889 | 6.9795321 | .002941176 |
| 341 | 116281 | 39651821 | 18.4661853 | 6.9863681 | .002932551 |
| 342 | 116964 | 40001688 | 18.4932420 | 6.9931906 | .002923977 |
| 343 | 117649 | 40353607 | 18.5202592 | 7.0000000 | .002915452 |
| 344 | 118336 | 40707584 | 18.5472370 | 7.0067962 | .002906977 |
| 345 | 119025 | 41063625 | 18.5741756 | 7.0135791 | .002898551 |
| 346 | 119716 | 41421736 | 18.6010752 | 7.0203490 | .002890173 |
| 347 | 120409 | 41781923 | 18.6279360 | 7.0271058 | .002881844 |
| 348 | 121104 | 42144192 | 18.6547581 | 7.0338497 | .002873563 |
| 349 | 121801 | 42508549 | 18.6815417 | 7.0405806 | .002865330 |
| 350 | 122500 | 42875000 | 18.7082869 | 7.0472987 | .002857143 |
| 351 | 123201 | 43243551 | 18.7349940 | 7.0540041 | .002849003 |
| 352 | 123904 | 43614208 | 18.7616630 | 7.0606967 | .002840909 |
| 353 | 124609 | 43986977 | 18.7882942 | 7.0673767 | .002832861 |
| 354 | 125316 | 44361864 | 18.8148877 | 7.0740440 | .002824859 |
| 355 | 126025 | 44738875 | 18.8414437 | 7.0806988 | .002816901 |
| 356 | 126736 | 45118016 | 18.8679623 | 7.0873411 | .002808989 |
| 357 | 127449 | 45499293 | 18.8944436 | 7.0939709 | .002801120 |
| 358 | 128164 | 45882712 | 18.9208879 | 7.1005885 | .002793296 |
| 359 | 128881 | 46268279 | 18.9472953 | 7.1071937 | .002785515 |
| 360 | 129600 | 46656000 | 18.9736660 | 7.1137866 | .002777778 |
| 361 | 130321 | 47045881 | 19 0000000 | 7.1203674 | .002770083 |
| 362 | 131044 | 47437928 | 19.0262976 | 7.1269360 | .002762431 |
| 363 | 131769 | 47832147 | 19.0525589 | 7.1334925 | .002754821 |
| 364 | 132496 | 48228544 | 19.0787840 | 7.1400370 | .002747253 |
| 365 | 133225 | 48627125 | 19.1049732 | 7.1465695 | .002739726 |
| 366 | 133956 | 49027896 | 19.1311265 | 7.1530901 | .002732240 |
| 367 | 134689 | 49430863 | 19.1572441 | 7.1595988 | .002724796 |
| 368 | 135424 | 49836032 | 19.1833261 | 7.1660957 | .002717391 |
| 369 | 136161 | 50243409 | 19.2093727 | 7.1725809 | .002710027 |
| 370 | 136900 | 50653000 | 19.2353841 | 7.1790544 | .002702703 |
| 371 | 137641 | 51064811 | 19.2613603 | 7.1855162 | .002695418 |
| 372 | 138384 | 51478848 | 19.2873015 | 7.1919663 | .002688172 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 373 | 139129 | 51895117 | 19.3132079 | 7.1984050 | .002680965 |
| 374 | 139876 | 52313624 | 19.3390796 | 7.2048322 | .002673797 |
| 375 | 140625 | 52734375 | 19.3649167 | 7.2112479 | .002666667 |
| 376 | 141376 | 53157376 | 19.3907194 | 7.2176522 | .002659574 |
| 377 | 142129 | 53582633 | 19.4164878 | 7.2240450 | .002652520 |
| 378 | 142884 | 54010152 | 19.4422221 | 7.2304268 | .002645503 |
| 379 | 143641 | 54439939 | 19.4679223 | 7.2367972 | .002638522 |
| 380 | 144400 | 54872000 | 19.4935887 | 7.2431565 | .002631579 |
| 381 | 145161 | 55306341 | 19.5192213 | 7.2495045 | .002624672 |
| 382 | 145924 | 55742968 | 19.5448203 | 7.2558415 | .002617801 |
| 383 | 146689 | 56181887 | 19.5703858 | 7.2621675 | .002610966 |
| 384 | 147456 | 56623104 | 19.5959179 | 7.2684824 | .002604167 |
| 385 | 148225 | 57066625 | 19.6214169 | 7.2747864 | .002597403 |
| 386 | 148996 | 57512456 | 19.6468827 | 7.2810794 | .002590674 |
| 387 | 149769 | 57960603 | 19.6723156 | 7.2873617 | .002583979 |
| 388 | 150544 | 58411072 | 19.6977156 | 7.2936330 | .002577320 |
| 389 | 151321 | 58863869 | 19.7230829 | 7.2998936 | .002570694 |
| 390 | 152100 | 59319000 | 19.7484177 | 7.3061436 | .002564103 |
| 391 | 152881 | 59776471 | 19.7737199 | 7.3123828 | .002557545 |
| 392 | 153664 | 60236288 | 19.7989899 | 7.3186114 | .002551020 |
| 393 | 154449 | 60698457 | 19.8242276 | 7.3248295 | .002544529 |
| 394 | 155236 | 61162984 | 19.8494332 | 7.3310369 | .002538071 |
| 395 | 156025 | 61629875 | 19.8746069 | 7.3372339 | .002531646 |
| 396 | 156816 | 62099136 | 19.8997487 | 7.3434205 | .002525253 |
| 397 | 157609 | 62570773 | 19.9248588 | 7.3495966 | .002518892 |
| 398 | 158404 | 63044792 | 19.9499373 | 7.3557624 | .002512563 |
| 399 | 159201 | 63521199 | 19.9749844 | 7.3619178 | .002506266 |
| 400 | 160000 | 64000000 | 20.0000000 | 7.3680630 | .002500000 |
| 401 | 160801 | 64481201 | 20.0249844 | 7.3741979 | .002493766 |
| 402 | 161604 | 64964808 | 20.0499377 | 7.3803227 | .002487562 |
| 403 | 162409 | 65450827 | 20.0748599 | 7.3864373 | .002481390 |
| 404 | 163216 | 65939264 | 20.0997512 | 7.3925418 | .002475248 |
| 405 | 164025 | 66430125 | 20.1246118 | 7.3986363 | .002469136 |
| 406 | 164836 | 66923416 | 20.1494417 | 7.4047206 | .002463054 |
| 407 | 165649 | 67419143 | 20.1742410 | 7.4107950 | .002457002 |
| 408 | 166464 | 67917312 | 20.1990099 | 7.4168595 | .002450980 |
| 409 | 167281 | 68417929 | 20.2237484 | 7.4229142 | .002444988 |
| 410 | 168100 | 68921000 | 20.2484567 | 7.4289589 | .002439024 |
| 411 | 168921 | 69426531 | 20.2731349 | 7.4349938 | .002433090 |
| 412 | 169744 | 69934528 | 20.2977831 | 7.4410189 | .002427184 |
| 413 | 170569 | 70444997 | 20.3224014 | 7.4470342 | .002421308 |
| 414 | 171396 | 70957944 | 20.3469899 | 7.4530399 | .002415459 |
| 415 | 172225 | 71473375 | 20.3715488 | 7.4590359 | .002409639 |
| 416 | 173056 | 71991296 | 20.3960781 | 7.4650223 | .002403846 |
| 417 | 173889 | 72511713 | 20.4205779 | 7.4709991 | .002398082 |
| 418 | 174724 | 73034632 | 20.4450483 | 7.4769664 | .002392344 |
| 419 | 175561 | 73560059 | 20.4694895 | 7.4829242 | .002386635 |
| 420 | 176400 | 74088000 | 20.4939015 | 7.4888724 | .002380952 |
| 421 | 177241 | 74618461 | 20.5182845 | 7.4948113 | .002375297 |
| 422 | 178084 | 75151448 | 20.5426386 | 7.5007406 | .002369668 |
| 423 | 178929 | 75686967 | 20.5669638 | 7.5066607 | .002364066 |
| 424 | 179776 | 76225024 | 20 5912603 | 7.5125715 | .002358491 |
| 425 | 180625 | 76765625 | 20.6155281 | 7.5184730 | .002352941 |
| 426 | 181476 | 77308776 | 20.6397674 | 7.5243652 | .002347418 |
| 427 | 182329 | 77854483 | 20.6639783 | 7.5302482 | .002341920 |
| 428 | 183184 | 78402752 | 20.6881609 | 7.5361221 | .002336449 |
| 429 | 184041 | 78953589 | 20.7123152 | 7.5419867 | .002331002 |
| 430 | 184900 | 79507000 | 20.7364414 | 7.5478423 | .002325581 |
| 431 | 185761 | 80062991 | 20.7605395 | 7.5536888 | .002320186 |
| 432 | 186624 | 80621568 | 20.7846097 | 7.5595263 | .002314815 |
| 433 | 187489 | 81182737 | 20.8086520 | 7.5653548 | .002309469 |
| 434 | 188356 | 81746504 | 20.8326667 | 7.5711743 | .002304147 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 435 | 189225 | 82312875 | 20.8566536 | 7.5769849 | .002298851 |
| 436 | 190096 | 82881856 | 20.8806130 | 7.5827865 | .002293578 |
| 437 | 190969 | 83453453 | 20.9045450 | 7.5885793 | .002288330 |
| 438 | 191844 | 84027672 | 20.9284495 | 7.5943633 | .002283105 |
| 439 | 192721 | 84604519 | 20.9523268 | 7.6001385 | .002277904 |
| 440 | 193600 | 85184000 | 20.9761770 | 7.6059049 | .002272727 |
| 441 | 194481 | 85766121 | 21.0000000 | 7.6116626 | .002267574 |
| 442 | 195364 | 86350888 | 21.0237960 | 7.6174116 | .002262443 |
| 443 | 196249 | 86938307 | 21.0475652 | 7.6231519 | .002257336 |
| 444 | 197136 | 87528384 | 21.0713075 | 7.6288837 | .002252252 |
| 445 | 198025 | 88121125 | 21.0950231 | 7.6346067 | .002247191 |
| 446 | 198916 | 88716536 | 21.1187121 | 7.6403213 | .002242152 |
| 447 | 199809 | 89314623 | 21.1423745 | 7.6460272 | .002237136 |
| 448 | 200704 | 89915392 | 21.1660105 | 7.6517247 | .002232143 |
| 449 | 201601 | 90518849 | 21.1896201 | 7.6574133 | .002227171 |
| 450 | 202500 | 91125000 | 21.2132034 | 7.6630943 | .002222222 |
| 451 | 203401 | 91733851 | 21.2367606 | 7.6687665 | .002217295 |
| 452 | 204304 | 92345408 | 21.2602916 | 7.6744303 | .002212389 |
| 453 | 205209 | 92959677 | 21.2837967 | 7.6800857 | .002207506 |
| 454 | 206116 | 93576664 | 21.3072758 | 7.6857328 | .002202643 |
| 455 | 207025 | 94196375 | 21.3307290 | 7.6913717 | .002197802 |
| 456 | 207936 | 94818816 | 21.3541565 | 7.6970023 | .002192982 |
| 457 | 208849 | 95443993 | 21.3775583 | 7.7026246 | .002188184 |
| 458 | 209764 | 96071912 | 21.4009346 | 7.7082388 | .002183406 |
| 459 | 210681 | 96702579 | 21.4242853 | 7.7138448 | .002178649 |
| 460 | 211600 | 97336000 | 21.4476106 | 7.7194426 | .002173913 |
| 461 | 212521 | 97972181 | 21.4709106 | 7.7250325 | .002169197 |
| 462 | 213444 | 98611128 | 21.4941853 | 7.7306141 | .002164502 |
| 463 | 214369 | 99252847 | 21.5174348 | 7.7361877 | .002159827 |
| 464 | 215296 | 99897344 | 21.5406592 | 7.7417532 | .002155172 |
| 465 | 216225 | 100544625 | 21.5638587 | 7.7473109 | .002150538 |
| 466 | 217156 | 101194696 | 21.5870331 | 7.7528606 | .002145923 |
| 467 | 218089 | 101847563 | 21.6101828 | 7.7584023 | .002141328 |
| 468 | 219024 | 102503232 | 21.6333077 | 7.7639361 | .002136752 |
| 469 | 219961 | 103161709 | 21.6564078 | 7.7694620 | .002132196 |
| 470 | 220900 | 103823000 | 21.6794834 | 7.7749801 | .002127660 |
| 471 | 221841 | 104487111 | 21.7025344 | 7.7804904 | .002123142 |
| 472 | 222784 | 105154048 | 21.7255610 | 7.7859928 | .002118644 |
| 473 | 223729 | 105823817 | 21.7485632 | 7.7914875 | .002114165 |
| 474 | 224676 | 106496424 | 21.7715411 | 7.7969745 | .002109705 |
| 475 | 225625 | 107171875 | 21.7944947 | 7.8024538 | .002105263 |
| 476 | 226576 | 107850176 | 21.8174242 | 7.8079254 | .002100840 |
| 477 | 227529 | 108531333 | 21.8403297 | 7.8133892 | .002096436 |
| 478 | 228484 | 109215352 | 21 8632111 | 7.8188456 | .002092050 |
| 479 | 229441 | 109902239 | 21.8860686 | 7.8242942 | .002087683 |
| 480 | 230400 | 110592000 | 21.9089023 | 7.8297353 | .002083333 |
| 481 | 231361 | 111284641 | 21.9317122 | 7.8351688 | .002079002 |
| 482 | 232324 | 111980168 | 21.9544984 | 7.8405949 | .002074689 |
| 483 | 233289 | 112678587 | 21.9772610 | 7.8460134 | .002070393 |
| 484 | 234256 | 113379904 | 22.0000000 | 7.8514244 | .002066116 |
| 485 | 235225 | 114084125 | 22.0227155 | 7.8568281 | .002061856 |
| 486 | 236196 | 114791256 | 22.0454077 | 7.8622242 | .002057613 |
| 487 | 237169 | 115501303 | 22.0680765 | 7.8676130 | .002053388 |
| 488 | 238144 | 116214272 | 22.0907220 | 7.8729944 | .002049180 |
| 489 | 239121 | 116930169 | 22.1133444 | 7.8783684 | .002044990 |
| 490 | 240100 | 117649000 | 22.1359436 | 7.8837352 | .002040816 |
| 491 | 241081 | 118370771 | 22.1585198 | 7.8890946 | .002036660 |
| 492 | 242064 | 119095488 | 22.1810730 | 7.8944468 | .002032520 |
| 493 | 243049 | 119823157 | 22.2036033 | 7.8997917 | .002028398 |
| 494 | 244036 | 120553784 | 22.2261108 | 7.9051294 | .002024291 |
| 495 | 245025 | 121287375 | 22.2485955 | 7.9104599 | .002020202 |
| 496 | 246016 | 122023936 | 22.2710575 | 7.9157832 | .002016129 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 497 | 247009 | 122763473 | 22.2934968 | 7.9210994 | .002012072 |
| 498 | 248004 | 123505992 | 22.3159136 | 7.9264085 | .002008032 |
| 499 | 249001 | 124251499 | 22.3383079 | 7.9317104 | .002004008 |
| 500 | 250000 | 125000000 | 22.3606798 | 7.9370053 | .002000000 |
| 501 | 251001 | 125751501 | 22.3830293 | 7.9422931 | .001996008 |
| 502 | 252004 | 126506008 | 22.4053565 | 7.9475739 | .001992032 |
| 503 | 253009 | 127263527 | 22.4276615 | 7.9528477 | .001988072 |
| 504 | 254016 | 128024064 | 22.4499443 | 7.9581144 | .001984127 |
| 505 | 255025 | 128787625 | 22.4722051 | 7.9633743 | .001980198 |
| 506 | 256036 | 129554216 | 22.4944438 | 7.9686271 | .001976285 |
| 507 | 257049 | 130323843 | 22.5166605 | 7.9738731 | .001972387 |
| 508 | 258064 | 131096512 | 22.5388553 | 7.9791122 | .001968504 |
| 509 | 259081 | 131872229 | 22.5610283 | 7.9843444 | .001964637 |
| 510 | 260100 | 132651000 | 22.5831796 | 7.9895697 | .001960784 |
| 511 | 261121 | 133432831 | 22.6053091 | 7.9947883 | .001956947 |
| 512 | 262144 | 134217728 | 22.6274170 | 8.0000000 | .001953125 |
| 513 | 263169 | 135005697 | 22.6495033 | 8.0052049 | .001949318 |
| 514 | 264196 | 135796744 | 22.6715681 | 8.0104032 | .001945525 |
| 515 | 265225 | 136590875 | 22.6936114 | 8.0155946 | .001941748 |
| 516 | 266256 | 137388096 | 22.7156334 | 8.0207794 | .001937984 |
| 517 | 267289 | 138188413 | 22.7376340 | 8.0259574 | .001934236 |
| 518 | 268324 | 138991832 | 22.7596134 | 8.0311287 | .001930502 |
| 519 | 269361 | 139798359 | 22.7815715 | 8.0362935 | .001926782 |
| 520 | 270400 | 140608000 | 22.8035085 | 8.0414515 | .001923077 |
| 521 | 271441 | 141420761 | 22.8254244 | 8.0466030 | .001919386 |
| 522 | 272484 | 142236648 | 22.8473193 | 8.0517479 | .001915709 |
| 523 | 273529 | 143055667 | 22.8691933 | 8.0568862 | .001912046 |
| 524 | 274576 | 143877824 | 22.8910463 | 8.0620180 | .001908397 |
| 525 | 275625 | 144703125 | 22.9128785 | 8.0671432 | .001904762 |
| 526 | 276676 | 145531576 | 22.9346899 | 8.0722620 | .001901141 |
| 527 | 277729 | 146363183 | 22.9564806 | 8.0773743 | .001897533 |
| 528 | 278784 | 147197952 | 22.9782506 | 8.0824800 | .001893939 |
| 529 | 279841 | 148035889 | 23.0000000 | 8.0875794 | .001890359 |
| 530 | 280900 | 148877000 | 23.0217289 | 8.0926723 | .001886792 |
| 531 | 281961 | 149721291 | 23.0434372 | 8.0977589 | .001883239 |
| 532 | 283024 | 150568768 | 23.0651252 | 8.1028390 | .001879699 |
| 533 | 284089 | 151419437 | 23.0867928 | 8.1079128 | .001876173 |
| 534 | 285156 | 152273304 | 23.1084400 | 8.1129803 | .001872659 |
| 535 | 286225 | 153130375 | 23.1300670 | 8.1180414 | .001869159 |
| 536 | 287296 | 153990656 | 23.1516738 | 8.1230962 | .001865672 |
| 537 | 288369 | 154854153 | 23.1732605 | 8.1281447 | .001862197 |
| 538 | 289444 | 155720872 | 23.1948270 | 8.1331870 | .001858736 |
| 539 | 290521 | 156590819 | 23.2163735 | 8.1382230 | .001855288 |
| 540 | 291600 | 157464000 | 23.2379001 | 8.1432529 | .001851852 |
| 541 | 292681 | 158340421 | 23.2594067 | 8.1482765 | .001848429 |
| 542 | 293764 | 159220088 | 23.2808935 | 8 1532939 | .001845018 |
| 543 | 294849 | 160103007 | 23.3023604 | 8.1583051 | .001841621 |
| 544 | 295936 | 160989184 | 23.3238076 | 8.1633102 | .001838235 |
| 545 | 297025 | 161878625 | 23.3452351 | 8.1683092 | .001834862 |
| 546 | 298116 | 162771336 | 23.3666429 | 8.1733020 | .001831502 |
| 547 | 299209 | 163667323 | 23.3880311 | 8.1782888 | .001828154 |
| 548 | 300304 | 164566592 | 23.4093998 | 8.1832695 | .001824818 |
| 549 | 301401 | 165469149 | 23.4307490 | 8.1882441 | .001821494 |
| 550 | 302500 | 166375000 | 23.4520788 | 8.1932127 | .001818182 |
| 551 | 303601 | 167284151 | 23.4733892 | 8.1981752 | .001814882 |
| 552 | 304704 | 168196608 | 23.4946802 | 8.2031319 | .001811594 |
| 553 | 305809 | 169112377 | 23.5159520 | 8.2080825 | .001808318 |
| 554 | 306916 | 170031464 | 23.5372046 | 8.2130271 | .001805054 |
| 555 | 308025 | 170953875 | 23.5584380 | 8.2179657 | .001801802 |
| 556 | 309136 | 171879616 | 23.5796522 | 8.2228985 | .001798561 |
| 557 | 310249 | 172808693 | 23.6008474 | 8.2278254 | .001795332 |
| 558 | 311364 | 173741112 | 23.6220236 | 8.2327463 | .001792115 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 559 | 312481 | 174676879 | 23.6431808 | 8.2376614 | .001788909 |
| 560 | 313600 | 175616000 | 23.6643191 | 8.2425706 | .001785714 |
| 561 | 314721 | 176558481 | 23.6854386 | 8.2474740 | .001782531 |
| 562 | 315844 | 177504328 | 23.7065392 | 8.2523715 | .001779359 |
| 563 | 316969 | 178453547 | 23.7276210 | 8.2572633 | .001776199 |
| 564 | 318096 | 179406144 | 23.7486842 | 8.2621492 | .001773050 |
| 565 | 319225 | 180362125 | 23.7697286 | 8.2670294 | .001769912 |
| 566 | 320356 | 181321496 | 23.7907545 | 8.2719039 | .001766784 |
| 567 | 321489 | 182284263 | 23.8117618 | 8.2767726 | .001763668 |
| 568 | 322624 | 183250432 | 23.8327506 | 8.2816355 | .001760563 |
| 569 | 323761 | 184220000 | 23.8537209 | 8.2864928 | .001757469 |
| 570 | 324900 | 185193000 | 23.8746728 | 8.2913444 | .001754386 |
| 571 | 326041 | 186169411 | 23.8956063 | 8.2961903 | .001751313 |
| 572 | 327184 | 187149248 | 23.9165215 | 8.3010304 | .001748252 |
| 573 | 328329 | 188132517 | 23.9374184 | 8.3058651 | .001745201 |
| 574 | 329476 | 189119224 | 23.9582971 | 8.3106941 | .001742160 |
| 575 | 330625 | 190109375 | 23.9791576 | 8.3155175 | .001739130 |
| 576 | 331776 | 191102976 | 24.0000000 | 8.3203353 | .001736111 |
| 577 | 332929 | 192100033 | 24.0208243 | 8.3251475 | .001733102 |
| 578 | 334084 | 193100552 | 24.0416306 | 8.3299542 | .001730104 |
| 579 | 335241 | 194104539 | 24.0624188 | 8.3347553 | .001727116 |
| 580 | 336400 | 195112000 | 24.0831891 | 8.3395509 | .001724138 |
| 581 | 337561 | 196122941 | 24.1039416 | 8.3443410 | .001721170 |
| 582 | 338724 | 197137368 | 24.1246762 | 8.3491256 | .001718213 |
| 583 | 339889 | 198155287 | 24.1453929 | 8.3539047 | .001715266 |
| 584 | 341056 | 199176704 | 24.1660919 | 8.3586784 | .001712329 |
| 585 | 342225 | 200201625 | 24.1867732 | 8.3634466 | .001709402 |
| 586 | 343396 | 201230056 | 24.2074369 | 8.3682095 | .001706485 |
| 587 | 344569 | 202262003 | 24.2280829 | 8.3729668 | .001703578 |
| 588 | 345744 | 203297472 | 24.2487113 | 8.3777188 | .001700680 |
| 589 | 346921 | 204336469 | 24.2693222 | 8.3824653 | .001697793 |
| 590 | 348100 | 205379000 | 24.2899156 | 8.3872065 | .001694915 |
| 591 | 349281 | 206425071 | 24.3104916 | 8.3919423 | .001692047 |
| 592 | 350464 | 207474688 | 24.3310501 | 8.3966729 | .001689189 |
| 593 | 351649 | 208527857 | 24.3515913 | 8.4013981 | .001686341 |
| 594 | 352836 | 209584584 | 24.3721152 | 8.4061180 | .001683502 |
| 595 | 354025 | 210644875 | 24.3926218 | 8.4108326 | .001680672 |
| 596 | 355216 | 211708736 | 24.4131112 | 8.4155419 | .001677852 |
| 597 | 356409 | 212776173 | 24.4335834 | 8.4202460 | .001675042 |
| 598 | 357604 | 213847192 | 24.4540385 | 8.4249448 | .001672241 |
| 599 | 358801 | 214921799 | 24.4744765 | 8.4296383 | .001669449 |
| 600 | 360000 | 216000000 | 24.4948974 | 8.4343267 | .001666667 |
| 601 | 361201 | 217081801 | 24.5153013 | 8.4390098 | .001663894 |
| 602 | 362404 | 218167208 | 24.5356883 | 8.4436877 | .001661130 |
| 603 | 363609 | 219256227 | 24.5560583 | 8.4483605 | .001658375 |
| 604 | 364816 | 220348864 | 24.5764115 | 8.4530281 | .001655629 |
| 605 | 366025 | 221445125 | 24.5967478 | 8.4576906 | .001652893 |
| 606 | 367236 | 222545016 | 24.6170673 | 8.4623479 | .001650165 |
| 607 | 368449 | 223648543 | 24.6373700 | 8.4670001 | .001647446 |
| 608 | 369664 | 224755712 | 24.6576560 | 8.4716471 | .001644737 |
| 609 | 370881 | 225866529 | 24.6779254 | 8.4762892 | .001642036 |
| 610 | 372100 | 226981000 | 24.6981781 | 8.4809261 | .001639344 |
| 611 | 373321 | 228099131 | 24.7184142 | 8.4855579 | .001636661 |
| 612 | 374544 | 229220928 | 24.7386338 | 8.4901848 | .001633987 |
| 613 | 375769 | 230346397 | 24.7588368 | 8.4948065 | .001631321 |
| 614 | 376996 | 231475544 | 24.7790234 | 8.4994233 | .001628664 |
| 615 | 378225 | 232608375 | 24.7991935 | 8.5040350 | .001626016 |
| 616 | 379456 | 233744896 | 24.8193473 | 8.5086417 | .001623377 |
| 617 | 380689 | 234885113 | 24.8394847 | 8.5132435 | .001620746 |
| 618 | 381924 | 236029032 | 24.8596058 | 8.5178403 | .001618123 |
| 619 | 383161 | 237176659 | 24.8797106 | 8.5224321 | .001615509 |
| 620 | 384400 | 238328000 | 24.8997992 | 8.5270189 | .001612903 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 621 | 385641 | 239483061 | 24.9198716 | 8.5316009 | .001610306 |
| 622 | 386884 | 240641848 | 24.9399278 | 8.5361780 | .001607717 |
| 623 | 388129 | 241804367 | 24.9599679 | 8.5407501 | .001605136 |
| 624 | 389376 | 242970624 | 24.9799920 | 8.5453173 | .001602564 |
| 625 | 390625 | 244140625 | 25.0000000 | 8.5498797 | .001600000 |
| 626 | 391876 | 245314376 | 25.0199920 | 8.5544372 | .001597444 |
| 627 | 393129 | 246491883 | 25.0399681 | 8.5589899 | .001594896 |
| 628 | 394384 | 247673152 | 25.0599282 | 8.5635377 | .001592357 |
| 629 | 395641 | 248858189 | 25.0798724 | 8.5680807 | .001589825 |
| 630 | 396900 | 250047000 | 25.0998008 | 8.5726189 | .001587302 |
| 631 | 398161 | 251239591 | 25.1197134 | 8.5771523 | .001584786 |
| 632 | 399424 | 252435968 | 25.1396102 | 8.5816809 | .001582278 |
| 633 | 400689 | 253636137 | 25.1594913 | 8.5862047 | .001579779 |
| 634 | 401956 | 254840104 | 25.1793566 | 8.5907238 | .001577287 |
| 635 | 403225 | 256047875 | 25.1992063 | 8.5952380 | .001574803 |
| 636 | 404496 | 257259456 | 25.2190404 | 8.5997476 | .001572327 |
| 637 | 405769 | 258474853 | 25.2388589 | 8.6042525 | .001569859 |
| 638 | 407044 | 259694072 | 25.2586619 | 8.6087526 | .001567398 |
| 639 | 408321 | 260917119 | 25.2784493 | 8.6132480 | .001564945 |
| 640 | 409600 | 262144000 | 25.2982213 | 8.6177388 | .001562500 |
| 641 | 410881 | 263374721 | 25.3179778 | 8.6222248 | .001560062 |
| 642 | 412164 | 264609288 | 25.3377189 | 8.6267063 | .001557632 |
| 643 | 413449 | 265847707 | 25.3574447 | 8.6311830 | .001555210 |
| 644 | 414736 | 267089984 | 25.3771551 | 8.6356551 | .001552795 |
| 645 | 416025 | 268336125 | 25.3968502 | 8.6401226 | .001550388 |
| 646 | 417316 | 269586136 | 25.4165301 | 8.6445855 | .001547988 |
| 647 | 418609 | 270840023 | 25.4361947 | 8.6490437 | .001545595 |
| 648 | 419904 | 272097792 | 25.4558441 | 8.6534974 | .001543210 |
| 649 | 421201 | 273359449 | 25.4754784 | 8.6579465 | .001540832 |
| 650 | 422500 | 274625000 | 25.4950976 | 8.6623911 | .001538462 |
| 651 | 423801 | 275894451 | 25.5147016 | 8.6668310 | .001536098 |
| 652 | 425104 | 277167808 | 25.5342907 | 8.6712665 | .001533742 |
| 653 | 426409 | 278445077 | 25.5538647 | 8.6756974 | .001531394 |
| 654 | 427716 | 279726264 | 25.5734237 | 8.6801237 | .001529052 |
| 655 | 429025 | 281011375 | 25.5929678 | 8.6845456 | .001526718 |
| 656 | 430336 | 282300416 | 25.6124969 | 8.6889630 | .001524390 |
| 657 | 431649 | 283593393 | 25.6320112 | 8.6933759 | .001522070 |
| 658 | 432964 | 284890312 | 25.6515107 | 8.6977843 | .001519757 |
| 659 | 434281 | 286191179 | 25.6709953 | 8.7021882 | .001517451 |
| 660 | 435600 | 287496000 | 25.6904652 | 8.7065877 | .001515152 |
| 661 | 436921 | 288804781 | 25.7099203 | 8.7109827 | .001512859 |
| 662 | 438244 | 290117528 | 25.7293607 | 8.7153734 | .001510574 |
| 663 | 439569 | 291434247 | 25.7487864 | 8.7197596 | .001508296 |
| 664 | 440896 | 292754944 | 25.7681975 | 8.7241414 | .001506024 |
| 665 | 442225 | 294079625 | 25.7875939 | 8.7285187 | .001503759 |
| 666 | 443556 | 295408296 | 25.8069758 | 8.7328918 | .001501502 |
| 667 | 444889 | 296740963 | 25.8263431 | 8.7372604 | .001499250 |
| 668 | 446224 | 298077632 | 25.8456960 | 8.7416246 | .001497006 |
| 669 | 447561 | 299418309 | 25.8650343 | 8.7459846 | .001494768 |
| 670 | 448900 | 300763000 | 25.8843582 | 8.7503401 | .001492537 |
| 671 | 450241 | 302111711 | 25.9036677 | 8.7546913 | .001490313 |
| 672 | 451584 | 303464448 | 25.9229628 | 8.7590383 | .001488095 |
| 673 | 452929 | 304821217 | 25.9422435 | 8.7633809 | .001485884 |
| 674 | 454276 | 306182024 | 25.9615100 | 8.7677192 | .001483680 |
| 675 | 455625 | 307546875 | 25.9807621 | 8.7720532 | .001481481 |
| 676 | 456976 | 308915776 | 26.0000000 | 8.7763830 | .001479290 |
| 677 | 458329 | 310288733 | 26.0192237 | 8.7807084 | .001477105 |
| 678 | 459684 | 311665752 | 26.0384331 | 8.7850296 | .001474926 |
| 679 | 461041 | 313046839 | 26.0576284 | 8.7893466 | .001472754 |
| 680 | 462400 | 314432000 | 26.0768096 | 8.7936593 | .001470588 |
| 681 | 463761 | 315821241 | 26.0959767 | 8.7979679 | .001468429 |
| 682 | 465124 | 317214568 | 26.1151297 | 8.8022721 | .001466276 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 683 | 466489 | 318611987 | 26.1342687 | 8.8065722 | .001464129 |
| 684 | 467856 | 320013504 | 26.1533937 | 8.8108681 | .001461988 |
| 685 | 469225 | 321419125 | 26.1725047 | 8.8151598 | .001459854 |
| 686 | 470596 | 322828856 | 26.1916017 | 8.8194474 | .001457726 |
| 687 | 471969 | 324242703 | 26.2106848 | 8.8237307 | .001455604 |
| 688 | 473344 | 325660672 | 26.2297541 | 8.8280099 | .001453488 |
| 689 | 474721 | 327082769 | 26.2488095 | 8.8322850 | .001451379 |
| 690 | 476100 | 328509000 | 26.2678511 | 8.8365559 | .001449275 |
| 691 | 477481 | 329939371 | 26.2868789 | 8.8408227 | .001447178 |
| 692 | 478864 | 331373888 | 26.3058929 | 8.8450854 | .001445087 |
| 693 | 480249 | 332812557 | 26.3248932 | 8.8493440 | .001443001 |
| 694 | 481636 | 334255384 | 26.3438797 | 8.8535985 | .001440922 |
| 695 | 483025 | 335702375 | 26.3628527 | 8.8578489 | .001438849 |
| 696 | 484416 | 337153536 | 26.3818119 | 8.8620952 | .001436782 |
| 697 | 485809 | 338608873 | 26.4007576 | 8.8663375 | .001434720 |
| 698 | 487204 | 340068392 | 26.4196896 | 8.8705757 | .001432665 |
| 699 | 488601 | 341532099 | 26.4386081 | 8.8748099 | .001430615 |
| 700 | 490000 | 343000000 | 26.4575131 | 8.8790400 | .001428571 |
| 701 | 491401 | 344472101 | 26.4764046 | 8.8832661 | .001426534 |
| 702 | 492804 | 345948408 | 26.4952826 | 8.8874882 | .001424501 |
| 703 | 494209 | 347428927 | 26.5141472 | 8.8917063 | .001422475 |
| 704 | 495616 | 348913664 | 26.5329983 | 8.8959204 | .001420455 |
| 705 | 497025 | 350402625 | 26.5518361 | 8.9001304 | .001418440 |
| 706 | 498436 | 351895816 | 26.5706605 | 8.9043366 | .001416431 |
| 707 | 499849 | 353393243 | 26.5894716 | 8.9085387 | .001414427 |
| 708 | 501264 | 354894912 | 26.6082694 | 8.9127369 | .001412429 |
| 709 | 502681 | 356400829 | 26 6270539 | 8.9169311 | .001410437 |
| 710 | 504100 | 357911000 | 26.6458252 | 8.9211214 | .001408451 |
| 711 | 505521 | 359425431 | 26.6645833 | 8.9253078 | .001406470 |
| 712 | 506944 | 360944128 | 26.6833281 | 8.9294902 | .001404494 |
| 713 | 508369 | 362467097 | 26.7020598 | 8.9336687 | .001402525 |
| 714 | 509796 | 363994344 | 26.7207784 | 8.9378433 | .001400560 |
| 715 | 511225 | 365525875 | 26.7394839 | 8.9420140 | .001398601 |
| 716 | 512656 | 367061696 | 26.7581763 | 8.9461809 | .001396648 |
| 717 | 514089 | 368601813 | 26.7768557 | 8.9503438 | .001394700 |
| 718 | 515524 | 370146232 | 26.7955220 | 8.9545029 | .001392758 |
| 719 | 516961 | 371694959 | 26.8141754 | 8.9586581 | .001390821 |
| 720 | 518400 | 373248000 | 26.8328157 | 8.9628095 | .001388889 |
| 721 | 519841 | 374805361 | 26.8514432 | 8.9669570 | .001386963 |
| 722 | 521284 | 376367048 | 26.8700577 | 8.9711007 | .001385042 |
| 723 | 522729 | 377933067 | 26.8886593 | 8.9752406 | .001383126 |
| 724 | 524176 | 379503424 | 26.9072481 | 8.9793766 | .001381215 |
| 725 | 525625 | 381078125 | 26.9258240 | 8.9835089 | .001379310 |
| 726 | 527076 | 382657176 | 26.9443872 | 8.9876373 | .001377410 |
| 727 | 528529 | 384240583 | 26.9629375 | 8.9917620 | .001375516 |
| 728 | 529984 | 385828352 | 26.9814751 | 8.9958829 | .001373626 |
| 729 | 531441 | 387420489 | 27.0000000 | 9.0000000 | .001371742 |
| 730 | 532900 | 389017000 | 27.0185122 | 9.0041134 | .001369863 |
| 731 | 534361 | 390617891 | 27.0370117 | 9.0082229 | .001367989 |
| 732 | 535824 | 392223168 | 27.0554985 | 9.0123288 | .001366120 |
| 733 | 537289 | 393832837 | 27.0739727 | 9.0164309 | .001364256 |
| 734 | 538756 | 395446904 | 27.0924344 | 9.0205293 | .001362398 |
| 735 | 540225 | 397065375 | 27.1108834 | 9.0246239 | .001360544 |
| 736 | 541696 | 398688256 | 27.1293199 | 9.0287149 | .001358696 |
| 737 | 543169 | 400315553 | 27.1477439 | 9.0328021 | .001356852 |
| 738 | 544644 | 401947272 | 27.1661554 | 9.0368857 | .001355014 |
| 739 | 546121 | 403583419 | 27.1845544 | 9.0409655 | .001353180 |
| 740 | 547600 | 405224000 | 27.2029410 | 9.0450419 | .001351351 |
| 741 | 549081 | 406869021 | 27.2213152 | 9.0491142 | .001349528 |
| 742 | 550564 | 408518488 | 27.2396769 | 9.0531831 | .001347709 |
| 743 | 552049 | 410172407 | 27.2580263 | 9.0572482 | .001345895 |
| 744 | 553536 | 411830784 | 27.2763634 | 9.0613098 | .001344086 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 745 | 555025 | 413493625 | 27.2946881 | 9.0653677 | .001342282 |
| 746 | 556516 | 415160936 | 27.3130006 | 9.0694220 | .001340483 |
| 747 | 558009 | 416832723 | 27.3313007 | 9.0734726 | .001338688 |
| 748 | 559504 | 418508992 | 27.3495887 | 9.0775197 | .001336898 |
| 749 | 561001 | 420189749 | 27.3678644 | 9.0815631 | .001335113 |
| 750 | 562500 | 421875000 | 27.3861279 | 9.0856030 | .001333333 |
| 751 | 564001 | 423564751 | 27.4043792 | 9.0896392 | .001331558 |
| 752 | 565504 | 425259008 | 27.4226184 | 9.0936719 | .001329787 |
| 753 | 567009 | 426957777 | 27.4408455 | 9.0977010 | .001328021 |
| 754 | 568516 | 428661064 | 27.4590604 | 9.1017265 | .001326260 |
| 755 | 570025 | 430368875 | 27.4772633 | 9.1057485 | .001324503 |
| 756 | 571536 | 432081216 | 27.4954542 | 9.1097669 | .001322751 |
| 757 | 573049 | 433798093 | 27.5136330 | 9.1137818 | .001321004 |
| 758 | 574564 | 435519512 | 27.5317998 | 9.1177931 | .001319261 |
| 759 | 576081 | 437245479 | 27.5499546 | 9.1218010 | .001317523 |
| 760 | 577600 | 438976000 | 27.5680975 | 9.1258053 | .001315789 |
| 761 | 579121 | 440711081 | 27.5862284 | 9.1298061 | .001314060 |
| 762 | 580644 | 442450728 | 27.6043475 | 9.1338034 | .001312336 |
| 763 | 582169 | 444194947 | 27.62[illegible]4546 | 9.1377971 | .001310616 |
| 764 | 583696 | 445943744 | 27.6405499 | 9.1417874 | .001308901 |
| 765 | 585225 | 447697125 | 27.6586334 | 9.1457742 | .001307190 |
| 766 | 586756 | 449455096 | 27.6767050 | 9.1497576 | .001305483 |
| 767 | 588289 | 451217663 | 27.6947648 | 9.1537375 | .001303781 |
| 768 | 589824 | 452984832 | 27.7128129 | 9.1577139 | .001302083 |
| 769 | 591361 | 454756609 | 27.7308492 | 9.1616869 | .001300390 |
| 770 | 592900 | 456533000 | 27.7488739 | 9.1656565 | .001298701 |
| 771 | 594441 | 458314011 | 27.7668868 | 9.1696225 | .001297017 |
| 772 | 595984 | 460099648 | 27.7848880 | 9.1735852 | .001295337 |
| 773 | 597529 | 461889917 | 27.8028775 | 9.1775445 | .001293661 |
| 774 | 599076 | 463684824 | 27.8208555 | 9.1815003 | .001291990 |
| 775 | 600625 | 465484375 | 27.8388218 | 9.1854527 | .001290323 |
| 776 | 602176 | 467288576 | 27.8567766 | 9.1894018 | .001288660 |
| 777 | 603729 | 469097433 | 27.8747197 | 9.1933474 | .001287001 |
| 778 | 605284 | 470910952 | 27.8926514 | 9.1972897 | .001285347 |
| 779 | 606841 | 472729139 | 27.9105715 | 9.2012286 | .001283697 |
| 780 | 608400 | 474552000 | 27.9284801 | 9.2051641 | .001282051 |
| 781 | 609961 | 476379541 | 27.9463772 | 9.2090962 | .001280410 |
| 782 | 611524 | 478211768 | 27.9642629 | 9.2130250 | .001278772 |
| 783 | 613089 | 480048687 | 27.9821372 | 9.2169505 | .001277139 |
| 784 | 614656 | 481890304 | 28.0000000 | 9.2208726 | .001275510 |
| 785 | 616225 | 483736625 | 28.0178515 | 9.2247914 | .001273885 |
| 786 | 617796 | 485587656 | 28.0356915 | 9.2287068 | .001272265 |
| 787 | 619369 | 487443403 | 28.0535203 | 9.2326189 | .001270648 |
| 788 | 620944 | 489303872 | 28.0713377 | 9.2365277 | .001269036 |
| 789 | 622521 | 491169069 | 28.0891438 | 9.2404333 | .001267427 |
| 790 | 624100 | 493039000 | 28.1069386 | 9.2443355 | .001265823 |
| 791 | 625681 | 494913671 | 28.1247222 | 9.2482344 | .001264223 |
| 792 | 627264 | 496793088 | 28.1424946 | 9.2521300 | .001262626 |
| 793 | 628849 | 498677257 | 28.1602557 | 9.2560224 | .001261034 |
| 794 | 630436 | 500566184 | 28.1780056 | 9.2599114 | .001259446 |
| 795 | 632025 | 502459875 | 28.1957444 | 9.2637973 | .001257862 |
| 796 | 633616 | 504358336 | 28.2134720 | 9.2676798 | .001256281 |
| 797 | 635209 | 506261573 | 28.2311884 | 9.2715592 | .001254705 |
| 798 | 636804 | 508169592 | 28.2488938 | 9.2754352 | .001253133 |
| 799 | 638401 | 510082399 | 28.2665881 | 9.2793081 | .001251564 |
| 800 | 640000 | 512000000 | 28.2842712 | 9.2831777 | .001250000 |
| 801 | 641601 | 513922401 | 28.3019434 | 9.2870440 | .001248439 |
| 802 | 643204 | 515849608 | 28.3196045 | 9.2909072 | .001246883 |
| 803 | 644809 | 517781627 | 28.3372546 | 9.2947671 | .001245330 |
| 804 | 646416 | 519718464 | 28.3548938 | 9.2986239 | .001243781 |
| 805 | 648025 | 521660125 | 28.3725219 | 9.3024775 | .001242236 |
| 806 | 649636 | 523606616 | 28.3901391 | 9.3063278 | .001240695 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 807 | 651249 | 525557943 | 28.4077454 | 9.3101750 | .001239157 |
| 808 | 652864 | 527514112 | 28.4253408 | 9.3140190 | .001237624 |
| 809 | 654481 | 529475129 | 28.4429253 | 9.3178599 | .001236094 |
| 810 | 656100 | 531441000 | 28.4604989 | 9.3216975 | .001234568 |
| 811 | 657721 | 533411731 | 28.4780617 | 9.3255320 | .001233046 |
| 812 | 659344 | 535387328 | 28.4956137 | 9.3293634 | .001231527 |
| 813 | 660969 | 537367797 | 28.5131549 | 9.3331916 | .001230012 |
| 814 | 662596 | 539353144 | 28.5306852 | 9.3370167 | .001228501 |
| 815 | 664225 | 541343375 | 28.5482048 | 9.3408386 | .001226994 |
| 816 | 665856 | 543338496 | 28.5657137 | 9.3446575 | .001225490 |
| 817 | 667489 | 545338513 | 28.5832119 | 9.3484731 | .001223990 |
| 818 | 669124 | 547343432 | 28.6006993 | 9.3522857 | .001222494 |
| 819 | 670761 | 549353259 | 28.6181760 | 9.3560952 | .001221001 |
| 820 | 672400 | 551368000 | 28.6356421 | 9.3599016 | .001219512 |
| 821 | 674041 | 553387661 | 28.6530976 | 9.3637049 | .001218027 |
| 822 | 675684 | 555412248 | 28.6705424 | 9.3675051 | .001216545 |
| 823 | 677329 | 557441767 | 28.6879766 | 9.3713022 | .001215067 |
| 824 | 678976 | 559476224 | 28.7054002 | 9.3750963 | .001213592 |
| 825 | 680625 | 561515625 | 28.7228132 | 9.3788873 | .001212121 |
| 826 | 682276 | 563559976 | 28.7402157 | 9.3826752 | .001210654 |
| 827 | 683929 | 565609283 | 28.7576077 | 9.3864600 | .001209190 |
| 828 | 685584 | 567663552 | 28.7749891 | 9.3902419 | .001207729 |
| 829 | 687241 | 569722789 | 28.7923601 | 9.3940206 | .001206273 |
| 830 | 688900 | 571787000 | 28.8097206 | 9.3977964 | .001204819 |
| 831 | 690561 | 573856191 | 28.8270706 | 9.4015691 | .001203369 |
| 832 | 692224 | 575930368 | 28.8444102 | 9.4053387 | .001201923 |
| 833 | 693889 | 578009537 | 28.8617394 | 9.4091054 | .001200480 |
| 834 | 695556 | 580093704 | 28.8790582 | 9.4128690 | .001199041 |
| 835 | 697225 | 582182875 | 28.8963666 | 9.4166297 | .001197605 |
| 836 | 698896 | 584277056 | 28.9136646 | 9.4203873 | .001196172 |
| 837 | 700569 | 586376253 | 28.9309523 | 9.4241420 | .001194743 |
| 838 | 702244 | 588480472 | 28.9482297 | 9.4278936 | .001193317 |
| 839 | 703921 | 590589719 | 28.9654967 | 9.4316423 | .001191895 |
| 840 | 705600 | 592704000 | 28.9827535 | 9.4353880 | .001190476 |
| 841 | 707281 | 594823321 | 29.0000000 | 9.4391307 | .001189061 |
| 842 | 708964 | 596947688 | 29.0172363 | 9.4428704 | .001187648 |
| 843 | 710649 | 599077107 | 29.0344623 | 9.4466072 | .001186240 |
| 844 | 712336 | 601211584 | 29.0516781 | 9.4503410 | .001184834 |
| 845 | 714025 | 603351125 | 29.0688837 | 9.4540719 | .001183432 |
| 846 | 715716 | 605495736 | 29.0860791 | 9.4577999 | .001182033 |
| 847 | 717409 | 607645423 | 29.1032644 | 9.4615249 | .001180638 |
| 848 | 719104 | 609800192 | 29.1204396 | 9.4652470 | .001179245 |
| 849 | 720801 | 611960049 | 29.1376046 | 9.4689661 | .001177856 |
| 850 | 722500 | 614125000 | 29.1547595 | 9.4726824 | .001176471 |
| 851 | 724201 | 616295051 | 29.1719043 | 9.4763957 | .001175088 |
| 852 | 725904 | 618470208 | 29.1890390 | 9.4801061 | .001173709 |
| 853 | 727609 | 620650477 | 29.2061637 | 9.4838136 | .001172333 |
| 854 | 729316 | 622835864 | 29.2232784 | 9.4875182 | .001170960 |
| 855 | 731025 | 625026375 | 29.2403830 | 9.4912200 | .001169591 |
| 856 | 732736 | 627222016 | 29.2574777 | 9.4949188 | .001168224 |
| 857 | 734449 | 629422793 | 29.2745623 | 9.4986147 | .001166861 |
| 858 | 736164 | 631628712 | 29.2916370 | 9.5023078 | .001165501 |
| 859 | 737881 | 633839779 | 29.3087018 | 9.5059980 | .001164144 |
| 860 | 739600 | 636056000 | 29.3257566 | 9.5096854 | .001162791 |
| 861 | 741321 | 638277381 | 29.3428015 | 9.5133699 | .001161440 |
| 862 | 743044 | 640503928 | 29.3598365 | 9.5170515 | .001160093 |
| 863 | 744769 | 642735647 | 29.3768616 | 9.5207303 | .001158749 |
| 864 | 746496 | 644972544 | 29.3938769 | 9.5244063 | .001157407 |
| 865 | 748225 | 647214625 | 29.4108823 | 9.5280794 | .001156069 |
| 866 | 749956 | 649461896 | 29.4278779 | 9.5317497 | .001154734 |
| 867 | 751689 | 651714363 | 29.4448637 | 9.5354172 | .001153403 |
| 868 | 753424 | 653972032 | 29.4618397 | 9.5390818 | .001152074 |

## TABLE XXIII.—SQUARES, CUBES, SQUARE ROOTS.

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 869 | 755161 | 656234909 | 29.4788059 | 9.5427437 | .001150748 |
| 870 | 756900 | 658503000 | 29.4957624 | 9.5464027 | .001149425 |
| 871 | 758641 | 660776311 | 29.5127091 | 9.5500589 | .001148106 |
| 872 | 760384 | 663054848 | 29.5296461 | 9.5537123 | .001146789 |
| 873 | 762129 | 665338617 | 29.5465734 | 9.5573630 | .001145475 |
| 874 | 763876 | 667627624 | 29.5634910 | 9.5610108 | .001144165 |
| 875 | 765625 | 669921875 | 29.5803989 | 9.5646559 | .001142857 |
| 876 | 767376 | 672221376 | 29.5972972 | 9.5682982 | .001141553 |
| 877 | 769129 | 674526133 | 29.6141858 | 9.5719377 | .001140251 |
| 878 | 770884 | 676836152 | 29.6310648 | 9.5755745 | .001138952 |
| 879 | 772641 | 679151439 | 29.6479342 | 9.5792085 | .001137656 |
| 880 | 774400 | 681472000 | 29.6647939 | 9.5828397 | .001136364 |
| 881 | 776161 | 683797841 | 29.6816442 | 9.5864682 | .001135074 |
| 882 | 777924 | 686128968 | 29.6984848 | 9.5900939 | .001133787 |
| 883 | 779689 | 688465387 | 29.7153159 | 9.5937169 | .001132503 |
| 884 | 781456 | 690807104 | 29.7321375 | 9.5973373 | .001131222 |
| 885 | 783225 | 693154125 | 29.7489496 | 9.6009548 | .001129944 |
| 886 | 784996 | 695506456 | 29.7657521 | 9.6045696 | .001128668 |
| 887 | 786769 | 697864103 | 29.7825452 | 9.6081817 | .001127396 |
| 888 | 788544 | 700227072 | 29.7993289 | 9.6117911 | .001126126 |
| 889 | 790321 | 702595369 | 29.8161030 | 9.6153977 | .001124859 |
| 890 | 792100 | 704969000 | 29.8328678 | 9.6190017 | .001123596 |
| 891 | 793881 | 707347971 | 29.8496231 | 9.6226030 | .001122334 |
| 892 | 795664 | 709732288 | 29.8663690 | 9.6262016 | .001121076 |
| 893 | 797449 | 712121957 | 29.8831056 | 9.6297975 | .001119821 |
| 894 | 799236 | 714516984 | 29.8998328 | 9.6333907 | .001118568 |
| 895 | 801025 | 716917375 | 29.9165506 | 9.6369812 | .001117318 |
| 896 | 802816 | 719323136 | 29.9332591 | 9.6405690 | .001116071 |
| 897 | 804609 | 721734273 | 29.9499583 | 9.6441542 | .001114827 |
| 898 | 806404 | 724150792 | 29.9666481 | 9.6477367 | .001113586 |
| 899 | 808201 | 726572699 | 29.9833287 | 9.6513166 | .001112347 |
| 900 | 810000 | 729000000 | 30.0000000 | 9.6548938 | .001111111 |
| 901 | 811801 | 731432701 | 30.0166620 | 9.6584684 | .001109878 |
| 902 | 813604 | 733870808 | 30.0333148 | 9.6620403 | .001108647 |
| 903 | 815409 | 736314327 | 30.0499584 | 9.6656096 | .001107420 |
| 904 | 817216 | 738763264 | 30.0665928 | 9.6691762 | .001106195 |
| 905 | 819025 | 741217625 | 30.0832179 | 9.6727403 | .001104972 |
| 906 | 820836 | 743677416 | 30.0998339 | 9.6763017 | .001103753 |
| 907 | 822649 | 746142643 | 30.1164407 | 9.6798604 | .001102536 |
| 908 | 824464 | 748613312 | 30.1330383 | 9.6834166 | .001101322 |
| 909 | 826281 | 751089429 | 30.1496269 | 9.6869701 | .001100110 |
| 910 | 828100 | 753571000 | 30.1662063 | 9.6905211 | .001098901 |
| 911 | 829921 | 756058031 | 30.1827765 | 9.6940694 | .001097695 |
| 912 | 831744 | 758550528 | 30.1993377 | 9.6976151 | .001096491 |
| 913 | 833569 | 761048497 | 30.2158899 | 9.7011583 | .001095290 |
| 914 | 835396 | 763551944 | 30.2324329 | 9.7046989 | .001094092 |
| 915 | 837225 | 766060875 | 30.2489669 | 9.7082369 | .001092896 |
| 916 | 839056 | 768575296 | 30.2654919 | 9.7117723 | .001091703 |
| 917 | 840889 | 771095213 | 30.2820079 | 9.7153051 | .001090513 |
| 918 | 842724 | 773620632 | 30.2985148 | 9.7188354 | .001089325 |
| 919 | 844561 | 776151559 | 30.3150128 | 9.7223631 | .001088139 |
| 920 | 846400 | 778688000 | 30.3315018 | 9.7258883 | .001086957 |
| 921 | 848241 | 781229961 | 30.3479818 | 9.7294109 | .001085776 |
| 922 | 850084 | 783777448 | 30.3644529 | 9.7329309 | .001084599 |
| 923 | 851929 | 786330467 | 30.3809151 | 9.7364484 | .001083423 |
| 924 | 853776 | 788889024 | 30.3973683 | 9.7399634 | .001082251 |
| 925 | 855625 | 791453125 | 30.4138127 | 9.7434758 | .001081081 |
| 926 | 857476 | 794022776 | 30.4302481 | 9.7469857 | .001079914 |
| 927 | 859329 | 796597983 | 30.4466747 | 9.7504930 | .001078749 |
| 928 | 861184 | 799178752 | 30.4630924 | 9.7539979 | .001077586 |
| 929 | 863041 | 801765089 | 30.4795013 | 9.7575002 | .001076426 |
| 930 | 864900 | 804357000 | 30.4959014 | 9.7610001 | .001075269 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 931 | 866761 | 806954491 | 30.5122926 | 9.7644974 | .001074114 |
| 932 | 868624 | 809557568 | 30.5286750 | 9.7679922 | .001072961 |
| 933 | 870489 | 812166237 | 30.5450487 | 9.7714845 | .001071811 |
| 934 | 872356 | 814780504 | 30.5614136 | 9.7749743 | .001070664 |
| 935 | 874225 | 817400375 | 30.5777697 | 9.7784616 | .001069519 |
| 936 | 876096 | 820025856 | 30.5941171 | 9.7819466 | .001068376 |
| 937 | 877969 | 822656953 | 30.6104557 | 9.7854288 | .001067236 |
| 938 | 879844 | 825293672 | 30.6267857 | 9.7889087 | .001066098 |
| 939 | 881721 | 827936019 | 30.6431069 | 9.7923861 | .001064963 |
| 940 | 883600 | 830584000 | 30.6594194 | 9.7958611 | .001063830 |
| 941 | 885481 | 833237621 | 30.6757233 | 9.7993336 | .001062699 |
| 942 | 887364 | 835896888 | 30.6920185 | 9.8028036 | .001061571 |
| 943 | 889249 | 838561807 | 30.7083051 | 9.8062711 | .001060445 |
| 944 | 891136 | 841232384 | 30.7245830 | 9.8097362 | .001059322 |
| 945 | 893025 | 843908625 | 30.7408523 | 9.8131989 | .001058201 |
| 946 | 894916 | 846590536 | 30.7571130 | 9.8166591 | .001057082 |
| 947 | 896809 | 849278123 | 30.7733651 | 9.8201169 | .001055966 |
| 948 | 898704 | 851971392 | 30.7896086 | 9.8235723 | .001054852 |
| 949 | 900601 | 854670349 | 30.8058436 | 9.8270252 | .001053741 |
| 950 | 902500 | 857375000 | 30.8220700 | 9.8304757 | .001052632 |
| 951 | 904401 | 860085351 | 30.8382879 | 9.8339238 | .001051525 |
| 952 | 906304 | 862801408 | 30.8544972 | 9.8373695 | .001050420 |
| 953 | 908209 | 865523177 | 30.8706981 | 9.8408127 | .001049318 |
| 954 | 910116 | 868250664 | 30.8868904 | 9.8442536 | .001048218 |
| 955 | 912025 | 870983875 | 30.9030743 | 9.8476920 | .001047120 |
| 956 | 913936 | 873722816 | 30.9192497 | 9.8511280 | .001046025 |
| 957 | 915849 | 876467493 | 30.9354166 | 9.8545617 | .001044932 |
| 958 | 917764 | 879217912 | 30.9515751 | 9.8579929 | .001043841 |
| 959 | 919681 | 881974079 | 30.9677251 | 9.8614218 | .001042753 |
| 960 | 921600 | 884736000 | 30.9838668 | 9.8648483 | .001041667 |
| 961 | 923521 | 887503681 | 31.0000000 | 9.8682724 | .001040583 |
| 962 | 925444 | 890277128 | 31.0161248 | 9.8716941 | .001039501 |
| 963 | 927369 | 893056347 | 31.0322413 | 9.8751135 | .001038422 |
| 964 | 929296 | 895841344 | 31.0483494 | 9.8785305 | .001037344 |
| 965 | 931225 | 898632125 | 31.0644491 | 9.8819451 | .001036269 |
| 966 | 933156 | 901428696 | 31.0805405 | 9.8853574 | .001035197 |
| 967 | 935089 | 904231063 | 31.0966236 | 9.8887673 | .001034126 |
| 968 | 937024 | 907039232 | 31.1126984 | 9.8921749 | .001033058 |
| 969 | 938961 | 909853209 | 31.1287648 | 9.8955801 | .001031992 |
| 970 | 940900 | 912673000 | 31.1448230 | 9.8989830 | .001030928 |
| 971 | 942841 | 915498611 | 31.1608729 | 9.9023835 | .001029866 |
| 972 | 944784 | 918330048 | 31.1769145 | 9.9057817 | .001028807 |
| 973 | 946729 | 921167317 | 31.1929479 | 9.9091776 | .001027749 |
| 974 | 948676 | 924010424 | 31.2089731 | 9.9125712 | .001026694 |
| 975 | 950625 | 926859375 | 31.2249900 | 9.9159624 | .001025641 |
| 976 | 952576 | 929714176 | 31.2409987 | 9.9193513 | .001024590 |
| 977 | 954529 | 932574833 | 31.2569992 | 9.9227379 | .001023541 |
| 978 | 956484 | 935441352 | 31.2729915 | 9.9261222 | .001022495 |
| 979 | 958441 | 938313739 | 31.2889757 | 9.9295042 | .001021450 |
| 980 | 960400 | 941192000 | 31.3049517 | 9.9328839 | .001020408 |
| 981 | 962361 | 944076141 | 31.3209195 | 9.9362613 | .001019368 |
| 982 | 964324 | 946966168 | 31.3368792 | 9.9396363 | .001018330 |
| 983 | 966289 | 949862087 | 31.3528308 | 9.9430092 | .001017294 |
| 984 | 968256 | 952763904 | 31.3687743 | 9.9463797 | .001016260 |
| 985 | 970225 | 955671625 | 31.3847097 | 9.9497479 | .001015228 |
| 986 | 972196 | 958585256 | 31.4006369 | 9 9531138 | .001014199 |
| 987 | 974169 | 961504803 | 31.4165561 | 9.9564775 | .001013171 |
| 988 | 976144 | 964430272 | 31.4324673 | 9.9598389 | .001012146 |
| 989 | 978121 | 967361669 | 31.4483704 | 9.9631981 | .001011122 |
| 990 | 980100 | 970299000 | 31.4642654 | 9.9665549 | .001010101 |
| [illegible] | 982081 | 973242271 | 31.4801525 | 9.9699095 | .001009082 |
| [illegible] | 984064 | 976191488 | 31.4960315 | 9.9732619 | .001008065 |

| No. | Squares. | Cubes. | Square Roots. | Cube Roots. | Reciprocals. |
|---|---|---|---|---|---|
| 993 | 986049 | 979146657 | 31.5119025 | 9.9766120 | .001007049 |
| 994 | 988036 | 982107784 | 31.5277655 | 9.9799599 | .001006036 |
| 995 | 990025 | 985074875 | 31.5436206 | 9.9833055 | .001005025 |
| 996 | 992016 | 988047936 | 31.5594677 | 9.9866488 | .001004016 |
| 997 | 994009 | 991026973 | 31.5753068 | 9.9899900 | .001003009 |
| 998 | 996004 | 994011992 | 31.5911380 | 9.9933289 | .001002004 |
| 999 | 998001 | 997002999 | 31.6069613 | 9.9966656 | .001001001 |
| 1000 | 1000000 | 1000000000 | 31.6227766 | 10.0000000 | .001000000 |
| 1001 | 1002001 | 1003003001 | 31.6385840 | 10.0033322 | .0009990010 |
| 1002 | 1004004 | 1006012008 | 31.6543836 | 10.0066622 | .0009980040 |
| 1003 | 1006009 | 1009027027 | 31.6701752 | 10.0099899 | .0009970090 |
| 1004 | 1008016 | 1012048064 | 31.6859590 | 10.0133155 | .0009960159 |
| 1005 | 1010025 | 1015075125 | 31.7017349 | 10.0166389 | .0009950249 |
| 1006 | 1012036 | 1018108216 | 31.7175030 | 10.0199601 | .0009940358 |
| 1007 | 1014049 | 1021147343 | 31.7332633 | 10.0232791 | .0009930487 |
| 1008 | 1016064 | 1024192512 | 31.7490157 | 10.0265958 | .0009920635 |
| 1009 | 1018081 | 1027243729 | 31.7647603 | 10.0299104 | .0009910803 |
| 1010 | 1020100 | 1030301000 | 31.7804972 | 10.0332228 | .0009900990 |
| 1011 | 1022121 | 1033364331 | 31.7962262 | 10.0365330 | .0009891197 |
| 1012 | 1024144 | 1036433728 | 31.8119474 | 10.0398410 | .0009881423 |
| 1013 | 1026169 | 1039509197 | 31.8276609 | 10.0431469 | .0009871668 |
| 1014 | 1028196 | 1042590744 | 31.8433666 | 10.0464506 | .0009861933 |
| 1015 | 1030225 | 1045678375 | 31.8590646 | 10.0497521 | .0009852217 |
| 1016 | 1032256 | 1048772096 | 31.8747549 | 10.0530514 | .0009842520 |
| 1017 | 1034289 | 1051871913 | 31.8904374 | 10.0563485 | .0009832842 |
| 1018 | 1036324 | 1054977832 | 31.9061123 | 10.0596435 | .0009823183 |
| 1019 | 1038361 | 1058089859 | 31.9217794 | 10.0629364 | .0009813543 |
| 1020 | 1040400 | 1061208000 | 31.9374388 | 10.0662271 | .0009803922 |
| 1021 | 1042441 | 1064332261 | 31.9530906 | 10.0695156 | .0009794319 |
| 1022 | 1044484 | 1067462648 | 31.9687347 | 10.0728020 | .0009784736 |
| 1023 | 1046529 | 1070599167 | 31.9843712 | 10.0760863 | .0009775171 |
| 1024 | 1048576 | 1073741824 | 32.0000000 | 10.0793684 | .0009765625 |
| 1025 | 1050625 | 1076890625 | 32.0156212 | 10.0826484 | .0009756098 |
| 1026 | 1052676 | 1080045576 | 32.0312348 | 10.0859262 | .0009746589 |
| 1027 | 1054729 | 1083206683 | 32.0468407 | 10.0892019 | .0009737098 |
| 1028 | 1056784 | 1086373952 | 32.0624391 | 10.0924755 | .0009727626 |
| 1029 | 1058841 | 1089547389 | 32.0780298 | 10.0957469 | .0009718173 |
| 1030 | 1060900 | 1092727000 | 32.0936131 | 10.0990163 | .0009708738 |
| 1031 | 1062961 | 1095912791 | 32.1091887 | 10.1022835 | .0009699321 |
| 1032 | 1065024 | 1099104768 | 32.1247568 | 10.1055487 | .00 9689922 |
| 1033 | 1067089 | 1102302937 | 32.1403173 | 10.1088117 | .0009680542 |
| 1034 | 1069156 | 1105507304 | 32.1558704 | 10.1120726 | .0009671180 |
| 1035 | 1071225 | 1108717875 | 32.1714159 | 10.1153314 | .0009661836 |
| 1036 | 1073296 | 1111934656 | 32.1869539 | 10.1185882 | .0009652510 |
| 1037 | 1075369 | 1115157653 | 32.2024844 | 10.1218428 | .0009643202 |
| 1038 | 1077444 | 1118386872 | 32.2180074 | 10.1250953 | .0009633911 |
| 1039 | 1079521 | 1121622319 | 32.2335229 | 10.1283457 | .0009624639 |
| 1040 | 1081600 | 1124864000 | 32.2490310 | 10.1315941 | .0009615385 |
| 1041 | 1083681 | 1128111921 | 32.2645316 | 10.1348403 | .0009606148 |
| 1042 | 1085764 | 1131366088 | 32.2800248 | 10.1380845 | .0009596929 |
| 1043 | 1087849 | 1134626507 | 32.2955105 | 10.1413266 | .0009587738 |
| 1044 | 1089936 | 1137893184 | 32.3109888 | 10.1445667 | .0009578544 |
| 1045 | 1092025 | 1141166125 | 32.3264598 | 10.1478047 | .0009569378 |
| 1046 | 1094116 | 1144445336 | 32.3419233 | 10.1510406 | .0009560229 |
| 1047 | 1096209 | 1147730823 | 32.3573794 | 10.1542744 | .0009551098 |
| 1048 | 1098304 | 1151022592 | 32.3728281 | 10.1575062 | .0009541985 |
| 1049 | 1100401 | 1154320649 | 32.3882695 | 10.1607359 | .0009532888 |
| 1050 | 1102500 | 1157625000 | 32.4037035 | 10.1639636 | .0009523810 |
| 1051 | 1104601 | 1160935651 | 32.4191301 | 10.1671893 | .0009514748 |
| 1052 | 1106704 | 1164252608 | 32.4345495 | 10.1704129 | .0009505703 |
| 1053 | 1108809 | 1167575877 | 32.4499615 | 10.1736344 | .0009496676 |
| 1054 | 1110916 | 1170905464 | 32.4653662 | 10.1768539 | .0009487666 |

No. 100 L. 000.] [No. 109 L. 040.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 000000 | 0434 | 0868 | 1301 | 1734 | 2166 | 2598 | 3029 | 3461 | 3891 | 432 |
| 1 | 4321 | 4751 | 5181 | 5609 | 6038 | 6466 | 6894 | 7321 | 7748 | 8174 | 428 |
| 2 | 8600 | 9026 | 9451 | 9876 | 0300 | 0724 | 1147 | 1570 | 1993 | 2415 | 424 |
| 3 | 012837 | 3259 | 3680 | 4100 | 4521 | 4940 | 5360 | 5779 | 6197 | 6616 | 420 |
| 4 | 7033 | 7451 | 7868 | 8284 | 8700 | 9116 | 9532 | 9947 | 0361 | 0775 | 416 |
| 5 | 021189 | 1603 | 2016 | 2428 | 2841 | 3252 | 3664 | 4075 | 4486 | 4896 | 412 |
| 6 | 5306 | 5715 | 6125 | 6533 | 6942 | 7350 | 7757 | 8164 | 8571 | 8978 | 408 |
| 7 | 9384 | 9789 | 0195 | 0600 | 1004 | 1408 | 1812 | 2216 | 2619 | 3021 | 404 |
| 8 | 033424 | 3826 | 4227 | 4628 | 5029 | 5430 | 5830 | 6230 | 6629 | 7028 | 400 |
| 9 | 7426 | 7825 | 8223 | 8620 | 9017 | 9414 | 9811 | 0207 | 0602 | 0998 | 397 |
| | 04 | | | | | | | | | | |

## Proportional Parts.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 434 | 43.4 | 86.8 | 130.2 | 173.6 | 217.0 | 260.4 | 303.8 | 347.2 | 390.6 |
| 433 | 43.3 | 86.6 | 129.9 | 173.2 | 216.5 | 259.8 | 303.1 | 346.4 | 389.7 |
| 432 | 43.2 | 86.4 | 129.6 | 172.8 | 216.0 | 259.2 | 302.4 | 345.6 | 388.8 |
| 431 | 43.1 | 86.2 | 129.3 | 172.4 | 215.5 | 258.6 | 301.7 | 344.8 | 387.9 |
| 430 | 43.0 | 86.0 | 129.0 | 172.0 | 215.0 | 258.0 | 301.0 | 344.0 | 387.0 |
| 429 | 42.9 | 85.8 | 128.7 | 171.6 | 214.5 | 257.4 | 300.3 | 343.2 | 386.1 |
| 428 | 42.8 | 85.6 | 128.4 | 171.2 | 214.0 | 256.8 | 299.6 | 342.4 | 385.2 |
| 427 | 42.7 | 85.4 | 128.1 | 170.8 | 213.5 | 256.2 | 298.9 | 341.6 | 384.3 |
| 426 | 42.6 | 85.2 | 127.8 | 170.4 | 213.0 | 255 6 | 298.2 | 340.8 | 383.4 |
| 425 | 42.5 | 85.0 | 127.5 | 170.0 | 212.5 | 255.0 | 297.5 | 340.0 | 382.5 |
| 424 | 42.4 | 84.8 | 127.2 | 169.6 | 212.0 | 254.4 | 296.8 | 339.2 | 381.6 |
| 423 | 42.3 | 84.6 | 126.9 | 169.2 | 211.5 | 253.8 | 296.1 | 338.4 | 380.7 |
| 422 | 42.2 | 84.4 | 126.6 | 168.8 | 211.0 | 253.2 | 295.4 | 337.6 | 379.8 |
| 421 | 42.1 | 84.2 | 126.3 | 168.4 | 210.5 | 252.6 | 294.7 | 336.8 | 378.9 |
| 420 | 42.0 | 84.0 | 126.0 | 168.0 | 210.0 | 252.0 | 294.0 | 336.0 | 378.0 |
| 419 | 41.9 | 83.8 | 125.7 | 167.6 | 209.5 | 251.4 | 293.3 | 335.2 | 377.1 |
| 418 | 41.8 | 83.6 | 125.4 | 167.2 | 209.0 | 250.8 | 292.6 | 334.4 | 376.2 |
| 417 | 41.7 | 83.4 | 125.1 | 166.8 | 208.5 | 250.2 | 291.9 | 333.6 | 375.3 |
| 416 | 41.6 | 83.2 | 124.8 | 166.4 | 208.0 | 249.6 | 291.2 | 332.8 | 374.4 |
| 415 | 41.5 | 83.0 | 124.5 | 166.0 | 207.5 | 249.0 | 290.5 | 332.0 | 373.5 |
| 414 | 41.4 | 82.8 | 124.2 | 165.6 | 207.0 | 248.4 | 289.8 | 331.2 | 372.6 |
| 413 | 41.3 | 82.6 | 123.9 | 165.2 | 206.5 | 247.8 | 289.1 | 330.4 | 371.7 |
| 412 | 41.2 | 82.4 | 123.6 | 164.8 | 206.0 | 247.2 | 288.4 | 329.6 | 370.8 |
| 411 | 41.1 | 82.2 | 123.3 | 164.4 | 205.5 | 246.6 | 287.7 | 328.8 | 369.9 |
| 410 | 41.0 | 82.0 | 123.0 | 164.0 | 205.0 | 246.0 | 287.0 | 328.0 | 369.0 |
| 409 | 40.9 | 81.8 | 122.7 | 163.6 | 204.5 | 245.4 | 286.3 | 327.2 | 368.1 |
| 408 | 40.8 | 81.6 | 122.4 | 163.2 | 204.0 | 244.8 | 285.6 | 326.4 | 367.2 |
| 407 | 40.7 | 81.4 | 122.1 | 162.8 | 203.5 | 244.2 | 284.9 | 325.6 | 366.3 |
| 406 | 40.6 | 81.2 | 121.8 | 162.4 | 203.0 | 243 6 | 284.2 | 324.8 | 365.4 |
| 405 | 40.5 | 81.0 | 121.5 | 162.0 | 202.5 | 243.0 | 283.5 | 324.0 | 364.5 |
| 404 | 40.4 | 80.8 | 121.2 | 161.6 | 202.0 | 242.4 | 282.8 | 323.2 | 363.6 |
| 403 | 40.3 | 80.6 | 120.9 | 161.2 | 201.5 | 241.8 | 282.1 | 322.4 | 362.7 |
| 402 | 40.2 | 80.4 | 120.6 | 160.8 | 201.0 | 241 2 | 281.4 | 321.6 | 361.8 |
| 401 | 40.1 | 80.2 | 120.3 | 160.4 | 200.[illegible] | 240.6 | 280.7 | 320.8 | 360.9 |
| 400 | 40.0 | 80·0 | 120.0 | 160.0 | 200.0 | 240.0 | 280.0 | 320.0 | 360.0 |
| 399 | 39.9 | 79.8 | 119.7 | 159.6 | 199.5 | 239.4 | 279.3 | 319.2 | 359.1 |
| 398 | 39.8 | 79.6 | 119.4 | 159.2 | 199.0 | 238.8 | 278.6 | 318.4 | 358.2 |
| 397 | 39.7 | 79.4 | 119.1 | 158.8 | 198.5 | 238.2 | 277.9 | 317.6 | 357.3 |
| 396 | 39.6 | 79.2 | 118.8 | 158.4 | 198.0 | 237.6 | 277.2 | 316.8 | 356.4 |
| 395 | 39.5 | 79.0 | 118.5 | 158.0 | 197 5 | 237.0 | 276.5 | 316 0 | 355.5 |

No. 110 L. 041.] [No. 119 L. 078.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 041393 | 1787 | 2182 | 2576 | 2969 | 3362 | 3755 | 4148 | 4540 | 4932 | 393 |
| 1 | 5323 | 5714 | 6105 | 6495 | 6885 | 7275 | 7664 | 8053 | 8442 | 8830 | 390 |
| 2 | 9218 | 9606 | 9993 | 0380 | 0766 | 1153 | 1538 | 1924 | 2309 | 2694 | 386 |
| 3 | 053078 | 3463 | 3846 | 4230 | 4613 | 4996 | 5378 | 5760 | 6142 | 6524 | 383 |
| 4 | 6905 | 7286 | 7666 | 8046 | 8426 | 8805 | 9185 | 9563 | 9942 | 0320 | 379 |
| 5 | 060698 | 1075 | 1452 | 1829 | 2206 | 2582 | 2958 | 3333 | 3709 | 4083 | 376 |
| 6 | 4458 | 4832 | 5206 | 5580 | 5953 | 6326 | 6699 | 7071 | 7443 | 7815 | 373 |
| 7 | 8186 | 8557 | 8928 | 9298 | 9668 | 0038 | 0407 | 0776 | 1145 | 1514 | 370 |
| 8 | 071882 | 2250 | 2617 | 2985 | 3352 | 3718 | 4085 | 4451 | 4816 | 5182 | 366 |
| 9 | 5547 | 5912 | 6276 | 6640 | 7004 | 7368 | 7731 | 8094 | 8457 | 8819 | 363 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 395 | 39.5 | 79.0 | 118.5 | 158.0 | 197.5 | 237.0 | 276.5 | 316.0 | 355.5 |
| 394 | 39.4 | 78.8 | 118.2 | 157.6 | 197.0 | 236.4 | 275.8 | 315.2 | 354.6 |
| 393 | 39.3 | 78.6 | 117.9 | 157.2 | 196.5 | 235.8 | 275.1 | 314.4 | 353.7 |
| 392 | 39.2 | 78.4 | 117.6 | 156.8 | 196.0 | 235.2 | 274.4 | 313.6 | 352.8 |
| 391 | 39.1 | 78.2 | 117.3 | 156.4 | 195.5 | 234.6 | 273.7 | 312.8 | 351.9 |
| 390 | 39.0 | 78.0 | 117.0 | 156.0 | 195.0 | 234.0 | 273.0 | 312.0 | 351.0 |
| 389 | 38.9 | 77.8 | 116.7 | 155.6 | 194.5 | 233.4 | 272.3 | 311.2 | 350.1 |
| 388 | 38.8 | 77.6 | 116.4 | 155.2 | 194.0 | 232.8 | 271.6 | 310.4 | 349.2 |
| 387 | 38.7 | 77.4 | 116.1 | 154.8 | 193.5 | 232.2 | 270.9 | 309.6 | 348.3 |
| 386 | 38.6 | 77.2 | 115.8 | 154.4 | 193.0 | 231.6 | 270.2 | 308.8 | 347.4 |
| 385 | 38.5 | 77.0 | 115.5 | 154.0 | 192.5 | 231.0 | 269.5 | 308.0 | 346.5 |
| 384 | 38.4 | 76.8 | 115.2 | 153.6 | 192.0 | 230.4 | 268.8 | 307.2 | 345.6 |
| 383 | 38.3 | 76.6 | 114.9 | 153.2 | 191.5 | 229.8 | 268.1 | 306.4 | 344.7 |
| 382 | 38.2 | 76.4 | 114.6 | 152.8 | 191.0 | 229.2 | 267.4 | 305.6 | 343.8 |
| 381 | 38.1 | 76.2 | 114.3 | 152.4 | 190.5 | 228.6 | 266.7 | 304.8 | 342.9 |
| 380 | 38.0 | 76.0 | 114.0 | 152.0 | 190.0 | 228.0 | 266.0 | 304.0 | 342.0 |
| 379 | 37.9 | 75.8 | 113.7 | 151.6 | 189.5 | 227.4 | 265.3 | 303.2 | 341.1 |
| 378 | 37.8 | 75.6 | 113.4 | 151.2 | 189.0 | 226.8 | 264.6 | 302.4 | 340.2 |
| 377 | 37.7 | 75.4 | 113.1 | 150.8 | 188.5 | 226.2 | 263.9 | 301.6 | 339.3 |
| 376 | 37.6 | 75.2 | 112.8 | 150.4 | 188.0 | 225.6 | 263.2 | 300.8 | 338.4 |
| 375 | 37.5 | 75.0 | 112.5 | 150.0 | 187.5 | 225.0 | 262.5 | 300.0 | 337.5 |
| 374 | 37.4 | 74.8 | 112.2 | 149.6 | 187.0 | 224.4 | 261.8 | 299.2 | 336.6 |
| 373 | 37.3 | 74.6 | 111.9 | 149.2 | 186.5 | 223.8 | 261.1 | 298.4 | 335.7 |
| 372 | 37.2 | 74.4 | 111.6 | 148.8 | 186.0 | 223.2 | 260.4 | 297.6 | 334.8 |
| 371 | 37.1 | 74.2 | 111.3 | 148.4 | 185.5 | 222.6 | 259.7 | 296.8 | 333.9 |
| 370 | 37.0 | 74.0 | 111.0 | 148.0 | 185.0 | 222.0 | 259.0 | 296.0 | 333.0 |
| 369 | 36.9 | 73.8 | 110.7 | 147.6 | 184.5 | 221.4 | 258.3 | 295.2 | 332.1 |
| 368 | 36.8 | 73.6 | 110.4 | 147.2 | 184.0 | 220.8 | 257.6 | 294.4 | 331.2 |
| 367 | 36.7 | 73.4 | 110.1 | 146.8 | 183.5 | 220.2 | 256.9 | 293.6 | 330.3 |
| 366 | 36.6 | 73.2 | 109.8 | 146.4 | 183.0 | 219.6 | 256.2 | 292.8 | 329.4 |
| 365 | 36.5 | 73.0 | 109.5 | 146.0 | 182.5 | 219.0 | 255.7 | 292.0 | 328.5 |
| 364 | 36.4 | 72.8 | 109.2 | 145.6 | 182.0 | 218.4 | 254.8 | 291.2 | 327.6 |
| 363 | 36.3 | 72.6 | 108.9 | 145.2 | 181.5 | 217.8 | 254.1 | 290.4 | 326.7 |
| 362 | 36.2 | 72.4 | 108.6 | 144.8 | 181.0 | 217.2 | 253.4 | 289.6 | 325.8 |
| 361 | 36.1 | 72.2 | 108.3 | 144.4 | 180.5 | 216.6 | 252.7 | 288.8 | 324.9 |
| 360 | 36.0 | 72.0 | 108.0 | 144.0 | 180.0 | 216.0 | 252.0 | 288.0 | 324.0 |
| 359 | 35.9 | 71.8 | 107.7 | 143.6 | 179.5 | 215.4 | 251.3 | 287.2 | 323.1 |
| 358 | 35.8 | 71.6 | 107.4 | 143.2 | 179.0 | 214.8 | 250.6 | 286.4 | 322.2 |
| 357 | 35.7 | 71.4 | 107.1 | 142.8 | 178.5 | 214.2 | 249.9 | 285.6 | 321.3 |
| 356 | 35.6 | 71.2 | 106.8 | 142.4 | 178.0 | 213.6 | 249.2 | 284.8 | 320.4 |

No. 120 L. 079.] [No. 134 L. 130.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 120 | 079181 | 9543 | 9904 | 0266 | 0626 | 0987 | 1347 | 1707 | 2067 | 2426 | 360 |
| 1 | 082785 | 3144 | 3503 | 3861 | 4219 | 4576 | 4934 | 5291 | 5647 | 6004 | 357 |
| 2 | 6360 | 6716 | 7071 | 7426 | 7781 | 8136 | 8490 | 8845 | 9198 | 9552 | 355 |
| 3 | 9905 | 0258 | 0611 | 0963 | 1315 | 1667 | 2018 | 2370 | 2721 | 3071 | 352 |
| 4 | 093422 | 3772 | 4122 | 4471 | 4820 | 5169 | 5518 | 5866 | 6215 | 6562 | 349 |
| 5 | 6910 | 7257 | 7604 | 7951 | 8298 | 8644 | 8990 | 9335 | 9681 | 0026 | 346 |
| 6 | 100371 | 0715 | 1059 | 1403 | 1747 | 2091 | 2434 | 2777 | 3119 | 3462 | 343 |
| 7 | 3804 | 4146 | 4487 | 4828 | 5169 | 5510 | 5851 | 6191 | 6531 | 6871 | 341 |
| 8 | 7210 | 7549 | 7888 | 8227 | 8565 | 8903 | 9241 | 9579 | 9916 | 0253 | 338 |
| 9 | 110590 | 0926 | 1263 | 1599 | 1934 | 2270 | 2605 | 2940 | 3275 | 3609 | 335 |
| 130 | 3943 | 4277 | 4611 | 4944 | 5278 | 5611 | 5943 | 6276 | 6608 | 6940 | 333 |
| 1 | 7271 | 7603 | 7934 | 8265 | 8595 | 8926 | 9256 | 9586 | 9915 | 0245 | 330 |
| 2 | 120574 | 0903 | 1231 | 1560 | 1888 | 2216 | 2544 | 2871 | 3198 | 3525 | 328 |
| 3 | 3852 | 4178 | 4504 | 4830 | 5156 | 5481 | 5806 | 6131 | 6456 | 6781 | 325 |
| 4 | 7105 | 7429 | 7753 | 8076 | 8399 | 8722 | 9045 | 9368 | 9690 | 0012 | 323 |
| | 13 | | | | | | | | | | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 355 | 35.5 | 71.0 | 106.5 | 142.0 | 177.5 | 213.0 | 248.5 | 284.0 | 319.5 |
| 354 | 35.4 | 70.8 | 106.2 | 141.6 | 177.0 | 212.4 | 247.8 | 283.2 | 318.6 |
| 353 | 35.3 | 70.6 | 105.9 | 141.2 | 176.5 | 211.8 | 247.1 | 282.4 | 317.7 |
| 352 | 35.2 | 70.4 | 105.6 | 140.8 | 176.0 | 211.2 | 246.4 | 281.6 | 316.8 |
| 351 | 35.1 | 70.2 | 105.3 | 140.4 | 175.5 | 210.6 | 245.7 | 280.8 | 315.9 |
| 350 | 35.0 | 70.0 | 105.0 | 140.0 | 175.0 | 210.0 | 245.0 | 280.0 | 315.0 |
| 349 | 34.9 | 69.8 | 104.7 | 139.6 | 174.5 | 209.4 | 244.3 | 279.2 | 314.1 |
| 348 | 34.8 | 69.6 | 104.4 | 139.2 | 174.0 | 208.8 | 243.6 | 278.4 | 313.2 |
| 347 | 34.7 | 69.4 | 104.1 | 138.8 | 173.5 | 208.2 | 242.9 | 277.6 | 312.3 |
| 346 | 34.6 | 69.2 | 103.8 | 138.4 | 173.0 | 207.6 | 242.2 | 276.8 | 311.4 |
| 345 | 34.5 | 69.0 | 103.5 | 138.0 | 172.5 | 207.0 | 241.5 | 276.0 | 310.5 |
| 344 | 34.4 | 68.8 | 103.2 | 137.6 | 172.0 | 206.4 | 240.8 | 275.2 | 309.6 |
| 343 | 34.3 | 68.6 | 102.9 | 137.2 | 171.5 | 205.8 | 240.1 | 274.4 | 308.7 |
| 342 | 34.2 | 68.4 | 102.6 | 136.8 | 171.0 | 205.2 | 239.4 | 273.6 | 307.8 |
| 341 | 34.1 | 68.2 | 102.3 | 136.4 | 170.5 | 204.6 | 238.7 | 272.8 | 306.9 |
| 340 | 34.0 | 68.0 | 102.0 | 136.0 | 170.0 | 204.0 | 238.0 | 272.0 | 306.0 |
| 339 | 33.9 | 67.8 | 101.7 | 135.6 | 169.5 | 203.4 | 237.3 | 271.2 | 305.1 |
| 338 | 33.8 | 67.6 | 101.4 | 135.2 | 169.0 | 202.8 | 236.6 | 270.4 | 304.2 |
| 337 | 33.7 | 67.4 | 101.1 | 134.8 | 168.5 | 202.2 | 235.9 | 269.6 | 303.3 |
| 336 | 33.6 | 67.2 | 100.8 | 134.4 | 168.0 | 201.6 | 235.2 | 268.8 | 302.4 |
| 335 | 33.5 | 67.0 | 100.5 | 134.0 | 167.5 | 201.0 | 234.5 | 268.0 | 301.5 |
| 334 | 33.4 | 66.8 | 100.2 | 133.6 | 167.0 | 200.4 | 233.8 | 267.2 | 300.6 |
| 333 | 33.3 | 66.6 | 99.9 | 133.2 | 166.5 | 199.8 | 233.1 | 266.4 | 299.7 |
| 332 | 33.2 | 66.4 | 99.6 | 132.8 | 166.0 | 199.2 | 232.4 | 265.6 | 298.8 |
| 331 | 33.1 | 66.2 | 99.3 | 132.4 | 165.5 | 198.6 | 231.7 | 264.8 | 297.9 |
| 330 | 33.0 | 66.0 | 99.0 | 132.0 | 165.0 | 198.0 | 231.0 | 264.0 | 297.0 |
| 329 | 32.9 | 65.8 | 98.7 | 131.6 | 164.5 | 197.4 | 230.3 | 263.2 | 296.1 |
| 328 | 32.8 | 65.6 | 98.4 | 131.2 | 164.0 | 196.8 | 229.6 | 262.4 | 295.2 |
| 327 | 32.7 | 65.4 | 98.1 | 130.8 | 163.5 | 196.2 | 228.9 | 261.6 | 294.3 |
| 326 | 32.6 | 65.2 | 97.8 | 130.4 | 163.0 | 195.6 | 228.2 | 260.8 | 293.4 |
| 325 | 32.5 | 65.0 | 97.5 | 130.0 | 162.5 | 195.0 | 227.5 | 260.0 | 292.5 |
| 324 | 32.4 | 64.8 | 97.2 | 129.6 | 162.0 | 194.4 | 226.8 | 259.2 | 291.6 |
| 323 | 32.3 | 64.6 | 96.9 | 129.2 | 161.5 | 193.8 | 226.1 | 258.4 | 290.7 |
| 322 | 32.2 | 64.4 | 96.6 | 128.8 | 161.0 | 193.2 | 225.4 | 257.6 | 289.8 |

No. 135 L. 130.] [No. 149 L. 175.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 135 | 130334 | 0655 | 0977 | 1298 | 1619 | 1939 | 2260 | 2580 | 2900 | 3219 | 321 |
| 6 | 3539 | 3858 | 4177 | 4496 | 4814 | 5133 | 5451 | 5769 | 6086 | 6403 | 318 |
| 7 | 6721 | 7037 | 7354 | 7671 | 7987 | 8303 | 8618 | 8934 | 9249 | 9564 | 316 |
| 8 | 9879 | 0194 | 0508 | 0822 | 1136 | 1450 | 1763 | 2076 | 2389 | 2702 | 314 |
| 9 | 143015 | 3327 | 3639 | 3951 | 4263 | 4574 | 4885 | 5196 | 5507 | 5818 | 311 |
| 140 | 6128 | 6438 | 6748 | 7058 | 7367 | 7676 | 7985 | 8294 | 8603 | 8911 | 309 |
| 1 | 9219 | 9527 | 9835 | 0142 | 0449 | 0756 | 1063 | 1370 | 1676 | 1982 | 307 |
| 2 | 152288 | 2594 | 2900 | 3205 | 3510 | 3815 | 4120 | 4424 | 4728 | 5032 | 305 |
| 3 | 5336 | 5640 | 5943 | 6246 | 6549 | 6852 | 7154 | 7457 | 7759 | 8061 | 303 |
| 4 | 8362 | 8664 | 8965 | 9266 | 9567 | 9868 | 0168 | 0469 | 0769 | 1068 | 301 |
| 5 | 161368 | 1667 | 1967 | 2266 | 2564 | 2863 | 3161 | 3460 | 3758 | 4055 | 299 |
| 6 | 4353 | 4650 | 4947 | 5244 | 5541 | 5838 | 6134 | 6430 | 6726 | 7022 | 297 |
| 7 | 7317 | 7613 | 7908 | 8203 | 8497 | 8792 | 9086 | 9380 | 9674 | 9968 | 295 |
| 8 | 170262 | 0555 | 0848 | 1141 | 1434 | 1726 | 2019 | 2311 | 2603 | 2895 | 293 |
| 9 | 3186 | 3478 | 3769 | 4060 | 4351 | 4641 | 4932 | 5222 | 5512 | 5802 | 291 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 321 | 32.1 | 64.2 | 96.3 | 128.4 | 160.5 | 192.6 | 224.7 | 256.8 | 288.9 |
| 320 | 32.0 | 64.0 | 96.0 | 128.0 | 160.0 | 192.0 | 224.0 | 256.0 | 288.0 |
| 319 | 31.9 | 63.8 | 95.7 | 127.6 | 159.5 | 191.4 | 223.3 | 255.2 | 287.1 |
| 318 | 31.8 | 63.6 | 95.4 | 127.2 | 159.0 | 190.8 | 222.6 | 254.4 | 286.2 |
| 317 | 31.7 | 63.4 | 95.1 | 126.8 | 158.5 | 190.2 | 221.9 | 253.6 | 285.3 |
| 316 | 31.6 | 63.2 | 94.8 | 126.4 | 158.0 | 189.6 | 221.2 | 252.8 | 284.4 |
| 315 | 31.5 | 63.0 | 94.5 | 126.0 | 157.5 | 189.0 | 220.5 | 252.0 | 283.5 |
| 314 | 31.4 | 62.8 | 94.2 | 125.6 | 157.0 | 188.4 | 219.8 | 251.2 | 282.6 |
| 313 | 31.3 | 62.6 | 93.9 | 125.2 | 156.5 | 187.8 | 219.1 | 250.4 | 281.7 |
| 312 | 31.2 | 62.4 | 93.6 | 124.8 | 156.0 | 187.2 | 218.4 | 249.6 | 280.8 |
| 311 | 31.1 | 62.2 | 93.3 | 124.4 | 155.5 | 186.6 | 217.7 | 248.8 | 279.9 |
| 310 | 31.0 | 62.0 | 93.0 | 124.0 | 155.0 | 186.0 | 217.0 | 248.0 | 279.0 |
| 309 | 30.9 | 61.8 | 92.7 | 123.6 | 154.5 | 185.4 | 216.3 | 247.2 | 278.1 |
| 308 | 30.8 | 61.6 | 92.4 | 123.2 | 154.0 | 184.8 | 215.6 | 246.4 | 277.2 |
| 307 | 30.7 | 61.4 | 92.1 | 122.8 | 153.5 | 184.2 | 214.9 | 245.6 | 276.3 |
| 306 | 30.6 | 61.2 | 91.8 | 122.4 | 153.0 | 183.6 | 214.2 | 244.8 | 275.4 |
| 305 | 30.5 | 61.0 | 91.5 | 122.0 | 152.5 | 183.0 | 213.5 | 244.0 | 274.5 |
| 304 | 30.4 | 60.8 | 91.2 | 121.6 | 152.0 | 182.4 | 212.8 | 243.2 | 273.6 |
| 303 | 30.3 | 60.6 | 90.9 | 121.2 | 151.5 | 181.8 | 212.1 | 242.4 | 272.7 |
| 302 | 30.2 | 60.4 | 90.6 | 120.8 | 151.0 | 181.2 | 211.4 | 241.6 | 271.8 |
| 301 | 30.1 | 60.2 | 90.3 | 120.4 | 150.5 | 180.6 | 210.7 | 240.8 | 270.9 |
| 300 | 30.0 | 60.0 | 90.0 | 120.0 | 150.0 | 180.0 | 210.0 | 240.0 | 270.0 |
| 299 | 29.9 | 59.8 | 89.7 | 119.6 | 149.5 | 179.4 | 209.3 | 239.2 | 269.1 |
| 298 | 29.8 | 59.6 | 89.4 | 119.2 | 149.0 | 178.8 | 208.6 | 238.4 | 268.2 |
| 297 | 29.7 | 59.4 | 89.1 | 118.8 | 148.5 | 178.2 | 207.9 | 237.6 | 267.3 |
| 296 | 29.6 | 59.2 | 88.8 | 118.4 | 148.0 | 177.6 | 207.2 | 236.8 | 266.4 |
| 295 | 29.5 | 59.0 | 88.5 | 118.0 | 147.5 | 177.0 | 206.5 | 236.0 | 265.5 |
| 294 | 29.4 | 58.8 | 88.2 | 117.6 | 147.0 | 176.4 | 205.8 | 235.2 | 264.6 |
| 293 | 29.3 | 58.6 | 87.9 | 117.2 | 146.5 | 175.8 | 205.1 | 234.4 | 263.7 |
| 292 | 29.2 | 58.4 | 87.6 | 116.8 | 146.0 | 175.2 | 204.4 | 233.6 | 262.8 |
| 291 | 29.1 | 58.2 | 87.3 | 116.4 | 145.5 | 174.6 | 203.7 | 232.8 | 261.9 |
| 290 | 29.0 | 58.0 | 87.0 | 116.0 | 145.0 | 174.0 | 203.0 | 232.0 | 261.0 |
| 289 | 28.9 | 57.8 | 86.7 | 115.6 | 144.5 | 173.4 | 202.3 | 231.2 | 260.1 |
| 288 | 28.8 | 57.6 | 86.4 | 115.2 | 144.0 | 172.8 | 201.6 | 230.4 | 259.2 |
| 287 | 28.7 | 57.4 | 86.1 | 114.8 | 143.5 | 172.2 | 200.9 | 229.6 | 258.3 |
| 286 | 28.6 | 57.2 | 85.8 | 114.4 | 143.0 | 171.6 | 200.2 | 228.8 | 257.4 |

No. 150 L. 176.] [No. 169 L. 230.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 150 | 176091 | 6381 | 6670 | 6959 | 7248 | 7536 | 7825 | 8113 | 8401 | 8689 | 289 |
| 1 | 8977 | 9264 | 9552 | 9839 | | | | | | | |
| | | | | | 0126 | 0413 | 0699 | 0986 | 1272 | 1558 | 287 |
| 2 | 181844 | 2129 | 2415 | 2700 | 2985 | 3270 | 3555 | 3839 | 4123 | 4407 | 285 |
| 3 | 4691 | 4975 | 5259 | 5542 | 5825 | 6108 | 6591 | 6674 | 6956 | 7239 | 283 |
| 4 | 7521 | 7803 | 8084 | 8366 | 8647 | 8928 | 9209 | 9490 | 9771 | | |
| | | | | | | | | | | 0051 | 281 |
| 5 | 190332 | 0612 | 0892 | 1171 | 1451 | 1730 | 2010 | 2289 | 2567 | 2846 | 279 |
| 6 | 3125 | 3403 | 3681 | 3959 | 4237 | 4514 | 4792 | 5069 | 5346 | 5623 | 278 |
| 7 | 5900 | 6176 | 6453 | 6729 | 7005 | 7281 | 7556 | 7832 | 8107 | 8382 | 276 |
| 8 | 8657 | 8932 | 9206 | 9481 | 9755 | | | | | | |
| | | | | | | 0029 | 0303 | 0577 | 0850 | 1124 | 274 |
| 9 | 201397 | 1670 | 1943 | 2216 | 2488 | 2761 | 3033 | 3305 | 3577 | 3848 | 272 |
| 160 | 4120 | 4391 | 4663 | 4934 | 5204 | 5475 | 5746 | 6016 | 6286 | 6556 | 271 |
| 1 | 6826 | 7096 | 7365 | 7634 | 7904 | 8173 | 8441 | 8710 | 8979 | 9247 | 269 |
| 2 | 9515 | 9783 | | | | | | | | | |
| | | | 0051 | 0319 | 0586 | 0853 | 1121 | 1388 | 1654 | 1921 | 267 |
| 3 | 212188 | 2454 | 2720 | 2986 | 3252 | 3518 | 3783 | 4049 | 4314 | 4579 | 266 |
| 4 | 4844 | 5109 | 5373 | 5638 | 5902 | 6166 | 6430 | 6694 | 6957 | 7221 | 264 |
| 5 | 7484 | 7747 | 8010 | 8273 | 8536 | 8798 | 9060 | 9323 | 9585 | 9846 | 262 |
| 6 | 220108 | 0370 | 0631 | 0892 | 1153 | 1414 | 1675 | 1936 | 2196 | 2456 | 261 |
| 7 | 2716 | 2976 | 3236 | 3496 | 3755 | 4015 | 4274 | 4533 | 4792 | 5051 | 259 |
| 8 | 5309 | 5568 | 5826 | 6084 | 6342 | 6600 | 6858 | 7115 | 7372 | 7630 | 258 |
| 9 | 7887 | 8144 | 8400 | 8657 | 8913 | 9170 | 9426 | 9682 | 9938 | | |
| | 23 | | | | | | | | | 0193 | 256 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 285 | 28.5 | 57.0 | 85.5 | 114.0 | 142.5 | 171.0 | 199.5 | 228.0 | 256.5 |
| 284 | 28.4 | 56.8 | 85.2 | 113.6 | 142.0 | 170.4 | 198.8 | 227.2 | 255.6 |
| 283 | 28.3 | 56.6 | 84.9 | 113.2 | 141.5 | 169.8 | 198.1 | 226.4 | 254.7 |
| 282 | 28.2 | 56.4 | 84.6 | 112.8 | 141.0 | 169.2 | 197.4 | 225.6 | 253.8 |
| 281 | 28.1 | 56.2 | 84.3 | 112 4 | 140.5 | 168.6 | 196.7 | 224.8 | 252.9 |
| 280 | 28.0 | 56.0 | 84.0 | 112.0 | 140.0 | 168.0 | 196.0 | 224.0 | 252.0 |
| 279 | 27.9 | 55.8 | 83.7 | 111.6 | 139.5 | 167.4 | 195.3 | 223.2 | 251.1 |
| 278 | 27.8 | 55.6 | 83.4 | 111.2 | 139.0 | 166.8 | 194.6 | 222.4 | 250.2 |
| 277 | 27.7 | 55.4 | 83.1 | 110.8 | 138.5 | 166.2 | 193.9 | 221.6 | 249.3 |
| 276 | 27.6 | 55.2 | 82.8 | 110.4 | 138.0 | 165.6 | 193.2 | 220.8 | 248.4 |
| 275 | 27.5 | 55.0 | 82.5 | 110.0 | 137.5 | 165.0 | 192.5 | 220.0 | 247.5 |
| 274 | 27.4 | 54.8 | 82.2 | 109.6 | 137.0 | 164.4 | 191.8 | 219.2 | 246.6 |
| 273 | 27.3 | 54.6 | 81.9 | 109.2 | 136.5 | 163.8 | 191.1 | 218.4 | 245.7 |
| 272 | 27.2 | 54.4 | 81.6 | 108.8 | 136.0 | 163.2 | 190.4 | 217.6 | 244.8 |
| 271 | 27.1 | 54.2 | 81.3 | 108.4 | 135.5 | 162.6 | 189.7 | 216.8 | 243.9 |
| 270 | 27.0 | 54.0 | 81.0 | 108.0 | 135.0 | 162.0 | 189.0 | 216.0 | 243.0 |
| 269 | 26.9 | 53.8 | 80.7 | 107.6 | 134.5 | 161.4 | 188.3 | 215.2 | 242.1 |
| 268 | 26.8 | 53.6 | 80.4 | 107.2 | 134.0 | 160.8 | 187.6 | 214.4 | 241.2 |
| 267 | 26.7 | 53.4 | 80.1 | 106.8 | 133.5 | 160.2 | 186.9 | 213.6 | 240.3 |
| 266 | 26.6 | 53.2 | 79.8 | 106.4 | 133.0 | 159.6 | 186.2 | 212.8 | 239.4 |
| 265 | 26.5 | 53.0 | 79.5 | 106.0 | 132.5 | 159.0 | 185.5 | 212.0 | 238.5 |
| 264 | 26.4 | 52.8 | 79.2 | 105.6 | 132.0 | 158.4 | 184.8 | 211.2 | 237.6 |
| 263 | 26.3 | 52.6 | 78.9 | 105.2 | 131.5 | 157.8 | 184.1 | 210.4 | 236.7 |
| 262 | 26.2 | 52.4 | 78.6 | 104.8 | 131.0 | 157.2 | 183.4 | 209.6 | 235.8 |
| 261 | 26.1 | 52.2 | 78.3 | 104.4 | 130.5 | 156.6 | 182.7 | 208.8 | 234.9 |
| 260 | 26.0 | 52.0 | 78.0 | 104.0 | 130.0 | 156.0 | 182.0 | 208.0 | 234.0 |
| 259 | 25.9 | 51.8 | 77.7 | 103.6 | 129.5 | 155.4 | 181.3 | 207.2 | 233.1 |
| 258 | 25.8 | 51.6 | 77.4 | 103.2 | 129.0 | 154.8 | 180.6 | 206.4 | 232.2 |
| 257 | 25.7 | 51.4 | 77.1 | 102.8 | 128.5 | 154.2 | 179.9 | 205.6 | 231.3 |
| 256 | 25.6 | 51.2 | 76.8 | 102.4 | 128.0 | 153.6 | 179.2 | 204.8 | 230.4 |
| 255 | 25.5 | 51.0 | 76.5 | 102.0 | 127.5 | 153.0 | 178.5 | 204.0 | 229.5 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 170 | 230449 | 0704 | 0960 | 1215 | 1470 | 1724 | 1979 | 2234 | 2488 | 2742 | 255 |
| 1 | 2996 | 3250 | 3504 | 3757 | 4011 | 4264 | 4517 | 4770 | 5023 | 5276 | 253 |
| 2 | 5528 | 5781 | 6033 | 6285 | 6537 | 6789 | 7041 | 7292 | 7544 | 7795 | 252 |
| 3 | 8046 | 8297 | 8548 | 8799 | 9049 | 9299 | 9550 | 9800 | 0050 | 0300 | 250 |
| 4 | 240549 | 0799 | 1048 | 1297 | 1546 | 1795 | 2044 | 2293 | 2541 | 2790 | 249 |
| 5 | 3038 | 3286 | 3534 | 3782 | 4030 | 4277 | 4525 | 4772 | 5019 | 5266 | 248 |
| 6 | 5513 | 5759 | 6006 | 6252 | 6499 | 6745 | 6991 | 7237 | 7482 | 7728 | 246 |
| 7 | 7973 | 8219 | 8464 | 8709 | 8954 | 9198 | 9443 | 9687 | 9932 | 0176 | 245 |
| 8 | 250420 | 0664 | 0908 | 1151 | 1395 | 1638 | 1881 | 2125 | 2368 | 2610 | 243 |
| 9 | 2853 | 3096 | 3338 | 3580 | 3822 | 4064 | 4306 | 4548 | 4790 | 5031 | 242 |
| 180 | 5273 | 5514 | 5755 | 5996 | 6237 | 6477 | 6718 | 6958 | 7198 | 7439 | 241 |
| 1 | 7679 | 7918 | 8158 | 8398 | 8637 | 8877 | 9116 | 9355 | 9594 | 9833 | 239 |
| 2 | 260071 | 0310 | 0548 | 0787 | 1025 | 1263 | 1501 | 1739 | 1976 | 2214 | 238 |
| 3 | 2451 | 2688 | 2925 | 3162 | 3399 | 3636 | 3873 | 4109 | 4346 | 4582 | 237 |
| 4 | 4818 | 5054 | 5290 | 5525 | 5761 | 5996 | 6232 | 6467 | 6702 | 6937 | 235 |
| 5 | 7172 | 7406 | 7641 | 7875 | 8110 | 8344 | 8578 | 8812 | 9046 | 9279 | 234 |
| 6 | 9513 | 9746 | 9980 | 0213 | 0446 | 0679 | 0912 | 1144 | 1377 | 1609 | 233 |
| 7 | 271842 | 2074 | 2306 | 2538 | 2770 | 3001 | 3233 | 3464 | 3696 | 3927 | 232 |
| 8 | 4158 | 4389 | 4620 | 4850 | 5081 | 5311 | 5542 | 5772 | 6002 | 6232 | 230 |
| 9 | 6462 | 6692 | 6921 | 7151 | 7380 | 7609 | 7838 | 8067 | 8296 | 8525 | 229 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 255 | 25.5 | 51.0 | 76.5 | 102.0 | 127.5 | 153.0 | 178.5 | 204.0 | 229.5 |
| 254 | 25.4 | 50.8 | 76.2 | 101.6 | 127.0 | 152.4 | 177.8 | 203.2 | 228.6 |
| 253 | 25.3 | 50.6 | 75.9 | 101.2 | 126.5 | 151.8 | 177.1 | 202.4 | 227.7 |
| 252 | 25.2 | 50.4 | 75.6 | 100.8 | 126.0 | 151.2 | 176.4 | 201.6 | 226.8 |
| 251 | 25.1 | 50.2 | 75.3 | 100.4 | 125.5 | 150.6 | 175.7 | 200.8 | 225.9 |
| 250 | 25.0 | 50.0 | 75.0 | 100.0 | 125.0 | 150.0 | 175.0 | 200.0 | 225.0 |
| 249 | 24.9 | 49.8 | 74.7 | 99.6 | 124.5 | 149.4 | 174.3 | 199.2 | 224.1 |
| 248 | 24.8 | 49.6 | 74.4 | 99.2 | 124.0 | 148.8 | 173.6 | 198.4 | 223.2 |
| 247 | 24.7 | 49.4 | 74.1 | 98.8 | 123.5 | 148.2 | 172.9 | 197.6 | 222.3 |
| 246 | 24.6 | 49.2 | 73.8 | 98.4 | 123.0 | 147.6 | 172.2 | 196.8 | 221.4 |
| 245 | 24.5 | 49.0 | 73.5 | 98.0 | 122.5 | 147.0 | 171.5 | 196.0 | 220.5 |
| 244 | 24.4 | 48.8 | 73.2 | 97.6 | 122.0 | 146.4 | 170.8 | 195.2 | 219.6 |
| 243 | 24.3 | 48.6 | 72.9 | 97.2 | 121.5 | 145.8 | 170.1 | 194.4 | 218.7 |
| 242 | 24.2 | 48.4 | 72.6 | 96.8 | 121.0 | 145.2 | 169.4 | 193.6 | 217.8 |
| 241 | 24.1 | 48.2 | 72.3 | 96.4 | 120.5 | 144.6 | 168.7 | 192.8 | 216.9 |
| 240 | 24.0 | 48.0 | 72.0 | 96.0 | 120.0 | 144.0 | 168.0 | 192.0 | 216.0 |
| 239 | 23.9 | 47.8 | 71.7 | 95.6 | 119.5 | 143.4 | 167.3 | 191.2 | 215.1 |
| 238 | 23.8 | 47.6 | 71.4 | 95.2 | 119.0 | 142.8 | 166.6 | 190.4 | 214.2 |
| 237 | 23.7 | 47.4 | 71.1 | 94.8 | 118.5 | 142.2 | 165.9 | 189.6 | 213.3 |
| 236 | 23.6 | 47.2 | 70.8 | 94.4 | 118.0 | 141.6 | 165.2 | 188.8 | 212.4 |
| 235 | 23.5 | 47.0 | 70.5 | 94.0 | 117.5 | 141.0 | 164.5 | 188.0 | 211.5 |
| 234 | 23.4 | 46.8 | 70.2 | 93.6 | 117.0 | 140.4 | 163.8 | 187.2 | 210.6 |
| 233 | 23.3 | 46.6 | 69.9 | 93.2 | 116.5 | 139.8 | 163.1 | 186.4 | 209.7 |
| 232 | 23.2 | 46.4 | 69.6 | 92.8 | 116.0 | 139.2 | 162.4 | 185.6 | 208.8 |
| 231 | 23.1 | 46.2 | 69.3 | 92.4 | 115.5 | 138.6 | 161.7 | 184.8 | 207.9 |
| 230 | 23.0 | 46.0 | 69.0 | 92.0 | 115.0 | 138.0 | 161.0 | 184.0 | 207.0 |
| 229 | 22.9 | 45.8 | 68.7 | 91.6 | 114.5 | 137.4 | 160.3 | 183.2 | 206.1 |
| 228 | 22.8 | 45.6 | 68.4 | 91.2 | 114.0 | 136.8 | 159.6 | 182.4 | 205.2 |
| 227 | 22.7 | 45.4 | 68.1 | 90.8 | 113.5 | 136.2 | 158.9 | 181.6 | 204.3 |
| 226 | 22.6 | 45.2 | 67.8 | 90.4 | 113.0 | 135.6 | 158.2 | 180.8 | 203.4 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 190 | 278754 | 8982 | 9211 | 9439 | 9667 | 9895 | 0123 | 0351 | 0578 | 0806 | 228 |
| 1 | 281033 | 1261 | 1488 | 1715 | 1942 | 2169 | 2396 | 2622 | 2849 | 3075 | 227 |
| 2 | 3301 | 3527 | 3753 | 3979 | 4205 | 4431 | 4656 | 4882 | 5107 | 5332 | 226 |
| 3 | 5557 | 5782 | 6007 | 6232 | 6456 | 6681 | 6905 | 7130 | 7354 | 7578 | 225 |
| 4 | 7802 | 8026 | 8249 | 8473 | 8696 | 8920 | 9143 | 9366 | 9589 | 9812 | 223 |
| 5 | 290035 | 0257 | 0480 | 0702 | 0925 | 1147 | 1369 | 1591 | 1813 | 2034 | 222 |
| 6 | 2256 | 2478 | 2699 | 2920 | 3141 | 3363 | 3584 | 3804 | 4025 | 4246 | 221 |
| 7 | 4466 | 4687 | 4907 | 5127 | 5347 | 5567 | 5787 | 6007 | 6226 | 6446 | 220 |
| 8 | 6665 | 6884 | 7104 | 7323 | 7542 | 7761 | 7979 | 8198 | 8416 | 8635 | 219 |
| 9 | 8853 | 9071 | 9289 | 9507 | 9725 | 9943 | 0161 | 0378 | 0595 | 0813 | 218 |
| 200 | 301030 | 1247 | 1464 | 1681 | 1898 | 2114 | 2331 | 2547 | 2764 | 2980 | 217 |
| 1 | 3196 | 3412 | 3628 | 3844 | 4059 | 4275 | 4491 | 4706 | 4921 | 5136 | 216 |
| 2 | 5351 | 5566 | 5781 | 5996 | 6211 | 6425 | 6639 | 6854 | 7068 | 7282 | 215 |
| 3 | 7496 | 7710 | 7924 | 8137 | 8351 | 8564 | 8778 | 8991 | 9204 | 9417 | 213 |
| 4 | 9630 | 9843 | 0056 | 0268 | 0481 | 0693 | 0906 | 1118 | 1330 | 1542 | 212 |
| 5 | 311754 | 1966 | 2177 | 2389 | 2600 | 2812 | 3023 | 3234 | 3445 | 3656 | 211 |
| 6 | 3867 | 4078 | 4289 | 4499 | 4710 | 4920 | 5130 | 5340 | 5551 | 5760 | 210 |
| 7 | 5970 | 6180 | 6390 | 6599 | 6809 | 7018 | 7227 | 7436 | 7646 | 7854 | 209 |
| 8 | 8063 | 8272 | 8481 | 8689 | 8898 | 9106 | 9314 | 9522 | 9730 | 9938 | 208 |
| 9 | 320146 | 0354 | 0562 | 0769 | 0977 | 1184 | 1391 | 1598 | 1805 | 2012 | 207 |
| 210 | 2219 | 2426 | 2633 | 2839 | 3046 | 3252 | 3458 | 3665 | 3871 | 4077 | 206 |
| 1 | 4282 | 4488 | 4694 | 4899 | 5105 | 5310 | 5516 | 5721 | 5926 | 6131 | 205 |
| 2 | 6336 | 6541 | 6745 | 6950 | 7155 | 7359 | 7563 | 7767 | 7972 | 8176 | 204 |
| 3 | 8380 | 8583 | 8787 | 8991 | 9194 | 9398 | 9601 | 9805 | 0008 | 0211 | 203 |
| 4 | 330414 | 0617 | 0819 | 1022 | 1225 | 1427 | 1630 | 1832 | 2034 | 2236 | 202 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 225 | 22.5 | 45.0 | 67.5 | 90.0 | 112.5 | 135.0 | 157.5 | 180.0 | 202.5 |
| 224 | 22.4 | 44.8 | 67.2 | 89.6 | 112.0 | 134.4 | 156.8 | 179.2 | 201.6 |
| 223 | 22.3 | 44.6 | 66.9 | 89.2 | 111.5 | 133.8 | 156.1 | 178.4 | 200.7 |
| 222 | 22.2 | 44.4 | 66.6 | 88.8 | 111.0 | 133.2 | 155.4 | 177.6 | 199.8 |
| 221 | 22.1 | 44.2 | 66.3 | 88.4 | 110.5 | 132.6 | 154.7 | 176.8 | 198.9 |
| 220 | 22.0 | 44.0 | 66.0 | 88.0 | 110.0 | 132.0 | 154.0 | 176.0 | 198.0 |
| 219 | 21.9 | 43.8 | 65.7 | 87.6 | 109.5 | 131.4 | 153.3 | 175.2 | 197.1 |
| 218 | 21.8 | 43.6 | 65.4 | 87.2 | 109.0 | 130.8 | 152.6 | 174.4 | 196.2 |
| 217 | 21.7 | 43.4 | 65.1 | 86.8 | 108.5 | 130.2 | 151.9 | 173.6 | 195.3 |
| 216 | 21.6 | 43.2 | 64.8 | 86.4 | 108.0 | 129.6 | 151.2 | 172.8 | 194.4 |
| 215 | 21.5 | 43.0 | 64.5 | 86.0 | 107.5 | 129.0 | 150.5 | 172.0 | 193.5 |
| 214 | 21.4 | 42.8 | 64.2 | 85.6 | 107.0 | 128.4 | 149.8 | 171.2 | 192.6 |
| 213 | 21.3 | 42.6 | 63.9 | 85.2 | 106.5 | 127.8 | 149.1 | 170.4 | 191.7 |
| 212 | 21.2 | 42.4 | 63.6 | 84.8 | 106.0 | 127.2 | 148.4 | 169.6 | 190.8 |
| 211 | 21.1 | 42.2 | 63.3 | 84.4 | 105.5 | 126.6 | 147.7 | 168.8 | 189.9 |
| 210 | 21.0 | 42.0 | 63.0 | 84.0 | 105.0 | 126.0 | 147.0 | 168.0 | 189.0 |
| 209 | 20.9 | 41.8 | 62.7 | 83.6 | 104.5 | 125.4 | 146.3 | 167.2 | 188.1 |
| 208 | 20.8 | 41.6 | 62.4 | 83.2 | 104.0 | 124.8 | 145.6 | 166.4 | 187.2 |
| 207 | 20.7 | 41.4 | 62.1 | 82.8 | 103.5 | 124.2 | 144.9 | 165.6 | 186.3 |
| 206 | 20.6 | 41.2 | 61.8 | 82.4 | 103.0 | 123.6 | 144.2 | 164.8 | 185.4 |
| 205 | 20.5 | 41.0 | 61.5 | 82.0 | 102.5 | 123.0 | 143.5 | 164.0 | 184.5 |
| 204 | 20.4 | 40.8 | 61.2 | 81.6 | 102.0 | 122.4 | 142.8 | 163.2 | 183.6 |
| 203 | 20.3 | 40.6 | 60.9 | 81.2 | 101.5 | 121.8 | 142.1 | 162.4 | 182.7 |
| 202 | 20.2 | 40.4 | 60.6 | 80.8 | 101.0 | 121.2 | 141.4 | 161.6 | 181.8 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 215 | 332438 | 2640 | 2842 | 3044 | 3246 | 3447 | 3649 | 3850 | 4051 | 4253 | 202 |
| 6 | 4454 | 4655 | 4856 | 5057 | 5257 | 5458 | 5658 | 5859 | 6059 | 6260 | 201 |
| 7 | 6460 | 6660 | 6860 | 7060 | 7260 | 7459 | 7659 | 7858 | 8058 | 8257 | 200 |
| 8 | 8456 | 8656 | 8855 | 9054 | 9253 | 9451 | 9650 | 9849 | | | |
| | | | | | | | | | 0047 | 0246 | 199 |
| 9 | 340444 | 0642 | 0841 | 1039 | 1237 | 1435 | 1632 | 1830 | 2028 | 2225 | 198 |
| 220 | 2423 | 2620 | 2817 | 3014 | 3212 | 3409 | 3606 | 3802 | 3999 | 4196 | 197 |
| 1 | 4392 | 4589 | 4785 | 4981 | 5178 | 5374 | 5570 | 5766 | 5962 | 6157 | 196 |
| 2 | 6353 | 6549 | 6744 | 6939 | 7135 | 7330 | 7525 | 7720 | 7915 | 8110 | 195 |
| 3 | 8305 | 8500 | 8694 | 8889 | 9083 | 9278 | 9472 | 9666 | 9860 | | |
| | | | | | | | | | | 0054 | 194 |
| 4 | 350248 | 0442 | 0636 | 0829 | 1023 | 1216 | 1410 | 1603 | 1796 | 1989 | 193 |
| 5 | 2183 | 2375 | 2568 | 2761 | 2954 | 3147 | 3339 | 3532 | 3724 | 3916 | 193 |
| 6 | 4108 | 4301 | 4493 | 4685 | 4876 | 5068 | 5260 | 5452 | 5643 | 5834 | 192 |
| 7 | 6026 | 6217 | 6408 | 6599 | 6790 | 6981 | 7172 | 7363 | 7554 | 7744 | 191 |
| 8 | 7935 | 8125 | 8316 | 8506 | 8696 | 8886 | 9076 | 9266 | 9456 | 9646 | 190 |
| 9 | 9835 | | | | | | | | | | |
| | | 0025 | 0215 | 0404 | 0593 | 0783 | 0972 | 1161 | 1350 | 1539 | 189 |
| 230 | 361728 | 1917 | 2105 | 2294 | 2482 | 2671 | 2859 | 3048 | 3236 | 3424 | 188 |
| 1 | 3612 | 3800 | 3988 | 4176 | 4363 | 4551 | 4739 | 4926 | 5113 | 5301 | 188 |
| 2 | 5488 | 5675 | 5862 | 6049 | 6236 | 6423 | 6610 | 6796 | 6983 | 7169 | 187 |
| 3 | 7356 | 7542 | 7729 | 7915 | 8101 | 8287 | 8473 | 8659 | 8845 | 9030 | 186 |
| 4 | 9216 | 9401 | 9587 | 9772 | 9958 | | | | | | |
| | | | | | | 0143 | 0328 | 0513 | 0698 | 0883 | 185 |
| 5 | 371068 | 1253 | 1437 | 1622 | 1806 | 1991 | 2175 | 2360 | 2544 | 2728 | 184 |
| 6 | 2912 | 3096 | 3280 | 3464 | 3647 | 3831 | 4015 | 4198 | 4382 | 4565 | 184 |
| 7 | 4748 | 4932 | 5115 | 5298 | 5481 | 5664 | 5846 | 6029 | 6212 | 6394 | 183 |
| 8 | 6577 | 6759 | 6942 | 7124 | 7306 | 7488 | 7670 | 7852 | 8034 | 8216 | 182 |
| 9 | 8398 | 8580 | 8761 | 8943 | 9124 | 9306 | 9487 | 9668 | 9849 | | |
| | 38 | | | | | | | | | 0030 | 181 |

## Proportional Parts.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 202 | 20.2 | 40.4 | 60.6 | 80.8 | 101.0 | 121.2 | 141.4 | 161.6 | 181.8 |
| 201 | 20.1 | 40.2 | 60.3 | 80.4 | 100.5 | 120.6 | 140.7 | 160.8 | 180.9 |
| 200 | 20.0 | 40.0 | 60.0 | 80.0 | 100.0 | 120.0 | 140.0 | 160.0 | 180.0 |
| 199 | 19.9 | 39.8 | 59.7 | 79.6 | 99.5 | 119.4 | 139.3 | 159.2 | 179.1 |
| 198 | 19.8 | 39.6 | 59.4 | 79.2 | 99.0 | 118.8 | 138.6 | 158.4 | 178.2 |
| 197 | 19.7 | 39.4 | 59.1 | 78.8 | 98.5 | 118.2 | 137.9 | 157.6 | 177.3 |
| 196 | 19.6 | 39.2 | 58.8 | 78.4 | 98.0 | 117.6 | 137.2 | 156.8 | 176.4 |
| 195 | 19.5 | 39.0 | 58.5 | 78.0 | 97.5 | 117.0 | 136.5 | 156.0 | 175.5 |
| 194 | 19.4 | 38.8 | 58.2 | 77.6 | 97.0 | 116.4 | 135.8 | 155.2 | 174.6 |
| 193 | 19.3 | 38.6 | 57.9 | 77.2 | 96.5 | 115.8 | 135.1 | 154.4 | 173.7 |
| 192 | 19.2 | 38.4 | 57.6 | 76.8 | 96.0 | 115.2 | 134.4 | 153.6 | 172.8 |
| 191 | 19.1 | 38.2 | 57.3 | 76.4 | 95.5 | 114.6 | 133.7 | 152.8 | 171.9 |
| 190 | 19.0 | 38.0 | 57.0 | 76.0 | 95.0 | 114.0 | 133.0 | 152.0 | 171.0 |
| 189 | 18.9 | 37.8 | 56.7 | 75.6 | 94.5 | 113.4 | 132.3 | 151.2 | 170.1 |
| 188 | 18.8 | 37.6 | 56.4 | 75.2 | 94.0 | 112.8 | 131.6 | 150.4 | 169.2 |
| 187 | 18.7 | 37.4 | 56.1 | 74.8 | 93.5 | 112.2 | 130.9 | 149.6 | 168.3 |
| 186 | 18.6 | 37.2 | 55.8 | 74.4 | 93.0 | 111.6 | 130.2 | 148.8 | 167.4 |
| 185 | 18.5 | 37.0 | 55.5 | 74.0 | 92.5 | 111.0 | 129.5 | 148.0 | 166.5 |
| 184 | 18.4 | 36.8 | 55.2 | 73.6 | 92.0 | 110.4 | 128.8 | 147.2 | 165.6 |
| 183 | 18.3 | 36.6 | 54.9 | 73.2 | 91.5 | 109.8 | 128.1 | 146.4 | 164.7 |
| 182 | 18.2 | 36.4 | 54.6 | 72.8 | 91.0 | 109.2 | 127.4 | 145.6 | 163.8 |
| 181 | 18.1 | 36.2 | 54.3 | 72.4 | 90.5 | 108.6 | 126.7 | 144.8 | 162.9 |
| 180 | 18.0 | 36.0 | 54.0 | 72.0 | 90.0 | 108.0 | 126.0 | 144.0 | 162.0 |
| 179 | 17.9 | 35.8 | 53.7 | 71.6 | 89.5 | 107.4 | 125.3 | 143.2 | 161.1 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 240 | 380211 | 0392 | 0573 | 0754 | 0934 | 1115 | 1296 | 1476 | 1656 | 1837 | 181 |
| 1 | 2017 | 2197 | 2377 | 2557 | 2737 | 2917 | 3097 | 3277 | 3456 | 3636 | 180 |
| 2 | 3815 | 3995 | 4174 | 4353 | 4533 | 4712 | 4891 | 5070 | 5249 | 5428 | 179 |
| 3 | 5606 | 5785 | 5964 | 6142 | 6321 | 6499 | 6677 | 6856 | 7034 | 7212 | 178 |
| 4 | 7390 | 7568 | 7746 | 7924 | 8101 | 8279 | 8456 | 8634 | 8811 | 8989 | 178 |
| 5 | 9166 | 9343 | 9520 | 9698 | 9875 | | | | | | |
| | | | | | | 0051 | 0228 | 0405 | 0582 | 0759 | 177 |
| 6 | 390935 | 1112 | 1288 | 1464 | 1641 | 1817 | 1993 | 2169 | 2345 | 2521 | 176 |
| 7 | 2697 | 2873 | 3048 | 3224 | 3400 | 3575 | 3751 | 3926 | 4101 | 4277 | 176 |
| 8 | 4452 | 4627 | 4802 | 4977 | 5152 | 5326 | 5501 | 5676 | 5850 | 6025 | 175 |
| 9 | 6199 | 6374 | 6548 | 6722 | 6896 | 7071 | 7245 | 7419 | 7592 | 7766 | 174 |
| 250 | 7940 | 8114 | 8287 | 8461 | 8634 | 8808 | 8981 | 9154 | 9328 | 9501 | 173 |
| 1 | 9674 | 9847 | | | | | | | | | |
| | | | 0020 | 0192 | 0365 | 0538 | 0711 | 0883 | 1056 | 1228 | 173 |
| 2 | 401401 | 1573 | 1745 | 1917 | 2089 | 2261 | 2433 | 2605 | 2777 | 2949 | 172 |
| 3 | 3121 | 3292 | 3464 | 3635 | 3807 | 3978 | 4149 | 4320 | 4492 | 4663 | 171 |
| 4 | 4834 | 5005 | 5176 | 5346 | 5517 | 5688 | 5858 | 6029 | 6199 | 6370 | 171 |
| 5 | 6540 | 6710 | 6881 | 7051 | 7221 | 7391 | 7561 | 7731 | 7901 | 8070 | 170 |
| 6 | 8240 | 8410 | 8579 | 8749 | 8918 | 9087 | 9257 | 9426 | 9595 | 9764 | 169 |
| 7 | 9933 | | | | | | | | | | |
| | | 0102 | 0271 | 0440 | 0609 | 0777 | 0946 | 1114 | 1283 | 1451 | 169 |
| 8 | 411620 | 1788 | 1956 | 2124 | 2293 | 2461 | 2629 | 2796 | 2964 | 3132 | 168 |
| 9 | 3300 | 3467 | 3635 | 3803 | 3970 | 4137 | 4305 | 4472 | 4639 | 4806 | 167 |
| 260 | 4973 | 5140 | 5307 | 5474 | 5641 | 5808 | 5974 | 6141 | 6308 | 6474 | 167 |
| 1 | 6641 | 6807 | 6973 | 7139 | 7306 | 7472 | 7638 | 7804 | 7970 | 8135 | 166 |
| 2 | 8301 | 8467 | 8633 | 8798 | 8964 | 9129 | 9295 | 9460 | 9625 | 9791 | 165 |
| 3 | 9956 | | | | | | | | | | |
| | | 0121 | 0286 | 0451 | 0616 | 0781 | 0945 | 1110 | 1275 | 1439 | 165 |
| 4 | 421604 | 1768 | 1933 | 2097 | 2261 | 2426 | 2590 | 2754 | 2918 | 3082 | 164 |
| 5 | 3246 | 3410 | 3574 | 3737 | 3901 | 4065 | 4228 | 4392 | 4555 | 4718 | 164 |
| 6 | 4882 | 5045 | 5208 | 5371 | 5534 | 5697 | 5860 | 6023 | 6186 | 6349 | 163 |
| 7 | 6511 | 6674 | 6836 | 6999 | 7161 | 7324 | 7486 | 7648 | 7811 | 7973 | 162 |
| 8 | 8135 | 8297 | 8459 | 8621 | 8783 | 8944 | 9106 | 9268 | 9429 | 9591 | 162 |
| 9 | 9752 | 9914 | | | | | | | | | |
| | 43 | | 0075 | 0236 | 0398 | 0559 | 0720 | 0881 | 1042 | 1203 | 161 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 178 | 17.8 | 35.6 | 53.4 | 71.2 | 89.0 | 106.8 | 124.6 | 142.4 | 160.2 |
| 177 | 17.7 | 35.4 | 53.1 | 70.8 | 88.5 | 106.2 | 123.9 | 141.6 | 159.3 |
| 176 | 17.6 | 35.2 | 52.8 | 70.4 | 88.0 | 105.6 | 123.2 | 140.8 | 158.4 |
| 175 | 17.5 | 35.0 | 52.5 | 70.0 | 87.5 | 105.0 | 122.5 | 140.0 | 157.5 |
| 174 | 17.4 | 34.8 | 52.2 | 69.6 | 87.0 | 104.4 | 121.8 | 139.2 | 156.6 |
| 173 | 17.3 | 34.6 | 51.9 | 69.2 | 86.5 | 103.8 | 121.1 | 138.4 | 155.7 |
| 172 | 17.2 | 34.4 | 51.6 | 68.8 | 86.0 | 103.2 | 120.4 | 137.6 | 154.8 |
| 171 | 17.1 | 34.2 | 51.3 | 68.4 | 85.5 | 102.6 | 119.7 | 136.8 | 153.9 |
| 170 | 17.0 | 34.0 | 51.0 | 68.0 | 85.0 | 102.0 | 119.0 | 136.0 | 153.0 |
| 169 | 16.9 | 33.8 | 50.7 | 67.6 | 84.5 | 101.4 | 118.3 | 135.2 | 152.1 |
| 168 | 16.8 | 33.6 | 50.4 | 67.2 | 84.0 | 100.8 | 117.6 | 134.4 | 151.2 |
| 167 | 16.7 | 33.4 | 50.1 | 66.8 | 83.5 | 100.2 | 116.9 | 133.6 | 150.3 |
| 166 | 16.6 | 33.2 | 49.8 | 66.4 | 83.0 | 99.6 | 116.2 | 132.8 | 149.4 |
| 165 | 16.5 | 33.0 | 49.5 | 66.0 | 82.5 | 99.0 | 115.5 | 132.0 | 148.5 |
| 164 | 16.4 | 32.8 | 49.2 | 65.6 | 82.0 | 98.4 | 114.8 | 131.2 | 147.6 |
| 163 | 16.3 | 32.6 | 48.9 | 65.2 | 81.5 | 97.8 | 114.1 | 130.4 | 146.7 |
| 162 | 16.2 | 32.4 | 48.5 | 64.8 | 81.0 | 97.2 | 113.4 | 129.6 | 145.8 |
| 161 | 16.1 | 32.2 | 48.3 | 64.4 | 80.5 | 96.6 | 112.7 | 128.8 | 144.9 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 270 | 431364 | 1525 | 1685 | 1846 | 2007 | 2167 | 2328 | 2488 | 2649 | 2809 | 161 |
| 1 | 2969 | 3130 | 3290 | 3450 | 3610 | 3770 | 3930 | 4090 | 4249 | 4409 | 160 |
| 2 | 4569 | 4729 | 4888 | 5048 | 5207 | 5367 | 5526 | 5685 | 5844 | 6004 | 159 |
| 3 | 6163 | 6322 | 6481 | 6640 | 6799 | 6957 | 7116 | 7275 | 7433 | 7592 | 159 |
| 4 | 7751 | 7909 | 8067 | 8226 | 8384 | 8542 | 8701 | 8859 | 9017 | 9175 | 158 |
| 5 | 9333 | 9491 | 9648 | 9806 | 9964 | 0122 | 0279 | 0437 | 0594 | 0752 | 158 |
| 6 | 440909 | 1066 | 1224 | 1381 | 1538 | 1695 | 1852 | 2009 | 2166 | 2323 | 157 |
| 7 | 2480 | 2637 | 2793 | 2950 | 3106 | 3263 | 3419 | 3576 | 3732 | 3889 | 157 |
| 8 | 4045 | 4201 | 4357 | 4513 | 4669 | 4825 | 4981 | 5137 | 5293 | 5449 | 156 |
| 9 | 5604 | 5760 | 5915 | 6071 | 6226 | 6382 | 6537 | 6692 | 6848 | 7003 | 155 |
| 280 | 7158 | 7313 | 7468 | 7623 | 7778 | 7933 | 8088 | 8242 | 8397 | 8552 | 155 |
| 1 | 8706 | 8861 | 9015 | 9170 | 9324 | 9478 | 9633 | 9787 | 9941 | 0095 | 154 |
| 2 | 450249 | 0403 | 0557 | 0711 | 0865 | 1018 | 1172 | 1326 | 1479 | 1633 | 154 |
| 3 | 1786 | 1940 | 2093 | 2247 | 2400 | 2553 | 2706 | 2859 | 3012 | 3165 | 153 |
| 4 | 3318 | 3471 | 3624 | 3777 | 3930 | 4082 | 4235 | 4387 | 4540 | 4692 | 153 |
| 5 | 4845 | 4997 | 5150 | 5302 | 5454 | 5606 | 5758 | 5910 | 6062 | 6214 | 152 |
| 6 | 6366 | 6518 | 6670 | 6821 | 6973 | 7125 | 7276 | 7428 | 7579 | 7731 | 152 |
| 7 | 7882 | 8033 | 8184 | 8336 | 8487 | 8638 | 8789 | 8940 | 9091 | 9242 | 151 |
| 8 | 9392 | 9543 | 9694 | 9845 | 9995 | 0146 | 0296 | 0447 | 0597 | 0748 | 151 |
| 9 | 460898 | 1048 | 1198 | 1348 | 1499 | 1649 | 1799 | 1948 | 2098 | 2248 | 150 |
| 290 | 2398 | 2548 | 2697 | 2847 | 2997 | 3146 | 3296 | 3445 | 3594 | 3744 | 150 |
| 1 | 3893 | 4042 | 4191 | 4340 | 4490 | 4639 | 4788 | 4936 | 5085 | 5234 | 149 |
| 2 | 5383 | 5532 | 5680 | 5829 | 5977 | 6126 | 6274 | 6423 | 6571 | 6719 | 149 |
| 3 | 6868 | 7016 | 7164 | 7312 | 7460 | 7608 | 7756 | 7904 | 8052 | 8200 | 148 |
| 4 | 8347 | 8495 | 8643 | 8790 | 8938 | 9085 | 9233 | 9380 | 9527 | 9675 | 148 |
| 5 | 9822 | 9969 | 0116 | 0263 | 0410 | 0557 | 0704 | 0851 | 0998 | 1145 | 147 |
| 6 | 471292 | 1438 | 1585 | 1732 | 1878 | 2025 | 2171 | 2318 | 2464 | 2610 | 146 |
| 7 | 2756 | 2903 | 3049 | 3195 | 3341 | 3487 | 3633 | 3779 | 3925 | 4071 | 146 |
| 8 | 4216 | 4362 | 4508 | 4653 | 4799 | 4944 | 5090 | 5235 | 5381 | 5526 | 146 |
| 9 | 5671 | 5816 | 5962 | 6107 | 6252 | 6397 | 6542 | 6687 | 6832 | 6976 | 145 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 161 | 16.1 | 32.2 | 48.3 | 64.4 | 80.5 | 96.6 | 112.7 | 128.8 | 144.9 |
| 160 | 16.0 | 32.0 | 48.0 | 64.0 | 80.0 | 96.0 | 112.0 | 128.0 | 144.0 |
| 159 | 15.9 | 31.8 | 47.7 | 63.6 | 79.5 | 95.4 | 111.3 | 127.2 | 143.1 |
| 158 | 15.8 | 31.6 | 47.4 | 63.2 | 79.0 | 94.8 | 110.6 | 126.4 | 142.2 |
| 157 | 15.7 | 31.4 | 47.1 | 62.8 | 78.5 | 94.2 | 109.9 | 125.6 | 141.3 |
| 156 | 15.6 | 31.2 | 46.8 | 62.4 | 78.0 | 93.6 | 109.2 | 124.8 | 140.4 |
| 155 | 15.5 | 31.0 | 46.5 | 62.0 | 77.5 | 93.0 | 108.5 | 124.0 | 139.5 |
| 154 | 15.4 | 30.8 | 46.2 | 61.6 | 77.0 | 92.4 | 107.8 | 123.2 | 138.6 |
| 153 | 15.3 | 30.6 | 45.9 | 61.2 | 76.5 | 91.8 | 107.1 | 122.4 | 137.7 |
| 152 | 15.2 | 30.4 | 45.6 | 60.8 | 76.0 | 91.2 | 106.4 | 121.6 | 136.8 |
| 151 | 15.1 | 30.2 | 45.3 | 60.4 | 75.5 | 90.6 | 105.7 | 120.8 | 135.9 |
| 150 | 15.0 | 30.0 | 45.0 | 60.0 | 75.0 | 90.0 | 105.0 | 120.0 | 135.0 |
| 149 | 14.9 | 29.8 | 44.7 | 59.6 | 74.5 | 89.4 | 104.3 | 119.2 | 134.1 |
| 148 | 14.8 | 29.6 | 44.4 | 59.2 | 74.0 | 88.8 | 103.6 | 118.4 | 133.2 |
| 147 | 14.7 | 29.4 | 44.1 | 58.8 | 73.5 | 88.2 | 102.9 | 117.6 | 132.3 |
| 146 | 14.6 | 29.2 | 43.8 | 58.4 | 73.0 | 87.6 | 102.2 | 116.8 | 131.4 |
| 145 | 14.5 | 29.0 | 43.5 | 58.0 | 72.5 | 87.0 | 101.5 | 116.0 | 130.5 |
| 144 | 14.4 | 28.8 | 43.2 | 57.6 | 72.0 | 86.4 | 100.8 | 115.2 | 129.6 |
| 143 | 14.3 | 28.6 | 42.9 | 57.2 | 71.5 | 85.8 | 100.1 | 114.4 | 128.7 |
| 142 | 14.2 | 28.4 | 42.6 | 56.8 | 71.0 | 85.2 | 99.4 | 113.6 | 127.8 |
| 141 | 14.1 | 28.2 | 42.3 | 56.4 | 70.5 | 84.6 | 98.7 | 112.8 | 126.9 |
| 140 | 14.0 | 28.0 | 42.0 | 56.0 | 70.0 | 84.0 | 98.0 | 112.0 | 126.0 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 477121 | 7266 | 7411 | 7555 | 7700 | 7844 | 7989 | 8133 | 8278 | 8422 | 145 |
| 1 | 8566 | 8711 | 8855 | 8999 | 9143 | 9287 | 9431 | 9575 | 9719 | 9863 | 144 |
| 2 | 480007 | 0151 | 0294 | 0438 | 0582 | 0725 | 0869 | 1012 | 1156 | 1299 | 144 |
| 3 | 1443 | 1586 | 1729 | 1872 | 2016 | 2159 | 2302 | 2445 | 2588 | 2731 | 143 |
| 4 | 2874 | 3016 | 3159 | 3302 | 3445 | 3587 | 3730 | 3872 | 4015 | 4157 | 143 |
| 5 | 4300 | 4442 | 4585 | 4727 | 4869 | 5011 | 5153 | 5295 | 5437 | 5579 | 142 |
| 6 | 5721 | 5863 | 6005 | 6147 | 6289 | 6430 | 6572 | 6714 | 6855 | 6997 | 142 |
| 7 | 7138 | 7280 | 7421 | 7563 | 7704 | 7845 | 7986 | 8127 | 8269 | 8410 | 141 |
| 8 | 8551 | 8692 | 8833 | 8974 | 9114 | 9255 | 9396 | 9537 | 9677 | 9818 | 141 |
| 9 | 9958 | 0099 | 0239 | 0380 | 0520 | 0661 | 0801 | 0941 | 1081 | 1222 | 140 |
| 310 | 491362 | 1502 | 1642 | 1782 | 1922 | 2062 | 2201 | 2341 | 2481 | 2621 | 140 |
| 1 | 2760 | 2900 | 3040 | 3179 | 3319 | 3458 | 3597 | 3737 | 3876 | 4015 | 139 |
| 2 | 4155 | 4294 | 4433 | 4572 | 4711 | 4850 | 4989 | 5128 | 5267 | 5406 | 139 |
| 3 | 5544 | 5683 | 5822 | 5960 | 6099 | 6238 | 6376 | 6515 | 6653 | 6791 | 139 |
| 4 | 6930 | 7068 | 7206 | 7344 | 7483 | 7621 | 7759 | 7897 | 8035 | 8173 | 138 |
| 5 | 8311 | 8448 | 8586 | 8724 | 8862 | 8999 | 9137 | 9275 | 9412 | 9550 | 138 |
| 6 | 9687 | 9824 | 9962 | 0099 | 0236 | 0374 | 0511 | 0648 | 0785 | 0922 | 137 |
| 7 | 501059 | 1196 | 1333 | 1470 | 1607 | 1744 | 1880 | 2017 | 2154 | 2291 | 137 |
| 8 | 2427 | 2564 | 2700 | 2837 | 2973 | 3109 | 3246 | 3382 | 3518 | 3655 | 136 |
| 9 | 3791 | 3927 | 4063 | 4199 | 4335 | 4471 | 4607 | 4743 | 4878 | 5014 | 136 |
| 320 | 5150 | 5286 | 5421 | 5557 | 5693 | 5828 | 5964 | 6099 | 6234 | 6370 | 136 |
| 1 | 6505 | 6640 | 6776 | 6911 | 7046 | 7181 | 7316 | 7451 | 7586 | 7721 | 135 |
| 2 | 7856 | 7991 | 8126 | 8260 | 8395 | 8530 | 8664 | 8799 | 8934 | 9068 | 135 |
| 3 | 9203 | 9337 | 9471 | 9606 | 9740 | 9874 | 0009 | 0143 | 0277 | 0411 | 134 |
| 4 | 510545 | 0679 | 0813 | 0947 | 1081 | 1215 | 1349 | 1482 | 1616 | 1750 | 134 |
| 5 | 1883 | 2017 | 2151 | 2284 | 2418 | 2551 | 2684 | 2818 | 2951 | 3084 | 133 |
| 6 | 3218 | 3351 | 3484 | 3617 | 3750 | 3883 | 4016 | 4149 | 4282 | 4415 | 133 |
| 7 | 4548 | 4681 | 4813 | 4946 | 5079 | 5211 | 5344 | 5476 | 5609 | 5741 | 133 |
| 8 | 5874 | 6006 | 6139 | 6271 | 6403 | 6535 | 6668 | 6800 | 6932 | 7064 | 132 |
| 9 | 7196 | 7328 | 7460 | 7592 | 7724 | 7855 | 7987 | 8119 | 8251 | 8382 | 132 |
| 330 | 8514 | 8646 | 8777 | 8909 | 9040 | 9171 | 9303 | 9434 | 9566 | 9697 | 131 |
| 1 | 9828 | 9959 | 0090 | 0221 | 0353 | 0484 | 0615 | 0745 | 0876 | 1007 | 131 |
| 2 | 521138 | 1269 | 1400 | 1530 | 1661 | 1792 | 1922 | 2053 | 2183 | 2314 | 131 |
| 3 | 2444 | 2575 | 2705 | 2835 | 2966 | 3096 | 3226 | 3356 | 3486 | 3616 | 130 |
| 4 | 3746 | 3876 | 4006 | 4136 | 4266 | 4396 | 4526 | 4656 | 4785 | 4915 | 130 |
| 5 | 5045 | 5174 | 5304 | 5434 | 5563 | 5693 | 5822 | 5951 | 6081 | 6210 | 129 |
| 6 | 6339 | 6469 | 6598 | 6727 | 6856 | 6985 | 7114 | 7243 | 7372 | 7501 | 129 |
| 7 | 7630 | 7759 | 7888 | 8016 | 8145 | 8274 | 8402 | 8531 | 8660 | 8788 | 129 |
| 8 | 8917 | 9045 | 9174 | 9302 | 9430 | 9559 | 9687 | 9815 | 9943 | 0072 | 128 |
| 9 | 530200 | 0328 | 0456 | 0584 | 0712 | 0840 | 0968 | 1096 | 1223 | 1351 | 128 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 139 | 13.9 | 27.8 | 41.7 | 55.6 | 69.5 | 83.4 | 97.3 | 111.2 | 125.1 |
| 138 | 13.8 | 27.6 | 41.4 | 55.2 | 69.0 | 82.8 | 96.6 | 110.4 | 124.2 |
| 137 | 13.7 | 27.4 | 41.1 | 54.8 | 68.5 | 82.2 | 95.9 | 109.6 | 123.3 |
| 136 | 13.6 | 27.2 | 40.8 | 54.4 | 68.0 | 81.6 | 95.2 | 108.8 | 122.4 |
| 135 | 13.5 | 27.0 | 40.5 | 54.0 | 67.5 | 81.0 | 94.5 | 108.0 | 121.5 |
| 134 | 13.4 | 26.8 | 40.2 | 53.6 | 67.0 | 80.4 | 93.8 | 107.2 | 120.6 |
| 133 | 13.3 | 26.6 | 39.9 | 53.2 | 66.5 | 79.8 | 93.1 | 106.4 | 119.7 |
| 132 | 13.2 | 26.4 | 39.6 | 52.8 | 66.0 | 79.2 | 92.4 | 105.6 | 118.8 |
| 131 | 13.1 | 26.2 | 39.3 | 52.4 | 65.5 | 78.6 | 91.7 | 104.8 | 117.9 |
| 130 | 13.0 | 26.0 | 39.0 | 52.0 | 65.0 | 78.0 | 91.0 | 104.0 | 117.0 |
| 129 | 12.9 | 25.8 | 38.7 | 51.6 | 64.5 | 77.4 | 90.3 | 103.2 | 116.1 |
| 128 | 12.8 | 25.6 | 38.4 | 51.2 | 64.0 | 76.8 | 89.6 | 102.4 | 115.2 |
| 127 | 12.7 | 25.4 | 38.1 | 50.8 | 63.5 | 76.2 | 88.9 | 101.6 | 114.3 |

No. 340 L. 531.] [No. 379 L. 579.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 340 | 531479 | 1607 | 1734 | 1862 | 1990 | 2117 | 2245 | 2372 | 2500 | 2627 | 128 |
| 1 | 2754 | 2882 | 3009 | 3136 | 3264 | 3391 | 3518 | 3645 | 3772 | 3899 | 127 |
| 2 | 4026 | 4153 | 4280 | 4407 | 4534 | 4661 | 4787 | 4914 | 5041 | 5167 | 127 |
| 3 | 5294 | 5421 | 5547 | 5674 | 5800 | 5927 | 6053 | 6180 | 6306 | 6432 | 126 |
| 4 | 6558 | 6685 | 6811 | 6937 | 7063 | 7189 | 7315 | 7441 | 7567 | 7693 | 126 |
| 5 | 7819 | 7945 | 8071 | 8197 | 8322 | 8448 | 8574 | 8699 | 8825 | 8951 | 126 |
| 6 | 9076 | 9202 | 9327 | 9452 | 9578 | 9703 | 9829 | 9954 | 0079 | 0204 | 125 |
| 7 | 540329 | 0455 | 0580 | 0705 | 0830 | 0955 | 1080 | 1205 | 1330 | 1454 | 125 |
| 8 | 1579 | 1704 | 1829 | 1953 | 2078 | 2203 | 2327 | 2452 | 2576 | 2701 | 125 |
| 9 | 2825 | 2950 | 3074 | 3199 | 3323 | 3447 | 3571 | 3696 | 3820 | 3944 | 124 |
| 350 | 4068 | 4192 | 4316 | 4440 | 4564 | 4688 | 4812 | 4936 | 5060 | 5183 | 124 |
| 1 | 5307 | 5431 | 5555 | 5678 | 5802 | 5925 | 6049 | 6172 | 6296 | 6419 | 124 |
| 2 | 6543 | 6666 | 6789 | 6913 | 7036 | 7159 | 7282 | 7405 | 7529 | 7652 | 123 |
| 3 | 7775 | 7898 | 8021 | 8144 | 8267 | 8389 | 8512 | 8635 | 8758 | 8881 | 123 |
| 4 | 9003 | 9126 | 9249 | 9371 | 9494 | 9616 | 9739 | 9861 | 9984 | 0106 | 123 |
| 5 | 550228 | 0351 | 0473 | 0595 | 0717 | 0840 | 0962 | 1084 | 1206 | 1328 | 122 |
| 6 | 1450 | 1572 | 1694 | 1816 | 1938 | 2060 | 2181 | 2303 | 2425 | 2547 | 122 |
| 7 | 2668 | 2790 | 2911 | 3033 | 3155 | 3276 | 3398 | 3519 | 3640 | 3762 | 121 |
| 8 | 3883 | 4004 | 4126 | 4247 | 4368 | 4489 | 4610 | 4731 | 4852 | 4973 | 121 |
| 9 | 5094 | 5215 | 5336 | 5457 | 5578 | 5699 | 5820 | 5940 | 6061 | 6182 | 121 |
| 360 | 6303 | 6423 | 6544 | 6664 | 6785 | 6905 | 7026 | 7146 | 7267 | 7387 | 120 |
| 1 | 7507 | 7627 | 7748 | 7868 | 7988 | 8108 | 8228 | 8349 | 8469 | 8589 | 120 |
| 2 | 8709 | 8829 | 8948 | 9068 | 9188 | 9308 | 9428 | 9548 | 9667 | 9787 | 120 |
| 3 | 9907 | 0026 | 0146 | 0265 | 0385 | 0504 | 0624 | 0743 | 0863 | 0982 | 119 |
| 4 | 561101 | 1221 | 1340 | 1459 | 1578 | 1698 | 1817 | 1936 | 2055 | 2174 | 119 |
| 5 | 2293 | 2412 | 2531 | 2650 | 2769 | 2887 | 3006 | 3125 | 3244 | 3362 | 119 |
| 6 | 3481 | 3600 | 3718 | 3837 | 3955 | 4074 | 4192 | 4311 | 4429 | 4548 | 119 |
| 7 | 4666 | 4784 | 4903 | 5021 | 5139 | 5257 | 5376 | 5494 | 5612 | 5730 | 118 |
| 8 | 5848 | 5966 | 6084 | 6202 | 6320 | 6437 | 6555 | 6673 | 6791 | 6909 | 118 |
| 9 | 7026 | 7144 | 7262 | 7379 | 7497 | 7614 | 7732 | 7849 | 7967 | 8084 | 118 |
| 370 | 8202 | 8319 | 8436 | 8554 | 8671 | 8788 | 8905 | 9023 | 9140 | 9257 | 117 |
| 1 | 9374 | 9491 | 9608 | 9725 | 9842 | 9959 | 0076 | 0193 | 0309 | 0426 | 117 |
| 2 | 570543 | 0660 | 0776 | 0893 | 1010 | 1126 | 1243 | 1359 | 1476 | 1592 | 117 |
| 3 | 1709 | 1825 | 1942 | 2058 | 2174 | 2291 | 2407 | 2523 | 2639 | 2755 | 116 |
| 4 | 2872 | 2988 | 3104 | 3220 | 3336 | 3452 | 3568 | 3684 | 3800 | 3915 | 116 |
| 5 | 4031 | 4147 | 4263 | 4379 | 4494 | 4610 | 4726 | 4841 | 4957 | 5072 | 116 |
| 6 | 5188 | 5303 | 5419 | 5534 | 5650 | 5765 | 5880 | 5996 | 6111 | 6226 | 115 |
| 7 | 6341 | 6457 | 6572 | 6687 | 6802 | 6917 | 7032 | 7147 | 7262 | 7377 | 115 |
| 8 | 7492 | 7607 | 7722 | 7836 | 7951 | 8066 | 8181 | 8295 | 8410 | 8525 | 115 |
| 9 | 8639 | 8754 | 8868 | 8983 | 9097 | 9212 | 9326 | 9441 | 9555 | 9669 | 114 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 128 | 12.8 | 25.6 | 38.4 | 51.2 | 64.0 | 76.8 | 89.6 | 102.4 | 115.2 |
| 127 | 12.7 | 25.4 | 38.1 | 50.8 | 63.5 | 76.2 | 88.9 | 101.6 | 114.3 |
| 126 | 12.6 | 25.2 | 37.8 | 50.4 | 63.0 | 75.6 | 88.2 | 100.8 | 113.4 |
| 125 | 12.5 | 25.0 | 37.5 | 50.0 | 62.5 | 75.0 | 87.5 | 100.0 | 112.5 |
| 124 | 12.4 | 24.8 | 37.2 | 49.6 | 62.0 | 74.4 | 86.8 | 99.2 | 111.6 |
| 123 | 12.3 | 24.6 | 36.9 | 49.2 | 61.5 | 73.8 | 86.1 | 98.4 | 110.7 |
| 122 | 12.2 | 24.4 | 36.6 | 48.8 | 61.0 | 73.2 | 85.4 | 97.6 | 109.8 |
| 121 | 12.1 | 24.2 | 36.3 | 48.4 | 60.5 | 72.6 | 84.7 | 96.8 | 108.9 |
| 120 | 12.0 | 24.0 | 36.0 | 48.0 | 60.0 | 72.0 | 84.0 | 96.0 | 108.0 |
| 119 | 11.9 | 23.8 | 35.7 | 47.6 | 59.5 | 71.4 | 83.3 | 95.2 | 107.1 |

No. 380. L. 579.] [No. 414 L. 617.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 380 | 579784 | 9898 | 0012 | 0126 | 0241 | 0355 | 0469 | 0583 | 0697 | 0811 | 114 |
| 1 | 580925 | 1039 | 1153 | 1267 | 1381 | 1495 | 1608 | 1722 | 1836 | 1950 | |
| 2 | 2063 | 2177 | 2291 | 2404 | 2518 | 2631 | 2745 | 2858 | 2972 | 3085 | |
| 3 | 3199 | 3312 | 3426 | 3539 | 3652 | 3765 | 3879 | 3992 | 4105 | 4218 | |
| 4 | 4331 | 4444 | 4557 | 4670 | 4783 | 4896 | 5009 | 5122 | 5235 | 5348 | |
| 5 | 5461 | 5574 | 5686 | 5799 | 5912 | 6024 | 6137 | 6250 | 6362 | 6475 | 113 |
| 6 | 6587 | 6700 | 6812 | 6925 | 7037 | 7149 | 7262 | 7374 | 7486 | 7599 | |
| 7 | 7711 | 7823 | 7935 | 8047 | 8160 | 8272 | 8384 | 8496 | 8608 | 8720 | 112 |
| 8 | 8832 | 8944 | 9056 | 9167 | 9279 | 9391 | 9503 | 9615 | 9726 | 9838 | |
| 9 | 9950 | 0061 | 0173 | 0284 | 0396 | 0507 | 0619 | 0730 | 0842 | 0953 | |
| 390 | 591065 | 1176 | 1287 | 1399 | 1510 | 1621 | 1732 | 1843 | 1955 | 2066 | |
| 1 | 2177 | 2288 | 2399 | 2510 | 2621 | 2732 | 2843 | 2954 | 3064 | 3175 | 111 |
| 2 | 3286 | 3397 | 3508 | 3618 | 3729 | 3840 | 3950 | 4061 | 4171 | 4282 | |
| 3 | 4393 | 4503 | 4614 | 4724 | 4834 | 4945 | 5055 | 5165 | 5276 | 5386 | |
| 4 | 5496 | 5606 | 5717 | 5827 | 5937 | 6047 | 6157 | 6267 | 6377 | 6487 | |
| 5 | 6597 | 6707 | 6817 | 6927 | 7037 | 7146 | 7256 | 7366 | 7476 | 7586 | 110 |
| 6 | 7695 | 7805 | 7914 | 8024 | 8134 | 8243 | 8353 | 8462 | 8572 | 8681 | |
| 7 | 8791 | 8900 | 9009 | 9119 | 9228 | 9337 | 9446 | 9556 | 9665 | 9774 | |
| 8 | 9883 | 9992 | 0101 | 0210 | 0319 | 0428 | 0537 | 0646 | 0755 | 0864 | 109 |
| 9 | 600973 | 1082 | 1191 | 1299 | 1408 | 1517 | 1625 | 1734 | 1843 | 1951 | |
| 400 | 2060 | 2169 | 2277 | 2386 | 2494 | 2603 | 2711 | 2819 | 2928 | 3036 | |
| 1 | 3144 | 3253 | 3361 | 3469 | 3577 | 3686 | 3794 | 3902 | 4010 | 4118 | |
| 2 | 4226 | 4334 | 4442 | 4550 | 4658 | 4766 | 4874 | 4982 | 5089 | 5197 | 108 |
| 3 | 5305 | 5413 | 5521 | 5628 | 5736 | 5844 | 5951 | 6059 | 6166 | 6274 | |
| 4 | 6381 | 6489 | 6596 | 6704 | 6811 | 6919 | 7026 | 7133 | 7241 | 7348 | |
| 5 | 7455 | 7562 | 7669 | 7777 | 7884 | 7991 | 8098 | 8205 | 8312 | 8419 | |
| 6 | 8526 | 8633 | 8740 | 8847 | 8954 | 9061 | 9167 | 9274 | 9381 | 9488 | 107 |
| 7 | 9594 | 9701 | 9808 | 9914 | 0021 | 0128 | 0234 | 0341 | 0447 | 0554 | |
| 8 | 610660 | 0767 | 0873 | 0979 | 1086 | 1192 | 1298 | 1405 | 1511 | 1617 | |
| 9 | 1723 | 1829 | 1936 | 2042 | 2148 | 2254 | 2360 | 2466 | 2572 | 2678 | 106 |
| 410 | 2784 | 2890 | 2996 | 3102 | 3207 | 3313 | 3419 | 3525 | 3630 | 3736 | |
| 1 | 3842 | 3947 | 4053 | 4159 | 4264 | 4370 | 4475 | 4581 | 4686 | 4792 | |
| 2 | 4897 | 5003 | 5108 | 5213 | 5319 | 5424 | 5529 | 5634 | 5740 | 5845 | |
| 3 | 5950 | 6055 | 6160 | 6265 | 6370 | 6476 | 6581 | 6686 | 6790 | 6895 | 105 |
| 4 | 7000 | 7105 | 7210 | 7315 | 7420 | 7525 | 7629 | 7734 | 7839 | 7943 | |

## Proportional Parts.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 118 | 11.8 | 23.6 | 35.4 | 47.2 | 59.0 | 70.8 | 82.6 | 94.4 | 106.2 |
| 117 | 11.7 | 23.4 | 35.1 | 46.8 | 58.5 | 70.2 | 81.9 | 93.6 | 105.3 |
| 116 | 11.6 | 23.2 | 34.8 | 46.4 | 58.0 | 69.6 | 81.2 | 92.8 | 104.4 |
| 115 | 11.5 | 23.0 | 34.5 | 46.0 | 57.5 | 69.0 | 80.5 | 92.0 | 103.5 |
| 114 | 11.4 | 22.8 | 34.2 | 45.6 | 57.0 | 68.4 | 79.8 | 91.2 | 102.6 |
| 113 | 11.3 | 22.6 | 33.9 | 45.2 | 56.5 | 67.8 | 79.1 | 90.4 | 101 7 |
| 112 | 11.2 | 22.4 | 33.6 | 44.8 | 56.0 | 67.2 | 78.4 | 89.6 | 100.8 |
| 111 | 11.1 | 22.2 | 33.3 | 44.4 | 55.5 | 66.6 | 77.7 | 88.8 | 99.9 |
| 110 | 11.0 | 22.0 | 33.0 | 44.0 | 55.0 | 66.0 | 77.0 | 88.0 | 99.0 |
| 109 | 10.9 | 21.8 | 32.7 | 43.6 | 54.5 | 65.4 | 76.3 | 87.2 | 98.1 |
| 108 | 10.8 | 21.6 | 32.4 | 43.2 | 54.0 | 64.8 | 75.6 | 86,4 | 97.2 |
| 107 | 10.7 | 21.4 | 32.1 | 42.8 | 53.5 | 64.2 | 74.9 | 85.6 | 96.3 |
| 106 | 10.6 | 21.2 | 31.8 | 42.4 | 53.0 | 63.6 | 74.2 | 84.8 | 95.4 |
| 105 | 10.5 | 21.0 | 31.5 | 42.0 | 52.5 | 63.0 | 73.5 | 84.0 | 94.5 |
| 105 | 10.5 | 21.0 | 31.5 | 42.0 | 52.5 | 63.0 | 73.5 | 84.0 | 94.5 |
| 104 | 10.4 | 20.8 | 31.2 | 41.6 | 52.0 | 62.4 | 72.8 | 83.2 | 93.6 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 415 | 618048 | 8153 | 8257 | 8362 | 8466 | 8571 | 8676 | 8780 | 8884 | 8989 | 105 |
| 6 | 9093 | 9198 | 9302 | 9406 | 9511 | 9615 | 9719 | 9824 | 9928 | 0032 | |
| 7 | 620136 | 0240 | 0344 | 0448 | 0552 | 0656 | 0760 | 0864 | 0968 | 1072 | 104 |
| 8 | 1176 | 1280 | 1384 | 1488 | 1592 | 1695 | 1799 | 1903 | 2007 | 2110 | |
| 9 | 2214 | 2318 | 2421 | 2525 | 2628 | 2732 | 2835 | 2939 | 3042 | 3146 | |
| 420 | 3249 | 3353 | 3456 | 3559 | 3663 | 3766 | 3869 | 3973 | 4076 | 4179 | |
| 1 | 4282 | 4385 | 4488 | 4591 | 4695 | 4798 | 4901 | 5004 | 5107 | 5210 | 103 |
| 2 | 5312 | 5415 | 5518 | 5621 | 5724 | 5827 | 5929 | 6032 | 6135 | 6238 | |
| 3 | 6340 | 6443 | 6546 | 6648 | 6751 | 6853 | 6956 | 7058 | 7161 | 7263 | |
| 4 | 7366 | 7468 | 7571 | 7673 | 7775 | 7878 | 7980 | 8082 | 8185 | 8287 | |
| 5 | 8389 | 8491 | 8593 | 8695 | 8797 | 8900 | 9002 | 9104 | 9206 | 9308 | 102 |
| 6 | 9410 | 9512 | 9613 | 9715 | 9817 | 9919 | 0021 | 0123 | 0224 | 0326 | |
| 7 | 630428 | 0530 | 0631 | 0733 | 0835 | 0936 | 1038 | 1139 | 1241 | 1342 | |
| 8 | 1444 | 1545 | 1647 | 1748 | 1849 | 1951 | 2052 | 2153 | 2255 | 2356 | |
| 9 | 2457 | 2559 | 2660 | 2761 | 2862 | 2963 | 3064 | 3165 | 3266 | 3367 | |
| 430 | 3468 | 3569 | 3670 | 3771 | 3872 | 3973 | 4074 | 4175 | 4276 | 4376 | 101 |
| 1 | 4477 | 4578 | 4679 | 4779 | 4880 | 4981 | 5081 | 5182 | 5283 | 5383 | |
| 2 | 5484 | 5584 | 5685 | 5785 | 5886 | 5986 | 6087 | 6187 | 6287 | 6388 | |
| 3 | 6488 | 6588 | 6688 | 6789 | 6889 | 6989 | 7089 | 7189 | 7290 | 7390 | |
| 4 | 7490 | 7590 | 7690 | 7790 | 7890 | 7990 | 8090 | 8190 | 8290 | 8389 | 100 |
| 5 | 8489 | 8589 | 8689 | 8789 | 8888 | 8988 | 9088 | 9188 | 9287 | 9387 | |
| 6 | 9486 | 9586 | 9686 | 9785 | 9885 | 9984 | 0084 | 0183 | 0283 | 0382 | |
| 7 | 640481 | 0581 | 0680 | 0779 | 0879 | 0978 | 1077 | 1177 | 1276 | 1375 | |
| 8 | 1474 | 1573 | 1672 | 1771 | 1871 | 1970 | 2069 | 2168 | 2267 | 2366 | |
| 9 | 2465 | 2563 | 2662 | 2761 | 2860 | 2959 | 3058 | 3156 | 3255 | 3354 | 99 |
| 440 | 3453 | 3551 | 3650 | 3749 | 3847 | 3946 | 4044 | 4143 | 4242 | 4340 | |
| 1 | 4439 | 4537 | 4636 | 4734 | 4832 | 4931 | 5029 | 5127 | 5226 | 5324 | |
| 2 | 5422 | 5521 | 5619 | 5717 | 5815 | 5913 | 6011 | 6110 | 6208 | 6306 | |
| 3 | 6404 | 6502 | 6600 | 6698 | 6796 | 6894 | 6992 | 7089 | 7187 | 7285 | 98 |
| 4 | 7383 | 7481 | 7579 | 7676 | 7774 | 7872 | 7969 | 8067 | 8165 | 8262 | |
| 5 | 8360 | 8458 | 8555 | 8653 | 8750 | 8848 | 8945 | 9043 | 9140 | 9237 | |
| 6 | 9335 | 9432 | 9530 | 9627 | 9724 | 9821 | 9919 | 0016 | 0113 | 0210 | |
| 7 | 650308 | 0405 | 0502 | 0599 | 0696 | 0793 | 0890 | 0987 | 1084 | 1181 | |
| 8 | 1278 | 1375 | 1472 | 1569 | 1666 | 1762 | 1859 | 1956 | 2053 | 2150 | 97 |
| 9 | 2246 | 2343 | 2440 | 2536 | 2633 | 2730 | 2826 | 2923 | 3019 | 3116 | |
| 450 | 3213 | 3309 | 3405 | 3502 | 3598 | 3695 | 3791 | 3888 | 3984 | 4080 | |
| 1 | 4177 | 4273 | 4369 | 4465 | 4562 | 4658 | 4754 | 4850 | 4946 | 5042 | |
| 2 | 5138 | 5235 | 5331 | 5427 | 5523 | 5619 | 5715 | 5810 | 5906 | 6002 | 96 |
| 3 | 6098 | 6194 | 6290 | 6386 | 6482 | 6577 | 6673 | 6769 | 6864 | 6960 | |
| 4 | 7056 | 7152 | 7247 | 7343 | 7438 | 7534 | 7629 | 7725 | 7820 | 7916 | |
| 5 | 8011 | 8107 | 8202 | 8298 | 8393 | 8488 | 8584 | 8679 | 8774 | 8870 | |
| 6 | 8965 | 9060 | 9155 | 9250 | 9346 | 9441 | 9536 | 9631 | 9726 | 9821 | |
| 7 | 9916 | 0011 | 0106 | 0201 | 0296 | 0391 | 0486 | 0581 | 0676 | 0771 | 95 |
| 8 | 660865 | 0960 | 1055 | 1150 | 1245 | 1339 | 1434 | 1529 | 1623 | 1718 | |
| 9 | 1813 | 1907 | 2002 | 2096 | 2191 | 2286 | 2380 | 2475 | 2569 | 2663 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 105 | 10.5 | 21.0 | 31.5 | 42.0 | 52.5 | 63.0 | 73.5 | 84.0 | 94.5 |
| 104 | 10.4 | 20.8 | 31.2 | 41.6 | 52.0 | 62.4 | 72.8 | 83.2 | 93.6 |
| 103 | 10.3 | 20.6 | 30.9 | 41.2 | 51.5 | 61.8 | 72.1 | 82.4 | 92.7 |
| 102 | 10.2 | 20.4 | 30.6 | 40.8 | 51.0 | 61.2 | 71.4 | 81.6 | 91.8 |
| 101 | 10.1 | 20.2 | 30.3 | 40.4 | 50.5 | 60.6 | 70.7 | 80.8 | 90.9 |
| 100 | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 |
| 99 | 9.9 | 19.8 | 29.7 | 39.6 | 49.5 | 59.4 | 69.3 | 79.2 | 89.1 |

No. 460 L. 662.] [No. 499 L. 698.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 460 | 662758 | 2852 | 2947 | 3041 | 3135 | 3230 | 3324 | 3418 | 3512 | 3607 | |
| 1 | 3701 | 3795 | 3889 | 3983 | 4078 | 4172 | 4266 | 4360 | 4454 | 4548 | |
| 2 | 4642 | 4736 | 4830 | 4924 | 5018 | 5112 | 5206 | 5299 | 5393 | 5487 | 94 |
| 3 | 5581 | 5675 | 5769 | 5862 | 5956 | 6050 | 6143 | 6237 | 6331 | 6424 | |
| 4 | 6518 | 6612 | 6705 | 6799 | 6892 | 6986 | 7079 | 7173 | 7266 | 7360 | |
| 5 | 7453 | 7546 | 7640 | 7733 | 7826 | 7920 | 8013 | 8106 | 8199 | 8293 | |
| 6 | 8386 | 8479 | 8572 | 8665 | 8759 | 8852 | 8945 | 9038 | 9131 | 9224 | |
| 7 | 9317 | 9410 | 9503 | 9596 | 9689 | 9782 | 9875 | 9967 | 0060 | 0153 | 93 |
| 8 | 670246 | 0339 | 0431 | 0524 | 0617 | 0710 | 0802 | 0895 | 0988 | 1080 | |
| 9 | 1173 | 1265 | 1358 | 1451 | 1543 | 1636 | 1728 | 1821 | 1913 | 2005 | |
| 470 | 2098 | 2190 | 2283 | 2375 | 2467 | 2560 | 2652 | 2744 | 2836 | 2929 | |
| 1 | 3021 | 3113 | 3205 | 3297 | 3390 | 3482 | 3574 | 3666 | 3758 | 3850 | |
| 2 | 3942 | 4034 | 4126 | 4218 | 4310 | 4402 | 4494 | 4586 | 4677 | 4769 | 92 |
| 3 | 4861 | 4953 | 5045 | 5137 | 5228 | 5320 | 5412 | 5503 | 5595 | 5687 | |
| 4 | 5778 | 5870 | 5962 | 6053 | 6145 | 6236 | 6328 | 6419 | 6511 | 6602 | |
| 5 | 6694 | 6785 | 6876 | 6968 | 7059 | 7151 | 7242 | 7333 | 7424 | 7516 | |
| 6 | 7607 | 7698 | 7789 | 7881 | 7972 | 8063 | 8154 | 8245 | 8336 | 8427 | |
| 7 | 8518 | 8609 | 8700 | 8791 | 8882 | 8973 | 9064 | 9155 | 9246 | 9337 | 91 |
| 8 | 9428 | 9519 | 9610 | 9700 | 9791 | 9882 | 9973 | 0063 | 0154 | 0245 | |
| 9 | 680336 | 0426 | 0517 | 0607 | 0698 | 0789 | 0879 | 0970 | 1060 | 1151 | |
| 480 | 1241 | 1332 | 1422 | 1513 | 1603 | 1693 | 1784 | 1874 | 1964 | 2055 | |
| 1 | 2145 | 2235 | 2326 | 2416 | 2506 | 2596 | 2686 | 2777 | 2867 | 2957 | |
| 2 | 3047 | 3137 | 3227 | 3317 | 3407 | 3497 | 3587 | 3677 | 3767 | 3857 | 90 |
| 3 | 3947 | 4037 | 4127 | 4217 | 4307 | 4396 | 4486 | 4576 | 4666 | 4756 | |
| 4 | 4845 | 4935 | 5025 | 5114 | 5204 | 5294 | 5383 | 5473 | 5563 | 5652 | |
| 5 | 5742 | 5831 | 5921 | 6010 | 6100 | 6189 | 6279 | 6368 | 6458 | 6547 | |
| 6 | 6636 | 6726 | 6815 | 6904 | 6994 | 7083 | 7172 | 7261 | 7351 | 7440 | |
| 7 | 7529 | 7618 | 7707 | 7796 | 7886 | 7975 | 8064 | 8153 | 8242 | 8331 | |
| 8 | 8420 | 8509 | 8598 | 8687 | 8776 | 8865 | 8953 | 9042 | 9131 | 9220 | 89 |
| 9 | 9309 | 9398 | 9486 | 9575 | 9664 | 9753 | 9841 | 9930 | 0019 | 0107 | |
| 490 | 690196 | 0285 | 0373 | 0462 | 0550 | 0639 | 0728 | 0816 | 0905 | 0993 | |
| 1 | 1081 | 1170 | 1258 | 1347 | 1435 | 1524 | 1612 | 1700 | 1789 | 1877 | |
| 2 | 1965 | 2053 | 2142 | 2230 | 2318 | 2406 | 2494 | 2583 | 2671 | 2759 | |
| 3 | 2847 | 2935 | 3023 | 3111 | 3199 | 3287 | 3375 | 3463 | 3551 | 3639 | 88 |
| 4 | 3727 | 3815 | 3903 | 3991 | 4078 | 4166 | 4254 | 4342 | 4430 | 4517 | |
| 5 | 4605 | 4693 | 4781 | 4868 | 4956 | 5044 | 5131 | 5219 | 5307 | 5394 | |
| 6 | 5482 | 5569 | 5657 | 5744 | 5832 | 5919 | 6007 | 6094 | 6182 | 6269 | |
| 7 | 6356 | 6444 | 6531 | 6618 | 6706 | 6793 | 6880 | 6968 | 7055 | 7142 | |
| 8 | 7229 | 7317 | 7404 | 7491 | 7578 | 7665 | 7752 | 7839 | 7926 | 8014 | 87 |
| 9 | 8100 | 8188 | 8275 | 8362 | 8449 | 8535 | 8622 | 8709 | 8796 | 8883 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 98 | 9.8 | 19.6 | 29.4 | 39.2 | 49.0 | 58.8 | 68.6 | 78.4 | 88.2 |
| 97 | 9.7 | 19.4 | 29.1 | 38.8 | 48.5 | 58.2 | 67.9 | 77.6 | 87.3 |
| 96 | 9.6 | 19.2 | 28.8 | 38.4 | 48.0 | 57.6 | 67.2 | 76.8 | 86.4 |
| 95 | 9.5 | 19.0 | 28.5 | 38.0 | 47.5 | 57.0 | 66.5 | 76.0 | 85.5 |
| 94 | 9.4 | 18.8 | 28.2 | 37.6 | 47.0 | 56.4 | 65.8 | 75.2 | 84.6 |
| 93 | 9.3 | 18.6 | 27.9 | 37.2 | 46.5 | 55.8 | 65.1 | 74.4 | 83.7 |
| 92 | 9.2 | 18.4 | 27.6 | 36.8 | 46.0 | 55.2 | 64.4 | 73.6 | 82.8 |
| 91 | 9.1 | 18.2 | 27.3 | 36.4 | 45.5 | 54.6 | 63.7 | 72.8 | 81.9 |
| 90 | 9.0 | 18.0 | 27.0 | 36.0 | 45.0 | 54.0 | 63.0 | 72.0 | 81.0 |
| 89 | 8.9 | 17.8 | 26.7 | 35.6 | 44.5 | 53.4 | 62.3 | 71.2 | 80.1 |
| 88 | 8.8 | 17.6 | 26.4 | 35.2 | 44.0 | 52.8 | 61.6 | 70.4 | 79.2 |
| 87 | 8.7 | 17.4 | 26.1 | 34.8 | 43.5 | 52.2 | 60.9 | 69.6 | 78.3 |
| 86 | 8.6 | 17.2 | 25.8 | 34.4 | 43.0 | 51.6 | 60.2 | 68.8 | 77.4 |

No. 500 L. 698.] [No. 544 L. 736.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500 | 698970 | 9057 | 9144 | 9231 | 9317 | 9404 | 9491 | 9578 | 9664 | 9751 | |
| 1 | 9838 | 9924 | | | | | | | | | |
| | | | 0011 | 0098 | 0184 | 0271 | 0358 | 0444 | 0531 | 0617 | |
| 2 | 700704 | 0790 | 0877 | 0963 | 1050 | 1136 | 1222 | 1309 | 1395 | 1482 | |
| 3 | 1568 | 1654 | 1741 | 1827 | 1913 | 1999 | 2086 | 2172 | 2258 | 2344 | |
| 4 | 2431 | 2517 | 2603 | 2689 | 2775 | 2861 | 2947 | 3033 | 3119 | 3205 | |
| 5 | 3291 | 3377 | 3463 | 3549 | 3635 | 3721 | 3807 | 3893 | 3979 | 4065 | 86 |
| 6 | 4151 | 4236 | 4322 | 4408 | 4494 | 4579 | 4665 | 4751 | 4837 | 4922 | |
| 7 | 5008 | 5094 | 5179 | 5265 | 5350 | 5436 | 5522 | 5607 | 5693 | 5778 | |
| 8 | 5864 | 5949 | 6035 | 6120 | 6206 | 6291 | 6376 | 6462 | 6547 | 6632 | |
| 9 | 6718 | 6803 | 6888 | 6974 | 7059 | 7144 | 7229 | 7315 | 7400 | 7485 | |
| 510 | 7570 | 7655 | 7740 | 7826 | 7911 | 7996 | 8081 | 8166 | 8251 | 8336 | 85 |
| 1 | 8421 | 8506 | 8591 | 8676 | 8761 | 8846 | 8931 | 9015 | 9100 | 9185 | |
| 2 | 9270 | 9355 | 9440 | 9524 | 9609 | 9694 | 9779 | 9863 | 9948 | | |
| | | | | | | | | | | 0033 | |
| 3 | 710117 | 0202 | 0287 | 0371 | 0456 | 0540 | 0625 | 0710 | 0794 | 0879 | |
| 4 | 0963 | 1048 | 1132 | 1217 | 1301 | 1385 | 1470 | 1554 | 1639 | 1723 | |
| 5 | 1807 | 1892 | 1976 | 2060 | 2144 | 2229 | 2313 | 2397 | 2481 | 2566 | |
| 6 | 2650 | 2734 | 2818 | 2902 | 2986 | 3070 | 3154 | 3238 | 3323 | 3407 | |
| 7 | 3491 | 3575 | 3659 | 3742 | 3826 | 3910 | 3994 | 4078 | 4162 | 4246 | 84 |
| 8 | 4330 | 4414 | 4497 | 4581 | 4665 | 4749 | 4833 | 4916 | 5000 | 5084 | |
| 9 | 5167 | 5251 | 5335 | 5418 | 5502 | 5586 | 5669 | 5753 | 5836 | 5920 | |
| 520 | 6003 | 6087 | 6170 | 6254 | 6337 | 6421 | 6504 | 6588 | 6671 | 6754 | |
| 1 | 6838 | 6921 | 7004 | 7088 | 7171 | 7254 | 7338 | 7421 | 7504 | 7587 | |
| 2 | 7671 | 7754 | 7837 | 7920 | 8003 | 8086 | 8169 | 8253 | 8336 | 8419 | |
| 3 | 8502 | 8585 | 8668 | 8751 | 8834 | 8917 | 9000 | 9083 | 9165 | 9248 | 83 |
| 4 | 9331 | 9414 | 9497 | 9580 | 9663 | 9745 | 9828 | 9911 | 9994 | | |
| | | | | | | | | | | 0077 | |
| 5 | 720159 | 0242 | 0325 | 0407 | 0490 | 0573 | 0655 | 0738 | 0821 | 0903 | |
| 6 | 0986 | 1068 | 1151 | 1233 | 1316 | 1398 | 1481 | 1563 | 1646 | 1728 | |
| 7 | 1811 | 1893 | 1975 | 2058 | 2140 | 2222 | 2305 | 2387 | 2469 | 2552 | |
| 8 | 2634 | 2716 | 2798 | 2881 | 2963 | 3045 | 3127 | 3209 | 3291 | 3374 | |
| 9 | 3456 | 3538 | 3620 | 3702 | 3784 | 3866 | 3948 | 4030 | 4112 | 4194 | 82 |
| 530 | 4276 | 4358 | 4440 | 4522 | 4604 | 4685 | 4767 | 4849 | 4931 | 5013 | |
| 1 | 5095 | 5176 | 5258 | 5340 | 5422 | 5503 | 5585 | 5667 | 5748 | 5830 | |
| 2 | 5912 | 5993 | 6075 | 6156 | 6238 | 6320 | 6401 | 6483 | 6564 | 6646 | |
| 3 | 6727 | 6809 | 6890 | 6972 | 7053 | 7134 | 7216 | 7297 | 7379 | 7460 | |
| 4 | 7541 | 7623 | 7704 | 7785 | 7866 | 7948 | 8029 | 8110 | 8191 | 8273 | |
| 5 | 8354 | 8435 | 8516 | 8597 | 8678 | 8759 | 8841 | 8922 | 9003 | 9084 | |
| 6 | 9165 | 9246 | 9327 | 9408 | 9489 | 9570 | 9651 | 9732 | 9813 | 9893 | 81 |
| 7 | 9974 | | | | | | | | | | |
| | | 0055 | 0136 | 0217 | 0298 | 0378 | 0459 | 0540 | 0621 | 0702 | |
| 8 | 730782 | 0863 | 0944 | 1024 | 1105 | 1186 | 1266 | 1347 | 1428 | 1508 | |
| 9 | 1589 | 1669 | 1750 | 1830 | 1911 | 1991 | 2072 | 2152 | 2233 | 2313 | |
| 540 | 2394 | 2474 | 2555 | 2635 | 2715 | 2796 | 2876 | 2956 | 3037 | 3117 | |
| 1 | 3197 | 3278 | 3358 | 3438 | 3518 | 3598 | 3679 | 3759 | 3839 | 3919 | |
| 2 | 3999 | 4079 | 4160 | 4240 | 4320 | 4400 | 4480 | 4560 | 4640 | 4720 | |
| 3 | 4800 | 4880 | 4960 | 5040 | 5120 | 5200 | 5279 | 5359 | 5439 | 5519 | 80 |
| 4 | 5599 | 5679 | 5759 | 5838 | 5918 | 5998 | 6078 | 6157 | 6237 | 6317 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 87 | 8.7 | 17.4 | 26.1 | 34.8 | 43.5 | 52.2 | 60.9 | 69.6 | 78.3 |
| 86 | 8.6 | 17.2 | 25.8 | 34.4 | 43.0 | 51.6 | 60.2 | 68.8 | 77.4 |
| 85 | 8.5 | 17.0 | 25.5 | 34.0 | 42.5 | 51.0 | 59.5 | 68.0 | 76.5 |
| 84 | 8.4 | 16.8 | 25.2 | 33.6 | 42.0 | 50.4 | 58.8 | 67.2 | 75.6 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 545 | 736397 | 6476 | 6556 | 6635 | 6715 | 6795 | 6874 | 6954 | 7034 | 7113 | |
| 6 | 7193 | 7272 | 7352 | 7431 | 7511 | 7590 | 7670 | 7749 | 7829 | 7908 | |
| 7 | 7987 | 8067 | 8146 | 8225 | 8305 | 8384 | 8463 | 8543 | 8622 | 8701 | |
| 8 | 8781 | 8860 | 8939 | 9018 | 9097 | 9177 | 9256 | 9335 | 9414 | 9493 | |
| 9 | 9572 | 9651 | 9731 | 9810 | 9889 | 9968 | 0047 | 0126 | 0205 | 0284 | 79 |
| 550 | 740363 | 0442 | 0521 | 0600 | 0678 | 0757 | 0836 | 0915 | 0994 | 1073 | |
| 1 | 1152 | 1230 | 1309 | 1388 | 1467 | 1546 | 1624 | 1703 | 1782 | 1860 | |
| 2 | 1939 | 2018 | 2096 | 2175 | 2254 | 2332 | 2411 | 2489 | 2568 | 2647 | |
| 3 | 2725 | 2804 | 2882 | 2961 | 3039 | 3118 | 3196 | 3275 | 3353 | 3431 | |
| 4 | 3510 | 3588 | 3667 | 3745 | 3823 | 3902 | 3980 | 4058 | 4136 | 4215 | |
| 5 | 4293 | 4371 | 4449 | 4528 | 4606 | 4684 | 4762 | 4840 | 4919 | 4997 | |
| 6 | 5075 | 5153 | 5231 | 5309 | 5387 | 5465 | 5543 | 5621 | 5699 | 5777 | |
| 7 | 5855 | 5933 | 6011 | 6089 | 6167 | 6245 | 6323 | 6401 | 6479 | 6556 | 78 |
| 8 | 6634 | 6712 | 6790 | 6868 | 6945 | 7023 | 7101 | 7179 | 7256 | 7334 | |
| 9 | 7412 | 7489 | 7567 | 7645 | 7722 | 7800 | 7878 | 7955 | 8033 | 8110 | |
| 560 | 8188 | 8266 | 8343 | 8421 | 8498 | 8576 | 8653 | 8731 | 8808 | 8885 | |
| 1 | 8963 | 9040 | 9118 | 9195 | 9272 | 9350 | 9427 | 9504 | 9582 | 9659 | |
| 2 | 9736 | 9814 | 9891 | 9968 | 0045 | 0123 | 0200 | 0277 | 0354 | 0431 | |
| 3 | 750508 | 0586 | 0663 | 0740 | 0817 | 0894 | 0971 | 1048 | 1125 | 1202 | |
| 4 | 1279 | 1356 | 1433 | 1510 | 1587 | 1664 | 1741 | 1818 | 1895 | 1972 | |
| 5 | 2048 | 2125 | 2202 | 2279 | 2356 | 2433 | 2509 | 2586 | 2663 | 2740 | 77 |
| 6 | 2816 | 2893 | 2970 | 3047 | 3123 | 3200 | 3277 | 3353 | 3430 | 3506 | |
| 7 | 3583 | 3660 | 3736 | 3813 | 3889 | 3966 | 4042 | 4119 | 4195 | 4272 | |
| 8 | 4348 | 4425 | 4501 | 4578 | 4654 | 4730 | 4807 | 4883 | 4960 | 5036 | |
| 9 | 5112 | 5189 | 5265 | 5341 | 5417 | 5494 | 5570 | 5646 | 5722 | 5799 | |
| 570 | 5875 | 5951 | 6027 | 6103 | 6180 | 6256 | 6332 | 6408 | 6484 | 6560 | |
| 1 | 6636 | 6712 | 6788 | 6864 | 6940 | 7016 | 7092 | 7168 | 7244 | 7320 | |
| 2 | 7396 | 7472 | 7548 | 7624 | 7700 | 7775 | 7851 | 7927 | 8003 | 8079 | 76 |
| 3 | 8155 | 8230 | 8306 | 8382 | 8458 | 8533 | 8609 | 8685 | 8761 | 8836 | |
| 4 | 8912 | 8988 | 9063 | 9139 | 9214 | 9290 | 9366 | 9441 | 9517 | 9592 | |
| 5 | 9668 | 9743 | 9819 | 9894 | 9970 | 0045 | 0121 | 0196 | 0272 | 0347 | |
| 6 | 760422 | 0498 | 0573 | 0649 | 0724 | 0799 | 0875 | 0950 | 1025 | 1101 | |
| 7 | 1176 | 1251 | 1326 | 1402 | 1477 | 1552 | 1627 | 1702 | 1778 | 1853 | |
| 8 | 1928 | 2003 | 2078 | 2153 | 2228 | 2303 | 2378 | 2453 | 2529 | 2604 | |
| 9 | 2679 | 2754 | 2829 | 2904 | 2978 | 3053 | 3128 | 3203 | 3278 | 3353 | 75 |
| 580 | 3428 | 3503 | 3578 | 3653 | 3727 | 3802 | 3877 | 3952 | 4027 | 4101 | |
| 1 | 4176 | 4251 | 4326 | 4400 | 4475 | 4550 | 4624 | 4699 | 4774 | 4848 | |
| 2 | 4923 | 4998 | 5072 | 5147 | 5221 | 5296 | 5370 | 5445 | 5520 | 5594 | |
| 3 | 5669 | 5743 | 5818 | 5892 | 5966 | 6041 | 6115 | 6190 | 6264 | 6338 | |
| 4 | 6413 | 6487 | 6562 | 6636 | 6710 | 6785 | 6859 | 6933 | 7007 | 7082 | |

## Proportional Parts.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 83 | 8.3 | 16.6 | 24.9 | 33.2 | 41.5 | 49.8 | 58.1 | 66.4 | 74.7 |
| 82 | 8.2 | 16.4 | 24.6 | 32.8 | 41.0 | 49.2 | 57.4 | 65.6 | 73.8 |
| 81 | 8.1 | 16.2 | 24.3 | 32.4 | 40.5 | 48.6 | 56.7 | 64.8 | 72.9 |
| 80 | 8.0 | 16.0 | 24.0 | 32.0 | 40.0 | 48.0 | 56.0 | 64.0 | 72.0 |
| 79 | 7.9 | 15.8 | 23.7 | 31.6 | 39.5 | 47.4 | 55.3 | 63.2 | 71.1 |
| 78 | 7.8 | 15.6 | 23.4 | 31.2 | 39.0 | 46.8 | 54.6 | 62.4 | 70.2 |
| 77 | 7.7 | 15.4 | 23.1 | 30.8 | 38.5 | 46.2 | 53.9 | 61.6 | 69.3 |
| 76 | 7.6 | 15.2 | 22.8 | 30.4 | 38.0 | 45.6 | 53.2 | 60.8 | 68.4 |
| 75 | 7.5 | 15.0 | 22.5 | 30.0 | 37.5 | 45.0 | 52.5 | 60.0 | 67.5 |
| 74 | 7.4 | 14.8 | 22.2 | 29.6 | 37.0 | 44.4 | 51.8 | 59.2 | 66.6 |

No. 585 L. 767.] [No. 629 L. 799.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 585 | 767156 | 7230 | 7304 | 7379 | 7453 | 7527 | 7601 | 7675 | 7749 | 7823 | |
| 6 | 7898 | 7972 | 8046 | 8120 | 8194 | 8268 | 8342 | 8416 | 8490 | 8564 | 74 |
| 7 | 8638 | 8712 | 8786 | 8860 | 8934 | 9008 | 9082 | 9156 | 9230 | 9303 | |
| 8 | 9377 | 9451 | 9525 | 9599 | 9673 | 9746 | 9820 | 9894 | 9968 | 0042 | |
| 9 | 770115 | 0189 | 0263 | 0336 | 0410 | 0484 | 0557 | 0631 | 0705 | 0778 | |
| 590 | 0852 | 0926 | 0999 | 1073 | 1146 | 1220 | 1293 | 1367 | 1440 | 1514 | |
| 1 | 1587 | 1661 | 1734 | 1808 | 1881 | 1955 | 2028 | 2102 | 2175 | 2248 | |
| 2 | 2322 | 2395 | 2468 | 2542 | 2615 | 2688 | 2762 | 2835 | 2908 | 2981 | |
| 3 | 3055 | 3128 | 3201 | 3274 | 3348 | 3421 | 3494 | 3567 | 3640 | 3713 | |
| 4 | 3786 | 3860 | 3933 | 4006 | 4079 | 4152 | 4225 | 4298 | 4371 | 4444 | 73 |
| 5 | 4517 | 4590 | 4663 | 4736 | 4809 | 4882 | 4955 | 5028 | 5100 | 5173 | |
| 6 | 5246 | 5319 | 5392 | 5465 | 5538 | 5610 | 5683 | 5756 | 5829 | 5902 | |
| 7 | 5974 | 6047 | 6120 | 6193 | 6265 | 6338 | 6411 | 6483 | 6556 | 6629 | |
| 8 | 6701 | 6774 | 6846 | 6919 | 6992 | 7064 | 7137 | 7209 | 7282 | 7354 | |
| 9 | 7427 | 7499 | 7572 | 7644 | 7717 | 7789 | 7862 | 7934 | 8006 | 8079 | |
| 600 | 8151 | 8224 | 8296 | 8368 | 8441 | 8513 | 8585 | 8658 | 8730 | 8802 | |
| 1 | 8874 | 8947 | 9019 | 9091 | 9163 | 9236 | 9308 | 9380 | 9452 | 9524 | |
| 2 | 9596 | 9669 | 9741 | 9813 | 9885 | 9957 | 0029 | 0101 | 0173 | 0245 | |
| 3 | 780317 | 0389 | 0461 | 0533 | 0605 | 0677 | 0749 | 0821 | 0893 | 0965 | 72 |
| 4 | 1037 | 1109 | 1181 | 1253 | 1324 | 1396 | 1468 | 1540 | 1612 | 1684 | |
| 5 | 1755 | 1827 | 1899 | 1971 | 2042 | 2114 | 2186 | 2258 | 2329 | 2401 | |
| 6 | 2473 | 2544 | 2616 | 2688 | 2759 | 2831 | 2902 | 2974 | 3046 | 3117 | |
| 7 | 3189 | 3260 | 3332 | 3403 | 3475 | 3546 | 3618 | 3689 | 3761 | 3832 | |
| 8 | 3904 | 3975 | 4046 | 4118 | 4189 | 4261 | 4332 | 4403 | 4475 | 4546 | |
| 9 | 4617 | 4689 | 4760 | 4831 | 4902 | 4974 | 5045 | 5116 | 5187 | 5259 | |
| 610 | 5330 | 5401 | 5472 | 5543 | 5615 | 5686 | 5757 | 5828 | 5899 | 5970 | |
| 1 | 6041 | 6112 | 6183 | 6254 | 6325 | 6396 | 6467 | 6538 | 6609 | 6680 | 71 |
| 2 | 6751 | 6822 | 6893 | 6964 | 7035 | 7106 | 7177 | 7248 | 7319 | 7390 | |
| 3 | 7460 | 7531 | 7602 | 7673 | 7744 | 7815 | 7885 | 7956 | 8027 | 8098 | |
| 4 | 8168 | 8239 | 8310 | 8381 | 8451 | 8522 | 8593 | 8663 | 8734 | 8804 | |
| 5 | 8875 | 8946 | 9016 | 9087 | 9157 | 9228 | 9299 | 9369 | 9440 | 9510 | |
| 6 | 9581 | 9651 | 9722 | 9792 | 9863 | 9933 | 0004 | 0074 | 0144 | 0215 | |
| 7 | 790285 | 0356 | 0426 | 0496 | 0567 | 0637 | 0707 | 0778 | 0848 | 0918 | |
| 8 | 0988 | 1059 | 1129 | 1199 | 1269 | 1340 | 1410 | 1480 | 1550 | 1620 | |
| 9 | 1691 | 1761 | 1831 | 1901 | 1971 | 2041 | 2111 | 2181 | 2252 | 2322 | |
| 620 | 2392 | 2462 | 2532 | 2602 | 2672 | 2742 | 2812 | 2882 | 2952 | 3022 | 70 |
| 1 | 3092 | 3162 | 3231 | 3301 | 3371 | 3441 | 3511 | 3581 | 3651 | 3721 | |
| 2 | 3790 | 3860 | 3930 | 4000 | 4070 | 4139 | 4209 | 4279 | 4349 | 4418 | |
| 3 | 4488 | 4558 | 4627 | 4697 | 4767 | 4836 | 4906 | 4976 | 5045 | 5115 | |
| 4 | 5185 | 5254 | 5324 | 5393 | 5463 | 5532 | 5602 | 5672 | 5741 | 5811 | |
| 5 | 5880 | 5949 | 6019 | 6088 | 6158 | 6227 | 6297 | 6366 | 6436 | 6505 | |
| 6 | 6574 | 6644 | 6713 | 6782 | 6852 | 6921 | 6990 | 7060 | 7129 | 7198 | |
| 7 | 7268 | 7337 | 7406 | 7475 | 7545 | 7614 | 7683 | 7752 | 7821 | 7890 | |
| 8 | 7960 | 8029 | 8098 | 8167 | 8236 | 8305 | 8374 | 8443 | 8513 | 8582 | |
| 9 | 8651 | 8720 | 8789 | 8858 | 8927 | 8996 | 9065 | 9134 | 9203 | 9272 | 69 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 75 | 7.5 | 15.0 | 22.5 | 30.0 | 37.5 | 45.0 | 52.5 | 60.0 | 67.5 |
| 74 | 7.4 | 14.8 | 22.2 | 29.6 | 37.0 | 44.4 | 51.8 | 59.2 | 66.6 |
| 73 | 7.3 | 14.6 | 21.9 | 29.2 | 36.5 | 43.8 | 51.1 | 58.4 | 65.7 |
| 72 | 7.2 | 14.4 | 21.6 | 28.8 | 36.0 | 43.2 | 50.4 | 57.6 | 64.8 |
| 71 | 7.1 | 14.2 | 21.3 | 28.4 | 35.5 | 42.6 | 49.7 | 56.8 | 63.9 |
| 70 | 7.0 | 14.0 | 21.0 | 28.0 | 35.0 | 42.0 | 49.0 | 56.0 | 63.0 |
| 69 | 6.9 | 13.8 | 20.7 | 27.6 | 34.5 | 41.4 | 48.3 | 55.2 | 62.1 |

No. 630 L. 799.] [No. 674 L. 829.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 630 | 799341 | 9409 | 9478 | 9547 | 9616 | 9685 | 9754 | 9823 | 9892 | 9961 | |
| 1 | 800029 | 0098 | 0167 | 0236 | 0305 | 0373 | 0442 | 0511 | 0580 | 0648 | |
| 2 | 0717 | 0786 | 0854 | 0923 | 0992 | 1061 | 1129 | 1198 | 1266 | 1335 | |
| 3 | 1404 | 1472 | 1541 | 1609 | 1678 | 1747 | 1815 | 1884 | 1952 | 2021 | |
| 4 | 2089 | 2158 | 2226 | 2295 | 2363 | 2432 | 2500 | 2568 | 2637 | 2705 | |
| 5 | 2774 | 2842 | 2910 | 2979 | 3047 | 3116 | 3184 | 3252 | 3321 | 3389 | |
| 6 | 3457 | 3525 | 3594 | 3662 | 3730 | 3798 | 3867 | 3935 | 4003 | 4071 | |
| 7 | 4139 | 4208 | 4276 | 4344 | 4412 | 4480 | 4548 | 4616 | 4685 | 4753 | |
| 8 | 4821 | 4889 | 4957 | 5025 | 5093 | 5161 | 5229 | 5297 | 5365 | 5453 | 68 |
| 9 | 5501 | 5569 | 5637 | 5705 | 5773 | 5841 | 5908 | 5976 | 6044 | 6112 | |
| 640 | 806180 | 6248 | 6316 | 6384 | 6451 | 6519 | 6587 | 6655 | 6723 | 6790 | |
| 1 | 6858 | 6926 | 6994 | 7061 | 7129 | 7197 | 7264 | 7332 | 7400 | 7467 | |
| 2 | 7535 | 7603 | 7670 | 7738 | 7806 | 7873 | 7941 | 8008 | 8076 | 8143 | |
| 3 | 8211 | 8279 | 8346 | 8414 | 8481 | 8549 | 8616 | 8684 | 8751 | 8818 | |
| 4 | 8886 | 8953 | 9021 | 9088 | 9156 | 9223 | 9290 | 9358 | 9425 | 9492 | |
| 5 | 9560 | 9627 | 9694 | 9762 | 9829 | 9896 | 9964 | 0031 | 0098 | 0165 | |
| 6 | 810233 | 0300 | 0367 | 0434 | 0501 | 0569 | 0636 | 0703 | 0770 | 0837 | |
| 7 | 0904 | 0971 | 1039 | 1106 | 1173 | 1240 | 1307 | 1374 | 1441 | 1508 | 67 |
| 8 | 1575 | 1642 | 1709 | 1776 | 1843 | 1910 | 1977 | 2044 | 2111 | 2178 | |
| 9 | 2245 | 2312 | 2379 | 2445 | 2512 | 2579 | 2646 | 2713 | 2780 | 2847 | |
| 650 | 2913 | 2980 | 3047 | 3114 | 3181 | 3247 | 3314 | 3381 | 3448 | 3514 | |
| 1 | 3581 | 3648 | 3714 | 3781 | 3848 | 3914 | 3981 | 4048 | 4114 | 4181 | |
| 2 | 4248 | 4314 | 4381 | 4447 | 4514 | 4581 | 4647 | 4714 | 4780 | 4847 | |
| 3 | 4913 | 4980 | 5046 | 5113 | 5179 | 5246 | 5312 | 5378 | 5445 | 5511 | |
| 4 | 5578 | 5644 | 5711 | 5777 | 5843 | 5910 | 5976 | 6042 | 6109 | 6175 | |
| 5 | 6241 | 6308 | 6374 | 6440 | 6506 | 6573 | 6639 | 6705 | 6771 | 6838 | |
| 6 | 6904 | 6970 | 7036 | 7102 | 7169 | 7235 | 7301 | 7367 | 7433 | 7499 | |
| 7 | 7565 | 7631 | 7698 | 7764 | 7830 | 7896 | 7962 | 8028 | 8094 | 8160 | |
| 8 | 8226 | 8292 | 8358 | 8424 | 8490 | 8556 | 8622 | 8688 | 8754 | 8820 | |
| 9 | 8885 | 8951 | 9017 | 9083 | 9149 | 9215 | 9281 | 9346 | 9412 | 9478 | 66 |
| 660 | 9544 | 9610 | 9676 | 9741 | 9807 | 9873 | 9939 | 0004 | 0070 | 0136 | |
| 1 | 820201 | 0267 | 0333 | 0399 | 0464 | 0530 | 0595 | 0661 | 0727 | 0792 | |
| 2 | 0858 | 0924 | 0989 | 1055 | 1120 | 1186 | 1251 | 1317 | 1382 | 1448 | |
| 3 | 1514 | 1579 | 1645 | 1710 | 1775 | 1841 | 1906 | 1972 | 2037 | 2103 | |
| 4 | 2168 | 2233 | 2299 | 2364 | 2430 | 2495 | 2560 | 2626 | 2691 | 2756 | |
| 5 | 2822 | 2887 | 2952 | 3018 | 3083 | 3148 | 3213 | 3279 | 3344 | 3409 | |
| 6 | 3474 | 3539 | 3605 | 3670 | 3735 | 3800 | 3865 | 3930 | 3996 | 4061 | |
| 7 | 4126 | 4191 | 4256 | 4321 | 4386 | 4451 | 4516 | 4581 | 4646 | 4711 | |
| 8 | 4776 | 4841 | 4906 | 4971 | 5036 | 5101 | 5166 | 5231 | 5296 | 5361 | 65 |
| 9 | 5426 | 5491 | 5556 | 5621 | 5686 | 5751 | 5815 | 5880 | 5945 | 6010 | |
| 670 | 6075 | 6140 | 6204 | 6269 | 6334 | 6399 | 6464 | 6528 | 6593 | 6658 | |
| 1 | 6723 | 6787 | 6852 | 6917 | 6981 | 7046 | 7111 | 7175 | 7240 | 7305 | |
| 2 | 7369 | 7434 | 7499 | 7563 | 7628 | 7692 | 7757 | 7821 | 7886 | 7951 | |
| 3 | 8015 | 8080 | 8144 | 8209 | 8273 | 8338 | 8402 | 8467 | 8531 | 8595 | |
| 4 | 8660 | 8724 | 8789 | 8853 | 8918 | 8982 | 9046 | 9111 | 9175 | 9239 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 68 | 6.8 | 13.6 | 20.4 | 27.2 | 34.0 | 40.8 | 47.6 | 54.4 | 61.2 |
| 67 | 6.7 | 13.4 | 20.1 | 26.8 | 33.5 | 40.2 | 46.9 | 53.6 | 60.3 |
| 66 | 6.6 | 13.2 | 19.8 | 26.4 | 33.0 | 39.6 | 46.2 | 52.8 | 59.4 |
| 65 | 6.5 | 13.0 | 19.5 | 26.0 | 32.5 | 39.0 | 45.5 | 52.0 | 58.5 |
| 64 | 6.4 | 12.8 | 19.2 | 25.6 | 32.0 | 38.4 | 44.8 | 51.2 | 57.6 |

No. 675 L. 829.] [No. 719 L. 857.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 675 | 829304 | 9368 | 9432 | 9497 | 9561 | 9625 | 9690 | 9754 | 9818 | 9882 | |
| 6 | 9947 | 0011 | 0075 | 0139 | 0204 | 0268 | 0332 | 0396 | 0460 | 0525 | |
| 7 | 830589 | 0653 | 0717 | 0781 | 0845 | 0909 | 0973 | 1037 | 1102 | 1166 | |
| 8 | 1230 | 1294 | 1358 | 1422 | 1486 | 1550 | 1614 | 1678 | 1742 | 1806 | 64 |
| 9 | 1870 | 1934 | 1998 | 2062 | 2126 | 2189 | 2253 | 2317 | 2381 | 2445 | |
| 680 | 2509 | 2573 | 2637 | 2700 | 2764 | 2828 | 2892 | 2956 | 3020 | 3083 | |
| 1 | 3147 | 3211 | 3275 | 3338 | 3402 | 3466 | 3530 | 3593 | 3657 | 3721 | |
| 2 | 3784 | 3848 | 3912 | 3975 | 4039 | 4103 | 4166 | 4230 | 4294 | 4357 | |
| 3 | 4421 | 4484 | 4548 | 4611 | 4675 | 4739 | 4802 | 4866 | 4929 | 4993 | |
| 4 | 5056 | 5120 | 5183 | 5247 | 5310 | 5373 | 5437 | 5500 | 5564 | 5627 | |
| 5 | 5691 | 5754 | 5817 | 5881 | 5944 | 6007 | 6071 | 6134 | 6197 | 6261 | |
| 6 | 6324 | 6387 | 6451 | 6514 | 6577 | 6641 | 6704 | 6767 | 6830 | 6894 | |
| 7 | 6957 | 7020 | 7083 | 7146 | 7210 | 7273 | 7336 | 7399 | 7462 | 7525 | |
| 8 | 7588 | 7652 | 7715 | 7778 | 7841 | 7904 | 7967 | 8030 | 8093 | 8156 | |
| 9 | 8219 | 8282 | 8345 | 8408 | 8471 | 8534 | 8597 | 8660 | 8723 | 8786 | 63 |
| 690 | 8849 | 8912 | 8975 | 9038 | 9101 | 9164 | 9227 | 9289 | 9352 | 9415 | |
| 1 | 9478 | 9541 | 9604 | 9667 | 9729 | 9792 | 9855 | 9918 | 9981 | 0043 | |
| 2 | 840106 | 0169 | 0232 | 0294 | 0357 | 0420 | 0482 | 0545 | 0608 | 0671 | |
| 3 | 0733 | 0796 | 0859 | 0921 | 0984 | 1046 | 1109 | 1172 | 1234 | 1297 | |
| 4 | 1359 | 1422 | 1485 | 1547 | 1610 | 1672 | 1735 | 1797 | 1860 | 1922 | |
| 5 | 1985 | 2047 | 2110 | 2172 | 2235 | 2297 | 2360 | 2422 | 2484 | 2547 | |
| 6 | 2609 | 2672 | 2734 | 2796 | 2859 | 2921 | 2983 | 3046 | 3108 | 3170 | |
| 7 | 3233 | 3295 | 3357 | 3420 | 3482 | 3544 | 3606 | 3669 | 3731 | 3793 | |
| 8 | 3855 | 3918 | 3980 | 4042 | 4104 | 4166 | 4229 | 4291 | 4353 | 4415 | |
| 9 | 4477 | 4539 | 4601 | 4664 | 4726 | 4788 | 4850 | 4912 | 4974 | 5036 | |
| 700 | 5098 | 5160 | 5222 | 5284 | 5346 | 5408 | 5470 | 5532 | 5594 | 5656 | 62 |
| 1 | 5718 | 5780 | 5842 | 5904 | 5966 | 6028 | 6090 | 6151 | 6213 | 6275 | |
| 2 | 6337 | 6399 | 6461 | 6523 | 6585 | 6646 | 6708 | 6770 | 6832 | 6894 | |
| 3 | 6955 | 7017 | 7079 | 7141 | 7202 | 7264 | 7326 | 7388 | 7449 | 7511 | |
| 4 | 7573 | 7634 | 7696 | 7758 | 7819 | 7881 | 7943 | 8004 | 8066 | 8128 | |
| 5 | 8189 | 8251 | 8312 | 8374 | 8435 | 8497 | 8559 | 8620 | 8682 | 8743 | |
| 6 | 8805 | 8866 | 8928 | 8989 | 9051 | 9112 | 9174 | 9235 | 9297 | 9358 | |
| 7 | 9419 | 9481 | 9542 | 9604 | 9665 | 9726 | 9788 | 9849 | 9911 | 9972 | |
| 8 | 850033 | 0095 | 0156 | 0217 | 0279 | 0340 | 0401 | 0462 | 0524 | 0585 | |
| 9 | 0646 | 0707 | 0769 | 0830 | 0891 | 0952 | 1014 | 1075 | 1136 | 1197 | |
| 710 | 1258 | 1320 | 1381 | 1442 | 1503 | 1564 | 1625 | 1686 | 1747 | 1809 | |
| 1 | 1870 | 1931 | 1992 | 2053 | 2114 | 2175 | 2236 | 2297 | 2358 | 2419 | |
| 2 | 2480 | 2541 | 2602 | 2663 | 2724 | 2785 | 2846 | 2907 | 2968 | 3029 | 61 |
| 3 | 3090 | 3150 | 3211 | 3272 | 3333 | 3394 | 3455 | 3516 | 3577 | 3637 | |
| 4 | 3698 | 3759 | 3820 | 3881 | 3941 | 4002 | 4063 | 4124 | 4185 | 4245 | |
| 5 | 4306 | 4367 | 4428 | 4488 | 4549 | 4610 | 4670 | 4731 | 4792 | 4852 | |
| 6 | 4913 | 4974 | 5034 | 5095 | 5156 | 5216 | 5277 | 5337 | 5398 | 5459 | |
| 7 | 5519 | 5580 | 5640 | 5701 | 5761 | 5822 | 5882 | 5943 | 6003 | 6064 | |
| 8 | 6124 | 6185 | 6245 | 6306 | 6366 | 6427 | 6487 | 6548 | 6608 | 6668 | |
| 9 | 6729 | 6789 | 6850 | 6910 | 6970 | 7031 | 7091 | 7152 | 7212 | 7272 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 65 | 6.5 | 13.0 | 19.5 | 26.0 | 32.5 | 39.0 | 45.5 | 52.0 | 58.5 |
| 64 | 6.4 | 12.8 | 19.2 | 25.6 | 32.0 | 38.4 | 44.8 | 51.2 | 57.6 |
| 63 | 6.3 | 12.6 | 18.9 | 25.2 | 31.5 | 37.8 | 44.1 | 50.4 | 56.7 |
| 62 | 6.2 | 12.4 | 18.6 | 24.8 | 31.0 | 37.2 | 43.4 | 49.6 | 55.8 |
| 61 | 6.1 | 12.2 | 18.3 | 24.4 | 30.5 | 36.6 | 42.7 | 48.8 | 54.9 |
| 60 | 6.0 | 12.0 | 18.0 | 24.0 | 30.0 | 36.0 | 42.0 | 48.0 | 54.0 |

No. 720 L. 857.] [No. 764 L. 883.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 720 | 857332 | 7393 | 7453 | 7513 | 7574 | 7634 | 7694 | 7755 | 7815 | 7875 | |
| 1 | 7935 | 7995 | 8056 | 8116 | 8176 | 8236 | 8297 | 8357 | 8417 | 8477 | |
| 2 | 8537 | 8597 | 8657 | 8718 | 8778 | 8838 | 8898 | 8958 | 9018 | 9078 | |
| 3 | 9138 | 9198 | 9258 | 9318 | 9379 | 9439 | 9499 | 9559 | 9619 | 9679 | 60 |
| 4 | 9739 | 9799 | 9859 | 9918 | 9978 | 0038 | 0098 | 0158 | 0218 | 0278 | |
| 5 | 860338 | 0398 | 0458 | 0518 | 0578 | 0637 | 0697 | 0757 | 0817 | 0877 | |
| 6 | 0937 | 0996 | 1056 | 1116 | 1176 | 1236 | 1295 | 1355 | 1415 | 1475 | |
| 7 | 1534 | 1594 | 1654 | 1714 | 1773 | 1833 | 1893 | 1952 | 2012 | 2072 | |
| 8 | 2131 | 2191 | 2251 | 2310 | 2370 | 2430 | 2489 | 2549 | 2608 | 2668 | |
| 9 | 2728 | 2787 | 2847 | 2906 | 2966 | 3025 | 3085 | 3144 | 3204 | 3263 | |
| 730 | 3323 | 3382 | 3442 | 3501 | 3561 | 3620 | 3680 | 3739 | 3799 | 3858 | |
| 1 | 3917 | 3977 | 4036 | 4096 | 4155 | 4214 | 4274 | 4333 | 4392 | 4452 | |
| 2 | 4511 | 4570 | 4630 | 4689 | 4748 | 4808 | 4867 | 4926 | 4985 | 5045 | |
| 3 | 5104 | 5163 | 5222 | 5282 | 5341 | 5400 | 5459 | 5519 | 5578 | 5637 | |
| 4 | 5696 | 5755 | 5814 | 5874 | 5933 | 5992 | 6051 | 6110 | 6169 | 6228 | |
| 5 | 6287 | 6346 | 6405 | 6465 | 6524 | 6583 | 6642 | 6701 | 6760 | 6819 | |
| 6 | 6878 | 6937 | 6996 | 7055 | 7114 | 7173 | 7232 | 7291 | 7350 | 7409 | 59 |
| 7 | 7467 | 7526 | 7585 | 7644 | 7703 | 7762 | 7821 | 7880 | 7939 | 7998 | |
| 8 | 8056 | 8115 | 8174 | 8233 | 8292 | 8350 | 8409 | 8468 | 8527 | 8586 | |
| 9 | 8644 | 8703 | 8762 | 8821 | 8879 | 8938 | 8997 | 9056 | 9114 | 9173 | |
| 740 | 9232 | 9290 | 9349 | 9408 | 9466 | 9525 | 9584 | 9642 | 9701 | 9760 | |
| 1 | 9818 | 9877 | 9935 | 9994 | 0053 | 0111 | 0170 | 0228 | 0287 | 0345 | |
| 2 | 870404 | 0462 | 0521 | 0579 | 0638 | 0696 | 0755 | 0813 | 0872 | 0930 | |
| 3 | 0989 | 1047 | 1106 | 1164 | 1223 | 1281 | 1339 | 1398 | 1456 | 1515 | |
| 4 | 1573 | 1631 | 1690 | 1748 | 1806 | 1865 | 1923 | 1981 | 2040 | 2098 | |
| 5 | 2156 | 2215 | 2273 | 2331 | 2389 | 2448 | 2506 | 2564 | 2622 | 2681 | |
| 6 | 2739 | 2797 | 2855 | 2913 | 2972 | 3030 | 3088 | 3146 | 3204 | 3262 | |
| 7 | 3321 | 3379 | 3437 | 3495 | 3553 | 3611 | 3669 | 3727 | 3785 | 3844 | |
| 8 | 3902 | 3960 | 4018 | 4076 | 4134 | 4192 | 4250 | 4308 | 4366 | 4424 | 58 |
| 9 | 4482 | 4540 | 4598 | 4656 | 4714 | 4772 | 4830 | 4888 | 4945 | 5003 | |
| 750 | 5061 | 5119 | 5177 | 5235 | 5293 | 5351 | 5409 | 5466 | 5524 | 5582 | |
| 1 | 5640 | 5698 | 5756 | 5813 | 5871 | 5929 | 5987 | 6045 | 6102 | 6160 | |
| 2 | 6218 | 6276 | 6333 | 6391 | 6449 | 6507 | 6564 | 6622 | 6680 | 6737 | |
| 3 | 6795 | 6853 | 6910 | 6968 | 7026 | 7083 | 7141 | 7199 | 7256 | 7314 | |
| 4 | 7371 | 7429 | 7487 | 7544 | 7602 | 7659 | 7717 | 7774 | 7832 | 7889 | |
| 5 | 7947 | 8004 | 8062 | 8119 | 8177 | 8234 | 8292 | 8349 | 8407 | 8464 | |
| 6 | 8522 | 8579 | 8637 | 8694 | 8752 | 8809 | 8866 | 8924 | 8981 | 9039 | |
| 7 | 9096 | 9153 | 9211 | 9268 | 9325 | 9383 | 9440 | 9497 | 9555 | 9612 | |
| 8 | 9669 | 9726 | 9784 | 9841 | 9898 | 9956 | 0013 | 0070 | 0127 | 0185 | |
| 9 | 880242 | 0299 | 0356 | 0413 | 0471 | 0528 | 0585 | 0642 | 0699 | 0756 | |
| 760 | 0814 | 0871 | 0928 | 0985 | 1042 | 1099 | 1156 | 1213 | 1271 | 1328 | |
| 1 | 1385 | 1442 | 1499 | 1556 | 1613 | 1670 | 1727 | 1784 | 1841 | 1898 | |
| 2 | 1955 | 2012 | 2069 | 2126 | 2183 | 2240 | 2297 | 2354 | 2411 | 2468 | 57 |
| 3 | 2525 | 2581 | 2638 | 2695 | 2752 | 2809 | 2866 | 2923 | 2980 | 3037 | |
| 4 | 3093 | 3150 | 3207 | 3264 | 3321 | 3377 | 3434 | 3491 | 3548 | 3605 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 59 | 5.9 | 11.8 | 17.7 | 23.6 | 29.5 | 35.4 | 41.3 | 47.2 | 53.1 |
| 58 | 5.8 | 11.6 | 17.4 | 23.2 | 29.0 | 34.8 | 40.6 | 46.4 | 52.2 |
| 57 | 5.7 | 11.4 | 17.1 | 22.8 | 28.5 | 34.2 | 39.9 | 45.6 | 51.3 |
| 56 | 5.6 | 11.2 | 16.8 | 22.4 | 28.0 | 33.6 | 39.2 | 44.8 | 50.4 |

No. 765 L. 883.] [No. 809 L. 908.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 765 | 883661 | 3718 | 3775 | 3832 | 3888 | 3945 | 4002 | 4059 | 4115 | 4172 | |
| 6 | 4229 | 4285 | 4342 | 4399 | 4455 | 4512 | 4569 | 4625 | 4682 | 4739 | |
| 7 | 4795 | 4852 | 4909 | 4965 | 5022 | 5078 | 5135 | 5192 | 5248 | 5305 | |
| 8 | 5361 | 5418 | 5474 | 5531 | 5587 | 5644 | 5700 | 5757 | 5813 | 5870 | |
| 9 | 5926 | 5983 | 6039 | 6096 | 6152 | 6209 | 6265 | 6321 | 6378 | 6434 | |
| 770 | 6491 | 6547 | 6604 | 6660 | 6716 | 6773 | 6829 | 6885 | 6942 | 6998 | |
| 1 | 7054 | 7111 | 7167 | 7223 | 7280 | 7336 | 7392 | 7449 | 7505 | 7561 | |
| 2 | 7617 | 7674 | 7730 | 7786 | 7842 | 7898 | 7955 | 8011 | 8067 | 8123 | |
| 3 | 8179 | 8236 | 8292 | 8348 | 8404 | 8460 | 8516 | 8573 | 8629 | 8685 | |
| 4 | 8741 | 8797 | 8853 | 8909 | 8965 | 9021 | 9077 | 9134 | 9190 | 9246 | |
| 5 | 9302 | 9358 | 9414 | 9470 | 9526 | 9582 | 9638 | 9694 | 9750 | 9806 | 56 |
| 6 | 9862 | 9918 | 9974 | 0030 | 0086 | 0141 | 0197 | 0253 | 0309 | 0365 | |
| 7 | 890421 | 0477 | 0533 | 0589 | 0645 | 0700 | 0756 | 0812 | 0868 | 0924 | |
| 8 | 0980 | 1035 | 1091 | 1147 | 1203 | 1259 | 1314 | 1370 | 1426 | 1482 | |
| 9 | 1537 | 1593 | 1649 | 1705 | 1760 | 1816 | 1872 | 1928 | 1983 | 2039 | |
| 780 | 2095 | 2150 | 2206 | 2262 | 2317 | 2373 | 2429 | 2484 | 2540 | 2595 | |
| 1 | 2651 | 2707 | 2762 | 2818 | 2873 | 2929 | 2985 | 3040 | 3096 | 3151 | |
| 2 | 3207 | 3262 | 3318 | 3373 | 3429 | 3484 | 3540 | 3595 | 3651 | 3706 | |
| 3 | 3762 | 3817 | 3873 | 3928 | 3984 | 4039 | 4094 | 4150 | 4205 | 4261 | |
| 4 | 4316 | 4371 | 4427 | 4482 | 4538 | 4593 | 4648 | 4704 | 4759 | 4814 | |
| 5 | 4870 | 4925 | 4980 | 5036 | 5091 | 5146 | 5201 | 5257 | 5312 | 5367 | |
| 6 | 5423 | 5478 | 5533 | 5588 | 5644 | 5699 | 5754 | 5809 | 5864 | 5920 | |
| 7 | 5975 | 6030 | 6085 | 6140 | 6195 | 6251 | 6306 | 6361 | 6416 | 6471 | |
| 8 | 6526 | 6581 | 6636 | 6692 | 6747 | 6802 | 6857 | 6912 | 6967 | 7022 | |
| 9 | 7077 | 7132 | 7187 | 7242 | 7297 | 7352 | 7407 | 7462 | 7517 | 7572 | |
| 790 | 7627 | 7682 | 7737 | 7792 | 7847 | 7902 | 7957 | 8012 | 8067 | 8122 | 55 |
| 1 | 8176 | 8231 | 8286 | 8341 | 8396 | 8451 | 8506 | 8561 | 8615 | 8670 | |
| 2 | 8725 | 8780 | 8835 | 8890 | 8944 | 8999 | 9054 | 9109 | 9164 | 9218 | |
| 3 | 9273 | 9328 | 9383 | 9437 | 9492 | 9547 | 9602 | 9656 | 9711 | 9766 | |
| 4 | 9821 | 9875 | 9930 | 9985 | 0039 | 0094 | 0149 | 0203 | 0258 | 0312 | |
| 5 | 900367 | 0422 | 0476 | 0531 | 0586 | 0640 | 0695 | 0749 | 0804 | 0859 | |
| 6 | 0913 | 0968 | 1022 | 1077 | 1131 | 1186 | 1240 | 1295 | 1349 | 1404 | |
| 7 | 1458 | 1513 | 1567 | 1622 | 1676 | 1731 | 1785 | 1840 | 1894 | 1948 | |
| 8 | 2003 | 2057 | 2112 | 2166 | 2221 | 2275 | 2329 | 2384 | 2438 | 2492 | |
| 9 | 2547 | 2601 | 2655 | 2710 | 2764 | 2818 | 2873 | 2927 | 2981 | 3036 | |
| 800 | 3090 | 3144 | 3199 | 3253 | 3307 | 3361 | 3416 | 3470 | 3524 | 3578 | |
| 1 | 3633 | 3687 | 3741 | 3795 | 3849 | 3904 | 3958 | 4012 | 4066 | 4120 | |
| 2 | 4174 | 4229 | 4283 | 4337 | 4391 | 4445 | 4499 | 4553 | 4607 | 4661 | |
| 3 | 4716 | 4770 | 4824 | 4878 | 4932 | 4986 | 5040 | 5094 | 5148 | 5202 | |
| 4 | 5256 | 5310 | 5364 | 5418 | 5472 | 5526 | 5580 | 5634 | 5688 | 5742 | 54 |
| 5 | 5796 | 5850 | 5904 | 5958 | 6012 | 6066 | 6119 | 6173 | 6227 | 6281 | |
| 6 | 6335 | 6389 | 6443 | 6497 | 6551 | 6604 | 6658 | 6712 | 6766 | 6820 | |
| 7 | 6874 | 6927 | 6981 | 7035 | 7089 | 7143 | 7196 | 7250 | 7304 | 7358 | |
| 8 | 7411 | 7465 | 7519 | 7573 | 7626 | 7680 | 7734 | 7787 | 7841 | 7895 | |
| 9 | 7949 | 8002 | 8056 | 8110 | 8163 | 8217 | 8270 | 8324 | 8378 | 8431 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 57 | 5.7 | 11.4 | 17.1 | 22.8 | 28.5 | 34.2 | 39.9 | 45.6 | 51.3 |
| 56 | 5.6 | 11.2 | 16.8 | 22.4 | 28.0 | 33.6 | 39.2 | 44.8 | 50.4 |
| 55 | 5,5 | 11.0 | 16.5 | 22.0 | 27.5 | 33.0 | 38.5 | 44.0 | 49.5 |
| 54 | 5.4 | 10.8 | 16.2 | 21.6 | 27.0 | 32.4 | 37.8 | 43.2 | 48.6 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 810 | 908485 | 8539 | 8592 | 8646 | 8699 | 8753 | 8807 | 8860 | 8914 | 8967 | |
| 1 | 9021 | 9074 | 9128 | 9181 | 9235 | 9289 | 9342 | 9396 | 9449 | 9503 | |
| 2 | 9556 | 9610 | 9663 | 9716 | 9770 | 9823 | 9877 | 9930 | 9984 | 0037 | |
| 3 | 910091 | 0144 | 0197 | 0251 | 0304 | 0358 | 0411 | 0464 | 0518 | 0571 | |
| 4 | 0624 | 0678 | 0731 | 0784 | 0838 | 0891 | 0944 | 0998 | 1051 | 1104 | |
| 5 | 1158 | 1211 | 1264 | 1317 | 1371 | 1424 | 1477 | 1530 | 1584 | 1637 | |
| 6 | 1690 | 1743 | 1797 | 1850 | 1903 | 1956 | 2009 | 2063 | 2116 | 2169 | |
| 7 | 2222 | 2275 | 2328 | 2381 | 2435 | 2488 | 2541 | 2594 | 2647 | 2700 | |
| 8 | 2753 | 2806 | 2859 | 2913 | 2966 | 3019 | 3072 | 3125 | 3178 | 3231 | |
| 9 | 3284 | 3337 | 3390 | 3443 | 3496 | 3549 | 3602 | 3655 | 3708 | 3761 | 53 |
| 820 | 3814 | 3867 | 3920 | 3973 | 4026 | 4079 | 4132 | 4184 | 4237 | 4290 | |
| 1 | 4343 | 4396 | 4449 | 4502 | 4555 | 4608 | 4660 | 4713 | 4766 | 4819 | |
| 2 | 4872 | 4925 | 4977 | 5030 | 5083 | 5136 | 5189 | 5241 | 5294 | 5347 | |
| 3 | 5400 | 5453 | 5505 | 5558 | 5611 | 5664 | 5716 | 5769 | 5822 | 5875 | |
| 4 | 5927 | 5980 | 6033 | 6085 | 6138 | 6191 | 6243 | 6296 | 6349 | 6401 | |
| 5 | 6454 | 6507 | 6559 | 6612 | 6664 | 6717 | 6770 | 6822 | 6875 | 6927 | |
| 6 | 6980 | 7033 | 7085 | 7138 | 7190 | 7243 | 7295 | 7348 | 7400 | 7453 | |
| 7 | 7506 | 7558 | 7611 | 7663 | 7716 | 7768 | 7820 | 7873 | 7925 | 7978 | |
| 8 | 8030 | 8083 | 8135 | 8188 | 8240 | 8293 | 8345 | 8397 | 8450 | 8502 | |
| 9 | 8555 | 8607 | 8659 | 8712 | 8764 | 8816 | 8869 | 8921 | 8973 | 9026 | |
| 830 | 9078 | 9130 | 9183 | 9235 | 9287 | 9340 | 9392 | 9444 | 9496 | 9549 | |
| 1 | 9601 | 9653 | 9706 | 9758 | 9810 | 9862 | 9914 | 9967 | 0019 | 0071 | |
| 2 | 920123 | 0176 | 0228 | 0280 | 0332 | 0384 | 0436 | 0489 | 0541 | 0593 | |
| 3 | 0645 | 0697 | 0749 | 0801 | 0853 | 0906 | 0958 | 1010 | 1062 | 1114 | |
| 4 | 1166 | 1218 | 1270 | 1322 | 1374 | 1426 | 1478 | 1530 | 1582 | 1634 | 52 |
| 5 | 1686 | 1738 | 1790 | 1842 | 1894 | 1946 | 1998 | 2050 | 2102 | 2154 | |
| 6 | 2206 | 2258 | 2310 | 2362 | 2414 | 2466 | 2518 | 2570 | 2622 | 2674 | |
| 7 | 2725 | 2777 | 2829 | 2881 | 2933 | 2985 | 3037 | 3089 | 3140 | 3192 | |
| 8 | 3244 | 3296 | 3348 | 3399 | 3451 | 3503 | 3555 | 3607 | 3658 | 3710 | |
| 9 | 3762 | 3814 | 3865 | 3917 | 3969 | 4021 | 4072 | 4124 | 4176 | 4228 | |
| 840 | 4279 | 4331 | 4383 | 4434 | 4486 | 4538 | 4589 | 4641 | 4693 | 4744 | |
| 1 | 4796 | 4848 | 4899 | 4951 | 5003 | 5054 | 5106 | 5157 | 5209 | 5261 | |
| 2 | 5312 | 5364 | 5415 | 5467 | 5518 | 5570 | 5621 | 5673 | 5725 | 5776 | |
| 3 | 5828 | 5879 | 5931 | 5982 | 6034 | 6085 | 6137 | 6188 | 6240 | 6291 | |
| 4 | 6342 | 6394 | 6445 | 6497 | 6548 | 6600 | 6651 | 6702 | 6754 | 6805 | |
| 5 | 6857 | 6908 | 6959 | 7011 | 7062 | 7114 | 7165 | 7216 | 7268 | 7319 | |
| 6 | 7370 | 7422 | 7473 | 7524 | 7576 | 7627 | 7678 | 7730 | 7781 | 7832 | |
| 7 | 7883 | 7935 | 7986 | 8037 | 8088 | 8140 | 8191 | 8242 | 8293 | 8345 | |
| 8 | 8396 | 8447 | 8498 | 8549 | 8601 | 8652 | 8703 | 8754 | 8805 | 8857 | |
| 9 | 8908 | 8959 | 9010 | 9061 | 9112 | 9163 | 9215 | 9266 | 9317 | 9368 | |
| 850 | 9419 | 9470 | 9521 | 9572 | 9623 | 9674 | 9725 | 9776 | 9827 | 9879 | 51 |
| 1 | 9930 | 9981 | 0032 | 0083 | 0134 | 0185 | 0236 | 0287 | 0338 | 0389 | |
| 2 | 930440 | 0491 | 0542 | 0592 | 0643 | 0694 | 0745 | 0796 | 0847 | 0898 | |
| 3 | 0949 | 1000 | 1051 | 1102 | 1153 | 1204 | 1254 | 1305 | 1356 | 1407 | |
| 4 | 1458 | 1509 | 1560 | 1610 | 1661 | 1712 | 1763 | 1814 | 1865 | 1915 | |

## Proportional Parts.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 53 | 5.3 | 10.6 | 15.9 | 21.2 | 26.5 | 31.8 | 37.1 | 42.4 | 47.7 |
| 52 | 5.2 | 10.4 | 15.6 | 20.8 | 26.0 | 31.2 | 36.4 | 41.6 | 46.8 |
| 51 | 5.1 | 10.2 | 15.3 | 20.4 | 25.5 | 30.6 | 35.7 | 40.8 | 45.9 |
| 50 | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 855 | 931966 | 2017 | 2068 | 2118 | 2169 | 2220 | 2271 | 2322 | 2372 | 2423 | |
| 6 | 2474 | 2524 | 2575 | 2626 | 2677 | 2727 | 2778 | 2829 | 2879 | 2930 | |
| 7 | 2981 | 3031 | 3082 | 3133 | 3183 | 3234 | 3285 | 3335 | 3386 | 3437 | |
| 8 | 3487 | 3538 | 3589 | 3639 | 3690 | 3740 | 3791 | 3841 | 3892 | 3943 | |
| 9 | 3993 | 4044 | 4094 | 4145 | 4195 | 4246 | 4296 | 4347 | 4397 | 4448 | |
| 860 | 4498 | 4549 | 4599 | 4650 | 4700 | 4751 | 4801 | 4852 | 4902 | 4953 | |
| 1 | 5003 | 5054 | 5104 | 5154 | 5205 | 5255 | 5306 | 5356 | 5406 | 5457 | |
| 2 | 5507 | 5558 | 5608 | 5658 | 5709 | 5759 | 5809 | 5860 | 5910 | 5960 | |
| 3 | 6011 | 6061 | 6111 | 6162 | 6212 | 6262 | 6313 | 6363 | 6413 | 6463 | |
| 4 | 6514 | 6564 | 6614 | 6665 | 6715 | 6765 | 6815 | 6865 | 6916 | 6966 | |
| 5 | 7016 | 7066 | 7116 | 7167 | 7217 | 7267 | 7317 | 7367 | 7418 | 7468 | |
| 6 | 7518 | 7568 | 7618 | 7668 | 7718 | 7769 | 7819 | 7869 | 7919 | 7969 | |
| 7 | 8019 | 8069 | 8119 | 8169 | 8219 | 8269 | 8320 | 8370 | 8420 | 8470 | 50 |
| 8 | 8520 | 8570 | 8620 | 8670 | 8720 | 8770 | 8820 | 8870 | 8920 | 8970 | |
| 9 | 9020 | 9070 | 9120 | 9170 | 9220 | 9270 | 9320 | 9369 | 9419 | 9469 | |
| 870 | 9519 | 9569 | 9619 | 9669 | 9719 | 9769 | 9819 | 9869 | 9918 | 9968 | |
| 1 | 940018 | 0068 | 0118 | 0168 | 0218 | 0267 | 0317 | 0367 | 0417 | 0467 | |
| 2 | 0516 | 0566 | 0616 | 0666 | 0716 | 0765 | 0815 | 0865 | 0915 | 0964 | |
| 3 | 1014 | 1064 | 1114 | 1163 | 1213 | 1263 | 1313 | 1362 | 1412 | 1462 | |
| 4 | 1511 | 1561 | 1611 | 1660 | 1710 | 1760 | 1809 | 1859 | 1909 | 1958 | |
| 5 | 2008 | 2058 | 2107 | 2157 | 2207 | 2256 | 2306 | 2355 | 2405 | 2455 | |
| 6 | 2504 | 2554 | 2603 | 2653 | 2702 | 2752 | 2801 | 2851 | 2901 | 2950 | |
| 7 | 3000 | 3049 | 3099 | 3148 | 3198 | 3247 | 3297 | 3346 | 3396 | 3445 | |
| 8 | 3495 | 3544 | 3593 | 3643 | 3692 | 3742 | 3791 | 3841 | 3890 | 3939 | |
| 9 | 3989 | 4038 | 4088 | 4137 | 4186 | 4236 | 4285 | 4335 | 4384 | 4433 | |
| 880 | 4483 | 4532 | 4581 | 4631 | 4680 | 4729 | 4779 | 4828 | 4877 | 4927 | |
| 1 | 4976 | 5025 | 5074 | 5124 | 5173 | 5222 | 5272 | 5321 | 5370 | 5419 | |
| 2 | 5469 | 5518 | 5567 | 5616 | 5665 | 5715 | 5764 | 5813 | 5862 | 5912 | |
| 3 | 5961 | 6010 | 6059 | 6108 | 6157 | 6207 | 6256 | 6305 | 6354 | 6403 | |
| 4 | 6452 | 6501 | 6551 | 6600 | 6649 | 6698 | 6747 | 6796 | 6845 | 6894 | |
| 5 | 6943 | 6992 | 7041 | 7090 | 7139 | 7189 | 7238 | 7287 | 7336 | 7385 | |
| 6 | 7434 | 7483 | 7532 | 7581 | 7630 | 7679 | 7728 | 7777 | 7826 | 7875 | 49 |
| 7 | 7924 | 7973 | 8022 | 8070 | 8119 | 8168 | 8217 | 8266 | 8315 | 8364 | |
| 8 | 8413 | 8462 | 8511 | 8560 | 8608 | 8657 | 8706 | 8755 | 8804 | 8853 | |
| 9 | 8902 | 8951 | 8999 | 9048 | 9097 | 9146 | 9195 | 9244 | 9292 | 9341 | |
| 890 | 9390 | 9439 | 9488 | 9536 | 9585 | 9634 | 9683 | 9731 | 9780 | 9829 | |
| 1 | 9878 | 9926 | 9975 | 0024 | 0073 | 0121 | 0170 | 0219 | 0267 | 0316 | |
| 2 | 950365 | 0414 | 0462 | 0511 | 0560 | 0608 | 0657 | 0706 | 0754 | 0803 | |
| 3 | 0851 | 0900 | 0949 | 0997 | 1046 | 1095 | 1143 | 1192 | 1240 | 1289 | |
| 4 | 1338 | 1386 | 1435 | 1483 | 1532 | 1580 | 1629 | 1677 | 1726 | 1775 | |
| 5 | 1823 | 1872 | 1920 | 1969 | 2017 | 2066 | 2114 | 2163 | 2211 | 2260 | |
| 6 | 2308 | 2356 | 2405 | 2453 | 2502 | 2550 | 2599 | 2647 | 2696 | 2744 | |
| 7 | 2792 | 2841 | 2889 | 2938 | 2986 | 3034 | 3083 | 3131 | 3180 | 3228 | |
| 8 | 3276 | 3325 | 3373 | 3421 | 3470 | 3518 | 3566 | 3615 | 3663 | 3711 | |
| 9 | 3760 | 3808 | 3856 | 3905 | 3953 | 4001 | 4049 | 4098 | 4146 | 4194 | |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 51 | 5.1 | 10.2 | 15.3 | 20.4 | 25.5 | 30.6 | 35.7 | 40.8 | 45.9 |
| 50 | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 |
| 49 | 4.9 | 9.8 | 14.7 | 19.6 | 24.5 | 29.4 | 34.3 | 39.2 | 44.1 |
| 48 | 4.8 | 9.6 | 14.4 | 19.2 | 24.0 | 28.8 | 33.6 | 38.4 | 43.2 |

No 900 L. 954.] [No. 944 L. 975.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 900 | 954243 | 4291 | 4339 | 4387 | 4435 | 4484 | 4532 | 4580 | 4628 | 4677 | |
| 1 | 4725 | 4773 | 4821 | 4869 | 4918 | 4966 | 5014 | 5062 | 5110 | 5158 | |
| 2 | 5207 | 5255 | 5303 | 5351 | 5399 | 5447 | 5495 | 5543 | 5592 | 5640 | |
| 3 | 5688 | 5736 | 5784 | 5832 | 5880 | 5928 | 5976 | 6024 | 6072 | 6120 | |
| 4 | 6168 | 6216 | 6265 | 6313 | 6361 | 6409 | 6457 | 6505 | 6553 | 6601 | |
| 5 | 6649 | 6697 | 6745 | 6793 | 6840 | 6888 | 6936 | 6984 | 7032 | 7080 | 48 |
| 6 | 7128 | 7176 | 7224 | 7272 | 7320 | 7368 | 7416 | 7464 | 7512 | 7559 | |
| 7 | 7607 | 7655 | 7703 | 7751 | 7799 | 7847 | 7894 | 7942 | 7990 | 8038 | |
| 8 | 8086 | 8134 | 8181 | 8229 | 8277 | 8325 | 8373 | 8421 | 8468 | 8516 | |
| 9 | 8564 | 8612 | 8659 | 8707 | 8755 | 8803 | 8850 | 8898 | 8946 | 8994 | |
| 910 | 9041 | 9089 | 9137 | 9185 | 9232 | 9280 | 9328 | 9375 | 9423 | 9471 | |
| 1 | 9518 | 9566 | 9614 | 9661 | 9709 | 9757 | 9804 | 9852 | 9900 | 9947 | |
| 2 | 9995 | | | | | | | | | | |
| | | 0042 | 0090 | 0138 | 0185 | 0233 | 0280 | 0328 | 0376 | 0423 | |
| 3 | 960471 | 0518 | 0566 | 0613 | 0661 | 0709 | 0756 | 0804 | 0851 | 0899 | |
| 4 | 0946 | 0994 | 1041 | 1089 | 1136 | 1184 | 1231 | 1279 | 1326 | 1374 | |
| 5 | 1421 | 1469 | 1516 | 1563 | 1611 | 1658 | 1706 | 1753 | 1801 | 1848 | |
| 6 | 1895 | 1943 | 1990 | 2038 | 2085 | 2132 | 2180 | 2227 | 2275 | 2322 | |
| 7 | 2369 | 2417 | 2464 | 2511 | 2559 | 2606 | 2653 | 2701 | 2748 | 2795 | |
| 8 | 2843 | 2890 | 2937 | 2985 | 3032 | 3079 | 3126 | 3174 | 3221 | 3268 | |
| 9 | 3316 | 3363 | 3410 | 3457 | 3504 | 3552 | 3599 | 3646 | 3693 | 3741 | |
| 920 | 3788 | 3835 | 3882 | 3929 | 3977 | 4024 | 4071 | 4118 | 4165 | 4212 | |
| 1 | 4260 | 4307 | 4354 | 4401 | 4448 | 4495 | 4542 | 4590 | 4637 | 4684 | |
| 2 | 4731 | 4778 | 4825 | 4872 | 4919 | 4966 | 5013 | 5061 | 5108 | 5155 | |
| 3 | 5202 | 5249 | 5296 | 5343 | 5390 | 5437 | 5484 | 5531 | 5578 | 5625 | |
| 4 | 5672 | 5719 | 5766 | 5813 | 5860 | 5907 | 5954 | 6001 | 6048 | 6095 | 47 |
| 5 | 6142 | 6189 | 6236 | 6283 | 6329 | 6376 | 6423 | 6470 | 6517 | 6564 | |
| 6 | 6611 | 6658 | 6705 | 6752 | 6799 | 6845 | 6892 | 6939 | 6986 | 7033 | |
| 7 | 7080 | 7127 | 7173 | 7220 | 7267 | 7314 | 7361 | 7408 | 7454 | 7501 | |
| 8 | 7548 | 7595 | 7642 | 7688 | 7735 | 7782 | 7829 | 7875 | 7922 | 7969 | |
| 9 | 8016 | 8062 | 8109 | 8156 | 8203 | 8249 | 8296 | 8343 | 8390 | 8436 | |
| 930 | 8483 | 8530 | 8576 | 8623 | 8670 | 8716 | 8763 | 8810 | 8856 | 8903 | |
| 1 | 8950 | 8996 | 9043 | 9090 | 9136 | 9183 | 9229 | 9276 | 9323 | 9369 | |
| 2 | 9416 | 9463 | 9509 | 9556 | 9602 | 9649 | 9695 | 9742 | 9789 | 9835 | |
| 3 | 9882 | 9928 | 9975 | | | | | | | | |
| | | | | 0021 | 0068 | 0114 | 0161 | 0207 | 0254 | 0300 | |
| 4 | 970347 | 0393 | 0440 | 0486 | 0533 | 0579 | 0626 | 0672 | 0719 | 0765 | |
| 5 | 0812 | 0858 | 0904 | 0951 | 0997 | 1044 | 1090 | 1137 | 1183 | 1229 | |
| 6 | 1276 | 1322 | 1369 | 1415 | 1461 | 1508 | 1554 | 1601 | 1647 | 1693 | |
| 7 | 1740 | 1786 | 1832 | 1879 | 1925 | 1971 | 2018 | 2064 | 2110 | 2157 | |
| 8 | 2203 | 2249 | 2295 | 2342 | 2388 | 2434 | 2481 | 2527 | 2573 | 2619 | |
| 9 | 2666 | 2712 | 2758 | 2804 | 2851 | 2897 | 2943 | 2989 | 3035 | 3082 | |
| 940 | 3128 | 3174 | 3220 | 3266 | 3313 | 3359 | 3405 | 3451 | 3497 | 3543 | |
| 1 | 3590 | 3636 | 3682 | 3728 | 3774 | 3820 | 3866 | 3913 | 3959 | 4005 | |
| 2 | 4051 | 4097 | 4143 | 4189 | 4235 | 4281 | 4327 | 4374 | 4420 | 4466 | |
| 3 | 4512 | 4558 | 4604 | 4650 | 4696 | 4742 | 4788 | 4834 | 4880 | 4926 | |
| 4 | 4972 | 5018 | 5064 | 5110 | 5156 | 5202 | 5248 | 5294 | 5340 | 5386 | 46 |

PROPORTIONAL PARTS.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 47 | 4.7 | 9.4 | 14.1 | 18.8 | 23.5 | 28.2 | 32.9 | 37.6 | 42.3 |
| 46 | 4.6 | 9.2 | 13.8 | 18.4 | 23.0 | 27.6 | 32.2 | 36.8 | 41.4 |

No. 945 L. 975.] [No. 989 L. 995.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 945 | 975432 | 5478 | 5524 | 5570 | 5616 | 5662 | 5707 | 5753 | 5799 | 5845 | |
| 6 | 5891 | 5937 | 5983 | 6029 | 6075 | 6121 | 6167 | 6212 | 6258 | 6304 | |
| 7 | 6350 | 6396 | 6442 | 6488 | 6533 | 6579 | 6625 | 6671 | 6717 | 6763 | |
| 8 | 6808 | 6854 | 6900 | 6946 | 6992 | 7037 | 7083 | 7129 | 7175 | 7220 | |
| 9 | 7266 | 7312 | 7358 | 7403 | 7449 | 7495 | 7541 | 7586 | 7632 | 7678 | |
| 950 | 7724 | 7769 | 7815 | 7861 | 7906 | 7952 | 7998 | 8043 | 8089 | 8135 | |
| 1 | 8181 | 8226 | 8272 | 8317 | 8363 | 8409 | 8454 | 8500 | 8546 | 8591 | |
| 2 | 8637 | 8683 | 8728 | 8774 | 8819 | 8865 | 8911 | 8956 | 9002 | 9047 | |
| 3 | 9093 | 9138 | 9184 | 9230 | 9275 | 9321 | 9366 | 9412 | 9457 | 9503 | |
| 4 | 9548 | 9594 | 9639 | 9685 | 9730 | 9776 | 9821 | 9867 | 9912 | 9958 | |
| 5 | 980003 | 0049 | 0094 | 0140 | 0185 | 0231 | 0276 | 0322 | 0367 | 0412 | |
| 6 | 0458 | 0503 | 0549 | 0594 | 0640 | 0685 | 0730 | 0776 | 0821 | 0867 | |
| 7 | 0912 | 0957 | 1003 | 1048 | 1093 | 1139 | 1184 | 1229 | 1275 | 1320 | |
| 8 | 1366 | 1411 | 1456 | 1501 | 1547 | 1592 | 1637 | 1683 | 1728 | 1773 | |
| 9 | 1819 | 1864 | 1909 | 1954 | 2000 | 2045 | 2090 | 2135 | 2181 | 2226 | |
| 960 | 2271 | 2316 | 2362 | 2407 | 2452 | 2497 | 2543 | 2588 | 2633 | 2678 | |
| 1 | 2723 | 2769 | 2814 | 2859 | 2904 | 2949 | 2994 | 3040 | 3085 | 3130 | |
| 2 | 3175 | 3220 | 3265 | 3310 | 3356 | 3401 | 3446 | 3491 | 3536 | 3581 | |
| 3 | 3626 | 3671 | 3716 | 3762 | 3807 | 3852 | 3897 | 3942 | 3987 | 4032 | |
| 4 | 4077 | 4122 | 4167 | 4212 | 4257 | 4302 | 4347 | 4392 | 4437 | 4482 | |
| 5 | 4527 | 4572 | 4617 | 4662 | 4707 | 4752 | 4797 | 4842 | 4887 | 4932 | 45 |
| 6 | 4977 | 5022 | 5067 | 5112 | 5157 | 5202 | 5247 | 5292 | 5337 | 5382 | |
| 7 | 5426 | 5471 | 5516 | 5561 | 5606 | 5651 | 5696 | 5741 | 5786 | 5830 | |
| 8 | 5875 | 5920 | 5965 | 6010 | 6055 | 6100 | 6144 | 6189 | 6234 | 6279 | |
| 9 | 6324 | 6369 | 6413 | 6458 | 6503 | 6548 | 6593 | 6637 | 6682 | 6727 | |
| 970 | 6772 | 6817 | 6861 | 6906 | 6951 | 6996 | 7040 | 7085 | 7130 | 7175 | |
| 1 | 7219 | 7264 | 7309 | 7353 | 7398 | 7443 | 7488 | 7532 | 7577 | 7622 | |
| 2 | 7666 | 7711 | 7756 | 7800 | 7845 | 7890 | 7934 | 7979 | 8024 | 8068 | |
| 3 | 8113 | 8157 | 8202 | 8247 | 8291 | 8336 | 8381 | 8425 | 8470 | 8514 | |
| 4 | 8559 | 8604 | 8648 | 8693 | 8737 | 8782 | 8826 | 8871 | 8916 | 8960 | |
| 5 | 9005 | 9049 | 9094 | 9138 | 9183 | 9227 | 9272 | 9316 | 9361 | 9405 | |
| 6 | 9450 | 9494 | 9539 | 9583 | 9628 | 9672 | 9717 | 9761 | 9806 | 9850 | |
| 7 | 9895 | 9939 | 9983 | 0028 | 0072 | 0117 | 0161 | 0206 | 0250 | 0294 | |
| 8 | 990339 | 0383 | 0428 | 0472 | 0516 | 0561 | 0605 | 0650 | 0694 | 0738 | |
| 9 | 0783 | 0827 | 0871 | 0916 | 0960 | 1004 | 1049 | 1093 | 1137 | 1182 | |
| 980 | 1226 | 1270 | 1315 | 1359 | 1403 | 1448 | 1492 | 1536 | 1580 | 1625 | |
| 1 | 1669 | 1713 | 1758 | 1802 | 1846 | 1890 | 1935 | 1979 | 2023 | 2067 | |
| 2 | 2111 | 2156 | 2200 | 2244 | 2288 | 2333 | 2377 | 2421 | 2465 | 2509 | |
| 3 | 2554 | 2598 | 2642 | 2686 | 2730 | 2774 | 2819 | 2863 | 2907 | 2951 | |
| 4 | 2995 | 3039 | 3083 | 3127 | 3172 | 3216 | 3260 | 3304 | 3348 | 3392 | |
| 5 | 3436 | 3480 | 3524 | 3568 | 3613 | 3657 | 3701 | 3745 | 3789 | 3833 | |
| 6 | 3877 | 3921 | 3965 | 4009 | 4053 | 4097 | 4141 | 4185 | 4229 | 4273 | |
| 7 | 4317 | 4361 | 4405 | 4449 | 4493 | 4537 | 4581 | 4625 | 4669 | 4713 | 44 |
| 8 | 4757 | 4801 | 4845 | 4889 | 4933 | 4977 | 5021 | 5065 | 5108 | 5152 | |
| 9 | 5196 | 5240 | 5284 | 5328 | 5372 | 5416 | 5460 | 5504 | 5547 | 5591 | |

## Proportional Parts.

| Diff. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 4.6 | 9.2 | 13.8 | 18.4 | 23.0 | 27.6 | 32.2 | 36.8 | 41.4 |
| 45 | 4.5 | 9.0 | 13.5 | 18.0 | 22.5 | 27.0 | 31.5 | 36.0 | 40.5 |
| 44 | 4.4 | 8.8 | 13.2 | 17.6 | 22.0 | 26.4 | 30.8 | 35.2 | 39.6 |
| 43 | 4.3 | 8.6 | 12.9 | 17.2 | 21.5 | 25.8 | 30.1 | 34.4 | 38.7 |

No. 990 L. 995.] [No. 999 L. 999.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 990 | 995635 | 5679 | 5723 | 5767 | 5811 | 5854 | 5898 | 5942 | 5986 | 6030 | |
| 1 | 6074 | 6117 | 6161 | 6205 | 6249 | 6293 | 6337 | 6380 | 6424 | 6468 | 44 |
| 2 | 6512 | 6555 | 6599 | 6643 | 6687 | 6731 | 6774 | 6818 | 6862 | 6906 | |
| 3 | 6949 | 6993 | 7037 | 7080 | 7124 | 7168 | 7212 | 7255 | 7299 | 7343 | |
| 4 | 7386 | 7430 | 7474 | 7517 | 7561 | 7605 | 7648 | 7692 | 7736 | 7779 | |
| 5 | 7823 | 7867 | 7910 | 7954 | 7998 | 8041 | 8085 | 8129 | 8172 | 8216 | |
| 6 | 8259 | 8303 | 8347 | 8390 | 8434 | 8477 | 8521 | 8564 | 8608 | 8652 | |
| 7 | 8695 | 8739 | 8782 | 8826 | 8869 | 8913 | 8956 | 9000 | 9043 | 9087 | |
| 8 | 9131 | 9174 | 9218 | 9261 | 9305 | 9348 | 9392 | 9435 | 9479 | 9522 | |
| 9 | 9565 | 9609 | 9652 | 9696 | 9739 | 9783 | 9826 | 9870 | 9913 | 9957 | 43 |

LOGARITHMS OF NUMBERS FROM 1 TO 100.

| N. | Log. | N. | Log. | N. | Log. | N. | Log. | N. | Log. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000000 | 21 | 1.322219 | 41 | 1.612784 | 61 | 1.785330 | 81 | 1.908485 |
| 2 | 0.301030 | 22 | 1.342423 | 42 | 1.623249 | 62 | 1.792392 | 82 | 1.913814 |
| 3 | 0.477121 | 23 | 1.361728 | 43 | 1.633468 | 63 | 1.799341 | 83 | 1.919078 |
| 4 | 0.602060 | 24 | 1.380211 | 44 | 1.643453 | 64 | 1.806180 | 84 | 1.924279 |
| 5 | 0.698970 | 25 | 1.397940 | 45 | 1.653213 | 65 | 1.812913 | 85 | 1.929419 |
| 6 | 0.778151 | 26 | 1.414973 | 46 | 1.662758 | 66 | 1.819544 | 86 | 1.934498 |
| 7 | 0.845098 | 27 | 1.431364 | 47 | 1.672098 | 67 | 1.826075 | 87 | 1.939519 |
| 8 | 0.903090 | 28 | 1.447158 | 48 | 1.681241 | 68 | 1.832509 | 88 | 1.944483 |
| 9 | 0.954243 | 29 | 1.462398 | 49 | 1.690196 | 69 | 1.838849 | 89 | 1.949390 |
| 10 | 1.000000 | 30 | 1.477121 | 50 | 1.698970 | 70 | 1.845098 | 90 | 1.954243 |
| 11 | 1.041393 | 31 | 1.491362 | 51 | 1.707570 | 71 | 1.851258 | 91 | 1.959041 |
| 12 | 1.079181 | 32 | 1.505150 | 52 | 1.716003 | 72 | 1.857332 | 92 | 1.963788 |
| 13 | 1.113943 | 33 | 1.518514 | 53 | 1.724276 | 73 | 1.863323 | 93 | 1.968483 |
| 14 | 1.146128 | 34 | 1.531479 | 54 | 1.732394 | 74 | 1.869232 | 94 | 1.973128 |
| 15 | 1.176091 | 35 | 1.544068 | 55 | 1.740363 | 75 | 1.875061 | 95 | 1.977724 |
| 16 | 1.204120 | 36 | 1.556303 | 56 | 1.748188 | 76 | 1.880814 | 96 | 1.982271 |
| 17 | 1.230449 | 37 | 1.568202 | 57 | 1.755875 | 77 | 1.886491 | 97 | 1.986772 |
| 18 | 1.255273 | 38 | 1.579784 | 58 | 1.763428 | 78 | 1.892095 | 98 | 1.991226 |
| 19 | 1.278754 | 39 | 1.591065 | 59 | 1.770852 | 79 | 1.897627 | 99 | 1.995635 |
| 20 | 1.301030 | 40 | 1.602060 | 60 | 1.778151 | 80 | 1.903090 | 100 | 2.000000 |

| | Value at 0°. | Sign in 1st Quad. | Value at 90°. | Sign in 2d Quad. | Value at 180°. | Sign in 3d Quad. | Value at 270° | Sign in 4th Quad. | Value at 360°. |
|---|---|---|---|---|---|---|---|---|---|
| Sin........ | O | + | R | + | O | − | R | − | O |
| Tan........ | O | + | ∞ | − | O | + | ∞ | − | O |
| Sec ........ | R | + | ∞ | − | R | − | ∞ | + | R |
| Versin.... | O | + | R | + | 2 R | + | R | + | O |
| Cos ........ | R | + | O | − | R | − | O | + | R |
| Cot.... ... | ∞ | + | O | − | ∞ | + | O | − | ∞ |
| Cosec..... | ∞ | + | R | + | ∞ | − | R | − | ∞ |

R signifies equal to rad; ∞ signifies infinite; O signifies evanescent.

| ″ | ′ | Sine. | q − l | | Tang. | Cotang. | q + l | D 1″ | Cosine. | ′ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4.685 | | | | 15.314 | | | |
| 0 | 0 | Inf. neg. | 575 | 575 | Inf. neg. | Inf. pos. | 425 | | ten | 60 |
| 60 | 1 | 6.463726 | 575 | 575 | 6.463726 | 13.536274 | 425 | | ten | 59 |
| 120 | 2 | .764756 | 575 | 575 | .764756 | .235244 | 425 | | ten | 58 |
| 180 | 3 | 6.940847 | 575 | 575 | 6.940847 | 13.059153 | 425 | | ten | 57 |
| 240 | 4 | 7.065786 | 575 | 575 | 7.065786 | 12.934214 | 425 | | ten | 56 |
| 300 | 5 | .162696 | 575 | 575 | .162696 | .837304 | 425 | | ten | 55 |
| 360 | 6 | .241877 | 575 | 575 | .241878 | .758122 | 425 | .02 | 9.999999 | 54 |
| 420 | 7 | .308824 | 575 | 575 | .308825 | .691175 | 425 | .00 | .999999 | 53 |
| 480 | 8 | .366816 | 574 | 576 | .366817 | .633183 | 424 | .00 | .999999 | 52 |
| 540 | 9 | .417968 | 574 | 576 | .417970 | .582030 | 424 | .00 | .999999 | 51 |
| 600 | 10 | .463726 | 574 | 576 | .463727 | .536273 | 424 | .02 | .999998 | 50 |
| 660 | 11 | 7.505118 | 574 | 576 | 7.505120 | 12.494880 | 424 | .00 | 9.999998 | 49 |
| 720 | 12 | .542906 | 574 | 577 | .542909 | .457091 | 423 | .02 | .999997 | 48 |
| 780 | 13 | .577668 | 574 | 577 | .577672 | .422328 | 423 | .00 | .999997 | 47 |
| 840 | 14 | .609853 | 574 | 577 | .609857 | .390143 | 423 | .02 | .999996 | 46 |
| 900 | 15 | .639816 | 573 | 578 | .639820 | .360180 | 422 | .00 | .999996 | 45 |
| 960 | 16 | .667845 | 573 | 578 | .667849 | .332151 | 422 | .02 | .999995 | 44 |
| 1020 | 17 | .694173 | 573 | 578 | .694179 | .305821 | 422 | .00 | .999995 | 43 |
| 1080 | 18 | .718997 | 573 | 579 | .719003 | .280997 | 421 | .02 | .999994 | 42 |
| 1140 | 19 | .742478 | 573 | 579 | .742484 | .257516 | 421 | .02 | .999993 | 41 |
| 1200 | 20 | .764754 | 572 | 580 | .764761 | .235239 | 420 | .00 | .999993 | 40 |
| 1260 | 21 | 7.785943 | 572 | 580 | 7.785951 | 12.214049 | 420 | .02 | 9.999992 | 39 |
| 1320 | 22 | .806146 | 572 | 581 | .806155 | .193845 | 419 | .02 | .999991 | 38 |
| 1380 | 23 | .825451 | 572 | 581 | .825460 | .174540 | 419 | .02 | .999990 | 37 |
| 1440 | 24 | .843934 | 571 | 582 | .843944 | .156056 | 418 | .02 | .999989 | 36 |
| 1500 | 25 | .861662 | 571 | 583 | .861674 | .138326 | 417 | .00 | .999989 | 35 |
| 1560 | 26 | .878695 | 571 | 583 | .878708 | .121292 | 417 | .02 | .999988 | 34 |
| 1620 | 27 | .895085 | 570 | 584 | .895099 | .104901 | 416 | .02 | .999987 | 33 |
| 1680 | 28 | .910879 | 570 | 584 | .910894 | .089106 | 416 | .02 | .999986 | 32 |
| 1740 | 29 | .926119 | 570 | 585 | .926134 | .073866 | 415 | .02 | .999985 | 31 |
| 1800 | 30 | .940842 | 569 | 586 | .940858 | .059142 | 414 | .03 | .999983 | 30 |
| 1860 | 31 | 7.955082 | 569 | 587 | 7.955100 | 12.044900 | 413 | .02 | 9.999982 | 29 |
| 1920 | 32 | .968870 | 569 | 587 | .968889 | .031111 | 413 | .02 | .999981 | 28 |
| 1980 | 33 | .982233 | 568 | 588 | .982253 | .017747 | 412 | .02 | .999980 | 27 |
| 2040 | 34 | 7.995198 | 568 | 589 | 7.995219 | 12.004781 | 411 | .02 | .999979 | 26 |
| 2100 | 35 | 8.007787 | 567 | 590 | 8.007809 | 11.992191 | 410 | .03 | .999977 | 25 |
| 2160 | 36 | .020021 | 567 | 591 | .020044 | .979956 | 409 | .02 | .999976 | 24 |
| 2220 | 37 | .031919 | 566 | 592 | .031945 | .968055 | 408 | .02 | .999975 | 23 |
| 2280 | 38 | .043501 | 566 | 593 | .043527 | .956473 | 407 | .03 | .999973 | 22 |
| 2340 | 39 | .054781 | 566 | 593 | .054809 | .945191 | 407 | .02 | .999972 | 21 |
| 2400 | 40 | .065776 | 565 | 594 | .065806 | .934194 | 406 | .02 | .999971 | 20 |
| 2460 | 41 | 8.076500 | 565 | 595 | 8.076531 | 11.923469 | 405 | .03 | 9.999969 | 19 |
| 2520 | 42 | .086965 | 564 | 596 | .086997 | .913003 | 404 | .02 | .999968 | 18 |
| 2580 | 43 | .097183 | 564 | 598 | .097217 | .902783 | 402 | .03 | .999966 | 17 |
| 2640 | 44 | .107167 | 563 | 599 | .107203 | .892797 | 401 | .03 | .999964 | 16 |
| 2700 | 45 | .116926 | 562 | 600 | .116963 | .883037 | 400 | .02 | .999963 | 15 |
| 2760 | 46 | .126471 | 562 | 601 | .126510 | .873490 | 399 | .03 | .999961 | 14 |
| 2820 | 47 | .135810 | 561 | 602 | .135851 | .864149 | 398 | .03 | .999959 | 13 |
| 2880 | 48 | .144953 | 561 | 603 | .144996 | .855004 | 397 | .02 | .999958 | 12 |
| 2940 | 49 | .153907 | 560 | 604 | .153952 | .846048 | 396 | .03 | .999956 | 11 |
| 3000 | 50 | .162681 | 560 | 605 | .162727 | .837273 | 395 | .03 | .999954 | 10 |
| 3060 | 51 | 8.171280 | 559 | 607 | 8.171328 | 11.828672 | 393 | .03 | 9.999952 | 9 |
| 3120 | 52 | .179713 | 558 | 608 | .179763 | .820237 | 392 | .03 | .999950 | 8 |
| 3180 | 53 | .187985 | 558 | 609 | .188036 | .811964 | 391 | .03 | .999948 | 7 |
| 3240 | 54 | .196102 | 557 | 611 | .196156 | .803844 | 389 | .03 | .999946 | 6 |
| 3300 | 55 | .204070 | 556 | 612 | .204126 | .795874 | 388 | .03 | .999944 | 5 |
| 3360 | 56 | .211895 | 556 | 613 | .211953 | .788047 | 387 | .03 | .999942 | 4 |
| 3420 | 57 | .219581 | 555 | 615 | .219641 | .780359 | 385 | .03 | .999940 | 3 |
| 3480 | 58 | .227134 | 554 | 616 | .227195 | .772805 | 384 | .03 | .999938 | 2 |
| 3540 | 59 | .234557 | 554 | 618 | .234621 | .765379 | 382 | .03 | .999936 | 1 |
| 3600 | 60 | 8.241855 | 553 | 619 | 8.241921 | 11.758079 | 381 | .03 | 9.999934 | 0 |
| | | | 4.685 | | | | 15.314 | | | |
| ″ | ′ | Cosine. | q − l | | Cotang. | Tang. | q + l | D 1″ | Sine. | ′ |

| ″ | ′ | Sine. | q − l | | Tang. | Cotang. | q + l | D 1″ | Cosine. | ′ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4.685 | | | | 15.314 | | | |
| 3600 | 0 | 8.241855 | 553 | 619 | 8.241921 | 11.758079 | 381 | .05 | 9.999934 | 60 |
| 3660 | 1 | .249033 | 552 | 620 | .249102 | .750898 | 380 | .05 | .999932 | 59 |
| 3720 | 2 | .256094 | 551 | 622 | .256165 | .743835 | 378 | .03 | .999929 | 58 |
| 3780 | 3 | 263042 | 551 | 623 | .263115 | .736885 | 377 | .03 | .999927 | 57 |
| 3840 | 4 | .269881 | 550 | 625 | .269956 | .730044 | 375 | .05 | .999925 | 56 |
| 3900 | 5 | .276614 | 549 | 627 | .276691 | .723309 | 373 | .03 | .999922 | 55 |
| 3960 | 6 | .283243 | 548 | 628 | .283323 | .716677 | 372 | .03 | .999920 | 54 |
| 4020 | 7 | .289773 | 547 | 630 | .289856 | .710144 | 370 | .05 | .999918 | 53 |
| 4080 | 8 | .296207 | 546 | 632 | .296292 | .703708 | 368 | .03 | .999915 | 52 |
| 4140 | 9 | .302546 | 546 | 633 | .302634 | .697366 | 367 | .05 | .999913 | 51 |
| 4200 | 10 | .308794 | 545 | 635 | .308884 | 691116 | 365 | | .999910 | 50 |
| 4260 | 11 | 8.314954 | 544 | 637 | 8.315046 | 11.684954 | 363 | .05 | 9.999907 | 49 |
| 4320 | 12 | .321027 | 543 | 638 | .321122 | .678878 | 362 | .03 | .999905 | 48 |
| 4380 | 13 | .327016 | 542 | 640 | .327114 | .672886 | 360 | .05 | .999902 | 47 |
| 4440 | 14 | .332924 | 541 | 642 | .333025 | .666975 | 358 | .05 | .999899 | 46 |
| 4500 | 15 | .338753 | 540 | 644 | .338856 | .661144 | 356 | .03 | .999897 | 45 |
| 4560 | 16 | .344504 | 539 | 646 | .344610 | .655390 | 354 | .05 | .999894 | 44 |
| 4620 | 17 | .350181 | 539 | 648 | .350289 | .649711 | 352 | .05 | .999891 | 43 |
| 4680 | 18 | .355783 | 538 | 649 | .355895 | .644105 | 351 | .05 | .999888 | 42 |
| 4740 | 19 | .361315 | 537 | 651 | .361430 | .638570 | 349 | .05 | .999885 | 41 |
| 4800 | 20 | .366777 | 536 | 653 | .366895 | .633105 | 347 | .05 | .999882 | 40 |
| 4860 | 21 | 8.372171 | 535 | 655 | 8.372292 | 11.627708 | 345 | .05 | 9.999879 | 39 |
| 4920 | 22 | .377499 | 534 | 657 | .377622 | .622378 | 343 | .05 | .999876 | 38 |
| 4980 | 23 | .382762 | 533 | 659 | .382889 | .617111 | 341 | .05 | .999873 | 37 |
| 5040 | 24 | .387962 | 532 | 661 | .388092 | .611908 | 339 | .05 | .999870 | 36 |
| 5100 | 25 | .393101 | 531 | 663 | .393234 | .606766 | 337 | .05 | .999867 | 35 |
| 5160 | 26 | .398179 | 530 | 666 | .398315 | .601685 | 334 | .05 | .999864 | 34 |
| 5220 | 27 | .403199 | 529 | 668 | .403338 | .596662 | 332 | .05 | .999861 | 33 |
| 5280 | 28 | .408161 | 527 | 670 | .408304 | .591696 | 330 | .05 | .999858 | 32 |
| 5340 | 29 | .413068 | 526 | 672 | .413213 | .586787 | 328 | .07 | .999854 | 31 |
| 5400 | 30 | .417919 | 525 | 674 | .418068 | .581932 | 326 | .05 | .999851 | 30 |
| 5460 | 31 | 8.422717 | 524 | 676 | 8.422869 | 11.577131 | 324 | .05 | 9.999848 | 29 |
| 5520 | 32 | .427462 | 523 | 679 | .427618 | .572382 | 321 | .07 | .999844 | 28 |
| 5580 | 33 | .432156 | 522 | 681 | .432315 | .567685 | 319 | .05 | .999841 | 27 |
| 5640 | 34 | .436800 | 521 | 683 | .436962 | .563038 | 317 | .05 | .999838 | 26 |
| 5700 | 35 | .441394 | 520 | 685 | .441560 | .558440 | 315 | .07 | .999834 | 25 |
| 5760 | 36 | .445941 | 518 | 688 | .446110 | .553890 | 312 | .05 | .999831 | 24 |
| 5820 | 37 | .450440 | 517 | 690 | .450613 | .549387 | 310 | .07 | .999827 | 23 |
| 5880 | 38 | .454893 | 516 | 693 | .455070 | .544930 | 307 | .05 | .999824 | 22 |
| 5940 | 39 | .459301 | 515 | 695 | .459481 | .540519 | 305 | .07 | .999820 | 21 |
| 6000 | 40 | .463665 | 514 | 697 | .463849 | .536151 | 303 | .07 | .999816 | 20 |
| 6060 | 41 | 8.467985 | 512 | 700 | 8.468172 | 11.531828 | 300 | .05 | 9.999813 | 19 |
| 6120 | 42 | .472263 | 511 | 702 | .472454 | .527546 | 298 | .07 | .999809 | 18 |
| 6180 | 43 | .476498 | 510 | 705 | .476693 | .523307 | 295 | .07 | .999805 | 17 |
| 6240 | 44 | .480693 | 509 | 707 | .480892 | .519108 | 293 | .07 | .999801 | 16 |
| 6300 | 45 | .484848 | 507 | 710 | .485050 | .514950 | 290 | .07 | .999797 | 15 |
| 6360 | 46 | .488963 | 506 | 713 | .489170 | .510830 | 287 | .05 | .999794 | 14 |
| 6420 | 47 | .493040 | 505 | 715 | .493250 | .506750 | 285 | .07 | .999790 | 13 |
| 6480 | 48 | .497078 | 503 | 718 | .497293 | .502707 | 282 | .07 | .999786 | 12 |
| 6540 | 49 | .501080 | 502 | 720 | .501298 | .498702 | 280 | .07 | .999782 | 11 |
| 6600 | 50 | .505045 | 501 | 723 | .505267 | .494733 | 277 | .07 | .999778 | 10 |
| 6660 | 51 | 8.508974 | 499 | 726 | 8.509200 | 11.490800 | 274 | .07 | 9.999774 | 9 |
| 6720 | 52 | .512867 | 498 | 729 | .513098 | .486902 | 271 | .08 | .999769 | 8 |
| 6780 | 53 | .516726 | 497 | 731 | .516961 | .483039 | 269 | .07 | .999765 | 7 |
| 6840 | 54 | .520551 | 495 | 734 | .520790 | .479210 | 266 | .07 | .999761 | 6 |
| 6900 | 55 | .524343 | 494 | 737 | 524586 | .475414 | 263 | .07 | .999757 | 5 |
| 6960 | 56 | .528102 | 492 | 740 | .528349 | .471651 | 260 | .07 | .999753 | 4 |
| 7020 | 57 | .531828 | 491 | 743 | .532080 | .467920 | 257 | .08 | .999748 | 3 |
| 7080 | 58 | .535523 | 490 | 745 | .535779 | .464221 | 255 | .07 | .999744 | 2 |
| 7140 | 59 | .539186 | 488 | 748 | .539447 | .460553 | 252 | .07 | .999740 | 1 |
| 7200 | 60 | 8.542819 | 487 | 751 | 8.543084 | 11.456916 | 249 | .08 | 9.999735 | 0 |
| | | | 4.685 | | | | 15.314 | | | |
| ″ | ′ | Cosine. | q − l | | Cotang. | Tang. | q + l | D 1″ | Sine. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 8 542819 | 60.05 | 9.999735 | .07 | 8.543084 | 60.12 | 11.456916 | 60 |
| 1 | .546422 | 59.55 | .999731 | .08 | .546691 | 59.62 | .453309 | 59 |
| 2 | .549995 | 59.07 | .999726 | .07 | .550268 | 59.15 | .449732 | 58 |
| 3 | .553539 | 58.58 | .999722 | .08 | .553817 | 58.65 | .446183 | 57 |
| 4 | .557054 | 58.10 | .999717 | .07 | .557336 | 58.20 | .442664 | 56 |
| 5 | .560540 | 57.65 | .999713 | .08 | .560828 | 57.72 | .439172 | 55 |
| 6 | .563999 | 57.20 | .999708 | .07 | .564291 | 57.27 | .435709 | 54 |
| 7 | .567431 | 56.75 | .999704 | .08 | .567727 | 56.83 | .432273 | 53 |
| 8 | .570836 | 56.30 | .999699 | .08 | .571137 | 56.38 | .428863 | 52 |
| 9 | .574214 | 55.87 | .999694 | .08 | .574520 | 55.95 | .425480 | 51 |
| 10 | .577566 | 55.43 | .999689 | .07 | .577877 | 55.52 | .422123 | 50 |
| 11 | 8.580892 | 55.02 | 9.999685 | .08 | 8.581208 | 55.10 | 11.418792 | 49 |
| 12 | .584193 | 54.60 | .999680 | .08 | .584514 | 54.68 | .415486 | 48 |
| 13 | .587469 | 54.20 | .999675 | .08 | .587795 | 54.27 | .412205 | 47 |
| 14 | .590721 | 53.78 | .999670 | .08 | .591051 | 53.87 | .408949 | 46 |
| 15 | .593948 | 53.40 | .999665 | .08 | .594283 | 53.48 | .405717 | 45 |
| 16 | .597152 | 53.00 | .999660 | .08 | .597492 | 53.08 | .402508 | 44 |
| 17 | .600332 | 52.62 | .999655 | .08 | .600677 | 52.70 | .399323 | 43 |
| 18 | .603489 | 52.23 | .999650 | .08 | .603839 | 52.32 | .396161 | 42 |
| 19 | .606623 | 51.85 | .999645 | .08 | .606978 | 51.93 | .393022 | 41 |
| 20 | .609734 | 51.48 | .999640 | .08 | .610094 | 51.58 | .389906 | 40 |
| 21 | 8.612823 | 51.13 | 9.999635 | .10 | 8.613189 | 51.22 | 11.386811 | 39 |
| 22 | .615891 | 50.77 | .999629 | .08 | .616262 | 50.85 | .383738 | 38 |
| 23 | .618937 | 50.42 | .999624 | .08 | .619313 | 50.50 | .380687 | 37 |
| 24 | .621962 | 50.05 | .999619 | .08 | .622343 | 50.15 | .377657 | 36 |
| 25 | .624965 | 49.72 | .999614 | .10 | .625352 | 49.80 | .374648 | 35 |
| 26 | .627948 | 49.38 | .999608 | .08 | .628340 | 49.47 | .371660 | 34 |
| 27 | .630911 | 49.05 | .999603 | .10 | .631308 | 49.13 | .368692 | 33 |
| 28 | .633854 | 48.70 | .999597 | .08 | .634256 | 48.80 | .365744 | 32 |
| 29 | .636776 | 48.40 | .999592 | .10 | .637184 | 48.48 | .362816 | 31 |
| 30 | .639680 | 48.05 | .999586 | .08 | .640093 | 48.15 | .359907 | 30 |
| 31 | 8.642563 | 47.75 | 9.999581 | .10 | 8.642982 | 47.85 | 11.357018 | 29 |
| 32 | .645428 | 47.43 | .999575 | .08 | .645853 | 47.52 | .354147 | 28 |
| 33 | .648274 | 47.13 | .999570 | .10 | .648704 | 47.22 | .351296 | 27 |
| 34 | .651102 | 46.82 | .999564 | .10 | .651537 | 46.92 | .348463 | 26 |
| 35 | .653911 | 46.52 | .999558 | .08 | .654352 | 46.62 | .345648 | 25 |
| 36 | .656702 | 46.22 | .999553 | .10 | .657149 | 46.32 | .342851 | 24 |
| 37 | .659475 | 45.92 | .999547 | .10 | .659928 | 46.02 | .340072 | 23 |
| 38 | .662230 | 45.63 | .999541 | .10 | .662689 | 45.73 | .337311 | 22 |
| 39 | .664968 | 45.35 | .999535 | .10 | .665433 | 45.45 | .334567 | 21 |
| 40 | .667689 | 45.07 | .999529 | .08 | .668160 | 45.17 | .331840 | 20 |
| 41 | 8.670393 | 44.78 | 9.999524 | .10 | 8.670870 | 44.88 | 11.329130 | 19 |
| 42 | .673080 | 44.52 | .999518 | .10 | .673563 | 44.60 | .326437 | 18 |
| 43 | .675751 | 44.23 | .999512 | .10 | .676239 | 44.35 | .323761 | 17 |
| 44 | .678405 | 43.97 | .999506 | .10 | .678900 | 44.07 | .321100 | 16 |
| 45 | .681043 | 43.70 | .999500 | .12 | .681544 | 43.80 | .318456 | 15 |
| 46 | .683665 | 43.45 | .999493 | .10 | .684172 | 43.53 | .315828 | 14 |
| 47 | .686272 | 43.18 | .999487 | .10 | .686784 | 43.28 | .313216 | 13 |
| 48 | .688863 | 42.92 | .999481 | .10 | .689381 | 43.03 | .310619 | 12 |
| 49 | .691438 | 42.67 | .999475 | .10 | .691963 | 42.77 | .308037 | 11 |
| 50 | .693998 | 42.42 | .999469 | .10 | .694529 | 42.53 | .305471 | 10 |
| 51 | 8.696543 | 42.17 | 9.999463 | .12 | 8.697081 | 42.27 | 11.302919 | 9 |
| 52 | .699073 | 41.93 | .999456 | .10 | .699617 | 42.03 | .300383 | 8 |
| 53 | .701589 | 41.68 | .999450 | .12 | .702139 | 41.78 | .297861 | 7 |
| 54 | .704090 | 41.45 | .999443 | .10 | .704646 | 41.57 | .295354 | 6 |
| 55 | .706577 | 41.20 | .999437 | .10 | .707140 | 41.30 | .292860 | 5 |
| 56 | .709049 | 40.97 | .999431 | .12 | .709618 | 41.08 | .290382 | 4 |
| 57 | .711507 | 40.75 | .999424 | .10 | .712083 | 40.85 | .287917 | 3 |
| 58 | .713952 | 40.52 | .999418 | .12 | .714534 | 40.63 | .285466 | 2 |
| 59 | .716383 | 40.28 | .999411 | .12 | .716972 | 40.40 | .283028 | 1 |
| 60 | 8.718800 | | 9.999404 | | 8.719396 | | 11.280604 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 8.718800 | 40.07 | 9.999404 | .10 | 8.719396 | 40.17 | 11.280604 | 60 |
| 1 | .721204 | 39.85 | .999398 | .12 | .721806 | 39.97 | .278194 | 59 |
| 2 | .723595 | 39.62 | .999391 | .12 | .724204 | 39.73 | .275796 | 58 |
| 3 | .725972 | 39.42 | .999384 | .10 | .726588 | 39.52 | .273412 | 57 |
| 4 | .728337 | 39.18 | .999378 | .12 | .728959 | 39.30 | .271041 | 56 |
| 5 | .730688 | 38.98 | .999371 | .12 | .731317 | 39.10 | .268683 | 55 |
| 6 | .733027 | 38.78 | .999364 | .12 | .733663 | 38.88 | .266337 | 54 |
| 7 | .735354 | 38.55 | .999357 | .12 | .735996 | 38.68 | .264004 | 53 |
| 8 | .737667 | 38.37 | .999350 | .12 | .738317 | 38.48 | .261683 | 52 |
| 9 | .739969 | 38.17 | .999343 | .12 | .740626 | 38.27 | .259374 | 51 |
| 10 | .742259 | 37.95 | .999336 | .12 | .742922 | 38.08 | .257078 | 50 |
| 11 | 8.744536 | 37.77 | 9.999329 | .12 | 8.745207 | 37.87 | 11.254793 | 49 |
| 12 | .746802 | 37.55 | .999322 | .12 | .747479 | 37.68 | .252521 | 48 |
| 13 | .749055 | 37.37 | .999315 | .12 | .749740 | 37.48 | .250260 | 47 |
| 14 | .751297 | 37.18 | .999308 | .12 | .751989 | 37.30 | .248011 | 46 |
| 15 | .753528 | 36.98 | .999301 | .12 | .754227 | 37.10 | .245773 | 45 |
| 16 | .755747 | 36.80 | .999294 | .12 | .756453 | 36.92 | .243547 | 44 |
| 17 | .757955 | 36.60 | .999287 | .13 | .758668 | 36.73 | .241332 | 43 |
| 18 | .760151 | 36.43 | .999279 | .12 | .760872 | 36.55 | .239128 | 42 |
| 19 | .762337 | 36.23 | .999272 | .12 | .763065 | 36.35 | .236935 | 41 |
| 20 | .764511 | 36.07 | .999265 | .13 | .765246 | 36.18 | .234754 | 40 |
| 21 | 8.766675 | 35.88 | 9.999257 | .12 | 8.767417 | 36.02 | 11.232583 | 39 |
| 22 | .768828 | 35.70 | .999250 | .13 | .769578 | 35.82 | .230422 | 38 |
| 23 | .770970 | 35.52 | .999242 | .12 | .771727 | 35.65 | .228273 | 37 |
| 24 | .773101 | 35.37 | .999235 | .13 | .773866 | 35.48 | .226134 | 36 |
| 25 | .775223 | 35.17 | .999227 | .12 | .775995 | 35.32 | .224005 | 35 |
| 26 | .777333 | 35.02 | .999220 | .13 | .778114 | 35.13 | .221886 | 34 |
| 27 | .779434 | 34.83 | .999212 | .12 | .780222 | 34.97 | .219778 | 33 |
| 28 | .781524 | 34.68 | .999205 | .13 | .782320 | 34.80 | .217680 | 32 |
| 29 | .783605 | 34.50 | .999197 | .13 | .784408 | 34.63 | .215592 | 31 |
| 30 | .785675 | 34.35 | .999189 | .13 | .786486 | 34.47 | .213514 | 30 |
| 31 | 8.787736 | 34.18 | 9.999181 | .12 | 8.788554 | 34.32 | 11.211446 | 29 |
| 32 | .789787 | 34.02 | .999174 | .13 | .790613 | 34.15 | .209387 | 28 |
| 33 | .791828 | 33.85 | .999166 | .13 | .792662 | 33.98 | .207338 | 27 |
| 34 | .793859 | 33.70 | .999158 | .13 | .794701 | 33.83 | .205299 | 26 |
| 35 | .795881 | 33.55 | .999150 | .13 | .796731 | 33.68 | .203269 | 25 |
| 36 | .797894 | 33.38 | .999142 | .13 | .798752 | 33.52 | .201248 | 24 |
| 37 | .799897 | 33.25 | .999134 | .13 | .800763 | 33.37 | .199237 | 23 |
| 38 | .801892 | 33.07 | .999126 | .13 | .802765 | 33.22 | .197235 | 22 |
| 39 | .803876 | 32.93 | .999118 | .13 | .804758 | 33.07 | .195242 | 21 |
| 40 | .805852 | 32.78 | .999110 | .13 | .806742 | 32.92 | .193258 | 20 |
| 41 | 8.807819 | 32.63 | 9.999102 | .13 | 8.808717 | 32.77 | 11.191283 | 19 |
| 42 | .809777 | 32.48 | .999094 | .13 | .810683 | 32.63 | .189317 | 18 |
| 43 | .811726 | 32.35 | .999086 | .15 | .812641 | 32.47 | .187359 | 17 |
| 44 | .813667 | 32.20 | .999077 | .13 | .814589 | 32.33 | .185411 | 16 |
| 45 | .815599 | 32.05 | .999069 | .13 | .816529 | 32.20 | .183471 | 15 |
| 46 | .817522 | 31.90 | .999061 | .13 | .818461 | 32.05 | .181539 | 14 |
| 47 | .819436 | 31.78 | .999053 | .15 | .820384 | 31.90 | .179616 | 13 |
| 48 | .821343 | 31.62 | .999044 | .13 | .822298 | 31.78 | .177702 | 12 |
| 49 | .823240 | 31.50 | .999036 | .15 | .824205 | 31.63 | .175795 | 11 |
| 50 | .825130 | 31.35 | .999027 | .13 | .826103 | 31.48 | .173897 | 10 |
| 51 | 8.827011 | 31.22 | 9.999019 | .15 | 8.827992 | 31.37 | 11.172008 | 9 |
| 52 | .828884 | 31.08 | .999010 | .13 | .829874 | 31.23 | .170126 | 8 |
| 53 | .830749 | 30.97 | .999002 | .15 | .831748 | 31.08 | .168252 | 7 |
| 54 | .832607 | 30.82 | .998993 | .15 | .833613 | 30.97 | .166387 | 6 |
| 55 | .834456 | 30.68 | .998984 | .13 | .835471 | 30.83 | .164529 | 5 |
| 56 | .836297 | 30.55 | .998976 | .15 | .837321 | 30.70 | .162679 | 4 |
| 57 | .838130 | 30.43 | .998967 | .15 | .839163 | 30.58 | .160837 | 3 |
| 58 | .839956 | 30.30 | .998958 | .13 | .840998 | 30.45 | .159002 | 2 |
| 59 | .841774 | 30.18 | .998950 | .15 | .842825 | 30.32 | .157175 | 1 |
| 60 | 8.843585 | | 9.998941 | | 8.844644 | | 11.155356 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 8.843585 | 30.03 | 9.998941 | .15 | 8.844644 | 30.18 | 11.155356 | 60 |
| 1 | .845387 | 29.93 | .998932 | .15 | .846455 | 30.08 | .153545 | 59 |
| 2 | .847183 | 29.80 | .998923 | .15 | .848260 | 29.95 | .151740 | 58 |
| 3 | .848971 | 29.67 | .998914 | .15 | .850057 | 29.82 | .149943 | 57 |
| 4 | .850751 | 29.57 | .998905 | .15 | .851846 | 29.70 | .148154 | 56 |
| 5 | .852525 | 29.43 | .998896 | .15 | .853628 | 29.58 | .146372 | 55 |
| 6 | .854291 | 29.30 | .998887 | .15 | .855403 | 29.47 | .144597 | 54 |
| 7 | .856049 | 29.20 | .998878 | .15 | .857171 | 29.35 | .142829 | 53 |
| 8 | .857801 | 29.08 | .998869 | .15 | .858932 | 29.23 | .141068 | 52 |
| 9 | .859546 | 28.95 | .998860 | .15 | .860686 | 29.12 | .139314 | 51 |
| 10 | .861283 | 28.85 | .998851 | .17 | .862433 | 29.00 | .137567 | 50 |
| 11 | 8.863014 | 28.73 | 9.998841 | .15 | 8.864173 | 28.88 | 11.135827 | 49 |
| 12 | .864738 | 28.62 | .998832 | .15 | .865906 | 28.77 | .134094 | 48 |
| 13 | .866455 | 28.50 | .998823 | .17 | .867632 | 28.65 | .132368 | 47 |
| 14 | .868165 | 28.38 | .998813 | .15 | .869351 | 28.55 | .130649 | 46 |
| 15 | .869868 | 28.28 | .998804 | .15 | .871064 | 28.43 | .128936 | 45 |
| 16 | .871565 | 28.17 | .998795 | .17 | .872770 | 28.32 | .127230 | 44 |
| 17 | .873255 | 28.05 | .998785 | .15 | .874469 | 28.22 | .125531 | 43 |
| 18 | .874938 | 27.95 | .998776 | .17 | .876162 | 28.12 | .123838 | 42 |
| 19 | .876615 | 27.83 | .998766 | .15 | .877849 | 28.00 | .122151 | 41 |
| 20 | .878285 | 27.73 | .998757 | .17 | .879529 | 27.88 | .120471 | 40 |
| 21 | 8.879949 | 27.63 | 9.998747 | .15 | 8.881202 | 27.78 | 11.118798 | 39 |
| 22 | .881607 | 27.52 | .998738 | .17 | .882869 | 27.68 | .117131 | 38 |
| 23 | .883258 | 27.42 | .998728 | .17 | .884530 | 27.58 | .115470 | 37 |
| 24 | .884903 | 27.32 | .998718 | .17 | .886185 | 27.47 | .113815 | 36 |
| 25 | .886542 | 27.20 | .998708 | .15 | .887833 | 27.38 | .112167 | 35 |
| 26 | .888174 | 27.12 | .998699 | .17 | .889476 | 27.27 | .110524 | 34 |
| 27 | .889801 | 27.00 | .998689 | .17 | .891112 | 27.17 | .108888 | 33 |
| 28 | .891421 | 26.90 | .998679 | .17 | .892742 | 27.07 | .107258 | 32 |
| 29 | .893035 | 26.80 | .998669 | .17 | .894366 | 26.97 | .105634 | 31 |
| 30 | .894643 | 26.72 | .998659 | .17 | .895984 | 26.87 | .104016 | 30 |
| 31 | 8.896246 | 26.60 | 9.998649 | .17 | 8.897596 | 26.78 | 11.102404 | 29 |
| 32 | .897842 | 26.50 | .998639 | .17 | .899203 | 26.67 | .100797 | 28 |
| 33 | .899432 | 26.42 | .998629 | .17 | .900803 | 26.58 | .099197 | 27 |
| 34 | .901017 | 26.32 | .998619 | .17 | .902398 | 26.48 | .097602 | 26 |
| 35 | .902596 | 26.22 | .998609 | .17 | .903987 | 26.38 | .096013 | 25 |
| 36 | .904169 | 26.12 | .998599 | .17 | .905570 | 26.28 | .094430 | 24 |
| 37 | .905736 | 26.02 | .998589 | .18 | .907147 | 26.20 | .092853 | 23 |
| 38 | .907297 | 25.93 | .998578 | .17 | .908719 | 26.10 | .091281 | 22 |
| 39 | .908853 | 25.85 | .998568 | .17 | .910285 | 26.02 | .089715 | 21 |
| 40 | .910404 | 25.75 | .998558 | .17 | .911846 | 25.92 | .088154 | 20 |
| 41 | 8.911949 | 25.65 | 9.998548 | .18 | 8.913401 | 25.83 | 11.086599 | 19 |
| 42 | .913488 | 25.57 | .998537 | .17 | .914951 | 25.73 | .085049 | 18 |
| 43 | .915022 | 25.47 | .998527 | .18 | .916495 | 25.63 | .083505 | 17 |
| 44 | .916550 | 25.38 | .998516 | .17 | .918034 | 25.57 | .081966 | 16 |
| 45 | .918073 | 25.30 | .998506 | .18 | .919568 | 25.47 | .080432 | 15 |
| 46 | .919591 | 25.20 | .998495 | .17 | .921096 | 25.38 | .078904 | 14 |
| 47 | .921103 | 25.12 | .998485 | .18 | .922619 | 25.28 | .077381 | 13 |
| 48 | .922610 | 25.03 | .998474 | .17 | .924136 | 25.22 | .075864 | 12 |
| 49 | .924112 | 24.95 | .998464 | .18 | .925649 | 25.12 | .074351 | 11 |
| 50 | .925609 | 24.85 | .998453 | .18 | .927156 | 25.03 | .072844 | 10 |
| 51 | 8.927100 | 24.78 | 9.998442 | .18 | 8.928658 | 24.95 | 11.071342 | 9 |
| 52 | .928587 | 24.68 | .998431 | .17 | .930155 | 24.87 | .069845 | 8 |
| 53 | .930068 | 24.60 | .998421 | .18 | .931647 | 24.78 | .068353 | 7 |
| 54 | .931544 | 24.52 | .998410 | .18 | .933134 | 24.70 | .066866 | 6 |
| 55 | .933015 | 24.43 | .998399 | .18 | .934616 | 24.62 | .065384 | 5 |
| 56 | .934481 | 24.35 | .998388 | .18 | .936093 | 24.53 | .063907 | 4 |
| 57 | .935942 | 24.27 | .998377 | .18 | .937565 | 24.45 | .062435 | 3 |
| 58 | .937398 | 24.20 | .998366 | .18 | .939032 | 24.37 | .060968 | 2 |
| 59 | .938850 | 24.10 | .998355 | .18 | .940494 | 24.30 | .059506 | 1 |
| 60 | 8.940296 | | 9.998344 | | 8.941952 | | 11.058048 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 8.940296 | 24.03 | 9.998344 | .18 | 8.941952 | 24.20 | 11.058048 | 60 |
| 1 | .941738 | 23.93 | .998333 | .18 | .943404 | 24.13 | .056596 | 59 |
| 2 | .943174 | 23.87 | .998322 | .18 | .944852 | 24.05 | .055148 | 58 |
| 3 | .944606 | 23.80 | .998311 | .18 | .946295 | 23.98 | .053705 | 57 |
| 4 | .946034 | 23.70 | .998300 | .18 | .947734 | 23.90 | .052266 | 56 |
| 5 | .947456 | 23.63 | .998289 | .20 | .949168 | 23.82 | .050832 | 55 |
| 6 | .948874 | 23.55 | .998277 | .18 | .950597 | 23.73 | .049403 | 54 |
| 7 | .950287 | 23.48 | .998266 | .18 | .952021 | 23.67 | .047979 | 53 |
| 8 | .951696 | 23.40 | .998255 | .20 | .953441 | 23.58 | .046559 | 52 |
| 9 | .953100 | 23.32 | .998243 | .18 | .954856 | 23.52 | .045144 | 51 |
| 10 | .954499 | 23.25 | .998232 | .20 | .956267 | 23.45 | .043733 | 50 |
| 11 | 8.955894 | 23.17 | 9.998220 | .18 | 8.957674 | 23.35 | 11.042326 | 49 |
| 12 | .957284 | 23.10 | .998209 | .20 | .959075 | 23.30 | .040925 | 48 |
| 13 | .958670 | 23.03 | .998197 | .18 | .960473 | 23.22 | .039527 | 47 |
| 14 | .960052 | 22.95 | .998186 | .20 | .961866 | 23.15 | .038134 | 46 |
| 15 | .961429 | 22.87 | .998174 | .18 | .963255 | 23.07 | .036745 | 45 |
| 16 | .962801 | 22.82 | .998163 | .20 | .964639 | 23.00 | .035361 | 44 |
| 17 | .964170 | 22.73 | .998151 | .20 | .966019 | 22.92 | .033981 | 43 |
| 18 | .965534 | 22.65 | .998139 | .18 | .967394 | 22.87 | .032606 | 42 |
| 19 | .966893 | 22.60 | .998128 | .20 | .968766 | 22.78 | .031234 | 41 |
| 20 | .968249 | 22.52 | .998116 | .20 | .970133 | 22.72 | .029867 | 40 |
| 21 | 8.969600 | 22.45 | 9.998104 | .20 | 8.971496 | 22.65 | 11.028504 | 39 |
| 22 | .970947 | 22.37 | .998092 | .20 | .972855 | 22.57 | .027145 | 38 |
| 23 | .972289 | 22.32 | .998080 | .20 | .974209 | 22.52 | .025791 | 37 |
| 24 | .973628 | 22.23 | .998068 | .20 | .975560 | 22.43 | .024440 | 36 |
| 25 | .974962 | 22.18 | .998056 | .20 | .976906 | 22.37 | .023094 | 35 |
| 26 | .976293 | 22.10 | .998044 | .20 | .978248 | 22.30 | .021752 | 34 |
| 27 | .977619 | 22.03 | .998032 | .20 | .979586 | 22.25 | .020414 | 33 |
| 28 | .978941 | 21.97 | .998020 | .20 | .980921 | 22.17 | .019079 | 32 |
| 29 | .980259 | 21.90 | .998008 | .20 | .982251 | 22.10 | .017749 | 31 |
| 30 | .981573 | 21.83 | .997996 | .20 | .983577 | 22.03 | .016423 | 30 |
| 31 | 8.982883 | 21.77 | 9.997984 | .20 | 8.984899 | 21.97 | 11.015101 | 29 |
| 32 | .984189 | 21.72 | .997972 | .22 | .986217 | 21.92 | .013783 | 28 |
| 33 | .985491 | 21.63 | .997959 | .20 | .987532 | 21.83 | .012468 | 27 |
| 34 | .986789 | 21.57 | .997947 | .20 | .988842 | 21.78 | .011158 | 26 |
| 35 | .988083 | 21.52 | .997935 | .22 | .990149 | 21.70 | .009851 | 25 |
| 36 | .989374 | 21.43 | .997922 | .20 | .991451 | 21.65 | .008549 | 24 |
| 37 | .990660 | 21.38 | .997910 | .22 | .992750 | 21.58 | .007250 | 23 |
| 38 | .991943 | 21.32 | .997897 | .20 | .994045 | 21.53 | .005955 | 22 |
| 39 | .993222 | 21.25 | .997885 | .22 | .995337 | 21.45 | .004663 | 21 |
| 40 | .994497 | 21.18 | .997872 | .20 | .996624 | 21.40 | .003376 | 20 |
| 41 | 8.995768 | 21.13 | 9.997860 | .22 | 8.997908 | 21.33 | 11.002092 | 19 |
| 42 | .997036 | 21.05 | .997847 | .20 | 8.999188 | 21.28 | 11.000812 | 18 |
| 43 | .998299 | 21.02 | .997835 | .22 | 9.000465 | 21.22 | 10.999535 | 17 |
| 44 | 8.999560 | 20.93 | .997822 | .22 | .001738 | 21.15 | .998262 | 16 |
| 45 | 9.000816 | 20.88 | .997809 | .20 | .003007 | 21.08 | .996993 | 15 |
| 46 | .002069 | 20.82 | .997797 | .22 | .004272 | 21.03 | .995728 | 14 |
| 47 | .003318 | 20.75 | .997784 | .22 | .005534 | 20.97 | .994466 | 13 |
| 48 | .004563 | 20.70 | .997771 | .22 | .006792 | 20.92 | .993208 | 12 |
| 49 | .005805 | 20.65 | .997758 | .22 | .008047 | 20.85 | .991953 | 11 |
| 50 | .007044 | 20.57 | .997745 | .22 | .009298 | 20.80 | .990702 | 10 |
| 51 | 9.008278 | 20.53 | 9.997732 | .22 | 9.010546 | 20.73 | 10.989454 | 9 |
| 52 | .009510 | 20.45 | .997719 | .22 | .011790 | 20.68 | .988210 | 8 |
| 53 | .010737 | 20.42 | .997706 | .22 | .013031 | 20.62 | .986969 | 7 |
| 54 | .011962 | 20.33 | .997693 | .22 | .014268 | 20.57 | .985732 | 6 |
| 55 | .013182 | 20.30 | .997680 | .22 | .015502 | 20.50 | .984498 | 5 |
| 56 | .014400 | 20.22 | .997667 | .22 | .016732 | 20.45 | .983268 | 4 |
| 57 | .015613 | 20.18 | .997654 | .22 | .017959 | 20.40 | .982041 | 3 |
| 58 | .016824 | 20.12 | .997641 | .22 | .019183 | 20.33 | .980817 | 2 |
| 59 | .018031 | 20.07 | .997628 | .23 | .020403 | 20.28 | .979597 | 1 |
| 60 | 9.019235 | | 9.997614 | | 9.021620 | | 10.978380 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.019235 | 20.00 | 9.997614 | .22 | 9.021620 | 20.23 | 10.978380 | 60 |
| 1 | .020435 | 19.95 | .997601 | .22 | .022834 | 20.17 | .977166 | 59 |
| 2 | .021632 | 19.88 | .997588 | .23 | .024044 | 20.12 | .975956 | 58 |
| 3 | .022825 | 19.85 | .997574 | .22 | .025251 | 20.07 | .974749 | 57 |
| 4 | .024016 | 19.78 | .997561 | .23 | .026455 | 20.00 | .973545 | 56 |
| 5 | .025203 | 19.72 | .997547 | .22 | .027655 | 19.95 | .972345 | 55 |
| 6 | .026386 | 19.68 | .997534 | .23 | .028852 | 19.90 | .971148 | 54 |
| 7 | .027567 | 19.62 | .997520 | .22 | .030046 | 19.85 | .969954 | 53 |
| 8 | .028744 | 19.57 | .997507 | .23 | .031237 | 19.80 | .968763 | 52 |
| 9 | .029918 | 19.52 | .997493 | .22 | .032425 | 19.73 | .967575 | 51 |
| 10 | .031089 | 19.47 | .997480 | .23 | .033609 | 19.70 | .966391 | 50 |
| 11 | 9.032257 | 19.40 | 9.997466 | .23 | 9.034791 | 19.63 | 10.965209 | 49 |
| 12 | .033421 | 19.35 | .997452 | .22 | .035969 | 19.58 | .964031 | 48 |
| 13 | .034582 | 19.32 | .997439 | .23 | .037144 | 19.53 | .962856 | 47 |
| 14 | .035741 | 19.25 | .997425 | .23 | .038316 | 19.48 | .961684 | 46 |
| 15 | .036896 | 19.20 | .997411 | .23 | .039485 | 19.43 | .960515 | 45 |
| 16 | .038048 | 19.15 | .997397 | .23 | .040651 | 19.37 | .959349 | 44 |
| 17 | .039197 | 19.08 | .997383 | .23 | .041813 | 19.33 | .958187 | 43 |
| 18 | .040342 | 19.05 | .997369 | .23 | .042973 | 19.28 | .957027 | 42 |
| 19 | .041485 | 19.00 | .997355 | .23 | .044130 | 19.23 | .955870 | 41 |
| 20 | .042625 | 18.95 | .997341 | .23 | .045284 | 19.17 | .954716 | 40 |
| 21 | 9.043762 | 18.88 | 9.997327 | .23 | 9.046434 | 19.13 | 10.953566 | 39 |
| 22 | .044895 | 18.85 | .997313 | .23 | .047582 | 19.08 | .952418 | 38 |
| 23 | .046026 | 18.80 | .997299 | .23 | .048727 | 19.03 | .951273 | 37 |
| 24 | .047154 | 18.75 | .997285 | .23 | .049869 | 18.98 | .950131 | 36 |
| 25 | .048279 | 18.68 | .997271 | .23 | .051008 | 18.93 | .948992 | 35 |
| 26 | .049400 | 18.65 | .997257 | .25 | .052144 | 18.88 | .947856 | 34 |
| 27 | .050519 | 18.60 | .997242 | .23 | .053277 | 18.83 | .946723 | 33 |
| 28 | .051635 | 18.57 | .997228 | .23 | .054407 | 18.80 | .945593 | 32 |
| 29 | .052749 | 18.50 | .997214 | .25 | .055535 | 18.73 | .944465 | 31 |
| 30 | .053859 | 18.45 | .997199 | .23 | .056659 | 18.70 | .943341 | 30 |
| 31 | 9.054966 | 18.42 | 9.997185 | .25 | 9.057781 | 18.65 | 10.942219 | 29 |
| 32 | .056071 | 18.35 | .997170 | .23 | .058900 | 18.60 | .941100 | 28 |
| 33 | .057172 | 18.32 | .997156 | .25 | .060016 | 18.57 | .939984 | 27 |
| 34 | .058271 | 18.27 | .997141 | .23 | .061130 | 18.50 | .938870 | 26 |
| 35 | .059367 | 18.22 | .997127 | .25 | .062240 | 18.47 | .937760 | 25 |
| 36 | .060460 | 18.18 | .997112 | .23 | .063348 | 18.42 | .936652 | 24 |
| 37 | .061551 | 18.13 | .997098 | .25 | .064453 | 18.38 | .935547 | 23 |
| 38 | .062639 | 18.08 | .997083 | .25 | .065556 | 18.32 | .934444 | 22 |
| 39 | .063724 | 18.03 | .997068 | .25 | .066655 | 18.28 | .933345 | 21 |
| 40 | .064806 | 17.98 | .997053 | .23 | .067752 | 18.25 | .932248 | 20 |
| 41 | 9.065885 | 17.95 | 9.997039 | .25 | 9.068846 | 18.20 | 10.931154 | 19 |
| 42 | .066962 | 17.90 | .997024 | .25 | .069938 | 18.15 | .930062 | 18 |
| 43 | .068036 | 17.85 | .997009 | .25 | .071027 | 18.10 | .928973 | 17 |
| 44 | .069107 | 17.82 | .996994 | .25 | .072113 | 18.07 | .927887 | 16 |
| 45 | .070176 | 17.77 | .996979 | .25 | .073197 | 18.02 | .926803 | 15 |
| 46 | .071242 | 17.73 | .996964 | .25 | .074278 | 17.97 | .925722 | 14 |
| 47 | .072306 | 17.67 | .996949 | .25 | .075356 | 17.93 | .924644 | 13 |
| 48 | .073366 | 17.63 | .996934 | .25 | .076432 | 17.88 | .923568 | 12 |
| 49 | .074424 | 17.60 | .996919 | .25 | .077505 | 17.85 | .922495 | 11 |
| 50 | .075480 | 17.55 | .996904 | .25 | .078576 | 17.80 | .921424 | 10 |
| 51 | 9.076533 | 17.50 | 9.996889 | .25 | 9.079644 | 17.77 | 10.920356 | 9 |
| 52 | .077583 | 17.47 | .996874 | .27 | .080710 | 17.72 | .919290 | 8 |
| 53 | .078631 | 17.42 | .996858 | .25 | .081773 | 17.67 | .918227 | 7 |
| 54 | .079676 | 17.38 | .996843 | .27 | .082833 | 17.63 | .917167 | 6 |
| 55 | .080719 | 17.33 | .996828 | .27 | .083891 | 17.60 | .916109 | 5 |
| 56 | .081759 | 17.30 | .996812 | .25 | .084947 | 17.55 | .915053 | 4 |
| 57 | .082797 | 17.25 | .996797 | .25 | .086000 | 17.50 | .914000 | 3 |
| 58 | .083832 | 17.20 | .996782 | .27 | .087050 | 17.47 | .912950 | 2 |
| 59 | .084864 | 17.17 | .996766 | .25 | .088098 | 17.43 | .911902 | 1 |
| 60 | 9.085894 | | 9.996751 | | 9.089144 | | 10.910856 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.085894 | 17.13 | 9.996751 | .27 | 9.089144 | 17.38 | 10.910856 | 60 |
| 1 | .086922 | 17.08 | .996735 | .25 | .090187 | 17.35 | .909813 | 59 |
| 2 | .087947 | 17.05 | .996720 | .27 | .091228 | 17.30 | .908772 | 58 |
| 3 | .088970 | 17.00 | .996704 | .27 | .092266 | 17.27 | .907734 | 57 |
| 4 | .089990 | 16.97 | .996688 | .25 | .093302 | 17.23 | .906698 | 56 |
| 5 | .091008 | 16.93 | .996673 | .27 | .094336 | 17.18 | .905664 | 55 |
| 6 | .092024 | 16.88 | .996657 | .27 | .095367 | 17.13 | .904633 | 54 |
| 7 | .093037 | 16.83 | .996641 | .27 | .096395 | 17.12 | .903605 | 53 |
| 8 | .094047 | 16.82 | .996625 | .25 | .097422 | 17.07 | .902578 | 52 |
| 9 | .095056 | 16.77 | .996610 | .27 | .098446 | 17.03 | .901554 | 51 |
| 10 | .096062 | 16.72 | .996594 | .27 | .099468 | 16.98 | .900532 | 50 |
| 11 | 9.097065 | 16.68 | 9.996578 | .27 | 9.100487 | 16.95 | 10.899513 | 49 |
| 12 | .098066 | 16.65 | .996562 | .27 | .101504 | 16.92 | .898496 | 48 |
| 13 | .099065 | 16.62 | .996546 | .27 | .102519 | 16.88 | .897481 | 47 |
| 14 | .100062 | 16.57 | .996530 | .27 | .103532 | 16.83 | .896468 | 46 |
| 15 | .101056 | 16.53 | .996514 | .27 | .104542 | 16.80 | .895458 | 45 |
| 16 | .102048 | 16.48 | .996498 | .27 | .105550 | 16.77 | .894450 | 44 |
| 17 | .103037 | 16.47 | .996482 | .28 | .106556 | 16.72 | .893444 | 43 |
| 18 | .104025 | 16.42 | .996465 | .27 | .107559 | 16.68 | .892441 | 42 |
| 19 | .105010 | 16.37 | .996449 | .27 | .108560 | 16.65 | .891440 | 41 |
| 20 | .105992 | 16.35 | .996433 | .27 | .109559 | 16.62 | .890441 | 40 |
| 21 | 9.106973 | 16.30 | 9.996417 | .28 | 9.110556 | 16.58 | 10.889444 | 39 |
| 22 | .107951 | 16.27 | .996400 | .27 | .111551 | 16.53 | .888449 | 38 |
| 23 | .108927 | 16.23 | .996384 | .27 | .112543 | 16.50 | .887457 | 37 |
| 24 | .109901 | 16.20 | .996368 | .28 | .113533 | 16.47 | .886467 | 36 |
| 25 | .110873 | 16.15 | .996351 | .27 | .114521 | 16.43 | .885479 | 35 |
| 26 | .111842 | 16.12 | .996335 | .28 | .115507 | 16.40 | .884493 | 34 |
| 27 | .112809 | 16.08 | .996318 | .27 | .116491 | 16.35 | .883509 | 33 |
| 28 | .113774 | 16.05 | .996302 | .28 | .117472 | 16.33 | .882528 | 32 |
| 29 | .114737 | 16.02 | .996285 | .27 | .118452 | 16.28 | .881548 | 31 |
| 30 | .115698 | 15.97 | .996269 | .28 | .119429 | 16.25 | .880571 | 30 |
| 31 | 9.116656 | 15.95 | 9.996252 | .28 | 9.120404 | 16.22 | 10.879596 | 29 |
| 32 | .117613 | 15.90 | .996235 | .27 | .121377 | 16.18 | .878623 | 28 |
| 33 | .118567 | 15.87 | .996219 | .28 | .122348 | 16.15 | .877652 | 27 |
| 34 | .119519 | 15.83 | .996202 | .28 | .123317 | 16.12 | .876683 | 26 |
| 35 | .120469 | 15.80 | .996185 | .28 | .124284 | 16.08 | .875716 | 25 |
| 36 | .121417 | 15.75 | .996168 | .28 | .125249 | 16.03 | .874751 | 24 |
| 37 | .122362 | 15.73 | .996151 | .28 | .126211 | 16.02 | .873789 | 23 |
| 38 | .123306 | 15.70 | .996134 | .28 | .127172 | 15.97 | .872828 | 22 |
| 39 | .124248 | 15.65 | .996117 | .28 | .128130 | 15.95 | .871870 | 21 |
| 40 | .125187 | 15.63 | .996100 | .28 | .129087 | 15.90 | .870913 | 20 |
| 41 | 9.126125 | 15.58 | 9.996083 | .28 | 9.130041 | 15.88 | 10.869959 | 19 |
| 42 | .127060 | 15.55 | .996066 | .28 | .130994 | 15.83 | .869006 | 18 |
| 43 | .127993 | 15.53 | .996049 | .28 | .131944 | 15.82 | .868056 | 17 |
| 44 | .128925 | 15.48 | .996032 | .28 | .132893 | 15.77 | .867107 | 16 |
| 45 | .129854 | 15.45 | .996015 | .28 | .133839 | 15.75 | .866161 | 15 |
| 46 | .130781 | 15.42 | .995998 | .30 | .134784 | 15.70 | .865216 | 14 |
| 47 | .131706 | 15.40 | .995980 | .28 | .135726 | 15.68 | .864274 | 13 |
| 48 | .132630 | 15.35 | .995963 | .28 | .136667 | 15.63 | .863333 | 12 |
| 49 | .133551 | 15.32 | .995946 | .30 | .137605 | 15.62 | .862395 | 11 |
| 50 | .134470 | 15.28 | .995928 | .28 | .138542 | 15.57 | .861458 | 10 |
| 51 | 9.135387 | 15.27 | 9.995911 | .28 | 9.139476 | 15.55 | 10.860524 | 9 |
| 52 | .136303 | 15.22 | .995894 | .30 | .140409 | 15.52 | .859591 | 8 |
| 53 | .137216 | 15.20 | .995876 | .28 | .141340 | 15.48 | .858660 | 7 |
| 54 | .138128 | 15.15 | .995859 | .30 | .142269 | 15.45 | .857731 | 6 |
| 55 | .139037 | 15.12 | .995841 | .30 | .143196 | 15.42 | .856804 | 5 |
| 56 | .139944 | 15.10 | .995823 | .28 | .144121 | 15.38 | .855879 | 4 |
| 57 | .140850 | 15.07 | .995806 | .30 | .145044 | 15.37 | .854956 | 3 |
| 58 | .141754 | 15.02 | .995788 | .28 | .145966 | 15.32 | .854034 | 2 |
| 59 | .142655 | 15.00 | .995771 | .30 | .146885 | 15.30 | .853115 | 1 |
| 60 | 9.143555 | | 9.995753 | | 9.147803 | | 10.852197 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.143555 | 14.97 | 9.995753 | .30 | 9.147803 | 15.25 | 10.852197 | 60 |
| 1 | .144453 | 14.93 | .995735 | .30 | .148718 | 15.23 | .851282 | 59 |
| 2 | .145349 | 14.90 | .995717 | .30 | .149632 | 15.20 | .850368 | 58 |
| 3 | .146243 | 14.88 | .995699 | .30 | .150544 | 15.17 | .849456 | 57 |
| 4 | .147136 | 14.83 | .995681 | .28 | .151454 | 15.15 | .848546 | 56 |
| 5 | .148026 | 14.82 | .995664 | .30 | .152363 | 15.10 | .847637 | 55 |
| 6 | .148915 | 14.78 | .995646 | .30 | .153269 | 15.08 | .846731 | 54 |
| 7 | .149802 | 14.73 | .995628 | .30 | .154174 | 15.05 | .845826 | 53 |
| 8 | .150686 | 14.72 | .995610 | .32 | .155077 | 15.02 | .844923 | 52 |
| 9 | .151569 | 14.70 | .995591 | .30 | .155978 | 14.98 | .844022 | 51 |
| 10 | .152451 | 14.65 | .995573 | .30 | .156877 | 14.97 | .843123 | 50 |
| 11 | 9.153330 | 14.63 | 9.995555 | .30 | 9.157775 | 14.93 | 10.842225 | 49 |
| 12 | .154208 | 14.58 | .995537 | .30 | .158671 | 14.90 | .841329 | 48 |
| 13 | .155083 | 14.57 | .995519 | .30 | .159565 | 14.87 | .840435 | 47 |
| 14 | .155957 | 14.55 | .995501 | .32 | .160457 | 14.83 | .839543 | 46 |
| 15 | .156830 | 14.50 | .995482 | .30 | .161347 | 14.82 | .838653 | 45 |
| 16 | .157700 | 14.48 | .995464 | .30 | .162236 | 14.78 | .837764 | 44 |
| 17 | .158569 | 14.43 | .995446 | .32 | .163123 | 14.75 | .836877 | 43 |
| 18 | .159435 | 14.43 | .995427 | .30 | .164008 | 14.73 | .835992 | 42 |
| 19 | .160301 | 14.38 | .995409 | .32 | .164892 | 14.70 | .835108 | 41 |
| 20 | .161164 | 14.35 | .995390 | .30 | .165774 | 14.67 | .834226 | 40 |
| 21 | 9.162025 | 14.33 | 9.995372 | .32 | 9.166654 | 14.63 | 10.833346 | 39 |
| 22 | .162885 | 14.30 | .995353 | .32 | .167532 | 14.62 | .832468 | 38 |
| 23 | .163743 | 14.28 | .995334 | .30 | .168409 | 14.58 | .831591 | 37 |
| 24 | .164600 | 14.23 | .995316 | .32 | .169284 | 14.55 | .830716 | 36 |
| 25 | .165454 | 14.22 | .995297 | .32 | .170157 | 14.53 | .829843 | 35 |
| 26 | .166307 | 14.20 | .995278 | .30 | .171029 | 14.50 | .828971 | 34 |
| 27 | .167159 | 14.15 | .995260 | .32 | .171899 | 14.47 | .828101 | 33 |
| 28 | .168008 | 14.13 | .995241 | .32 | .172767 | 14.45 | .827233 | 32 |
| 29 | .168856 | 14.10 | .995222 | .32 | .173634 | 14.42 | .826366 | 31 |
| 30 | .169702 | 14.08 | .995203 | .32 | .174499 | 14.38 | .825501 | 30 |
| 31 | 9.170547 | 14.03 | 9.995184 | .32 | 9.175362 | 14.37 | 10.824638 | 29 |
| 32 | .171389 | 14.02 | .995165 | .32 | .176224 | 14.33 | .823776 | 28 |
| 33 | .172230 | 14.00 | .995146 | .32 | .177084 | 14.30 | .822916 | 27 |
| 34 | .173070 | 13.97 | .995127 | .32 | .177942 | 14.28 | .822058 | 26 |
| 35 | .173908 | 13.93 | .995108 | .32 | .178799 | 14.27 | .821201 | 25 |
| 36 | .174744 | 13.90 | .995089 | .32 | .179655 | 14.22 | .820345 | 24 |
| 37 | .175578 | 13.88 | .995070 | .32 | .180508 | 14.20 | .819492 | 23 |
| 38 | .176411 | 13.85 | .995051 | .32 | .181360 | 14.18 | .818640 | 22 |
| 39 | .177242 | 13.83 | .995032 | .32 | .182211 | 14.13 | .817789 | 21 |
| 40 | .178072 | 13.80 | .995013 | .33 | .183059 | 14.13 | .816941 | 20 |
| 41 | 9.178900 | 13.77 | 9.994993 | .32 | 9.183907 | 14.08 | 10.816093 | 19 |
| 42 | .179726 | 13.75 | .994974 | .32 | .184752 | 14.08 | .815248 | 18 |
| 43 | .180551 | 13.72 | .994955 | .33 | .185597 | 14.03 | .814403 | 17 |
| 44 | .181374 | 13.70 | .994935 | .32 | .186439 | 14.02 | .813561 | 16 |
| 45 | .182196 | 13.67 | .994916 | .33 | .187280 | 14.00 | .812720 | 15 |
| 46 | .183016 | 13.63 | .994896 | .32 | .188120 | 13.97 | .811880 | 14 |
| 47 | .183834 | 13.62 | .994877 | .33 | .188958 | 13.93 | .811042 | 13 |
| 48 | .184651 | 13.58 | .994857 | .32 | .189794 | 13.92 | .810206 | 12 |
| 49 | .185466 | 13.57 | .994838 | .33 | .190629 | 13.88 | .809371 | 11 |
| 50 | .186280 | 13.53 | .994818 | .33 | .191462 | 13.87 | .808538 | 10 |
| 51 | 9.187092 | 13.52 | 9.994798 | .32 | 9.192294 | 13.83 | 10.807706 | 9 |
| 52 | .187903 | 13.48 | .994779 | .33 | .193124 | 13.82 | .806876 | 8 |
| 53 | .188712 | 13.45 | .994759 | .33 | .193953 | 13.78 | .806047 | 7 |
| 54 | .189519 | 13.43 | .994739 | .32 | .194780 | 13.77 | .805220 | 6 |
| 55 | .190325 | 13.42 | .994720 | .33 | .195606 | 13.73 | .804394 | 5 |
| 56 | .191130 | 13.38 | .994700 | .33 | .196430 | 13.72 | .803570 | 4 |
| 57 | .191933 | 13.35 | .994680 | .33 | .197253 | 13.68 | .802747 | 3 |
| 58 | .192734 | 13.33 | .994660 | .33 | .198074 | 13.67 | .801926 | 2 |
| 59 | .193534 | 13.30 | .994640 | .33 | .198894 | 13.65 | .801106 | 1 |
| 60 | 9.194332 | | 9.994620 | | 9.199713 | | 10.800287 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.194332 | 13.28 | 9.994620 | .33 | 9.199713 | 13.60 | 10.800287 | 60 |
| 1 | .195129 | 13.27 | .994600 | .33 | .200529 | 13.60 | .799471 | 59 |
| 2 | .195925 | 13.23 | .994580 | .33 | .201345 | 13.57 | .798655 | 58 |
| 3 | .196719 | 13.20 | .994560 | .33 | .202159 | 13.53 | .797841 | 57 |
| 4 | .197511 | 13.18 | .994540 | .35 | .202971 | 13.52 | .797029 | 56 |
| 5 | .198302 | 13.15 | .994519 | .33 | .203782 | 13.50 | .796218 | 55 |
| 6 | .199091 | 13.13 | .994499 | .33 | .204592 | 13.47 | .795408 | 54 |
| 7 | .199879 | 13.12 | .994479 | .33 | .205400 | 13.45 | .794600 | 53 |
| 8 | .200666 | 13.08 | .994459 | .35 | .206207 | 13.43 | .793793 | 52 |
| 9 | .201451 | 13.05 | .994438 | .33 | .207013 | 13.40 | .792987 | 51 |
| 10 | .202234 | 13.05 | .994418 | .33 | .207817 | 13.37 | .792183 | 50 |
| 11 | 9.203017 | 13.00 | 9.994398 | .35 | 9.208619 | 13.35 | 10.791381 | 49 |
| 12 | .203797 | 13.00 | .994377 | .33 | .209420 | 13.33 | .790580 | 48 |
| 13 | .204577 | 12.95 | .994357 | .35 | .210220 | 13.30 | .789780 | 47 |
| 14 | .205354 | 12.95 | .994336 | .33 | .211018 | 13.28 | .788982 | 46 |
| 15 | .206131 | 12.92 | .994316 | .35 | .211815 | 13.27 | .788185 | 45 |
| 16 | .206906 | 12.88 | .994295 | .35 | .212611 | 13.23 | .787389 | 44 |
| 17 | .207679 | 12.88 | .994274 | .33 | .213405 | 13.22 | .786595 | 43 |
| 18 | .208452 | 12.83 | .994254 | .35 | .214198 | 13.18 | .785802 | 42 |
| 19 | .209222 | 12.83 | .994233 | .35 | .214989 | 13.18 | .785011 | 41 |
| 20 | .209992 | 12.80 | .994212 | .35 | .215780 | 13.13 | .784220 | 40 |
| 21 | 9.210760 | 12.77 | 9.994191 | .33 | 9.216568 | 13.13 | 10.783432 | 39 |
| 22 | .211526 | 12.75 | .994171 | .35 | .217356 | 13.10 | .782644 | 38 |
| 23 | .212291 | 12.73 | .994150 | .35 | .218142 | 13.07 | .781858 | 37 |
| 24 | .213055 | 12.72 | .994129 | .35 | .218926 | 13.07 | .781074 | 36 |
| 25 | .213818 | 12.68 | .994108 | .35 | .219710 | 13.03 | .780290 | 35 |
| 26 | .214579 | 12.65 | .994087 | .35 | .220492 | 13.00 | .779508 | 34 |
| 27 | .215338 | 12.65 | .994066 | .35 | .221272 | 13.00 | .778728 | 33 |
| 28 | .216097 | 12.62 | .994045 | .35 | .222052 | 12.97 | .777948 | 32 |
| 29 | .216854 | 12.58 | .994024 | .35 | .222830 | 12.95 | .777170 | 31 |
| 30 | .217609 | 12.57 | .994003 | .35 | .223607 | 12.92 | .776393 | 30 |
| 31 | 9.218363 | 12.55 | 9.993982 | .37 | 9.224382 | 12.90 | 10.775618 | 29 |
| 32 | .219116 | 12.53 | .993960 | .35 | .225156 | 12.88 | .774844 | 28 |
| 33 | .219868 | 12.50 | .993939 | .35 | .225929 | 12.85 | .774071 | 27 |
| 34 | .220618 | 12.48 | .993918 | .35 | .226700 | 12.85 | .773300 | 26 |
| 35 | .221367 | 12.47 | .993897 | .37 | .227471 | 12.80 | .772529 | 25 |
| 36 | .222115 | 12.43 | .993875 | .35 | .228239 | 12.80 | .771761 | 24 |
| 37 | .222861 | 12.42 | .993854 | .37 | .229007 | 12.77 | .770993 | 23 |
| 38 | .223606 | 12.38 | .993832 | .35 | .229773 | 12.77 | .770227 | 22 |
| 39 | .224349 | 12.38 | .993811 | .37 | .230539 | 12.72 | .769461 | 21 |
| 40 | .225092 | 12.35 | .993789 | .35 | .231302 | 12.72 | .768698 | 20 |
| 41 | 9.225833 | 12.33 | 9.993768 | .37 | 9.232065 | 12.68 | 10.767935 | 19 |
| 42 | .226573 | 12.30 | .993746 | .35 | .232826 | 12.67 | .767174 | 18 |
| 43 | .227311 | 12.28 | .993725 | .37 | .233586 | 12.65 | .766414 | 17 |
| 44 | .228048 | 12.27 | .993703 | .37 | .234345 | 12.63 | .765655 | 16 |
| 45 | .228784 | 12.23 | .993681 | .35 | .235103 | 12.60 | .764897 | 15 |
| 46 | .229518 | 12.23 | .993660 | .37 | .235859 | 12.58 | .764141 | 14 |
| 47 | .230252 | 12.20 | .993638 | .37 | .236614 | 12.57 | .763386 | 13 |
| 48 | .230984 | 12.18 | .993616 | .37 | .237368 | 12.53 | .762632 | 12 |
| 49 | .231715 | 12.15 | .993594 | .37 | .238120 | 12.53 | .761880 | 11 |
| 50 | .232444 | 12.13 | .993572 | .37 | .238872 | 12.50 | .761128 | 10 |
| 51 | 9.233172 | 12.12 | 9.993550 | .37 | 9.239622 | 12.48 | 10.760378 | 9 |
| 52 | .233899 | 12.10 | .993528 | .37 | .240371 | 12.45 | .759629 | 8 |
| 53 | .234625 | 12.07 | .993506 | .37 | .241118 | 12.45 | .758882 | 7 |
| 54 | .235349 | 12.07 | .993484 | .37 | .241865 | 12.42 | .758135 | 6 |
| 55 | .236073 | 12.03 | .993462 | .37 | .242610 | 12.40 | .757390 | 5 |
| 56 | .236795 | 12.00 | .993440 | .37 | .243354 | 12.38 | .756646 | 4 |
| 57 | .237515 | 12.00 | .993418 | .37 | .244097 | 12.37 | .755903 | 3 |
| 58 | .238235 | 11.97 | .993396 | .37 | .244839 | 12.33 | .755161 | 2 |
| 59 | .238953 | 11.95 | .993374 | .38 | .245579 | 12.33 | .754421 | 1 |
| 60 | 9.239670 | | 9.993351 | | 9.246319 | | 10.753681 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.239670 | 11.93 | 9.993351 | .37 | 9.246319 | 12.30 | 10.753681 | 60 |
| 1 | .240386 | 11.92 | .993329 | .37 | .247057 | 12.28 | .752943 | 59 |
| 2 | .241101 | 11.88 | .993307 | .38 | .247794 | 12.27 | .752206 | 58 |
| 3 | .241814 | 11.87 | .993284 | .37 | .248530 | 12.23 | .751470 | 57 |
| 4 | .242526 | 11.85 | .993262 | .37 | .249264 | 12.23 | .750736 | 56 |
| 5 | .243237 | 11.83 | .993240 | .38 | .249998 | 12.20 | .750002 | 55 |
| 6 | .243947 | 11.82 | .993217 | .37 | .250730 | 12.18 | .749270 | 54 |
| 7 | .244656 | 11.78 | .993195 | .38 | .251461 | 12.17 | .748539 | 53 |
| 8 | .245363 | 11.77 | .993172 | .38 | .252191 | 12.15 | .747809 | 52 |
| 9 | .246069 | 11.77 | .993149 | .37 | .252920 | 12.13 | .747080 | 51 |
| 10 | .246775 | 11.72 | .993127 | .38 | .253648 | 12.10 | .746352 | 50 |
| 11 | 9.247478 | 11.72 | 9.993104 | .38 | 9.254374 | 12.10 | 10.745626 | 49 |
| 12 | .248181 | 11.70 | .993081 | .37 | .255100 | 12.07 | .744900 | 48 |
| 13 | .248883 | 11.67 | .993059 | .38 | .255824 | 12.05 | .744176 | 47 |
| 14 | .249583 | 11.65 | .993036 | .38 | .256547 | 12.03 | .743453 | 46 |
| 15 | .250282 | 11.63 | .993013 | .38 | .257269 | 12.02 | .742731 | 45 |
| 16 | .250980 | 11.62 | .992990 | .38 | .257990 | 12.00 | .742010 | 44 |
| 17 | .251677 | 11.60 | .992967 | .38 | .258710 | 11.98 | .741290 | 43 |
| 18 | .252373 | 11.57 | .992944 | .38 | .259429 | 11.95 | .740571 | 42 |
| 19 | .253067 | 11.57 | .992921 | .38 | .260146 | 11.95 | .739854 | 41 |
| 20 | .253761 | 11.53 | .992898 | .38 | .260863 | 11.92 | .739137 | 40 |
| 21 | 9.254453 | 11.52 | 9.992875 | .38 | 9.261578 | 11.90 | 10.738422 | 39 |
| 22 | .255144 | 11.50 | .992852 | .38 | .262292 | 11.88 | .737708 | 38 |
| 23 | .255834 | 11.48 | .992829 | .38 | .263005 | 11.87 | .736995 | 37 |
| 24 | .256523 | 11.47 | .992806 | .38 | .263717 | 11.85 | .736283 | 36 |
| 25 | .257211 | 11.45 | .992783 | .40 | .264428 | 11.83 | .735572 | 35 |
| 26 | .257898 | 11.42 | .992759 | .38 | .265138 | 11.82 | .734862 | 34 |
| 27 | .258583 | 11.42 | .992736 | .38 | .265847 | 11.80 | .734153 | 33 |
| 28 | .259268 | 11.38 | .992713 | .38 | .266555 | 11.77 | .733445 | 32 |
| 29 | .259951 | 11.37 | .992690 | .40 | .267261 | 11.77 | .732739 | 31 |
| 30 | .260633 | 11.35 | .992666 | .38 | .267967 | 11.73 | .732033 | 30 |
| 31 | 9.261314 | 11.33 | 9.992643 | .40 | 9.268671 | 11.73 | 10.731329 | 29 |
| 32 | .261994 | 11.32 | .992619 | .38 | .269375 | 11.70 | .730625 | 28 |
| 33 | .262673 | 11.30 | .992596 | .40 | .270077 | 11.70 | .729923 | 27 |
| 34 | .263351 | 11.27 | .992572 | .38 | .270779 | 11.67 | .729221 | 26 |
| 35 | .264027 | 11.27 | .992549 | .40 | .271479 | 11.65 | .728521 | 25 |
| 36 | .264703 | 11.23 | .992525 | .40 | .272178 | 11.63 | .727822 | 24 |
| 37 | .265377 | 11.23 | .992501 | .38 | .272876 | 11.62 | .727124 | 23 |
| 38 | .266051 | 11.20 | .992478 | .40 | .273573 | 11.60 | .726427 | 22 |
| 39 | .266723 | 11.20 | .992454 | .40 | .274269 | 11.58 | .725731 | 21 |
| 40 | .267395 | 11.17 | .992430 | .40 | .274964 | 11.57 | .725036 | 20 |
| 41 | 9.268065 | 11.15 | 9.992406 | .40 | 9.275658 | 11.55 | 10.724342 | 19 |
| 42 | .268734 | 11.13 | .992382 | .38 | .276351 | 11.53 | .723649 | 18 |
| 43 | .269402 | 11.12 | .992359 | .40 | .277043 | 11.52 | .722957 | 17 |
| 44 | .270069 | 11.10 | .992335 | .40 | .277734 | 11.50 | .722266 | 16 |
| 45 | .270735 | 11.08 | .992311 | .40 | .278424 | 11.48 | .721576 | 15 |
| 46 | .271400 | 11.07 | .992287 | .40 | .279113 | 11.47 | .720887 | 14 |
| 47 | .272064 | 11.03 | .992263 | .40 | .279801 | 11.45 | .720199 | 13 |
| 48 | .272726 | 11.03 | .992239 | .42 | .280488 | 11.43 | .719512 | 12 |
| 49 | .273388 | 11.02 | .992214 | .40 | .281174 | 11.40 | .718826 | 11 |
| 50 | .274049 | 10.98 | .992190 | .40 | .281858 | 11.40 | .718142 | 10 |
| 51 | 9.274708 | 10.98 | 9.992166 | .40 | 9.282542 | 11.38 | 10.717458 | 9 |
| 52 | .275367 | 10.97 | .992142 | .40 | .283225 | 11.37 | .716775 | 8 |
| 53 | .276025 | 10.93 | .992118 | .42 | .283907 | 11.35 | .716093 | 7 |
| 54 | .276681 | 10.93 | .992093 | .40 | .284588 | 11.33 | .715412 | 6 |
| 55 | .277337 | 10.90 | .992069 | .42 | .285268 | 11.32 | .714732 | 5 |
| 56 | .277991 | 10.90 | .992044 | .40 | .285947 | 11.28 | .714053 | 4 |
| 57 | .278645 | 10.87 | .992020 | .40 | .286624 | 11.28 | .713376 | 3 |
| 58 | .279297 | 10.85 | .991996 | .42 | .287301 | 11.27 | .712699 | 2 |
| 59 | .279948 | 10.85 | .991971 | .40 | .287977 | 11.25 | .712023 | 1 |
| 60 | 9.280599 | | 9.991947 | | 9.288652 | | 10.711348 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.280599 | 10.82 | 9.991947 | .42 | 9.288652 | 11.23 | 10.711348 | 60 |
| 1 | .281248 | 10.82 | .991922 | .42 | .289326 | 11.22 | .710674 | 59 |
| 2 | .281897 | 10.78 | .991897 | .40 | .289999 | 11.20 | .710001 | 58 |
| 3 | .282544 | 10.77 | .991873 | .42 | .290671 | 11.18 | .709329 | 57 |
| 4 | .283190 | 10.77 | .991848 | .42 | .291342 | 11.18 | .708658 | 56 |
| 5 | .283836 | 10.73 | .991823 | .40 | .292013 | 11.15 | .707987 | 55 |
| 6 | .284480 | 10.73 | .991799 | .42 | .292682 | 11.13 | .707318 | 54 |
| 7 | .285124 | 10.70 | .991774 | .42 | .293350 | 11.12 | .706650 | 53 |
| 8 | .285766 | 10.70 | .991749 | .42 | .294017 | 11.12 | .705983 | 52 |
| 9 | .286408 | 10.67 | .991724 | .42 | .294684 | 11.08 | .705316 | 51 |
| 10 | .287048 | 10.67 | .991699 | .42 | .295349 | 11.07 | .704651 | 50 |
| 11 | 9.287688 | 10.63 | 9.991674 | .42 | 9.296013 | 11.07 | 10.703987 | 49 |
| 12 | .288326 | 10.63 | .991649 | .42 | .296677 | 11.03 | .703323 | 48 |
| 13 | .288964 | 10.60 | .991624 | .42 | .297339 | 11.03 | .702661 | 47 |
| 14 | .289600 | 10.60 | .991599 | .42 | .298001 | 11.02 | .701999 | 46 |
| 15 | .290236 | 10.57 | .991574 | .42 | .298662 | 11.00 | .701338 | 45 |
| 16 | .290870 | 10.57 | .991549 | .42 | .299322 | 10.97 | .700678 | 44 |
| 17 | .291504 | 10.55 | .991524 | .43 | .299980 | 10.97 | .700020 | 43 |
| 18 | .292137 | 10.52 | .991498 | .42 | .300638 | 10.95 | .699362 | 42 |
| 19 | .292768 | 10.52 | .991473 | .42 | .301295 | 10.93 | .698705 | 41 |
| 20 | .293399 | 10.50 | .991448 | .43 | .301951 | 10.93 | .698049 | 40 |
| 21 | 9.294029 | 10.48 | 9.991422 | .42 | 9.302607 | 10.90 | 10.697393 | 39 |
| 22 | .294658 | 10.47 | .991397 | .42 | .303261 | 10.88 | .696739 | 38 |
| 23 | .295286 | 10.45 | .991372 | .43 | .303914 | 10.88 | .696086 | 37 |
| 24 | .295913 | 10.43 | .991346 | .42 | .304567 | 10.85 | .695433 | 36 |
| 25 | .296539 | 10.42 | .991321 | .43 | .305218 | 10.85 | .694782 | 35 |
| 26 | .297164 | 10.40 | .991295 | .42 | .305869 | 10.83 | .694131 | 34 |
| 27 | .297788 | 10.40 | .991270 | .43 | .306519 | 10.82 | .693481 | 33 |
| 28 | .298412 | 10.37 | .991244 | .43 | .307168 | 10.80 | .692832 | 32 |
| 29 | .299034 | 10.35 | .991218 | .42 | .307816 | 10.78 | .692184 | 31 |
| 30 | .299655 | 10.35 | .991193 | .43 | .308463 | 10.77 | .691537 | 30 |
| 31 | 9.300276 | 10.32 | 9.991167 | .43 | 9.309109 | 10.75 | 10.690891 | 29 |
| 32 | .300895 | 10.32 | .991141 | .43 | .309754 | 10.75 | .690246 | 28 |
| 33 | .301514 | 10.30 | .991115 | .42 | .310399 | 10.72 | .689601 | 27 |
| 34 | .302132 | 10.27 | .991090 | .43 | .311042 | 10.72 | .688958 | 26 |
| 35 | .302748 | 10.27 | .991064 | .43 | .311685 | 10.70 | .688315 | 25 |
| 36 | .303364 | 10.25 | .991038 | .43 | .312327 | 10.68 | .687673 | 24 |
| 37 | .303979 | 10.23 | .991012 | .43 | .312968 | 10.67 | .687032 | 23 |
| 38 | .304593 | 10.23 | .990986 | .43 | .313608 | 10.65 | .686392 | 22 |
| 39 | .305207 | 10.20 | .990960 | .43 | .314247 | 10.63 | .685753 | 21 |
| 40 | .305819 | 10.18 | .990934 | .43 | .314885 | 10.63 | .685115 | 20 |
| 41 | 9.306430 | 10.18 | 9.990908 | .43 | 9.315523 | 10.60 | 10.684477 | 19 |
| 42 | .307041 | 10.15 | .990882 | .45 | .316159 | 10.60 | .683841 | 18 |
| 43 | .307650 | 10.15 | .990855 | .43 | .316795 | 10.58 | .683205 | 17 |
| 44 | .308259 | 10.13 | .990829 | .43 | .317430 | 10.57 | .682570 | 16 |
| 45 | .308867 | 10.12 | .990803 | .43 | .318064 | 10.55 | .681936 | 15 |
| 46 | .309474 | 10.10 | .990777 | .45 | .318697 | 10.55 | .681303 | 14 |
| 47 | .310080 | 10.08 | .990750 | .43 | 319330 | 10.52 | .680670 | 13 |
| 48 | .310685 | 10.07 | .990724 | .45 | .319961 | 10.52 | .680039 | 12 |
| 49 | .311289 | 10.07 | .990697 | .43 | .320592 | 10.50 | .679408 | 11 |
| 50 | .311893 | 10.03 | .990671 | .43 | .321222 | 10.48 | .678778 | 10 |
| 51 | 9.312495 | 10.03 | 9.990645 | .45 | 9.321851 | 10.47 | 10.678149 | 9 |
| 52 | .313097 | 10.02 | .990618 | .45 | .322479 | 10.45 | .677521 | 8 |
| 53 | .313698 | 9.98 | .990591 | .43 | .323106 | 10.45 | .676894 | 7 |
| 54 | .314297 | 10.00 | .990565 | .45 | .323733 | 10.42 | .676267 | 6 |
| 55 | .314897 | 9.97 | .990538 | .45 | .324358 | 10.42 | .675642 | 5 |
| 56 | .315495 | 9.95 | .990511 | .43 | .324983 | 10.40 | .675017 | 4 |
| 57 | .316092 | 9.95 | .990485 | .45 | .325607 | 10.40 | .674393 | 3 |
| 58 | .316689 | 9.92 | .990458 | .45 | .326231 | 10.37 | .673769 | 2 |
| 59 | .317284 | 9.92 | .990431 | .45 | .326853 | 10.37 | .673147 | 1 |
| 60 | 9.317879 | | 9.990404 | | 9.327475 | | 10.672525 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.317879 | 9.90 | 9.990404 | .43 | 9.327475 | 10.33 | 10.672525 | 60 |
| 1 | .318473 | 9.88 | .990378 | .45 | .328095 | 10.33 | .671905 | 59 |
| 2 | .319066 | 9.87 | .990351 | .45 | .328715 | 10.32 | .671285 | 58 |
| 3 | .319658 | 9.85 | .990324 | .45 | .329334 | 10.32 | .670666 | 57 |
| 4 | .320249 | 9.85 | .990297 | .45 | .329953 | 10.28 | .670047 | 56 |
| 5 | .320840 | 9.83 | .990270 | .45 | .330570 | 10.28 | .669430 | 55 |
| 6 | .321430 | 9.82 | .990243 | .47 | .331187 | 10.27 | .668813 | 54 |
| 7 | .322019 | 9.80 | .990215 | .45 | .331803 | 10.25 | .668197 | 53 |
| 8 | .322607 | 9.78 | .990188 | .45 | .332418 | 10.25 | .667582 | 52 |
| 9 | .323194 | 9.77 | .990161 | .45 | .333033 | 10.22 | .666967 | 51 |
| 10 | .323780 | 9.77 | .990134 | .45 | .333646 | 10.22 | .666354 | 50 |
| 11 | 9.324366 | 9.73 | 9.990107 | .47 | 9.334259 | 10.20 | 10.665741 | 49 |
| 12 | .324950 | 9.73 | .990079 | .45 | .334871 | 10.18 | .665129 | 48 |
| 13 | .325534 | 9.72 | .990052 | .45 | .335482 | 10.18 | .664518 | 47 |
| 14 | .326117 | 9.72 | .990025 | .47 | .336093 | 10.15 | .663907 | 46 |
| 15 | .326700 | 9.68 | .989997 | .45 | .336702 | 10.15 | .663298 | 45 |
| 16 | .327281 | 9.68 | .989970 | .47 | .337311 | 10.13 | .662689 | 44 |
| 17 | .327862 | 9.67 | .989942 | .45 | .337919 | 10.13 | .662081 | 43 |
| 18 | .328442 | 9.65 | .989915 | .47 | .338527 | 10.10 | .661473 | 42 |
| 19 | .329021 | 9.63 | .989887 | .45 | .339133 | 10.10 | .660867 | 41 |
| 20 | .329599 | 9.62 | .989860 | .47 | .339739 | 10.08 | .660261 | 40 |
| 21 | 9.330176 | 9.62 | 9.989832 | .47 | 9.340344 | 10.07 | 10.659656 | 39 |
| 22 | .330753 | 9.60 | .989804 | .45 | .340948 | 10.07 | .659052 | 38 |
| 23 | .331329 | 9.57 | .989777 | .47 | .341552 | 10.05 | .658448 | 37 |
| 24 | .331903 | 9.58 | .989749 | .47 | .342155 | 10.03 | .657845 | 36 |
| 25 | .332478 | 9.55 | .989721 | .47 | .342757 | 10.02 | .657243 | 35 |
| 26 | .333051 | 9.55 | .989693 | .47 | .343358 | 10.00 | .656642 | 34 |
| 27 | .333624 | 9.52 | .989665 | .47 | .343958 | 10.00 | .656042 | 33 |
| 28 | .334195 | 9.53 | .989637 | .45 | .344558 | 9.98 | .655442 | 32 |
| 29 | .334767 | 9.50 | .989610 | .47 | .345157 | 9.97 | .654843 | 31 |
| 30 | .335337 | 9.48 | .989582 | .48 | .345755 | 9.97 | .654245 | 30 |
| 31 | 9.335906 | 9.48 | 9.989553 | .47 | 9.346353 | 9.93 | 10.653647 | 29 |
| 32 | .336475 | 9.47 | .989525 | .47 | .346949 | 9.93 | .653051 | 28 |
| 33 | .337043 | 9.45 | .989497 | .47 | .347545 | 9.93 | .652455 | 27 |
| 34 | .337610 | 9.43 | .989469 | .47 | .348141 | 9.90 | .651859 | 26 |
| 35 | .338176 | 9.43 | .989441 | .47 | .348735 | 9.90 | .651265 | 25 |
| 36 | .338742 | 9.42 | .989413 | .47 | .349329 | 9.88 | .650671 | 24 |
| 37 | .339307 | 9.40 | .989385 | .48 | .349922 | 9.87 | .650078 | 23 |
| 38 | .339871 | 9.38 | .989356 | .47 | .350514 | 9.87 | .649486 | 22 |
| 39 | .340434 | 9.37 | .989328 | .47 | .351106 | 9.85 | .648894 | 21 |
| 40 | .340996 | 9.37 | .989300 | .48 | .351697 | 9.83 | .648303 | 20 |
| 41 | 9.341558 | 9.35 | 9.989271 | .47 | 9.352287 | 9.82 | 10.647713 | 19 |
| 42 | .342119 | 9.33 | .989243 | .48 | .352876 | 9.82 | .647124 | 18 |
| 43 | .342679 | 9.33 | .989214 | .47 | .353465 | 9.80 | .646535 | 17 |
| 44 | .343239 | 9.30 | .989186 | .48 | .354053 | 9.78 | .645947 | 16 |
| 45 | .343797 | 9.30 | .989157 | .48 | .354640 | 9.78 | .645360 | 15 |
| 46 | .344355 | 9.28 | .989128 | .47 | .355227 | 9.77 | .644773 | 14 |
| 47 | .344912 | 9.28 | .989100 | .48 | .355813 | 9.75 | .644187 | 13 |
| 48 | .345469 | 9.25 | .989071 | .48 | .356398 | 9.73 | .643602 | 12 |
| 49 | .346024 | 9.25 | .989042 | .47 | .356982 | 9.73 | .643018 | 11 |
| 50 | .346579 | 9.25 | .989014 | .48 | .357566 | 9.72 | .642434 | 10 |
| 51 | 9.347134 | 9.22 | 9.988985 | .48 | 9.358149 | 9.70 | 10.641851 | 9 |
| 52 | .347687 | 9.22 | .988956 | .48 | .358731 | 9.70 | .641269 | 8 |
| 53 | .348240 | 9.20 | .988927 | .48 | .359313 | 9.67 | .640687 | 7 |
| 54 | .348792 | 9.18 | .988898 | .48 | .359893 | 9.68 | .640107 | 6 |
| 55 | .349343 | 9.17 | .988869 | .48 | .360474 | 9.65 | .639526 | 5 |
| 56 | .349893 | 9.17 | .988840 | .48 | .361053 | 9.65 | .638947 | 4 |
| 57 | .350443 | 9.15 | .988811 | .48 | .361632 | 9.63 | .638368 | 3 |
| 58 | .350992 | 9.13 | .988782 | .48 | .362210 | 9.62 | .637790 | 2 |
| 59 | .351540 | 9.13 | .988753 | .48 | .362787 | 9.62 | .637213 | 1 |
| 60 | 9.352088 | | 9.988724 | | 9.363364 | | 10.636636 | 0 |
| ′ | Cosine. | D. 1″. | Sine, | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.352088 | 9.12 | 9.988724 | .48 | 9.363364 | 9.60 | 10.636636 | 60 |
| 1 | .352635 | 9.10 | .988695 | .48 | .363940 | 9.58 | .636060 | 59 |
| 2 | .353181 | 9.08 | .988666 | .50 | .364515 | 9.58 | .635485 | 58 |
| 3 | .353726 | 9.08 | .988636 | .48 | .365090 | 9.57 | .634910 | 57 |
| 4 | .354271 | 9.07 | .988607 | .48 | .365664 | 9.55 | .634336 | 56 |
| 5 | .354815 | 9.05 | .988578 | .50 | .366237 | 9.55 | .633763 | 55 |
| 6 | .355358 | 9.05 | .988548 | .48 | .366810 | 9.53 | .633190 | 54 |
| 7 | .355901 | 9.03 | .988519 | .50 | .367382 | 9.52 | .632618 | 53 |
| 8 | .356443 | 9.02 | .988489 | .48 | .367953 | 9.52 | .632047 | 52 |
| 9 | .356984 | 9.00 | .988460 | .50 | .368524 | 9.50 | .631476 | 51 |
| 10 | .357524 | 9.00 | .988430 | .48 | .369094 | 9.48 | .630906 | 50 |
| 11 | 9.358064 | 8.98 | 9.988401 | .50 | 9.369663 | 9.48 | 10.630337 | 49 |
| 12 | .358603 | 8.97 | .988371 | .48 | .370232 | 9.45 | .629768 | 48 |
| 13 | .359141 | 8.95 | .988342 | .50 | .370799 | 9.47 | .629201 | 47 |
| 14 | .359678 | 8.95 | .988312 | .50 | .371367 | 9.43 | .628633 | 46 |
| 15 | .360215 | 8.95 | .988282 | .50 | .371933 | 9.43 | .628067 | 45 |
| 16 | .360752 | 8.92 | .988252 | .48 | .372499 | 9.42 | .627501 | 44 |
| 17 | .361287 | 8.92 | .988223 | .50 | .373064 | 9.42 | .626936 | 43 |
| 18 | .361822 | 8.90 | .988193 | .50 | .373629 | 9.40 | .626371 | 42 |
| 19 | .362356 | 8.88 | .988163 | .50 | .374193 | 9.38 | .625807 | 41 |
| 20 | .362889 | 8.88 | .988133 | .50 | .374756 | 9.38 | .625244 | 40 |
| 21 | 9.363422 | 8.87 | 9.988103 | .50 | 9.375319 | 9.37 | 10.624681 | 39 |
| 22 | .363954 | 8.85 | .988073 | .50 | .375881 | 9.35 | .624119 | 38 |
| 23 | .364485 | 8.85 | .988043 | .50 | .376442 | 9.35 | .623558 | 37 |
| 24 | .365016 | 8.83 | .988013 | .50 | .377003 | 9.33 | .622997 | 36 |
| 25 | .365546 | 8.82 | .987983 | .50 | .377563 | 9.32 | .622437 | 35 |
| 26 | .366075 | 8.82 | .987953 | .52 | .378122 | 9.32 | .621878 | 34 |
| 27 | .366604 | 8.78 | .987922 | .50 | .378681 | 9.30 | .621319 | 33 |
| 28 | .367131 | 8.80 | .987892 | .50 | .379239 | 9.30 | .620761 | 32 |
| 29 | .367659 | 8.77 | .987862 | .50 | .379797 | 9.28 | .620203 | 31 |
| 30 | .368185 | 8.77 | .987832 | .52 | .380354 | 9.27 | .619646 | 30 |
| 31 | 9.368711 | 8.75 | 9.987801 | .50 | 9.380910 | 9.27 | 10.619090 | 29 |
| 32 | .369236 | 8.75 | .987771 | .52 | .381466 | 9.23 | .618534 | 28 |
| 33 | .369761 | 8.72 | .987740 | .50 | .382020 | 9.25 | .617980 | 27 |
| 34 | .370285 | 8.72 | .987710 | .52 | .382575 | 9.23 | .617425 | 26 |
| 35 | .370808 | 8.70 | .987679 | .50 | .383129 | 9.22 | .616871 | 25 |
| 36 | .371330 | 8.70 | .987649 | .52 | .383682 | 9.20 | .616318 | 24 |
| 37 | .371852 | 8.68 | .987618 | .50 | .384234 | 9.20 | .615766 | 23 |
| 38 | .372373 | 8.68 | .987588 | .52 | .384786 | 9.18 | .615214 | 22 |
| 39 | .372894 | 8.67 | .987557 | .52 | .385337 | 9.18 | .614663 | 21 |
| 40 | .373414 | 8.65 | .987526 | .50 | .385888 | 9.17 | .614112 | 20 |
| 41 | 9.373933 | 8.65 | 9.987496 | .52 | 9.386438 | 9.15 | 10.613562 | 19 |
| 42 | .374452 | 8.63 | .987465 | .52 | .386987 | 9.15 | .613013 | 18 |
| 43 | .374970 | 8.62 | .987434 | .52 | .387536 | 9.13 | .612464 | 17 |
| 44 | .375487 | 8.60 | .987403 | .52 | .388084 | 9.12 | .611916 | 16 |
| 45 | .376003 | 8.60 | .987372 | .52 | .388631 | 9.12 | .611369 | 15 |
| 46 | .376519 | 8.60 | .987341 | .52 | .389178 | 9.10 | .610822 | 14 |
| 47 | .377035 | 8.57 | .987310 | .52 | .389724 | 9.10 | .610276 | 13 |
| 48 | .377549 | 8.57 | .987279 | .52 | .390270 | 9.08 | .609730 | 12 |
| 49 | .378063 | 8.57 | .987248 | .52 | .390815 | 9.08 | .609185 | 11 |
| 50 | .378577 | 8.53 | .987217 | .52 | .391360 | 9.05 | .608640 | 10 |
| 51 | 9.379089 | 8.53 | 9.987186 | .52 | 9.391903 | 9.07 | 10.608097 | 9 |
| 52 | .379601 | 8.53 | .987155 | .52 | .392447 | 9.03 | .607553 | 8 |
| 53 | .380113 | 8.52 | .987124 | .53 | .392989 | 9.03 | .607011 | 7 |
| 54 | .380624 | 8.50 | .987092 | .52 | .393531 | 9.03 | .606469 | 6 |
| 55 | .381134 | 8.48 | .987061 | .52 | .394073 | 9.02 | .605927 | 5 |
| 56 | .381643 | 8.48 | .987030 | .53 | .394614 | 9.00 | .605386 | 4 |
| 57 | .382152 | 8.48 | .986998 | .52 | .395154 | 9.00 | .604846 | 3 |
| 58 | .382661 | 8.45 | .986967 | .52 | .395694 | 8.98 | .604306 | 2 |
| 59 | .383168 | 8.45 | .986936 | .53 | .396233 | 8.97 | .603767 | 1 |
| 60 | 9.383675 | | 9.986904 | | 9.396771 | | 10.603229 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.383675 | 8.45 | 9.986904 | .52 | 9.396771 | 8.97 | 10.603229 | 60 |
| 1 | .384182 | 8.42 | .986873 | .53 | .397309 | 8.95 | .602691 | 59 |
| 2 | .384687 | 8.42 | .986841 | .53 | .397846 | 8.95 | .602154 | 58 |
| 3 | .385192 | 8.42 | .986809 | .52 | .398383 | 8.93 | .601617 | 57 |
| 4 | .385697 | 8.40 | .986778 | .53 | .398919 | 8.93 | .601081 | 56 |
| 5 | .386201 | 8.38 | .986746 | .53 | .399455 | 8.92 | .600545 | 55 |
| 6 | .386704 | 8.38 | .986714 | .52 | .399990 | 8.90 | .600010 | 54 |
| 7 | .387207 | 8.37 | .986683 | .53 | .400524 | 8.90 | .599476 | 53 |
| 8 | .387709 | 8.35 | .986651 | .53 | .401058 | 8.88 | .598942 | 52 |
| 9 | .388210 | 8.35 | .986619 | .53 | .401591 | 8.88 | .598409 | 51 |
| 10 | .388711 | 8.33 | .986587 | .53 | .402124 | 8.87 | .597876 | 50 |
| 11 | 9.389211 | 8.33 | 9.986555 | .53 | 9.402656 | 8.85 | 10.597344 | 49 |
| 12 | .389711 | 8.32 | .986523 | .53 | .403187 | 8.85 | .596813 | 48 |
| 13 | .390210 | 8.30 | .986491 | .53 | .403718 | 8.85 | .596282 | 47 |
| 14 | .390708 | 8.30 | .986459 | .53 | .404249 | 8.82 | .595751 | 46 |
| 15 | .391206 | 8.28 | .986427 | .53 | .404778 | 8.83 | .595222 | 45 |
| 16 | .391703 | 8.27 | .986395 | .53 | .405308 | 8.80 | .594692 | 44 |
| 17 | .392199 | 8.27 | .986363 | .53 | .405836 | 8.80 | .594164 | 43 |
| 18 | .392695 | 8.27 | .986331 | .53 | .406364 | 8.80 | .593636 | 42 |
| 19 | .393191 | 8.23 | .986299 | .55 | .406892 | 8.78 | .593108 | 41 |
| 20 | .393685 | 8.23 | .986266 | .53 | .407419 | 8.77 | .592581 | 40 |
| 21 | 9.394179 | 8.23 | 9.986234 | .53 | 9.407945 | 8.77 | 10.592055 | 39 |
| 22 | .394673 | 8.22 | .986202 | .55 | .408471 | 8.75 | .591529 | 38 |
| 23 | .395166 | 8.20 | .986169 | .53 | .408996 | 8.75 | .591004 | 37 |
| 24 | .395658 | 8.20 | .986137 | .55 | .409521 | 8.73 | .590479 | 36 |
| 25 | .396150 | 8.18 | .986104 | .53 | .410045 | 8.73 | .589955 | 35 |
| 26 | .396641 | 8.18 | .986072 | .55 | .410569 | 8.72 | .589431 | 34 |
| 27 | .397132 | 8.15 | .986039 | .53 | .411092 | 8.72 | .588908 | 33 |
| 28 | .397621 | 8.17 | .986007 | .55 | .411615 | 8.70 | .588385 | 32 |
| 29 | .398111 | 8.15 | .985974 | .53 | .412137 | 8.68 | .587863 | 31 |
| 30 | .398600 | 8.13 | .985942 | .55 | .412658 | 8.68 | .587342 | 30 |
| 31 | 9.399088 | 8.12 | 9.985909 | .55 | 9.413179 | 8.67 | 10.586821 | 29 |
| 32 | .399575 | 8.12 | .985876 | .55 | .413699 | 8.67 | .586301 | 28 |
| 33 | .400062 | 8.12 | .985843 | .53 | .414219 | 8.65 | .585781 | 27 |
| 34 | .400549 | 8.10 | .985811 | .55 | .414738 | 8.65 | .585262 | 26 |
| 35 | .401035 | 8.08 | .985778 | .55 | .415257 | 8.63 | .584743 | 25 |
| 36 | .401520 | 8.08 | .985745 | .55 | .415775 | 8.63 | .584225 | 24 |
| 37 | .402005 | 8.07 | .985712 | .55 | .416293 | 8.62 | .583707 | 23 |
| 38 | .402489 | 8.05 | .985679 | .55 | .416810 | 8.60 | .583190 | 22 |
| 39 | .402972 | 8.05 | .985646 | .55 | .417326 | 8.60 | .582674 | 21 |
| 40 | .403455 | 8.05 | .985613 | .55 | .417842 | 8.60 | .582158 | 20 |
| 41 | 9.403938 | 8.03 | 9.985580 | .55 | 9.418358 | 8.58 | 10.581642 | 19 |
| 42 | .404420 | 8.02 | .985547 | .55 | .418873 | 8.57 | .581127 | 18 |
| 43 | .404901 | 8.02 | .985514 | .57 | .419387 | 8.57 | .580613 | 17 |
| 44 | .405382 | 8.00 | .985480 | .55 | .419901 | 8.57 | .580099 | 16 |
| 45 | .405862 | 7.98 | .985447 | .55 | .420415 | 8.55 | .579585 | 15 |
| 46 | .406341 | 7.98 | .985414 | .55 | .420927 | 8.55 | .579073 | 14 |
| 47 | .406820 | 7.98 | .985381 | .57 | .421440 | 8.53 | .578560 | 13 |
| 48 | .407299 | 7.97 | .985347 | .55 | .421952 | 8.52 | .578048 | 12 |
| 49 | .407777 | 7.95 | .985314 | .57 | .422463 | 8.52 | .577537 | 11 |
| 50 | .408254 | 7.95 | .985280 | .55 | .422974 | 8.50 | .577026 | 10 |
| 51 | 9.408731 | 7.93 | 9.985247 | .57 | 9.423484 | 8.48 | 10.576516 | 9 |
| 52 | .409207 | 7.93 | .985213 | .55 | .423993 | 8.50 | .576007 | 8 |
| 53 | .409682 | 7.92 | .985180 | .57 | .424503 | 8.47 | .575497 | 7 |
| 54 | .410157 | 7.92 | .985146 | .55 | .425011 | 8.47 | .574989 | 6 |
| 55 | .410632 | 7.90 | .985113 | .57 | .425519 | 8.47 | .574481 | 5 |
| 56 | .411106 | 7.88 | .985079 | .57 | .426027 | 8.45 | .573973 | 4 |
| 57 | .411579 | 7.88 | .985045 | .57 | .426534 | 8.45 | .573466 | 3 |
| 58 | .412052 | 7.87 | .985011 | .55 | .427041 | 8.43 | .572959 | 2 |
| 59 | .412524 | 7.87 | .984978 | .57 | .427547 | 8.42 | .572453 | 1 |
| 60 | 9.412996 | | 9.984944 | | 9.428052 | | 10.571948 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.412996 | 7.85 | 9.984944 | .57 | 9.428052 | 8.43 | 10.571948 | 60 |
| 1 | .413467 | 7.85 | .984910 | .57 | .428558 | 8.40 | .571442 | 59 |
| 2 | .413938 | 7.83 | .984876 | .57 | .429062 | 8.40 | .570938 | 58 |
| 3 | .414408 | 7.83 | .984842 | .57 | .429566 | 8.40 | .570434 | 57 |
| 4 | .414878 | 7.82 | .984808 | .57 | .430070 | 8.38 | .569930 | 56 |
| 5 | .415347 | 7.80 | .984774 | .57 | .430573 | 8.37 | .569427 | 55 |
| 6 | .415815 | 7.80 | .984740 | .57 | .431075 | 8.37 | .568925 | 54 |
| 7 | .416283 | 7.80 | .984706 | .57 | .431577 | 8.37 | .568423 | 53 |
| 8 | .416751 | 7.77 | .984672 | .57 | .432079 | 8.35 | .567921 | 52 |
| 9 | .417217 | 7.78 | .984638 | .58 | .432580 | 8.33 | .567420 | 51 |
| 10 | .417684 | 7.77 | .984603 | .57 | .433080 | 8.33 | .566920 | 50 |
| 11 | 9.418150 | 7.75 | 9.984569 | .57 | 9.433580 | 8.33 | 10.566420 | 49 |
| 12 | .418615 | 7.73 | .984535 | .58 | .434080 | 8.32 | .565920 | 48 |
| 13 | .419079 | 7.75 | .984500 | .57 | .434579 | 8.32 | .565421 | 47 |
| 14 | .419544 | 7.72 | .984466 | .57 | .435078 | 8.30 | .564922 | 46 |
| 15 | .420007 | 7.72 | .984432 | .58 | .435576 | 8.28 | .564424 | 45 |
| 16 | .420470 | 7.72 | .984397 | .57 | .436073 | 8.28 | .563927 | 44 |
| 17 | .420933 | 7.70 | .984363 | .58 | .436570 | 8.28 | .563430 | 43 |
| 18 | .421395 | 7.70 | .984328 | .57 | .437067 | 8.27 | .562933 | 42 |
| 19 | .421857 | 7.68 | .984294 | .58 | .437563 | 8.27 | .562437 | 41 |
| 20 | .422318 | 7.67 | .984259 | .58 | .438059 | 8.25 | .561941 | 40 |
| 21 | 9.422778 | 7.67 | 9.984224 | .57 | 9.438554 | 8.23 | 10.561446 | 39 |
| 22 | .423238 | 7.65 | .984190 | .58 | .439048 | 8.25 | .560952 | 38 |
| 23 | .423697 | 7.65 | .984155 | .58 | .439543 | 8.22 | .560457 | 37 |
| 24 | .424156 | 7.65 | .984120 | .58 | .440036 | 8.22 | .559964 | 36 |
| 25 | .424615 | 7.63 | .984085 | .58 | .440529 | 8.22 | .559471 | 35 |
| 26 | .425073 | 7.62 | .984050 | .58 | .441022 | 8.20 | .558978 | 34 |
| 27 | .425530 | 7.62 | .984015 | .57 | .441514 | 8.20 | .558486 | 33 |
| 28 | 425987 | 7.60 | .983981 | .58 | .442006 | 8.18 | .557994 | 32 |
| 29 | .426443 | 7.60 | .983946 | .58 | .442497 | 8.18 | .557503 | 31 |
| 30 | .426899 | 7.58 | .983911 | .60 | .442988 | 8.18 | 557012 | 30 |
| 31 | 9.427354 | 7.58 | 9.983875 | .58 | 9.443479 | 8.15 | 10.556521 | 29 |
| 32 | .427809 | 7.57 | .983840 | .58 | .443968 | 8.17 | .556032 | 28 |
| 33 | .428263 | 7.57 | .983805 | .58 | .444458 | 8.15 | .555542 | 27 |
| 34 | .428717 | 7.55 | .983770 | .58 | .444947 | 8.13 | .555053 | 26 |
| 35 | .429170 | 7.55 | .983735 | .58 | .445435 | 8.13 | .554565 | 25 |
| 36 | .429623 | 7.53 | .983700 | .60 | .445923 | 8.13 | .554077 | 24 |
| 37 | .430075 | 7.53 | .983664 | .58 | .446411 | 8.12 | .553589 | 23 |
| 38 | .430527 | 7.52 | .983629 | .58 | .446898 | 8.10 | .553102 | 22 |
| 39 | .430978 | 7.52 | .983594 | .60 | .447384 | 8.10 | .552616 | 21 |
| 40 | .431429 | 7.50 | .983558 | .58 | .447870 | 8.10 | .552130 | 20 |
| 41 | 9.431879 | 7.50 | 9.983523 | .60 | 9.448356 | 8.08 | 10.551644 | 19 |
| 42 | .432329 | 7.48 | .983487 | .58 | .448841 | 8.08 | .551159 | 18 |
| 43 | .432778 | 7.47 | .983452 | .60 | .449326 | 8.07 | .550674 | 17 |
| 44 | .433226 | 7.48 | .983416 | .58 | .449810 | 8.07 | .550190 | 16 |
| 45 | .433675 | 7.45 | .983381 | .60 | .450294 | 8.05 | .549706 | 15 |
| 46 | :434122 | 7.45 | .983345 | .60 | .450777 | 8.05 | .549223 | 14 |
| 47 | .434569 | 7.45 | .983309 | .60 | .451260 | 8.05 | .548740 | 13 |
| 48 | .435016 | 7.43 | .983273 | .58 | .451743 | 8.03 | .548257 | 12 |
| 49 | .435462 | 7.43 | .983238 | .60 | .452225 | 8.02 | .547775 | 11 |
| 50 | .435908 | 7.42 | .983202 | .60 | .452706 | 8.02 | .547294 | 10 |
| 51 | 9.436353 | 7.42 | 9.983166 | .60 | 9.453187 | 8.02 | 10.546813 | 9 |
| 52 | .436798 | 7.40 | .983130 | .60 | .453668 | 8.00 | .546332 | 8 |
| 53 | .437242 | 7.40 | .983094 | .60 | .454148 | 8.00 | .545852 | 7 |
| 54 | .437686 | 7.38 | .983058 | .60 | .454628 | 7.98 | .545372 | 6 |
| 55 | .438129 | 7.38 | .983022 | .60 | .455107 | 7.98 | .544893 | 5 |
| 56 | .438572 | 7.37 | .982986 | .60 | .455586 | 7.97 | .544414 | 4 |
| 57 | .439014 | 7.37 | .982950 | .60 | .456064 | 7.97 | .543936 | 3 |
| 58 | .439456 | 7.35 | .982914 | .60 | .456542 | 7.95 | .543458 | 2 |
| 59 | .439897 | 7.35 | .982878 | .60 | .457019 | 7.95 | .542981 | 1 |
| 60 | 9.440338 | | 9.982842 | | 9.457496 | | 10.542504 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.440338 | 7.33 | 9.982842 | .62 | 9.457496 | 7.95 | 10.542504 | 60 |
| 1 | .440778 | 7.33 | .982805 | .60 | .457973 | 7.93 | .542027 | 59 |
| 2 | .441218 | 7.33 | .982769 | .60 | .458449 | 7.93 | .541551 | 58 |
| 3 | .441658 | 7.30 | .982733 | .62 | .458925 | 7.92 | .541075 | 57 |
| 4 | .442096 | 7.32 | .982696 | .60 | .459400 | 7.92 | .540600 | 56 |
| 5 | .442535 | 7.30 | .982660 | .60 | .459875 | 7.90 | .540125 | 55 |
| 6 | .442973 | 7.28 | .982624 | .62 | .460349 | 7.90 | .539651 | 54 |
| 7 | .443410 | 7.28 | .982587 | .60 | .460823 | 7.90 | .539177 | 53 |
| 8 | .443847 | 7.28 | .982551 | .62 | .461297 | 7.88 | .538703 | 52 |
| 9 | .444284 | 7.27 | .982514 | .62 | .461770 | 7.87 | .538230 | 51 |
| 10 | .444720 | 7.25 | .982477 | .60 | .462242 | 7.88 | .537758 | 50 |
| 11 | 9.445155 | 7.25 | 9.982441 | .62 | 9.462715 | 7.85 | 10.537285 | 49 |
| 12 | .445590 | 7.25 | .982404 | .62 | .463186 | 7.87 | .536814 | 48 |
| 13 | .446025 | 7.23 | .982367 | .60 | .463658 | 7.83 | .536342 | 47 |
| 14 | .446459 | 7.23 | .982331 | .62 | .464128 | 7.85 | .535872 | 46 |
| 15 | .446893 | 7.22 | .982294 | .62 | .464599 | 7.83 | .535401 | 45 |
| 16 | .447326 | 7.22 | .982257 | .62 | .465069 | 7.83 | .534931 | 44 |
| 17 | .447759 | 7.20 | .982220 | .62 | .465539 | 7.82 | .534461 | 43 |
| 18 | .448191 | 7.20 | .982183 | .62 | .466008 | 7.82 | .533992 | 42 |
| 19 | .448623 | 7.18 | .982146 | .62 | .466477 | 7.80 | .533523 | 41 |
| 20 | .449054 | 7.18 | .982109 | .62 | .466945 | 7.80 | .533055 | 40 |
| 21 | 9.449485 | 7.17 | 9.982072 | .62 | 9.467413 | 7.78 | 10.532587 | 39 |
| 22 | .449915 | 7.17 | .982035 | .62 | .467880 | 7.78 | .532120 | 38 |
| 23 | .450345 | 7.17 | .981998 | .62 | .468347 | 7.78 | .531653 | 37 |
| 24 | .450775 | 7.15 | .981961 | .62 | .468814 | 7.77 | .531186 | 36 |
| 25 | .451204 | 7.13 | .981924 | .63 | .469280 | 7.77 | .530720 | 35 |
| 26 | .451632 | 7.13 | .981886 | .62 | .469746 | 7.75 | .530254 | 34 |
| 27 | .452060 | 7.13 | .981849 | .62 | .470211 | 7.75 | .529789 | 33 |
| 28 | .452488 | 7.12 | .981812 | .63 | .470676 | 7.75 | .529324 | 32 |
| 29 | .452915 | 7.12 | .981774 | .62 | .471141 | 7.73 | .528859 | 31 |
| 30 | .453342 | 7.10 | .981737 | .62 | .471605 | 7.73 | .528395 | 30 |
| 31 | 9.453768 | 7.10 | 9.981700 | .63 | 9.472069 | 7.72 | 10.527931 | 29 |
| 32 | .454194 | 7.08 | .981662 | .62 | .472532 | 7.72 | .527468 | 28 |
| 33 | .454619 | 7.08 | .981625 | .63 | .472995 | 7.70 | .527005 | 27 |
| 34 | .455044 | 7.08 | .981587 | .63 | .473457 | 7.70 | .526543 | 26 |
| 35 | .455469 | 7.07 | .981549 | .62 | .473919 | 7.70 | .526081 | 25 |
| 36 | .455893 | 7.05 | .981512 | .63 | .474381 | 7.68 | .525619 | 24 |
| 37 | .456316 | 7.05 | .981474 | .63 | .474842 | 7.68 | .525158 | 23 |
| 38 | .456739 | 7.05 | .981436 | .62 | .475303 | 7.67 | .524697 | 22 |
| 39 | .457162 | 7.03 | .981399 | .63 | .475763 | 7.67 | .524237 | 21 |
| 40 | .457584 | 7.03 | .981361 | .63 | .476223 | 7.67 | .523777 | 20 |
| 41 | 9.458006 | 7.02 | 9.981323 | .63 | 9.476683 | 7.65 | 10.523317 | 19 |
| 42 | .458427 | 7.02 | .981285 | .63 | .477142 | 7.65 | .522858 | 18 |
| 43 | .458848 | 7.00 | .981247 | .63 | .477601 | 7.63 | .522399 | 17 |
| 44 | .459268 | 7.00 | .981209 | .63 | .478059 | 7.63 | .521941 | 16 |
| 45 | .459688 | 7.00 | .981171 | .63 | .478517 | 7.63 | .521483 | 15 |
| 46 | .460108 | 6.98 | .981133 | .63 | .478975 | 7.62 | .521025 | 14 |
| 47 | .460527 | 6.98 | .981095 | .63 | .479432 | 7.62 | .520568 | 13 |
| 48 | .460946 | 6.97 | .981057 | .63 | .479889 | 7.60 | .520111 | 12 |
| 49 | .461364 | 6.97 | .981019 | .63 | .480345 | 7.60 | .519655 | 11 |
| 50 | .461782 | 6.95 | .980981 | .65 | .480801 | 7.60 | .519199 | 10 |
| 51 | 9.462199 | 6.95 | 9.980942 | .63 | 9.481257 | 7.58 | 10.518743 | 9 |
| 52 | .462616 | 6.93 | .980904 | .63 | .481712 | 7.58 | .518288 | 8 |
| 53 | .463032 | 6.93 | .980866 | .65 | .482167 | 7.57 | .517833 | 7 |
| 54 | .463448 | 6.93 | .980827 | .63 | .482621 | 7.57 | .517379 | 6 |
| 55 | .463864 | 6.92 | .980789 | .65 | .483075 | 7.57 | .516925 | 5 |
| 56 | .464279 | 6.92 | .980750 | .63 | .483529 | 7.55 | .516471 | 4 |
| 57 | .464694 | 6.90 | .980712 | .65 | .483982 | 7.55 | .516018 | 3 |
| 58 | .465108 | 6.90 | .980673 | .63 | .484435 | 7.53 | .515565 | 2 |
| 59 | .465522 | 6.88 | .980635 | .65 | .484887 | 7.53 | .515113 | 1 |
| 60 | 9.465935 | | 9.980596 | | 9.485339 | | 10.514661 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.465935 | 6.88 | 9.980596 | .63 | 9.485339 | 7.53 | 10.514661 | 60 |
| 1 | .466348 | 6.88 | .980558 | .65 | .485791 | 7.52 | .514209 | 59 |
| 2 | .466761 | 6.87 | .980519 | .65 | .486242 | 7.52 | .513758 | 58 |
| 3 | .467173 | 6.87 | .980480 | .63 | .486693 | 7.50 | .513307 | 57 |
| 4 | .467585 | 6.85 | .980442 | .65 | .487143 | 7.50 | .512857 | 56 |
| 5 | .467996 | 6.85 | .980403 | .65 | .487593 | 7.50 | .512407 | 55 |
| 6 | .468407 | 6.83 | .980364 | .65 | .488043 | 7.48 | .511957 | 54 |
| 7 | .468817 | 6.83 | .980325 | .65 | .488492 | 7.48 | .511508 | 53 |
| 8 | .469227 | 6.83 | .980286 | .65 | .488941 | 7.48 | .511059 | 52 |
| 9 | .469637 | 6.82 | .980247 | .65 | .489390 | 7.47 | .510610 | 51 |
| 10 | .470046 | 6.82 | .980208 | .65 | .489838 | 7.47 | .510162 | 50 |
| 11 | 9.470455 | 6.80 | 9.980169 | .65 | 9.490286 | 7.45 | 10.509714 | 49 |
| 12 | .470863 | 6.80 | .980130 | .65 | .490733 | 7.45 | .509267 | 48 |
| 13 | .471271 | 6.80 | .980091 | .65 | .491180 | 7.45 | .508820 | 47 |
| 14 | .471679 | 6.78 | .980052 | .67 | .491627 | 7.43 | .508373 | 46 |
| 15 | .472086 | 6.77 | .980012 | .65 | .492073 | 7.43 | .507927 | 45 |
| 16 | .472492 | 6.77 | .979973 | .65 | .492519 | 7.43 | .507481 | 44 |
| 17 | .472898 | 6.77 | .979934 | .65 | .492965 | 7.42 | .507035 | 43 |
| 18 | .473304 | 6.77 | .979895 | .67 | .493410 | 7.40 | .506590 | 42 |
| 19 | .473710 | 6.75 | .979855 | .65 | .493854 | 7.42 | .506146 | 41 |
| 20 | .474115 | 6.73 | .979816 | .67 | .494299 | 7.40 | .505701 | 40 |
| 21 | 9.474519 | 6.73 | 9.979776 | .65 | 9.494743 | 7.38 | 10.505257 | 39 |
| 22 | .474923 | 6.73 | .979737 | .67 | .495186 | 7.40 | .504814 | 38 |
| 23 | .475327 | 6.72 | .979697 | .65 | .495630 | 7.38 | .504370 | 37 |
| 24 | .475730 | 6.72 | .979658 | .67 | .496073 | 7.37 | .503927 | 36 |
| 25 | .476133 | 6.72 | .979618 | .65 | .496515 | 7.37 | .503485 | 35 |
| 26 | .476536 | 6.70 | .979579 | .67 | .496957 | 7.37 | .503043 | 34 |
| 27 | .476938 | 6.70 | .979539 | .67 | .497399 | 7.37 | .502601 | 33 |
| 28 | .477340 | 6.68 | .979499 | .67 | .497841 | 7.35 | .502159 | 32 |
| 29 | .477741 | 6.68 | .979459 | .65 | .498282 | 7.33 | .501718 | 31 |
| 30 | .478142 | 6.67 | .979420 | .67 | .498722 | 7.35 | .501278 | 30 |
| 31 | 9.478542 | 6.67 | 9.979380 | .67 | 9.499163 | 7.33 | 10.500837 | 29 |
| 32 | .478942 | 6.67 | .979340 | .67 | .499603 | 7.32 | .500397 | 28 |
| 33 | .479342 | 6.65 | .979300 | .67 | .500042 | 7.32 | .499958 | 27 |
| 34 | .479741 | 6.65 | .979260 | .67 | .500481 | 7.32 | .499519 | 26 |
| 35 | .480140 | 6.65 | .979220 | .67 | .500920 | 7.32 | .499080 | 25 |
| 36 | .480539 | 6.63 | .979180 | .67 | .501359 | 7.30 | .498641 | 24 |
| 37 | .480937 | 6.62 | .979140 | .67 | .501797 | 7.30 | .498203 | 23 |
| 38 | .481334 | 6.62 | .979100 | .68 | .502235 | 7.28 | .497765 | 22 |
| 39 | .481731 | 6.62 | .979059 | .67 | .502672 | 7.28 | .497328 | 21 |
| 40 | .482128 | 6.62 | .979019 | .67 | .503109 | 7.28 | .496891 | 20 |
| 41 | 9.482525 | 6.60 | 9.978979 | .67 | 9.503546 | 7.27 | 10.496454 | 19 |
| 42 | .482921 | 6.58 | .978939 | .68 | .503982 | 7.27 | .496018 | 18 |
| 43 | .483316 | 6.60 | .978898 | .67 | .504418 | 7.27 | .495582 | 17 |
| 44 | .483712 | 6.58 | .978858 | .68 | .504854 | 7.25 | .495146 | 16 |
| 45 | .484107 | 6.57 | .978817 | .67 | .505289 | 7.25 | .494711 | 15 |
| 46 | .484501 | 6.57 | .978777 | .67 | .505724 | 7.25 | .494276 | 14 |
| 47 | .484895 | 6.57 | .978737 | .68 | .506159 | 7.23 | .493841 | 13 |
| 48 | .485289 | 6.55 | .978696 | .68 | .506593 | 7.23 | .493407 | 12 |
| 49 | .485682 | 6.55 | .978655 | .67 | .507027 | 7.23 | .492973 | 11 |
| 50 | .486075 | 6.53 | .978615 | .68 | .507460 | 7.22 | .492540 | 10 |
| 51 | 9.486467 | 6.55 | 9.978574 | .68 | 9.507893 | 7.22 | 10.492107 | 9 |
| 52 | .486860 | 6.52 | .978533 | .67 | .508326 | 7.22 | .491674 | 8 |
| 53 | .487251 | 6.53 | .978493 | .68 | .508759 | 7.20 | .491241 | 7 |
| 54 | .487643 | 6.52 | .978452 | .68 | .509191 | 7.18 | .490809 | 6 |
| 55 | .488034 | 6.50 | .978411 | .68 | .509622 | 7.20 | .490378 | 5 |
| 56 | .488424 | 6.50 | .978370 | .68 | .510054 | 7.18 | .489946 | 4 |
| 57 | .488814 | 6.50 | .978329 | .68 | .510485 | 7.18 | .489515 | 3 |
| 58 | .489204 | 6.48 | .978288 | .68 | .510916 | 7.17 | .489084 | 2 |
| 59 | .489593 | 6.48 | .978247 | .68 | .511346 | 7.17 | .488654 | 1 |
| 60 | 9.489982 | | 9.978206 | | 9.511776 | | 10.488224 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.489982 | 6.48 | 9.978206 | .68 | 9.511776 | 7.17 | 10.488224 | 60 |
| 1 | .490371 | 6.47 | .978165 | .68 | .512206 | 7.15 | .487794 | 59 |
| 2 | .490759 | 6.47 | .978124 | .68 | .512635 | 7.15 | .487365 | 58 |
| 3 | .491147 | 6.47 | .978083 | .68 | .513064 | 7.15 | .486936 | 57 |
| 4 | .491535 | 6.45 | .978042 | .68 | .513493 | 7.13 | .486507 | 56 |
| 5 | .491922 | 6.43 | .978001 | .70 | .513921 | 7.13 | .486079 | 55 |
| 6 | .492308 | 6.45 | .977959 | .68 | .514349 | 7.13 | .485651 | 54 |
| 7 | .492695 | 6.43 | .977918 | .68 | .514777 | 7.12 | .485223 | 53 |
| 8 | .493081 | 6.42 | .977877 | .70 | .515204 | 7.12 | .484796 | 52 |
| 9 | .493466 | 6.42 | .977835 | .68 | .515631 | 7.10 | .484369 | 51 |
| 10 | .493851 | 6.42 | .977794 | .70 | .516057 | 7.12 | .483943 | 50 |
| 11 | 9.494236 | 6.42 | 9.977752 | .68 | 9.516484 | 7.10 | 10.483516 | 49 |
| 12 | .494621 | 6.40 | .977711 | .70 | .516910 | 7.08 | .483090 | 48 |
| 13 | .495005 | 6.38 | .977669 | .68 | .517335 | 7.10 | .482665 | 47 |
| 14 | .495388 | 6.40 | .977628 | .70 | .517761 | 7.08 | .482239 | 46 |
| 15 | .495772 | 6.37 | .977586 | .70 | .518186 | 7.07 | .481814 | 45 |
| 16 | .496154 | 6.38 | .977544 | .68 | .518610 | 7.07 | .481390 | 44 |
| 17 | .496537 | 6.37 | .977503 | .70 | .519034 | 7.07 | .480966 | 43 |
| 18 | .496919 | 6.37 | .977461 | .70 | .519458 | 7.07 | .480542 | 42 |
| 19 | .497301 | 6.35 | .977419 | .70 | .519882 | 7.05 | .480118 | 41 |
| 20 | .497682 | 6.35 | .977377 | .70 | .520305 | 7.05 | .479695 | 40 |
| 21 | 9.498064 | 6.33 | 9.977335 | .70 | 9.520728 | 7.05 | 10.479272 | 39 |
| 22 | .498444 | 6.35 | .977293 | .70 | .521151 | 7.03 | .478849 | 38 |
| 23 | .498825 | 6.32 | .977251 | .70 | .521573 | 7.03 | .478427 | 37 |
| 24 | .499204 | 6.33 | .977209 | .70 | .521995 | 7.03 | .478005 | 36 |
| 25 | .499584 | 6.32 | .977167 | .70 | .522417 | 7.02 | .477583 | 35 |
| 26 | .499963 | 6.32 | .977125 | .70 | .522838 | 7.02 | .477162 | 34 |
| 27 | .500342 | 6.32 | .977083 | .70 | .523259 | 7.02 | .476741 | 33 |
| 28 | .500721 | 6.30 | .977041 | .70 | .523680 | 7.00 | .476320 | 32 |
| 29 | .501099 | 6.28 | .976999 | .70 | .524100 | 7.00 | .475900 | 31 |
| 30 | .501476 | 6.30 | .976957 | .72 | .524520 | 7.00 | .475480 | 30 |
| 31 | 9.501854 | 6.28 | 9.976914 | .70 | 9.524940 | 6.98 | 10.475060 | 29 |
| 32 | .502231 | 6.27 | .976872 | .70 | .525359 | 6.98 | .474641 | 28 |
| 33 | .502607 | 6.28 | .976830 | .72 | .525778 | 6.98 | .474222 | 27 |
| 34 | .502984 | 6.27 | .976787 | .70 | .526197 | 6.97 | .473803 | 26 |
| 35 | .503360 | 6.25 | .976745 | .72 | .526615 | 6.97 | .473385 | 25 |
| 36 | .503735 | 6.25 | .976702 | .70 | .527033 | 6.97 | .472967 | 24 |
| 37 | .504110 | 6.25 | .976660 | .72 | .527451 | 6.95 | .472549 | 23 |
| 38 | .504485 | 6.25 | .976617 | .72 | .527868 | 6.95 | .472132 | 22 |
| 39 | .504860 | 6.23 | .976574 | .70 | .528285 | 6.95 | .471715 | 21 |
| 40 | .505234 | 6.23 | .976532 | .72 | .528702 | 6.95 | .471298 | 20 |
| 41 | 9.505608 | 6.22 | 9.976489 | .72 | 9.529119 | 6.93 | 10.470881 | 19 |
| 42 | .505981 | 6.22 | .976446 | .70 | .529535 | 6.93 | .470465 | 18 |
| 43 | .506354 | 6.22 | .976404 | .72 | .529951 | 6.92 | .470049 | 17 |
| 44 | .506727 | 6.20 | .976361 | .72 | .530366 | 6.92 | .469634 | 16 |
| 45 | .507099 | 6.20 | .976318 | .72 | .530781 | 6.92 | .469219 | 15 |
| 46 | .507471 | 6.20 | .976275 | .72 | .531196 | 6.92 | .468804 | 14 |
| 47 | .507843 | 6.18 | .976232 | .72 | .531611 | 6.90 | .468389 | 13 |
| 48 | .508214 | 6.18 | .976189 | .72 | .532025 | 6.90 | .467975 | 12 |
| 49 | .508585 | 6.18 | .976146 | .72 | .532439 | 6.90 | .467561 | 11 |
| 50 | .508956 | 6.17 | .976103 | .72 | .532853 | 6.88 | .467147 | 10 |
| 51 | 9.509326 | 6.17 | 9.976060 | .72 | 9.533266 | 6.88 | 10.466734 | 9 |
| 52 | .509696 | 6.15 | .976017 | .72 | .533679 | 6.88 | .466321 | 8 |
| 53 | .510065 | 6.15 | .975974 | .73 | .534092 | 6.87 | .465908 | 7 |
| 54 | .510434 | 6.15 | .975930 | .72 | .534504 | 6.87 | .465496 | 6 |
| 55 | .510803 | 6.15 | .975887 | .72 | .534916 | 6.87 | .465084 | 5 |
| 56 | .511172 | 6.13 | .975844 | .73 | .535328 | 6.85 | .464672 | 4 |
| 57 | .511540 | 6.12 | .975800 | .72 | .535739 | 6.85 | .464261 | 3 |
| 58 | .511907 | 6.13 | .975757 | .72 | .536150 | 6.85 | .463850 | 2 |
| 59 | .512275 | 6.12 | .975714 | .73 | .536561 | 6.85 | .463439 | 1 |
| 60 | 9.512642 | | 9.975670 | | 9.536972 | | 10.463028 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.512642 | 6.12 | 9.975670 | .72 | 9.536972 | 6.83 | 10.463028 | 60 |
| 1 | .513009 | 6.10 | .975627 | .73 | .537382 | 6.83 | .462618 | 59 |
| 2 | .513375 | 6.10 | .975583 | .73 | .537792 | 6.83 | .462208 | 58 |
| 3 | .513741 | 6.10 | .975539 | .72 | .538202 | 6.82 | .461798 | 57 |
| 4 | .514107 | 6.08 | .975496 | .73 | .538611 | 6.82 | .461389 | 56 |
| 5 | .514472 | 6.08 | .975452 | .73 | .539020 | 6.82 | .460980 | 55 |
| 6 | .514837 | 6.08 | .975408 | .72 | .539429 | 6.80 | .460571 | 54 |
| 7 | .515202 | 6.07 | .975365 | .73 | .539837 | 6.80 | .460163 | 53 |
| 8 | .515566 | 6.07 | .975321 | .73 | .540245 | 6.80 | .459755 | 52 |
| 9 | .515930 | 6.07 | .975277 | .73 | .540653 | 6.80 | .459347 | 51 |
| 10 | .516294 | 6.05 | .975233 | .73 | .541061 | 6.78 | .458939 | 50 |
| 11 | 9.516657 | 6.05 | 9.975189 | .73 | 9.541468 | 6.78 | 10.458532 | 49 |
| 12 | .517020 | 6.03 | .975145 | .73 | .541875 | 6.77 | .458125 | 48 |
| 13 | .517382 | 6.05 | .975101 | .73 | .542281 | 6.78 | .457719 | 47 |
| 14 | .517745 | 6.03 | .975057 | .73 | .542688 | 6.77 | .457312 | 46 |
| 15 | .518107 | 6.02 | .975013 | .73 | .543094 | 6.75 | .456906 | 45 |
| 16 | .518468 | 6.02 | .974969 | .73 | .543499 | 6.77 | .456501 | 44 |
| 17 | .518829 | 6.02 | .974925 | .75 | .543905 | 6.75 | .456095 | 43 |
| 18 | .519190 | 6.02 | .974880 | .73 | .544310 | 6.75 | .455690 | 42 |
| 19 | .519551 | 6.00 | .974836 | .73 | .544715 | 6.73 | .455285 | 41 |
| 20 | .519911 | 6.00 | .974792 | .73 | .545119 | 6.75 | .454881 | 40 |
| 21 | 9.520271 | 6.00 | 9.974748 | .75 | 9.545524 | 6.73 | 10.454476 | 39 |
| 22 | .520631 | 5.98 | .974703 | .73 | .545928 | 6.72 | .454072 | 38 |
| 23 | .520990 | 5.98 | .974659 | .75 | .546331 | 6.73 | .453669 | 37 |
| 24 | .521349 | 5.97 | .974614 | .73 | .546735 | 6.72 | .453265 | 36 |
| 25 | .521707 | 5.98 | .974570 | .75 | .547138 | 6.70 | .452862 | 35 |
| 26 | .522066 | 5.97 | .974525 | .73 | .547540 | 6.72 | .452460 | 34 |
| 27 | .522424 | 5.95 | .974481 | .75 | .547943 | 6.70 | .452057 | 33 |
| 28 | .522781 | 5.95 | .974436 | .75 | .548345 | 6.70 | .451655 | 32 |
| 29 | .523138 | 5.95 | .974391 | .73 | .548747 | 6.70 | .451253 | 31 |
| 30 | .523495 | 5.95 | .974347 | .75 | .549149 | 6.68 | .450851 | 30 |
| 31 | 9.523852 | 5.93 | 9.974302 | .75 | 9.549550 | 6.68 | 10.450450 | 29 |
| 32 | .524208 | 5.93 | .974257 | .75 | .549951 | 6.68 | .450049 | 28 |
| 33 | .524564 | 5.93 | .974212 | .75 | .550352 | 6.67 | .449648 | 27 |
| 34 | .524920 | 5.92 | .974167 | .75 | .550752 | 6.68 | .449248 | 26 |
| 35 | .525275 | 5.92 | .974122 | .75 | .551153 | 6.65 | .448847 | 25 |
| 36 | .525630 | 5.90 | .974077 | .75 | .551552 | 6.67 | .448448 | 24 |
| 37 | .525984 | 5.92 | .974032 | .75 | .551952 | 6.65 | .448048 | 23 |
| 38 | .526339 | 5.90 | .973987 | .75 | .552351 | 6.65 | .447649 | 22 |
| 39 | .526693 | 5.88 | .973942 | .75 | .552750 | 6.65 | .447250 | 21 |
| 40 | .527046 | 5.90 | .973897 | .75 | .553149 | 6.65 | .446851 | 20 |
| 41 | 9.527400 | 5.88 | 9.973852 | .75 | 9.553548 | 6.63 | 10.446452 | 19 |
| 42 | .527753 | 5.87 | .973807 | .77 | .553946 | 6.63 | .446054 | 18 |
| 43 | .528105 | 5.88 | .973761 | .75 | .554344 | 6.62 | .445656 | 17 |
| 44 | .528458 | 5.87 | .973716 | .75 | .554741 | 6.63 | .445259 | 16 |
| 45 | .528810 | 5.85 | .973671 | .77 | .555139 | 6.62 | .444861 | 15 |
| 46 | .529161 | 5.87 | .973625 | .75 | .555536 | 6.62 | .444464 | 14 |
| 47 | .529513 | 5.85 | .973580 | .75 | .555933 | 6.60 | .444067 | 13 |
| 48 | .529864 | 5.85 | .973535 | .77 | .556329 | 6.60 | .443671 | 12 |
| 49 | .530215 | 5.83 | .973489 | .75 | .556725 | 6.60 | .443275 | 11 |
| 50 | .530565 | 5.83 | .973444 | .77 | .557121 | 6.60 | .442879 | 10 |
| 51 | 9.530915 | 5.83 | 9.973398 | .77 | 9.557517 | 6.60 | 10.442483 | 9 |
| 52 | .531265 | 5.82 | .973352 | .75 | .557913 | 6.58 | .442087 | 8 |
| 53 | .531614 | 5.82 | .973307 | .77 | .558308 | 6.58 | .441692 | 7 |
| 54 | .531963 | 5.82 | .973261 | .77 | .558703 | 6.57 | .441297 | 6 |
| 55 | .532312 | 5.82 | .973215 | .77 | .559097 | 6.57 | .440903 | 5 |
| 56 | .532661 | 5.80 | .973169 | .75 | .559491 | 6.57 | .440509 | 4 |
| 57 | .533009 | 5.80 | .973124 | .77 | .559885 | 6.57 | .440115 | 3 |
| 58 | .533357 | 5.78 | .973078 | .77 | .560279 | 6.57 | .439721 | 2 |
| 59 | .533704 | 5.80 | .973032 | .77 | .560673 | 6.55 | .439327 | 1 |
| 60 | 9.534052 | | 9.972986 | | 9.561066 | | 10.438934 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.534052 | 5.78 | 9.972986 | .77 | 9.561066 | 6.55 | 10.438934 | 60 |
| 1 | .534399 | 5.77 | .972940 | .77 | .561459 | 6.53 | .438541 | 59 |
| 2 | .534745 | 5.78 | .972894 | .77 | .561851 | 6.55 | .438149 | 58 |
| 3 | .535092 | 5.77 | .972848 | .77 | .562244 | 6.53 | .437756 | 57 |
| 4 | .535438 | 5.75 | .972802 | .78 | .562636 | 6.53 | .437364 | 56 |
| 5 | .535783 | 5.77 | .972755 | .77 | .563028 | 6.52 | .436972 | 55 |
| 6 | .536129 | 5.75 | .972709 | .77 | .563419 | 6.53 | .436581 | 54 |
| 7 | .536474 | 5.73 | .972663 | .77 | .563811 | 6.52 | .436189 | 53 |
| 8 | .536818 | 5.75 | .972617 | .78 | .564202 | 6.52 | .435798 | 52 |
| 9 | .537163 | 5.73 | .972570 | .77 | .564593 | 6.50 | .435407 | 51 |
| 10 | .537507 | 5.73 | .972524 | .77 | .564983 | 6.50 | .435017 | 50 |
| 11 | 9.537851 | 5.72 | 9.972478 | .78 | 9.565373 | 6.50 | 10.434627 | 49 |
| 12 | .538194 | 5.73 | .972431 | .77 | .565763 | 6.50 | .434237 | 48 |
| 13 | .538538 | 5.70 | .972385 | .78 | .566153 | 6.48 | .433847 | 47 |
| 14 | .538880 | 5.72 | .972338 | .78 | .566542 | 6.50 | .433458 | 46 |
| 15 | .539223 | 5.70 | .972291 | .77 | .566932 | 6.47 | .433068 | 45 |
| 16 | .539565 | 5.70 | .972245 | .78 | .567320 | 6.48 | .432680 | 44 |
| 17 | .539907 | 5.68 | .972198 | .78 | .567709 | 6.48 | .432291 | 43 |
| 18 | .540249 | 5.68 | .972151 | .77 | .568098 | 6.47 | .431902 | 42 |
| 19 | .540590 | 5.68 | .972105 | .78 | .568486 | 6.45 | .431514 | 41 |
| 20 | .540931 | 5.68 | .972058 | .78 | .568873 | 6.47 | .431127 | 40 |
| 21 | 9.541272 | 5.68 | 9.972011 | .78 | 9.569261 | 6.45 | 10.430739 | 39 |
| 22 | .541613 | 5.67 | .971964 | .78 | .569648 | 6.45 | .430352 | 38 |
| 23 | .541953 | 5.67 | .971917 | .78 | .570035 | 6.45 | .429965 | 37 |
| 24 | .542293 | 5.65 | .971870 | .78 | .570422 | 6.45 | .429578 | 36 |
| 25 | .542632 | 5.65 | .971823 | .78 | .570809 | 6.43 | .429191 | 35 |
| 26 | .542971 | 5.65 | .971776 | .78 | .571195 | 6.43 | .428805 | 34 |
| 27 | .543310 | 5.65 | .971729 | .78 | .571581 | 6.43 | .428419 | 33 |
| 28 | .543649 | 5.63 | .971682 | .78 | .571967 | 6.42 | .428033 | 32 |
| 29 | .543987 | 5.63 | .971635 | .78 | .572352 | 6.43 | .427648 | 31 |
| 30 | .544325 | 5.63 | .971588 | .80 | .572738 | 6.42 | .427262 | 30 |
| 31 | 9.544663 | 5.62 | 9.971540 | .78 | 9.573123 | 6.40 | 10.426877 | 29 |
| 32 | .545000 | 5.63 | .971493 | .78 | .573507 | 6.42 | .426493 | 28 |
| 33 | .545338 | 5.60 | .971446 | .80 | .573892 | 6.40 | .426108 | 27 |
| 34 | .545674 | 5.62 | .971398 | .78 | .574276 | 6.40 | .425724 | 26 |
| 35 | .546011 | 5.60 | .971351 | .80 | .574660 | 6.40 | .425340 | 25 |
| 36 | .546347 | 5.60 | .971303 | .78 | .575044 | 6.38 | .424956 | 24 |
| 37 | .546683 | 5.60 | .971256 | .80 | .575427 | 6.38 | .424573 | 23 |
| 38 | .547019 | 5.58 | .971208 | .78 | .575810 | 6.38 | .424190 | 22 |
| 39 | .547354 | 5.58 | .971161 | .80 | .576193 | 6.38 | .423807 | 21 |
| 40 | .547689 | 5.58 | .971113 | .78 | .576576 | 6.38 | .423424 | 20 |
| 41 | 9.548024 | 5.58 | 9.971066 | .80 | 9.576959 | 6.37 | 10.423041 | 19 |
| 42 | .548359 | 5.57 | .971018 | .80 | .577341 | 6.37 | .422659 | 18 |
| 43 | .548693 | 5.57 | .970970 | .80 | .577723 | 6.35 | .422277 | 17 |
| 44 | .549027 | 5.55 | .970922 | .80 | .578104 | 6.37 | .421896 | 16 |
| 45 | .549360 | 5.55 | .970874 | .78 | .578486 | 6.35 | .421514 | 15 |
| 46 | .549693 | 5.55 | .970827 | .80 | .578867 | 6.35 | .421133 | 14 |
| 47 | .550026 | 5.55 | .970779 | .80 | .579248 | 6.35 | .420752 | 13 |
| 48 | .550359 | 5.55 | .970731 | .80 | .579629 | 6.33 | .420371 | 12 |
| 49 | .550692 | 5.53 | .970683 | .80 | .580009 | 6.33 | .419991 | 11 |
| 50 | .551024 | 5.53 | .970635 | .82 | .580389 | 6.33 | .419611 | 10 |
| 51 | 9.551356 | 5.52 | 9.970586 | .80 | 9.580769 | 6.33 | 10.419231 | 9 |
| 52 | .551687 | 5.52 | .970538 | .80 | .581149 | 6.32 | .418851 | 8 |
| 53 | .552018 | 5.52 | .970490 | .80 | .581528 | 6.32 | .418472 | 7 |
| 54 | .552349 | 5.52 | .970442 | .80 | .581907 | 6.32 | .418093 | 6 |
| 55 | .552680 | 5.50 | .970394 | .82 | .582286 | 6.32 | .417714 | 5 |
| 56 | .553010 | 5.52 | .970345 | .80 | .582665 | 6.32 | .417335 | 4 |
| 57 | .553341 | 5.48 | .970297 | .80 | .583044 | 6.30 | .416956 | 3 |
| 58 | .553670 | 5.50 | .970249 | .82 | .583422 | 6.30 | .416578 | 2 |
| 59 | .554000 | 5.48 | .970200 | .80 | .583800 | 6.28 | .416200 | 1 |
| 60 | 9.554329 | | 9.970152 | | 9.584177 | | 10.415823 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.554329 | 5.48 | 9.970152 | .82 | 9.584177 | 6.30 | 10.415823 | 60 |
| 1 | .554658 | 5.48 | .970103 | .80 | .584555 | 6.28 | .415445 | 59 |
| 2 | .554987 | 5.47 | .970055 | .82 | .584932 | 6.28 | .415068 | 58 |
| 3 | .555315 | 5.47 | .970006 | .82 | .585309 | 6.28 | .414691 | 57 |
| 4 | .555643 | 5.47 | .969957 | .80 | .585686 | 6.27 | .414314 | 56 |
| 5 | .555971 | 5.47 | .969909 | .82 | .586062 | 6.28 | .413938 | 55 |
| 6 | .556299 | 5.45 | .969860 | .82 | .586439 | 6.27 | .413561 | 54 |
| 7 | .556626 | 5.45 | .969811 | .82 | .586815 | 6.25 | .413185 | 53 |
| 8 | .556953 | 5.45 | .969762 | .80 | .587190 | 6.27 | .412810 | 52 |
| 9 | .557280 | 5.43 | .969714 | .82 | .587566 | 6.25 | .412434 | 51 |
| 10 | .557606 | 5.43 | .969665 | .82 | .587941 | 6.25 | .412059 | 50 |
| 11 | 9.557932 | 5.43 | 9.969616 | .82 | 9.588316 | 6.25 | 10.411684 | 49 |
| 12 | .558258 | 5.42 | .969567 | .82 | .588691 | 6.25 | .411309 | 48 |
| 13 | .558583 | 5.43 | .969518 | .82 | .589066 | 6.23 | .410934 | 47 |
| 14 | .558909 | 5.42 | .969469 | .82 | .589440 | 6.23 | .410560 | 46 |
| 15 | .559234 | 5.40 | .969420 | .83 | .589814 | 6.23 | .410186 | 45 |
| 16 | .559558 | 5.42 | .969370 | .82 | .590188 | 6.23 | .409812 | 44 |
| 17 | .559883 | 5.40 | .969321 | .82 | .590562 | 6.22 | .409438 | 43 |
| 18 | .560207 | 5.40 | .969272 | .82 | .590935 | 6.22 | .409065 | 42 |
| 19 | .560531 | 5.40 | .969223 | .83 | .591308 | 6.22 | .408692 | 41 |
| 20 | .560855 | 5.38 | .969173 | .82 | .591681 | 6.22 | .408319 | 40 |
| 21 | 9.561178 | 5.38 | 9.969124 | .82 | 9.592054 | 6.20 | 10.407946 | 39 |
| 22 | .561501 | 5.38 | .969075 | .83 | .592426 | 6.22 | .407574 | 38 |
| 23 | .561824 | 5.37 | .969025 | .82 | .592799 | 6.20 | .407201 | 37 |
| 24 | .562146 | 5.37 | .968976 | .83 | .593171 | 6.18 | .406829 | 36 |
| 25 | .562468 | 5.37 | .968926 | .82 | .593542 | 6.20 | .406458 | 35 |
| 26 | .562790 | 5.37 | .968877 | .83 | .593914 | 6.18 | .406086 | 34 |
| 27 | .563112 | 5.35 | .968827 | .83 | .594285 | 6.18 | .405715 | 33 |
| 28 | .563433 | 5.37 | .968777 | .82 | .594656 | 6.18 | .405344 | 32 |
| 29 | .563755 | 5.33 | .968728 | .83 | .595027 | 6.18 | .404973 | 31 |
| 30 | .564075 | 5.35 | .968678 | .83 | .595398 | 6.17 | .404602 | 30 |
| 31 | 9.564396 | 5.33 | 9.968628 | .83 | 9.595768 | 6.17 | 10.404232 | 29 |
| 32 | .564716 | 5.33 | .968578 | .83 | .596138 | 6.17 | .403862 | 28 |
| 33 | .565036 | 5.33 | .968528 | .82 | .596508 | 6.17 | .403492 | 27 |
| 34 | .565356 | 5.33 | .968479 | .83 | .596878 | 6.15 | .403122 | 26 |
| 35 | .565676 | 5.32 | .968429 | .83 | .597247 | 6.15 | .402753 | 25 |
| 36 | .565995 | 5.32 | .968379 | .83 | .597616 | 6.15 | .402384 | 24 |
| 37 | .566314 | 5.30 | .968329 | .85 | .597985 | 6.15 | .402015 | 23 |
| 38 | .566632 | 5.32 | .968278 | .83 | .598354 | 6.13 | .401646 | 22 |
| 39 | .566951 | 5.30 | .968228 | .83 | .598722 | 6.15 | .401278 | 21 |
| 40 | .567269 | 5.30 | .968178 | .83 | .599091 | 6.13 | .400909 | 20 |
| 41 | 9.567587 | 5.28 | 9.968128 | .83 | 9.599459 | 6.13 | 10.400541 | 19 |
| 42 | .567904 | 5.30 | .968078 | .85 | .599827 | 6.12 | .400173 | 18 |
| 43 | .568222 | 5.28 | .968027 | .83 | .600194 | 6.13 | .399806 | 17 |
| 44 | .568539 | 5.28 | .967977 | .83 | .600562 | 6.12 | .399438 | 16 |
| 45 | .568856 | 5.27 | .967927 | .85 | .600929 | 6.12 | .399071 | 15 |
| 46 | .569172 | 5.27 | .967876 | .83 | .601296 | 6.12 | .398704 | 14 |
| 47 | .569488 | 5.27 | .967826 | .85 | .601663 | 6.10 | .398337 | 13 |
| 48 | .569804 | 5.27 | .967775 | .83 | .602029 | 6.10 | .397971 | 12 |
| 49 | .570120 | 5.25 | .967725 | .85 | .602395 | 6.10 | .397605 | 11 |
| 50 | .570435 | 5.27 | .967674 | .83 | .602761 | 6.10 | .397239 | 10 |
| 51 | 9.570751 | 5.25 | 9.967624 | .85 | 9.603127 | 6.10 | 10.396873 | 9 |
| 52 | .571066 | 5.23 | .967573 | .85 | .603493 | 6.08 | .396507 | 8 |
| 53 | .571380 | 5.25 | .967522 | .85 | .603858 | 6.08 | .396142 | 7 |
| 54 | .571695 | 5.23 | .967471 | .83 | .604223 | 6.08 | .395777 | 6 |
| 55 | .572009 | 5.23 | .967421 | .85 | .604588 | 6.08 | .395412 | 5 |
| 56 | .572323 | 5.22 | .967370 | .85 | .604953 | 6.07 | .395047 | 4 |
| 57 | .572636 | 5.23 | .967319 | .85 | .605317 | 6.08 | .394683 | 3 |
| 58 | .572950 | 5.22 | .967268 | .85 | .605682 | 6.07 | .394318 | 2 |
| 59 | .573263 | 5.20 | .967217 | .85 | .606046 | 6.07 | .393954 | 1 |
| 60 | 9.573575 | | 9.967166 | | 9.606410 | | 10.393590 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.573575 | 5.22 | 9.967166 | .85 | 9.606410 | 6.05 | 10.393590 | 60 |
| 1 | .573888 | 5.20 | .967115 | .85 | .606773 | 6.07 | .393227 | 59 |
| 2 | .574200 | 5.20 | .967064 | .85 | .607137 | 6.05 | .392863 | 58 |
| 3 | .574512 | 5.20 | .967013 | .87 | .607500 | 6.05 | .392500 | 57 |
| 4 | .574824 | 5.20 | .966961 | .85 | .607863 | 6.03 | .392137 | 56 |
| 5 | .575136 | 5.18 | .966910 | .85 | .608225 | 6.05 | .391775 | 55 |
| 6 | .575447 | 5.18 | .966859 | .85 | .608588 | 6.03 | .391412 | 54 |
| 7 | .575758 | 5.18 | .966808 | .87 | .608950 | 6.03 | .391050 | 53 |
| 8 | .576069 | 5.17 | .966756 | .85 | .609312 | 6.03 | .390688 | 52 |
| 9 | .576379 | 5.17 | .966705 | .87 | .609674 | 6.03 | .390326 | 51 |
| 10 | .576689 | 5.17 | .966653 | .85 | .610036 | 6.02 | .389964 | 50 |
| 11 | 9.576999 | 5.17 | 9.966602 | .87 | 9.610397 | 6.03 | 10.389603 | 49 |
| 12 | .577309 | 5.15 | .966550 | .85 | .610759 | 6.02 | .389241 | 48 |
| 13 | .577618 | 5.15 | .966499 | .87 | .611120 | 6.00 | .388880 | 47 |
| 14 | .577927 | 5.15 | .966447 | .87 | .611480 | 6.02 | .388520 | 46 |
| 15 | .578236 | 5.15 | .966395 | .85 | .611841 | 6.00 | .388159 | 45 |
| 16 | .578545 | 5.13 | .966344 | .87 | .612201 | 6.00 | .387799 | 44 |
| 17 | .578853 | 5.15 | .966292 | .87 | .612561 | 6.00 | .387439 | 43 |
| 18 | .579162 | 5.13 | .966240 | .87 | .612921 | 6.00 | .387079 | 42 |
| 19 | .579470 | 5.12 | .966188 | .87 | .613281 | 6.00 | .386719 | 41 |
| 20 | .579777 | 5.13 | .966136 | .85 | .613641 | 5.98 | .386359 | 40 |
| 21 | 9.580085 | 5.12 | 9.966085 | .87 | 9.614000 | 5.98 | 10.386000 | 39 |
| 22 | .580392 | 5.12 | .966033 | .87 | .614359 | 5.98 | .385641 | 38 |
| 23 | .580699 | 5.10 | .965981 | .87 | .614718 | 5.98 | .385282 | 37 |
| 24 | .581005 | 5.12 | .965929 | .88 | .615077 | 5.97 | .384923 | 36 |
| 25 | .581312 | 5.10 | .965876 | .87 | .615435 | 5.97 | .384565 | 35 |
| 26 | .581618 | 5.10 | .965824 | .87 | .615793 | 5.97 | .384207 | 34 |
| 27 | .581924 | 5.08 | .965772 | .87 | .616151 | 5.97 | .383849 | 33 |
| 28 | .582229 | 5.10 | .965720 | .87 | .616509 | 5.97 | .383491 | 32 |
| 29 | .582535 | 5.08 | .965668 | .88 | .616867 | 5.95 | .383133 | 31 |
| 30 | .582840 | 5.08 | .965615 | .87 | .617224 | 5.97 | .382776 | 30 |
| 31 | 9.583145 | 5.07 | 9.965563 | .87 | 9.617582 | 5.95 | 10.382418 | 29 |
| 32 | .583449 | 5.08 | .965511 | .88 | .617939 | 5.93 | .382061 | 28 |
| 33 | .583754 | 5.07 | .965458 | .87 | .618295 | 5.95 | .381705 | 27 |
| 34 | .584058 | 5.05 | .965406 | .88 | .618652 | 5.93 | .381348 | 26 |
| 35 | .584361 | 5.07 | .965353 | .87 | .619008 | 5.93 | .380992 | 25 |
| 36 | .584665 | 5.05 | .965301 | .88 | .619364 | 5.93 | .380636 | 24 |
| 37 | .584968 | 5.07 | .965248 | .88 | .619720 | 5.93 | .380280 | 23 |
| 38 | .585272 | 5.03 | .965195 | .87 | .620076 | 5.93 | .379924 | 22 |
| 39 | .585574 | 5.05 | .965143 | .88 | .620432 | 5.92 | .379568 | 21 |
| 40 | .585877 | 5.03 | .965090 | .88 | .620787 | 5.92 | .379213 | 20 |
| 41 | 9.586179 | 5.05 | 9.965037 | .88 | 9.621142 | 5.92 | 10.378858 | 19 |
| 42 | .586482 | 5.02 | .964984 | .88 | .621497 | 5.92 | .378503 | 18 |
| 43 | .586783 | 5.03 | .964931 | .87 | .621852 | 5.92 | .378148 | 17 |
| 44 | .587085 | 5.02 | .964879 | .88 | .622207 | 5.90 | .377793 | 16 |
| 45 | .587386 | 5.03 | .964826 | .88 | .622561 | 5.90 | .377439 | 15 |
| 46 | .587688 | 5.02 | .964773 | .88 | .622915 | 5.90 | .377085 | 14 |
| 47 | .587989 | 5.00 | .964720 | .90 | .623269 | 5.90 | .376731 | 13 |
| 48 | .588289 | 5.02 | .964666 | .88 | .623623 | 5.88 | .376377 | 12 |
| 49 | .588590 | 5.00 | .964613 | .88 | .623976 | 5.90 | .376024 | 11 |
| 50 | .588890 | 5.00 | .964560 | .88 | .624330 | 5.88 | .375670 | 10 |
| 51 | 9.589190 | 4.98 | 9.964507 | .88 | 9.624683 | 5.88 | 10.375317 | 9 |
| 52 | .589489 | 5.00 | .964454 | .90 | .625036 | 5.87 | .374964 | 8 |
| 53 | .589789 | 4.98 | .964400 | .88 | .625388 | 5.88 | .374612 | 7 |
| 54 | .590088 | 4.98 | .964347 | .88 | .625741 | 5.87 | .374259 | 6 |
| 55 | .590387 | 4.98 | .964294 | .90 | .626093 | 5.87 | .373907 | 5 |
| 56 | .590686 | 4.97 | .964240 | .88 | .626445 | 5.87 | .373555 | 4 |
| 57 | .590984 | 4.97 | .964187 | .90 | .626797 | 5.87 | .373203 | 3 |
| 58 | .591282 | 4.97 | .964133 | .88 | .627149 | 5.87 | .372851 | 2 |
| 59 | .591580 | 4.97 | .964080 | .90 | .627501 | 5.85 | .372499 | 1 |
| 60 | 9.591878 | | 9.964026 | | 9.627852 | | 10.372148 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.591878 | 4.97 | 9.964026 | .90 | 9.627852 | 5.85 | 10.372148 | 60 |
| 1 | .592176 | 4.95 | .963972 | .88 | .628203 | 5.85 | .371797 | 59 |
| 2 | .592473 | 4.95 | .963919 | .90 | .628554 | 5.85 | .371446 | 58 |
| 3 | .592770 | 4.95 | .963865 | .90 | .628905 | 5.83 | .371095 | 57 |
| 4 | .593067 | 4.93 | .963811 | .90 | .629255 | 5.85 | .370745 | 56 |
| 5 | .593362 | 4.93 | .963757 | .88 | .629606 | 5.83 | .370394 | 55 |
| 6 | .593659 | 4.93 | .963704 | .90 | .629956 | 5.83 | .370044 | 54 |
| 7 | .593955 | 4.93 | .963650 | .90 | .630306 | 5.83 | .369694 | 53 |
| 8 | .594251 | 4.93 | .963596 | .90 | .630656 | 5.82 | .369344 | 52 |
| 9 | .594547 | 4.92 | .963542 | .90 | .631005 | 5.83 | .368995 | 51 |
| 10 | .594842 | 4.92 | .963488 | .90 | .631355 | 5.82 | .368645 | 50 |
| 11 | 9.595137 | 4.92 | 9.963434 | .92 | 9.631704 | 5.82 | 10.368296 | 49 |
| 12 | .595432 | 4.92 | .963379 | .90 | .632053 | 5.82 | .367947 | 48 |
| 13 | .595727 | 4.90 | .963325 | .90 | .632402 | 5.80 | .367598 | 47 |
| 14 | .596021 | 4.90 | .963271 | .90 | .632750 | 5.82 | .367250 | 46 |
| 15 | .596315 | 4.90 | .963217 | .90 | .633099 | 5.80 | .366901 | 45 |
| 16 | .596609 | 4.90 | .963163 | .92 | .633447 | 5.80 | .366553 | 44 |
| 17 | .596903 | 4.88 | .963108 | .90 | .633795 | 5.80 | .366205 | 43 |
| 18 | .597196 | 4.90 | .963054 | .92 | .634143 | 5.78 | .365857 | 42 |
| 19 | .597490 | 4.88 | .962999 | .90 | .634490 | 5.80 | .365510 | 41 |
| 20 | .597783 | 4.87 | .962945 | .92 | .634838 | 5.78 | .365162 | 40 |
| 21 | 9.598075 | 4.88 | 9.962890 | .90 | 9.635185 | 5.78 | 10.364815 | 39 |
| 22 | .598368 | 4.87 | .962836 | .92 | .635532 | 5.78 | .364468 | 38 |
| 23 | .598660 | 4.87 | .962781 | .90 | .635879 | 5.78 | .364121 | 37 |
| 24 | .598952 | 4.87 | .962727 | .92 | .636226 | 5.77 | .363774 | 36 |
| 25 | .599244 | 4.87 | .962672 | .92 | .636572 | 5.78 | .363428 | 35 |
| 26 | .599536 | 4.85 | .962617 | .92 | .636919 | 5.77 | .363081 | 34 |
| 27 | .599827 | 4.85 | .962562 | .90 | .637265 | 5.77 | .362735 | 33 |
| 28 | .600118 | 4.85 | .962508 | .92 | .637611 | 5.75 | .362389 | 32 |
| 29 | .600409 | 4.85 | .962453 | .92 | .637956 | 5.77 | .362044 | 31 |
| 30 | .600700 | 4.83 | .962398 | .92 | .638302 | 5.75 | .361698 | 30 |
| 31 | 9.600990 | 4.83 | 9.962343 | .92 | 9.638647 | 5.75 | 10.361353 | 29 |
| 32 | .601280 | 4.83 | .962288 | .92 | .638992 | 5.75 | .361008 | 28 |
| 33 | .601570 | 4.83 | .962233 | .92 | .639337 | 5.75 | .360663 | 27 |
| 34 | .601860 | 4.83 | .962178 | .92 | .639682 | 5.75 | .360318 | 26 |
| 35 | .602150 | 4.82 | .962123 | .93 | .640027 | 5.73 | .359973 | 25 |
| 36 | .602439 | 4.82 | .962067 | .92 | .640371 | 5.75 | .359629 | 24 |
| 37 | .602728 | 4.82 | .962012 | .92 | .640716 | 5.73 | .359284 | 23 |
| 38 | .603017 | 4.80 | .961957 | .92 | .641060 | 5.73 | .358940 | 22 |
| 39 | .603305 | 4.82 | .961902 | .93 | .641404 | 5.72 | .358596 | 21 |
| 40 | .603594 | 4.80 | .961846 | .92 | .641747 | 5.73 | .358253 | 20 |
| 41 | 9.603882 | 4.80 | 9.961791 | .93 | 9.642091 | 5.72 | 10.357909 | 19 |
| 42 | .604170 | 4.78 | .961735 | .92 | .642434 | 5.72 | .357566 | 18 |
| 43 | .604457 | 4.80 | .961680 | .93 | .642777 | 5.72 | .357223 | 17 |
| 44 | .604745 | 4.78 | .961624 | .92 | .643120 | 5.72 | .356880 | 16 |
| 45 | .605032 | 4.78 | .961569 | .93 | .643463 | 5.72 | .356537 | 15 |
| 46 | .605319 | 4.78 | .961513 | .92 | .643806 | 5.70 | .356194 | 14 |
| 47 | .605606 | 4.77 | .961458 | .93 | .644148 | 5.70 | .355852 | 13 |
| 48 | .605892 | 4.78 | .961402 | .93 | .644490 | 5.70 | .355510 | 12 |
| 49 | .606179 | 4.77 | .961346 | .93 | .644832 | 5.70 | .355168 | 11 |
| 50 | .606465 | 4.77 | .961290 | .92 | .645174 | 5.70 | .354826 | 10 |
| 51 | 9.606751 | 4.75 | 9.961235 | .93 | 9.645516 | 5.68 | 10.354484 | 9 |
| 52 | .607036 | 4.77 | .961179 | .93 | .645857 | 5.70 | .354143 | 8 |
| 53 | .607322 | 4.75 | .961123 | .93 | .646199 | 5.68 | .353801 | 7 |
| 54 | .607607 | 4.75 | .961067 | .93 | .646540 | 5.68 | .353460 | 6 |
| 55 | .607892 | 4.75 | .961011 | .93 | .646881 | 5.68 | .353119 | 5 |
| 56 | .608177 | 4.73 | .960955 | .93 | .647222 | 5.67 | .352778 | 4 |
| 57 | .608461 | 4.73 | .960899 | .93 | .647562 | 5.68 | .352438 | 3 |
| 58 | .608745 | 4.73 | .960843 | .95 | .647903 | 5.67 | .352097 | 2 |
| 59 | .609029 | 4.73 | .960786 | .93 | .648243 | 5.67 | .351757 | 1 |
| 60 | 9.609313 | | 9.960730 | | 9.648583 | | 10.351417 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.609313 | 4.73 | 9.960730 | .93 | 9.648583 | 5.67 | 10.351417 | 60 |
| 1 | .609597 | 4.72 | .960674 | .93 | .648923 | 5.67 | .351077 | 59 |
| 2 | .609880 | 4.73 | .960618 | .95 | .649263 | 5.65 | .350737 | 58 |
| 3 | .610164 | 4.72 | .960561 | .93 | .649602 | 5.67 | .350398 | 57 |
| 4 | .610447 | 4.70 | .960505 | .95 | .649942 | 5.65 | .350058 | 56 |
| 5 | .610729 | 4.72 | .960448 | .93 | .650281 | 5.65 | .349719 | 55 |
| 6 | .611012 | 4.70 | .960392 | .95 | .650620 | 5.65 | .349380 | 54 |
| 7 | .611294 | 4.70 | .960335 | .93 | .650959 | 5.63 | .349041 | 53 |
| 8 | .611576 | 4.70 | .960279 | .95 | .651297 | 5.65 | .348703 | 52 |
| 9 | .611858 | 4.70 | .960222 | .95 | .651636 | 5.63 | .348364 | 51 |
| 10 | .612140 | 4.68 | .960165 | .93 | .651974 | 5.63 | .348026 | 50 |
| 11 | 9.612421 | 4.68 | 9.960109 | .95 | 9.652312 | 5.63 | 10.347688 | 49 |
| 12 | .612702 | 4.68 | .960052 | .95 | .652650 | 5.63 | .347350 | 48 |
| 13 | .612983 | 4.68 | .959995 | .95 | .652988 | 5.63 | .347012 | 47 |
| 14 | .613264 | 4.68 | .959938 | .93 | .653326 | 5.62 | .346674 | 46 |
| 15 | .613545 | 4.67 | .959882 | .95 | .653663 | 5.62 | .346337 | 45 |
| 16 | .613825 | 4.67 | .959825 | .95 | .654000 | 5.62 | .346000 | 44 |
| 17 | .614105 | 4.67 | .959768 | .95 | .654337 | 5.62 | .345663 | 43 |
| 18 | .614385 | 4.67 | .959711 | .95 | .654674 | 5.62 | .345326 | 42 |
| 19 | .614665 | 4.65 | .959654 | .97 | .655011 | 5.62 | .344989 | 41 |
| 20 | .614944 | 4.65 | .959596 | .95 | .655348 | 5.60 | .344652 | 40 |
| 21 | 9.615223 | 4.65 | 9.959539 | .95 | 9.655684 | 5.60 | 10.344316 | 39 |
| 22 | .615502 | 4.65 | .959482 | .95 | .656020 | 5.60 | .343980 | 38 |
| 23 | .615781 | 4.65 | .959425 | .95 | .656356 | 5.60 | .343644 | 37 |
| 24 | .616060 | 4.63 | .959368 | .97 | .656692 | 5.60 | .343308 | 36 |
| 25 | .616338 | 4.63 | .959310 | .95 | .657028 | 5.60 | .342972 | 35 |
| 26 | .616616 | 4.63 | .959253 | .97 | .657364 | 5.58 | .342636 | 34 |
| 27 | .616894 | 4.63 | .959195 | .95 | .657699 | 5.58 | .342301 | 33 |
| 28 | .617172 | 4.63 | .959138 | .97 | .658034 | 5.58 | .341966 | 32 |
| 29 | .617450 | 4.62 | .959080 | .95 | .658369 | 5.58 | .341631 | 31 |
| 30 | .617727 | 4.62 | .959023 | .97 | .658704 | 5.58 | .341296 | 30 |
| 31 | 9.618004 | 4.62 | 9.958965 | .95 | 9.659039 | 5.57 | 10.340961 | 29 |
| 32 | .618281 | 4.62 | .958908 | .97 | .659373 | 5.58 | .340627 | 28 |
| 33 | .618558 | 4.60 | .958850 | .97 | .659708 | 5.57 | .340292 | 27 |
| 34 | .618834 | 4.60 | .958792 | .97 | .660042 | 5.57 | .339958 | 26 |
| 35 | .619110 | 4.60 | .958734 | .95 | .660376 | 5.57 | .339624 | 25 |
| 36 | .619386 | 4.60 | .958677 | .97 | .660710 | 5.55 | .339290 | 24 |
| 37 | .619662 | 4.60 | .958619 | .97 | .661043 | 5.57 | .338957 | 23 |
| 38 | .619938 | 4.58 | .958561 | .97 | .661377 | 5.55 | .338623 | 22 |
| 39 | .620213 | 4.58 | .958503 | .97 | .661710 | 5.55 | .338290 | 21 |
| 40 | .620488 | 4.58 | .958445 | .97 | .662043 | 5.55 | .337957 | 20 |
| 41 | 9.620763 | 4.58 | 9.958387 | .97 | 9.662376 | 5.55 | 10.337624 | 19 |
| 42 | .621038 | 4.58 | .958329 | .97 | .662709 | 5.55 | .337291 | 18 |
| 43 | .621313 | 4.57 | .958271 | .97 | .663042 | 5.55 | .336958 | 17 |
| 44 | .621587 | 4.57 | .958213 | .98 | .663375 | 5.53 | .336625 | 16 |
| 45 | .621861 | 4.57 | .958154 | .97 | .663707 | 5.53 | .336293 | 15 |
| 46 | .622135 | 4.57 | .958096 | .97 | .664039 | 5.53 | .335961 | 14 |
| 47 | .622409 | 4.55 | .958038 | .98 | .664371 | 5.53 | .335629 | 13 |
| 48 | .622682 | 4.57 | .957979 | .97 | .664703 | 5.53 | .335297 | 12 |
| 49 | .622956 | 4.55 | .957921 | .97 | .665035 | 5.52 | .334965 | 11 |
| 50 | .623229 | 4.55 | .957863 | .98 | .665366 | 5.53 | .334634 | 10 |
| 51 | 9.623502 | 4.53 | 9.957804 | .97 | 9.665698 | 5.52 | 10.334302 | 9 |
| 52 | .623774 | 4.55 | .957746 | .98 | .666029 | 5.52 | .333971 | 8 |
| 53 | .624047 | 4.53 | .957687 | .98 | .666360 | 5.52 | .333640 | 7 |
| 54 | .624319 | 4.53 | .957628 | .97 | .666691 | 5.50 | .333309 | 6 |
| 55 | .624591 | 4.53 | .957570 | .98 | .667021 | 5.52 | .332979 | 5 |
| 56 | .624863 | 4.53 | .957511 | .98 | .667352 | 5.50 | .332648 | 4 |
| 57 | .625135 | 4.52 | .957452 | .98 | .667682 | 5.52 | .332318 | 3 |
| 58 | .625406 | 4.52 | .957393 | .97 | .668013 | 5.50 | .331987 | 2 |
| 59 | .625677 | 4.52 | .957335 | .98 | .668343 | 5.50 | .331657 | 1 |
| 60 | 9.625948 | | 9.957276 | | 9.668673 | | 10.331327 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.625948 | 4.52 | 9.957276 | .98 | 9.668673 | 5.48 | 10.331327 | 60 |
| 1 | .626219 | 4.52 | .957217 | .98 | .669002 | 5.50 | .330998 | 59 |
| 2 | .626490 | 4.50 | .957158 | .98 | .669332 | 5.48 | .330668 | 58 |
| 3 | .626760 | 4.50 | .957099 | .98 | .669661 | 5.50 | .330339 | 57 |
| 4 | .627030 | 4.50 | .957040 | .98 | .669991 | 5.48 | .330009 | 56 |
| 5 | .627300 | 4.50 | .956981 | 1.00 | .670320 | 5.48 | .329680 | 55 |
| 6 | .627570 | 4.50 | .956921 | .98 | .670649 | 5.47 | .329351 | 54 |
| 7 | .627840 | 4.48 | .956862 | .98 | .670977 | 5.48 | .329023 | 53 |
| 8 | .628109 | 4.48 | .956803 | .98 | .671306 | 5.48 | .328694 | 52 |
| 9 | .628378 | 4.48 | .956744 | 1.00 | .671635 | 5.47 | .328365 | 51 |
| 10 | .628647 | 4.48 | .956684 | .98 | .671963 | 5.47 | .328037 | 50 |
| 11 | 9.628916 | 4.48 | 9.956625 | .98 | 9.672291 | 5.47 | 10.327709 | 49 |
| 12 | .629185 | 4.47 | .956566 | 1.00 | .672619 | 5.47 | .327381 | 48 |
| 13 | .629453 | 4.47 | .956506 | .98 | .672947 | 5.45 | .327053 | 47 |
| 14 | .629721 | 4.47 | .956447 | 1.00 | .673274 | 5.47 | .326726 | 46 |
| 15 | .629989 | 4.47 | .956387 | 1.00 | .673602 | 5.45 | .326398 | 45 |
| 16 | .630257 | 4.45 | .956327 | .98 | .673929 | 5.47 | .326071 | 44 |
| 17 | .630524 | 4.47 | .956268 | 1.00 | .674257 | 5.45 | .325743 | 43 |
| 18 | .630792 | 4.45 | .956208 | 1.00 | .674584 | 5.45 | .325416 | 42 |
| 19 | .631059 | 4.45 | .956148 | .98 | .674911 | 5.43 | .325089 | 41 |
| 20 | .631326 | 4.45 | .956089 | 1.00 | .675237 | 5.45 | .324763 | 40 |
| 21 | 9.631593 | 4.43 | 9.956029 | 1.00 | 9.675564 | 5.43 | 10.324436 | 39 |
| 22 | .631859 | 4.43 | .955969 | 1.00 | .675890 | 5.45 | .324110 | 38 |
| 23 | .632125 | 4.45 | .955909 | 1.00 | .676217 | 5.43 | .323783 | 37 |
| 24 | .632392 | 4.43 | .955849 | 1.00 | .676543 | 5.43 | .323457 | 36 |
| 25 | .632658 | 4.42 | .955789 | 1.00 | .676869 | 5.42 | .323131 | 35 |
| 26 | .632923 | 4.43 | .955729 | 1.00 | .677194 | 5.43 | .322806 | 34 |
| 27 | .633189 | 4.42 | .955669 | 1.00 | .677520 | 5.43 | .322480 | 33 |
| 28 | .633454 | 4.42 | .955609 | .98 | .677846 | 5.42 | .322154 | 32 |
| 29 | .633719 | 4.42 | .955548 | 1.00 | .678171 | 5.42 | .321829 | 31 |
| 30 | .633984 | 4.42 | .955488 | 1.00 | .678496 | 5.42 | .321504 | 30 |
| 31 | 9.634249 | 4.42 | 9.955428 | 1.00 | 9.678821 | 5.42 | 10.321179 | 29 |
| 32 | .634514 | 4.40 | .955368 | 1.02 | .679146 | 5.42 | .320854 | 28 |
| 33 | .634778 | 4.40 | .955307 | 1.00 | .679471 | 5.40 | .320529 | 27 |
| 34 | .635042 | 4.40 | .955247 | 1.02 | .679795 | 5.42 | .320205 | 26 |
| 35 | .635306 | 4.40 | .955186 | 1.00 | .680120 | 5.40 | .319880 | 25 |
| 36 | .635570 | 4.40 | .955126 | 1.02 | .680444 | 5.40 | .319556 | 24 |
| 37 | .635834 | 4.38 | .955065 | 1.00 | .680768 | 5.40 | .319232 | 23 |
| 38 | .636097 | 4.38 | .955005 | 1.02 | .681092 | 5.40 | .318908 | 22 |
| 39 | .636360 | 4.38 | .954944 | 1.02 | .681416 | 5.40 | .318584 | 21 |
| 40 | .636623 | 4.38 | .954883 | 1.00 | .681740 | 5.38 | .318260 | 20 |
| 41 | 9.636886 | 4.37 | 9.954823 | 1.02 | 9.682063 | 5.40 | 10.317937 | 19 |
| 42 | .637148 | 4.38 | .954762 | 1.02 | .682387 | 5.38 | .317613 | 18 |
| 43 | .637411 | 4.37 | .954701 | 1.02 | .682710 | 5.38 | .317290 | 17 |
| 44 | .637673 | 4.37 | .954640 | 1.02 | .683033 | 5.38 | .316967 | 16 |
| 45 | .637935 | 4.37 | .954579 | 1.02 | .683356 | 5.38 | .316644 | 15 |
| 46 | .638197 | 4.35 | .954518 | 1.02 | .683679 | 5.37 | .316321 | 14 |
| 47 | .638458 | 4.37 | .954457 | 1.02 | .684001 | 5.38 | .315999 | 13 |
| 48 | .638720 | 4.35 | .954396 | 1.02 | .684324 | 5.37 | .315676 | 12 |
| 49 | .638981 | 4.35 | .954335 | 1.02 | .684646 | 5.37 | .315354 | 11 |
| 50 | .639242 | 4.35 | .954274 | 1.02 | .684968 | 5.37 | .315032 | 10 |
| 51 | 9.639503 | 4.35 | 9.954213 | 1.02 | 9.685290 | 5.37 | 10.314710 | 9 |
| 52 | .639764 | 4.33 | .954152 | 1.03 | .685612 | 5.37 | .314388 | 8 |
| 53 | .640024 | 4.33 | .954090 | 1.02 | .685934 | 5.35 | .314066 | 7 |
| 54 | .640284 | 4.33 | .954029 | 1.02 | .686255 | 5.37 | .313745 | 6 |
| 55 | .640544 | 4.33 | .953968 | 1.03 | .686577 | 5.35 | .313423 | 5 |
| 56 | .640804 | 4.33 | .953906 | 1.02 | .686898 | 5.35 | .313102 | 4 |
| 57 | .641064 | 4.33 | .953845 | 1.03 | .687219 | 5.35 | .312781 | 3 |
| 58 | .641324 | 4.32 | .953783 | 1.02 | .687540 | 5.35 | .312460 | 2 |
| 59 | .641583 | 4.32 | .953722 | 1.03 | .687861 | 5.35 | .312139 | 1 |
| 60 | 9.641842 | | 9.953660 | | 9.688182 | | 10.311818 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.641842 | 4.32 | 9.953660 | 1.02 | 9.688182 | 5.33 | 10.311818 | 60 |
| 1 | .642101 | 4.32 | .953599 | 1.03 | .688502 | 5.32 | .311498 | 59 |
| 2 | .642360 | 4.30 | .953537 | 1.03 | .688823 | 5.33 | .311177 | 58 |
| 3 | .642618 | 4.32 | .953475 | 1.03 | .689143 | 5.33 | .310857 | 57 |
| 4 | .642877 | 4.30 | .953413 | 1.02 | .689463 | 5.33 | .310537 | 56 |
| 5 | .643135 | 4.30 | .953352 | 1.03 | .689783 | 5.33 | .310217 | 55 |
| 6 | .643393 | 4.28 | .953290 | 1.03 | .690103 | 5.33 | .309897 | 54 |
| 7 | .643650 | 4.30 | .953228 | 1.03 | .690423 | 5.32 | .309577 | 53 |
| 8 | .643908 | 4.28 | .953166 | 1.03 | .690742 | 5.33 | .309258 | 52 |
| 9 | .644165 | 4.30 | .953104 | 1.03 | .691062 | 5.32 | .308938 | 51 |
| 10 | .644423 | 4.28 | .953042 | 1.03 | .691381 | 5.32 | .308619 | 50 |
| 11 | 9.644680 | 4.27 | 9.952980 | 1.03 | 9.691700 | 5.32 | 10.308300 | 49 |
| 12 | .644936 | 4.28 | .952918 | 1.05 | .692019 | 5.32 | .307981 | 48 |
| 13 | .645193 | 4.28 | .952855 | 1.03 | .6923 8 | 5.30 | .307662 | 47 |
| 14 | .645450 | 4.27 | .952793 | 1.03 | .692656 | 5.32 | .307344 | 46 |
| 15 | .645706 | 4.27 | .952731 | 1.03 | .692975 | 5.30 | .307025 | 45 |
| 16 | .645962 | 4.27 | .952669 | 1.05 | .693293 | 5.32 | .306707 | 44 |
| 17 | .646218 | 4.27 | .952606 | 1.03 | .693612 | 5.30 | .306388 | 43 |
| 18 | .646474 | 4.25 | .952544 | 1.05 | .693930 | 5.30 | .306070 | 42 |
| 19 | .646729 | 4.25 | .952481 | 1.03 | .694248 | 5.30 | .305752 | 41 |
| 20 | .646984 | 4.27 | .952419 | 1.05 | .694566 | 5.28 | .305434 | 40 |
| 21 | 9.647240 | 4.23 | 9.952356 | 1.03 | 9.694883 | 5.30 | 10.305117 | 39 |
| 22 | .647494 | 4.25 | .952294 | 1.05 | .695201 | 5.28 | .304799 | 38 |
| 23 | .647749 | 4.25 | .952231 | 1.05 | .695518 | 5.30 | .304482 | 37 |
| 24 | .648004 | 4.23 | .952168 | 1.03 | .695836 | 5.28 | .304164 | 36 |
| 25 | .648258 | 4.23 | .952106 | 1.05 | .696153 | 5.28 | .303847 | 35 |
| 26 | .648512 | 4.23 | .952043 | 1.05 | .696470 | 5.28 | .303530 | 34 |
| 27 | .648766 | 4.23 | .951980 | 1.05 | .696787 | 5.27 | .303213 | 33 |
| 28 | .649020 | 4.23 | .951917 | 1.05 | .697103 | 5.28 | .302897 | 32 |
| 29 | .649274 | 4.22 | .951854 | 1.05 | .697420 | 5.27 | .302580 | 31 |
| 30 | .649527 | 4.23 | .951791 | 1.05 | .697736 | 5.28 | .302264 | 30 |
| 31 | 9.649781 | 4.22 | 9.951728 | 1.05 | 9.698053 | 5.27 | 10.301947 | 29 |
| 32 | .650034 | 4.22 | .951665 | 1.05 | .698369 | 5.27 | .301631 | 28 |
| 33 | .650287 | 4.20 | .951602 | 1.05 | .698685 | 5.27 | .301315 | 27 |
| 34 | .650539 | 4.22 | .951539 | 1.05 | .699001 | 5.25 | .300999 | 26 |
| 35 | .650792 | 4.20 | .951476 | 1.07 | .699316 | 5.27 | .300684 | 25 |
| 36 | .651044 | 4.22 | .951412 | 1.05 | .699632 | 5.25 | .300368 | 24 |
| 37 | .651297 | 4.20 | .951349 | 1.05 | .699947 | 5.27 | .300053 | 23 |
| 38 | .651549 | 4.18 | .951286 | 1.07 | .700263 | 5.25 | .299737 | 22 |
| 39 | .651800 | 4.20 | .951222 | 1.05 | .700578 | 5.25 | .299422 | 21 |
| 40 | .652052 | 4.20 | .951159 | 1.05 | .700893 | 5.25 | .299107 | 20 |
| 41 | 9.652304 | 4.18 | 9.951096 | 1.07 | 9.701208 | 5.25 | 10.298792 | 19 |
| 42 | .652555 | 4.18 | .951032 | 1.07 | .701523 | 5.23 | .298477 | 18 |
| 43 | .652806 | 4.18 | .950968 | 1.05 | .701837 | 5.25 | .298163 | 17 |
| 44 | .653057 | 4.18 | .950905 | 1.07 | .702152 | 5.23 | .297848 | 16 |
| 45 | 653308 | 4.17 | .950841 | 1.05 | .702466 | 5.25 | .297534 | 15 |
| 46 | .653558 | 4.17 | .950778 | 1.07 | .702781 | 5.23 | .297219 | 14 |
| 47 | .653808 | 4.18 | .950714 | 1.07 | .703095 | 5.23 | .296905 | 13 |
| 48 | .654059 | 4.17 | .950650 | 1.07 | .703409 | 5.22 | .296591 | 12 |
| 49 | .654309 | 4.15 | .950586 | 1.07 | .703722 | 5.23 | .296278 | 11 |
| 50 | .654558 | 4.17 | .950522 | 1.07 | .704036 | 5.23 | .295964 | 10 |
| 51 | 9.654808 | 4.17 | 9.950458 | 1.07 | 9.704350 | 5.22 | 10.295650 | 9 |
| 52 | .655058 | 4.15 | .950394 | 1.07 | .704663 | 5.22 | .295337 | 8 |
| 53 | .655307 | 4.15 | .950330 | 1.07 | .704976 | 5.23 | .295024 | 7 |
| 54 | .655556 | 4.15 | .950266 | 1.07 | .705290 | 5.22 | .294710 | 6 |
| 55 | .655805 | 4.15 | .950202 | 1.07 | .705603 | 5.22 | .294397 | 5 |
| 56 | .656054 | 4.13 | .950138 | 1.07 | .705916 | 5.20 | .294084 | 4 |
| 57 | 656302 | 4.15 | .950074 | 1.07 | .706228 | 5.22 | .293772 | 3 |
| 58 | .656551 | 4.13 | .950010 | 1.08 | .706541 | 5.22 | .293459 | 2 |
| 59 | .656799 | 4.13 | .949945 | 1.07 | .706854 | 5.20 | .293146 | 1 |
| 60 | 9.657047 | | 9.949881 | | 9.707166 | | 10.292834 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.657047 | 4.13 | 9.949881 | 1.08 | 9.707166 | 5.20 | 10.292834 | 60 |
| 1 | .657295 | 4.12 | .949816 | 1.07 | .707478 | 5.20 | .292522 | 59 |
| 2 | .657542 | 4.13 | .949752 | 1.07 | .707790 | 5.20 | .292210 | 58 |
| 3 | .657790 | 4.12 | .949688 | 1.08 | .708102 | 5.20 | .291898 | 57 |
| 4 | .658037 | 4.12 | .949623 | 1.08 | .708414 | 5.20 | .291586 | 56 |
| 5 | .658284 | 4.12 | .949558 | 1.07 | .708726 | 5.18 | .291274 | 55 |
| 6 | .658531 | 4.12 | .949494 | 1.08 | .709037 | 5.20 | .290963 | 54 |
| 7 | .658778 | 4.12 | .949429 | 1.08 | .709349 | 5.18 | .290651 | 53 |
| 8 | .659025 | 4.10 | .949364 | 1.07 | .709660 | 5.18 | .290340 | 52 |
| 9 | .659271 | 4.10 | .949300 | 1.08 | .709971 | 5.18 | .290029 | 51 |
| 10 | .659517 | 4.10 | .949235 | 1.08 | .710282 | 5.18 | .289718 | 50 |
| 11 | 9.659763 | 4.10 | 9.949170 | 1.08 | 9.710593 | 5.18 | 10.289407 | 49 |
| 12 | .660009 | 4.10 | .949105 | 1.08 | .710904 | 5.18 | .289096 | 48 |
| 13 | .660255 | 4.10 | .949040 | 1.08 | .711215 | 5.17 | .288785 | 47 |
| 14 | .660501 | 4.08 | .948975 | 1.08 | .711525 | 5.18 | .288475 | 46 |
| 15 | .660746 | 4.08 | .948910 | 1.08 | .711836 | 5.17 | .288164 | 45 |
| 16 | .660991 | 4.08 | .948845 | 1.08 | .712146 | 5.17 | .287854 | 44 |
| 17 | .661236 | 4.08 | .948780 | 1.08 | .712456 | 5.17 | .287544 | 43 |
| 18 | .661481 | 4.08 | .948715 | 1.08 | .712766 | 5.17 | .287234 | 42 |
| 19 | .661726 | 4.07 | .948650 | 1.10 | .713076 | 5.17 | .286924 | 41 |
| 20 | .661970 | 4.07 | .948584 | 1.08 | .713386 | 5.17 | .286614 | 40 |
| 21 | 9.662214 | 4.08 | 9.948519 | 1.08 | 9.713696 | 5.15 | 10.286304 | 39 |
| 22 | .662459 | 4.07 | .948454 | 1.10 | .714005 | 5.15 | .285995 | 38 |
| 23 | .662703 | 4.05 | .948388 | 1.08 | .714314 | 5.17 | .285686 | 37 |
| 24 | .662946 | 4.07 | .948323 | 1.10 | .714624 | 5.15 | .285376 | 36 |
| 25 | .663190 | 4.05 | .948257 | 1.08 | .714933 | 5.15 | .285067 | 35 |
| 26 | .663433 | 4.07 | .948192 | 1.10 | .715242 | 5.15 | .284758 | 34 |
| 27 | .663677 | 4.05 | .948126 | 1.10 | .715551 | 5.15 | .284449 | 33 |
| 28 | .663920 | 4.05 | .948060 | 1.08 | .715860 | 5.13 | .284140 | 32 |
| 29 | .664163 | 4.05 | .947995 | 1.10 | .716168 | 5.15 | .283832 | 31 |
| 30 | .664406 | 4.03 | .947929 | 1.10 | .716477 | 5.13 | .283523 | 30 |
| 31 | 9.664648 | 4.05 | 9.947863 | 1.10 | 9.716785 | 5.13 | 10.283215 | 29 |
| 32 | .664891 | 4.03 | .947797 | 1.10 | .717093 | 5.13 | .282907 | 28 |
| 33 | .665133 | 4.03 | .947731 | 1.10 | .717401 | 5.13 | .282599 | 27 |
| 34 | .665375 | 4.03 | .947665 | 1.08 | .717709 | 5.13 | .282291 | 26 |
| 35 | .665617 | 4.03 | .947600 | 1.12 | .718017 | 5.13 | .281983 | 25 |
| 36 | .665859 | 4.02 | .947533 | 1.10 | .718325 | 5.13 | .281675 | 24 |
| 37 | .666100 | 4.03 | .947467 | 1.10 | .718633 | 5.12 | .281367 | 23 |
| 38 | .666342 | 4.02 | .947401 | 1.10 | .718940 | 5.13 | .281060 | 22 |
| 39 | .666583 | 4.02 | .947335 | 1.10 | .719248 | 5.12 | .280752 | 21 |
| 40 | .666824 | 4.02 | .947269 | 1.10 | .719555 | 5.12 | .280445 | 20 |
| 41 | 9.667065 | 4.00 | 9.947203 | 1.12 | 9.719862 | 5.12 | 10.280138 | 19 |
| 42 | .667305 | 4.02 | .947136 | 1.10 | .720169 | 5.12 | .279831 | 18 |
| 43 | .667546 | 4.00 | .947070 | 1.10 | .720476 | 5.12 | .279524 | 17 |
| 44 | .667786 | 4.02 | .947004 | 1.12 | .720783 | 5.10 | .279217 | 16 |
| 45 | .668027 | 4.00 | .946937 | 1.10 | .721089 | 5.12 | .278911 | 15 |
| 46 | .668267 | 3.98 | .946871 | 1.12 | .721396 | 5.10 | .278604 | 14 |
| 47 | .668506 | 4.00 | .946804 | 1.10 | .721702 | 5.12 | .278298 | 13 |
| 48 | .668746 | 4.00 | .946738 | 1.12 | .722009 | 5.10 | .277991 | 12 |
| 49 | .668986 | 3.98 | .946671 | 1.12 | .722315 | 5.10 | .277685 | 11 |
| 50 | .669225 | 3.98 | .946604 | 1.10 | .722621 | 5.10 | .277379 | 10 |
| 51 | 9.669464 | 3.98 | 9.946538 | 1.12 | 9.722927 | 5.08 | 10.277073 | 9 |
| 52 | .669703 | 3.98 | .946471 | 1.12 | .723232 | 5.10 | .276768 | 8 |
| 53 | .669942 | 3.98 | .946404 | 1.12 | .723538 | 5.10 | .276462 | 7 |
| 54 | .670181 | 3.97 | .946337 | 1.12 | .723844 | 5.08 | .276156 | 6 |
| 55 | .670419 | 3.98 | .946270 | 1.12 | .724149 | 5.08 | .275851 | 5 |
| 56 | .670658 | 3.97 | .946203 | 1.12 | .724454 | 5.10 | .275546 | 4 |
| 57 | .670896 | 3.97 | .946136 | 1.12 | .724760 | 5.08 | .275240 | 3 |
| 58 | .671134 | 3.97 | .946069 | 1.12 | .725065 | 5.08 | .274935 | 2 |
| 59 | .671372 | 3.95 | .946002 | 1.12 | .725370 | 5.07 | .274630 | 1 |
| 60 | 9.671609 | | 9.945935 | | 9.725674 | | 10.274326 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.671609 | 3.97 | 9.945935 | 1.12 | 9.725674 | 5.08 | 10.274326 | 60 |
| 1 | .671847 | 3.95 | .945868 | 1.13 | .725979 | 5.08 | .274021 | 59 |
| 2 | .672084 | 3.95 | .945800 | 1.12 | .726284 | 5.07 | .273716 | 58 |
| 3 | .672321 | 3.95 | .945733 | 1.12 | .726588 | 5.07 | .273412 | 57 |
| 4 | .672558 | 3.95 | .945666 | 1.13 | .726892 | 5.05 | .273108 | 56 |
| 5 | .672795 | 3.95 | .945598 | 1.12 | .727197 | 5.07 | .272803 | 55 |
| 6 | .673032 | 3.93 | .945531 | 1.12 | .727501 | 5.07 | .272499 | 54 |
| 7 | .673268 | 3.95 | .945464 | 1.13 | .727805 | 5.07 | .272195 | 53 |
| 8 | .673505 | 3.93 | .945396 | 1.13 | .728109 | 5.05 | .271891 | 52 |
| 9 | .673741 | 3.93 | .945328 | 1.12 | .728412 | 5.07 | .271588 | 51 |
| 10 | .673977 | 3.93 | .945261 | 1.13 | .728716 | 5.07 | .271284 | 50 |
| 11 | 9.674213 | 3.92 | 9.945193 | 1.13 | 9.729020 | 5.05 | 10.270980 | 49 |
| 12 | .674448 | 3.93 | .945125 | 1.12 | .729323 | 5.05 | .270677 | 48 |
| 13 | .674684 | 3.92 | .945058 | 1.13 | .729626 | 5.05 | .270374 | 47 |
| 14 | .674919 | 3.93 | .944990 | 1.13 | .729929 | 5.07 | .270071 | 46 |
| 15 | .675155 | 3.92 | .944922 | 1.13 | .730233 | 5.03 | .269767 | 45 |
| 16 | .675390 | 3.90 | .944854 | 1.13 | .730535 | 5.05 | .269465 | 44 |
| 17 | .675624 | 3.92 | .944786 | 1.13 | .730838 | 5.05 | .269162 | 43 |
| 18 | .675859 | 3.92 | .944718 | 1.13 | .731141 | 5.05 | .268859 | 42 |
| 19 | .676094 | 3.90 | .944650 | 1.13 | .731444 | 5.03 | .268556 | 41 |
| 20 | .676328 | 3.90 | .944582 | 1.13 | .731746 | 5.03 | .268254 | 40 |
| 21 | 9.676562 | 3.90 | 9.944514 | 1.13 | 9.732048 | 5.05 | 10.267952 | 39 |
| 22 | .676796 | 3.90 | .944446 | 1.15 | .732351 | 5.03 | .267649 | 38 |
| 23 | .677030 | 3.90 | .944377 | 1.13 | .732653 | 5.03 | .267347 | 37 |
| 24 | .677264 | 3.90 | .944309 | 1.13 | .732955 | 5.03 | .267045 | 36 |
| 25 | .677498 | 3.88 | .944241 | 1.15 | .733257 | 5.02 | .266743 | 35 |
| 26 | .677731 | 3.88 | .944172 | 1.13 | .733558 | 5.03 | .266442 | 34 |
| 27 | .677964 | 3.88 | .944104 | 1.13 | .733860 | 5.03 | .266140 | 33 |
| 28 | .678197 | 3.88 | .944036 | 1.15 | .734162 | 5.02 | .265838 | 32 |
| 29 | .678430 | 3.88 | .943967 | 1.13 | .734463 | 5.02 | .265537 | 31 |
| 30 | .678663 | 3.87 | .943899 | 1.15 | .734764 | 5.03 | .265236 | 30 |
| 31 | 9.678895 | 3.88 | 9.943830 | 1.15 | 9.735066 | 5.02 | 10.264934 | 29 |
| 32 | .679128 | 3.87 | .943761 | 1.13 | .735367 | 5.02 | .264633 | 28 |
| 33 | .679360 | 3.87 | .943693 | 1.15 | .735668 | 5.02 | .264332 | 27 |
| 34 | .679592 | 3.87 | .943624 | 1.15 | .735969 | 5.00 | .264031 | 26 |
| 35 | .679824 | 3.87 | .943555 | 1.15 | .736269 | 5.02 | .263731 | 25 |
| 36 | .680056 | 3.87 | .943486 | 1.15 | .736570 | 5.00 | .263430 | 24 |
| 37 | .680288 | 3.85 | .943417 | 1.15 | .736870 | 5.02 | .263130 | 23 |
| 38 | .680519 | 3.85 | .943348 | 1.15 | .737171 | 5.00 | .262829 | 22 |
| 39 | .680750 | 3.87 | .943279 | 1.15 | .737471 | 5.00 | .262529 | 21 |
| 40 | .680982 | 3.85 | .943210 | 1.15 | .737771 | 5.00 | .262229 | 20 |
| 41 | 9.681213 | 3.83 | 9.943141 | 1.15 | 9.738071 | 5.00 | 10.261929 | 19 |
| 42 | .681443 | 3.85 | .943072 | 1.15 | .738371 | 5.00 | .261629 | 18 |
| 43 | .681674 | 3.85 | .943003 | 1.15 | .738671 | 5.00 | .261329 | 17 |
| 44 | .681905 | 3.83 | .942934 | 1.17 | .738971 | 5.00 | .261029 | 16 |
| 45 | .682135 | 3.83 | .942864 | 1.15 | .739271 | 4.98 | .260729 | 15 |
| 46 | .682365 | 3.83 | .942795 | 1.15 | .7395[illegible]0 | 5.00 | .260430 | 14 |
| 47 | .682595 | 3.83 | .942726 | 1.17 | .739870 | 4.98 | .260130 | 13 |
| 48 | .682825 | 3.83 | .942656 | 1.15 | .740169 | 4.98 | .259831 | 12 |
| 49 | .683055 | 3.82 | .942587 | 1.17 | .740468 | 4.98 | .259532 | 11 |
| 50 | .683284 | 3.83 | .942517 | 1.15 | .740767 | 4.98 | .259233 | 10 |
| 51 | 9.683514 | 3.82 | 9.942448 | 1.17 | 9.741066 | 4.98 | 10.258934 | 9 |
| 52 | .683743 | 3.82 | .942378 | 1.17 | .741365 | 4.98 | .258635 | 8 |
| 53 | .683972 | 3.82 | .942308 | 1.15 | .741664 | 4.97 | .258336 | 7 |
| 54 | .684201 | 3.82 | .942239 | 1.17 | .741962 | 4.98 | .258038 | 6 |
| 55 | .684430 | 3.80 | .942169 | 1.17 | .742261 | 4.97 | .257739 | 5 |
| 56 | .684658 | 3.82 | .942099 | 1.17 | .742559 | 4.98 | .257441 | 4 |
| 57 | .684887 | 3.80 | .942029 | 1.17 | .742858 | 4.97 | .257142 | 3 |
| 58 | .685115 | 3.80 | .941959 | 1.17 | .743156 | 4.97 | .256844 | 2 |
| 59 | .685343 | 3.80 | .941889 | 1.17 | .743454 | 4.97 | .256546 | 1 |
| 60 | 9.685571 | | 9.941819 | | 9.743752 | | 10.256248 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.685571 | 3.80 | 9.941819 | 1.17 | 9.743752 | 4.97 | 10.256248 | 60 |
| 1 | .685799 | 3.80 | .941749 | 1.17 | .744050 | 4.97 | .255950 | 59 |
| 2 | .686027 | 3.78 | .941679 | 1.17 | .744348 | 4.95 | .255652 | 58 |
| 3 | .686254 | 3.80 | .941609 | 1.17 | .744645 | 4.97 | .255355 | 57 |
| 4 | .686482 | 3.78 | .941539 | 1.17 | .744943 | 4.95 | .255057 | 56 |
| 5 | .686709 | 3.78 | .941469 | 1.18 | .745240 | 4.97 | .254760 | 55 |
| 6 | .686936 | 3.78 | .941398 | 1.17 | .745538 | 4.95 | .254462 | 54 |
| 7 | .687163 | 3.77 | .941328 | 1.17 | .745835 | 4.95 | .254165 | 53 |
| 8 | .687389 | 3.78 | .941258 | 1.18 | .746132 | 4.95 | .253868 | 52 |
| 9 | .687616 | 3.78 | .941187 | 1.17 | .746429 | 4.95 | .253571 | 51 |
| 10 | .687843 | 3.77 | .941117 | 1.18 | .746726 | 4.95 | .253274 | 50 |
| 11 | 9.688069 | 3.77 | 9.941046 | 1.18 | 9.747023 | 4.93 | 10.252977 | 49 |
| 12 | .688295 | 3.77 | .940975 | 1.17 | .747319 | 4.95 | .252681 | 48 |
| 13 | .688521 | 3.77 | .940905 | 1.18 | .747616 | 4.95 | .252384 | 47 |
| 14 | .688747 | 3.75 | .940834 | 1.18 | .747913 | 4.93 | .252087 | 46 |
| 15 | .688972 | 3.77 | .940763 | 1.17 | .748209 | 4.93 | .251791 | 45 |
| 16 | .689198 | 3.75 | .940693 | 1.18 | .748505 | 4.93 | .251495 | 44 |
| 17 | .689423 | 3.75 | .940622 | 1.18 | .748801 | 4.93 | .251199 | 43 |
| 18 | .689648 | 3.75 | .940551 | 1.18 | .749097 | 4.93 | .250903 | 42 |
| 19 | .689873 | 3.75 | .940480 | 1.18 | .749393 | 4.93 | .250607 | 41 |
| 20 | .690098 | 3.75 | .940409 | 1.18 | .749689 | 4.93 | .250311 | 40 |
| 21 | 9.690323 | 3.75 | 9.940338 | 1.18 | 9.749985 | 4.93 | 10.250015 | 39 |
| 22 | .690548 | 3.73 | .940267 | 1.18 | .750281 | 4.92 | .249719 | 38 |
| 23 | .690772 | 3.73 | .940196 | 1.18 | .750576 | 4.93 | .249424 | 37 |
| 24 | .690996 | 3.73 | .940125 | 1.18 | .750872 | 4.92 | .249128 | 36 |
| 25 | .691220 | 3.73 | .940054 | 1.20 | .751167 | 4.92 | .248833 | 35 |
| 26 | .691444 | 3.73 | .939982 | 1.18 | .751462 | 4.92 | .248538 | 34 |
| 27 | .691668 | 3.73 | .939911 | 1.18 | .751757 | 4.92 | .248243 | 33 |
| 28 | .691892 | 3.72 | .939840 | 1.20 | .752052 | 4.92 | .247948 | 32 |
| 29 | .692115 | 3.73 | .939768 | 1.18 | .752347 | 4.92 | .247653 | 31 |
| 30 | .692339 | 3.72 | .939697 | 1.20 | .752642 | 4.92 | .247358 | 30 |
| 31 | 9.692562 | 3.72 | 9.939625 | 1.18 | 9.752937 | 4.90 | 10.247063 | 29 |
| 32 | .692785 | 3.72 | .939554 | 1.20 | .753231 | 4.92 | .246769 | 28 |
| 33 | .693008 | 3.72 | .939482 | 1 20 | .753526 | 4.90 | .246474 | 27 |
| 34 | .693231 | 3.70 | .939410 | 1.18 | .753820 | 4.92 | .246180 | 26 |
| 35 | .693453 | 3.72 | .939339 | 1.20 | .754115 | 4.90 | .245885 | 25 |
| 36 | .693676 | 3.70 | .939267 | 1.20 | .754409 | 4.90 | .245591 | 24 |
| 37 | .693898 | 3.70 | .939195 | 1.20 | .754703 | 4.90 | .245297 | 23 |
| 38 | .694120 | 3.70 | .939123 | 1.18 | .754997 | 4.90 | .245003 | 22 |
| 39 | .694342 | 3.70 | .939052 | 1.20 | .755291 | 4.90 | .244709 | 21 |
| 40 | .694564 | 3.70 | .938980 | 1.20 | .755585 | 4.88 | .244415 | 20 |
| 41 | 9.694786 | 3.68 | 9.938908 | 1.20 | 9.755878 | 4.90 | 10.244122 | 19 |
| 42 | .695007 | 3.70 | .938836 | 1.22 | .756172 | 4.88 | .243828 | 18 |
| 43 | .695229 | 3.68 | .938763 | 1.20 | .756465 | 4.90 | .243535 | 17 |
| 44 | .695450 | 3.68 | .938691 | 1.20 | .756759 | 4.88 | .243241 | 16 |
| 45 | .695671 | 3.68 | .938619 | 1.20 | .757052 | 4.88 | .242948 | 15 |
| 46 | .695892 | 3.68 | .938547 | 1.20 | .757345 | 4.88 | .242655 | 14 |
| 47 | .696113 | 3.68 | .938475 | 1.22 | .757638 | 4.88 | .242362 | 13 |
| 48 | .696334 | 3.67 | .938402 | 1.20 | .757931 | 4.88 | .242069 | 12 |
| 49 | .696554 | 3.68 | .938330 | 1.20 | .758224 | 4.88 | .241776 | 11 |
| 50 | .696775 | 3.67 | .938258 | 1.22 | .758517 | 4.88 | .241483 | 10 |
| 51 | 9.696995 | 3.67 | 9.938185 | 1.20 | 9.758810 | 4.87 | 10.241190 | 9 |
| 52 | .697215 | 3.67 | .938113 | 1.22 | .759102 | 4.88 | .240898 | 8 |
| 53 | .697435 | 3.65 | .938040 | 1.22 | .759395 | 4.87 | .240605 | 7 |
| 54 | .697654 | 3.67 | .937967 | 1.20 | .759687 | 4.87 | .240313 | 6 |
| 55 | .697874 | 3.67 | .937895 | 1.22 | .759979 | 4.88 | .240021 | 5 |
| 56 | .698094 | 3.65 | .937822 | 1.22 | .760272 | 4.87 | .239728 | 4 |
| 57 | .698313 | 3.65 | .937749 | 1.22 | .760564 | 4.87 | .239436 | 3 |
| 58 | .698532 | 3.65 | .937676 | 1.20 | .760856 | 4.87 | .239144 | 2 |
| 59 | .698751 | 3.65 | .937604 | 1.22 | .761148 | 4.85 | .238852 | 1 |
| 60 | 9.698970 | | 9.937531 | | 9.761439 | | 10.238561 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.698970 | 3.65 | 9.937531 | 1.22 | 9.761439 | 4.87 | 10.238561 | 60 |
| 1 | .699189 | 3.63 | .937458 | 1.22 | .761731 | 4.87 | .238269 | 59 |
| 2 | .699407 | 3.65 | .937385 | 1.22 | .762023 | 4.85 | .237977 | 58 |
| 3 | .699626 | 3.63 | .937312 | 1.23 | .762314 | 4.87 | .237686 | 57 |
| 4 | .699844 | 3.63 | .937238 | 1.22 | .762606 | 4.85 | .237394 | 56 |
| 5 | .700062 | 3.63 | .937165 | 1.22 | .762897 | 4.85 | .237103 | 55 |
| 6 | .700280 | 3.63 | .937092 | 1.22 | .763188 | 4.85 | .236812 | 54 |
| 7 | .700498 | 3.63 | .937019 | 1.22 | .763479 | 4.85 | .236521 | 53 |
| 8 | .700716 | 3.62 | .936946 | 1.23 | .763770 | 4.85 | .236230 | 52 |
| 9 | .700933 | 3.63 | .936872 | 1.22 | .764061 | 4.85 | .235939 | 51 |
| 10 | .701151 | 3.62 | .936799 | 1.23 | .764352 | 4.85 | .235648 | 50 |
| 11 | 9.701368 | 3.62 | 9.936725 | 1.22 | 9.764643 | 4.83 | 10.235357 | 49 |
| 12 | .701585 | 3.62 | .936652 | 1.23 | .764933 | 4.85 | .235067 | 48 |
| 13 | .701802 | 3.62 | .936578 | 1.22 | .765224 | 4.83 | .234776 | 47 |
| 14 | .702019 | 3.62 | .936505 | 1.23 | .765514 | 4.85 | .234486 | 46 |
| 15 | .702236 | 3.60 | .936431 | 1.23 | .765805 | 4.83 | .234195 | 45 |
| 16 | .702452 | 3.62 | .936357 | 1.22 | .766095 | 4.83 | .233905 | 44 |
| 17 | .702669 | 3.60 | .936284 | 1.23 | .766285 | 4.83 | .233615 | 43 |
| 18 | .702885 | 3.60 | .936210 | 1.23 | .766675 | 4.83 | .233325 | 42 |
| 19 | .703101 | 3.60 | .936136 | 1.23 | .766965 | 4.83 | .233035 | 41 |
| 20 | .703317 | 3.60 | .936062 | 1.23 | .767255 | 4.83 | .232745 | 40 |
| 21 | 9.703533 | 3.60 | 9.935988 | 1.23 | 9.767545 | 4.82 | 10.232455 | 39 |
| 22 | .703749 | 3.58 | .935914 | 1.23 | .767834 | 4.83 | .232166 | 38 |
| 23 | .703964 | 3.58 | .935840 | 1.23 | .768124 | 4.83 | .231876 | 37 |
| 24 | .704179 | 3.60 | .935766 | 1.23 | .768414 | 4.82 | .231586 | 36 |
| 25 | .704395 | 3.58 | .935692 | 1.23 | .768703 | 4.82 | .231297 | 35 |
| 26 | .704610 | 3.58 | .935618 | 1.25 | .768992 | 4.82 | .231008 | 34 |
| 27 | .704825 | 3.58 | .935543 | 1.23 | .769281 | 4.83 | .230719 | 33 |
| 28 | .705040 | 3.57 | .935469 | 1.23 | .769571 | 4.82 | .230429 | 32 |
| 29 | .705254 | 3.58 | .935395 | 1.25 | .769860 | 4.80 | .230140 | 31 |
| 30 | .705469 | 3.57 | .935320 | 1.23 | .770148 | 4.82 | .229852 | 30 |
| 31 | 9.705683 | 3.58 | 9.935246 | 1.25 | 9.770437 | 4.82 | 10.229563 | 29 |
| 32 | .705898 | 3.57 | .935171 | 1.23 | .770726 | 4.82 | .229274 | 28 |
| 33 | .706112 | 3.57 | .935097 | 1.25 | .771015 | 4.80 | .228985 | 27 |
| 34 | .706326 | 3.55 | .935022 | 1.23 | .771303 | 4.82 | .228697 | 26 |
| 35 | .706539 | 3.57 | .934948 | 1.25 | .771592 | 4.80 | .228408 | 25 |
| 36 | .706753 | 3.57 | .934873 | 1.25 | .771880 | 4.80 | .228120 | 24 |
| 37 | .706967 | 3.55 | .934798 | 1.25 | .772168 | 4.82 | .227832 | 23 |
| 38 | .707180 | 3·55 | .934723 | 1.23 | .772457 | 4.80 | .227543 | 22 |
| 39 | .707393 | 3.55 | .934649 | 1.25 | .772745 | 4.80 | .227255 | 21 |
| 40 | .707606 | 3.55 | .934574 | 1.25 | .773033 | 4.80 | .226967 | 20 |
| 41 | 9.707819 | 3.55 | 9.934499 | 1.25 | 9.773321 | 4.78 | 10.226679 | 19 |
| 42 | .708032 | 3.55 | .934424 | 1.25 | .773608 | 4.80 | .226392 | 18 |
| 43 | .708245 | 3.55 | .934349 | 1.25 | .773896 | 4.80 | .226104 | 17 |
| 44 | .708458 | 3.53 | .934274 | 1.25 | .774184 | 4.78 | .225816 | 16 |
| 45 | .708670 | 3.53 | .934199 | 1.27 | .774471 | 4.80 | .225529 | 15 |
| 46 | .708882 | 3.53 | .934123 | 1.25 | .774[illegible]59 | 4.78 | .225241 | 14 |
| 47 | .709094 | 3.53 | .934048 | 1.25 | .775046 | 4.78 | .224954 | 13 |
| 48 | .709306 | 3.53 | .933973 | 1.25 | .775333 | 4.80 | .224667 | 12 |
| 49 | .709518 | 3.53 | .933898 | 1.27 | .775621 | 4.78 | .224379 | 11 |
| 50 | .709730 | 3.52 | .933822 | 1.25 | .775908 | 4.78 | .224092 | 10 |
| 51 | 9.709941 | 3.53 | 9.933747 | 1.27 | 9.776195 | 4.78 | 10.223805 | 9 |
| 52 | .710153 | 3.52 | .933671 | 1.25 | .776482 | 4.77 | .223518 | 8 |
| 53 | .710364 | 3.52 | .933596 | 1.27 | .776768 | 4.78 | .223232 | 7 |
| 54 | .710575 | 3.52 | .933520 | 1.25 | .777055 | 4.78 | .222945 | 6 |
| 55 | .710786 | 3.52 | .933445 | 1.27 | .777342 | 4.77 | .222658 | 5 |
| 56 | .710997 | 3.52 | .933369 | 1.27 | .777628 | 4.78 | .222372 | 4 |
| 57 | .711208 | 3.52 | .933293 | 1.27 | .777915 | 4.77 | .222085 | 3 |
| 58 | .711419 | 3.50 | .933217 | 1.27 | .778201 | 4.78 | .221799 | 2 |
| 59 | .711629 | 3.50 | .933141 | 1.25 | .778488 | 4.77 | .221512 | 1 |
| 60 | 9.711839 | | 9.933066 | | 9.778774 | | 10.221226 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.711839 | 3.52 | 9.933066 | 1.27 | 9.778774 | 4.77 | 10.221226 | 60 |
| 1 | .712050 | 3.50 | .932990 | 1.27 | .779060 | 4.77 | .220940 | 59 |
| 2 | .712260 | 3.48 | .932914 | 1.27 | .779346 | 4.77 | .220654 | 58 |
| 3 | .712469 | 3.50 | .932838 | 1.27 | .779632 | 4.77 | .220368 | 57 |
| 4 | .712679 | 3.50 | .932762 | 1.28 | .779918 | 4.75 | .220082 | 56 |
| 5 | .712889 | 3.48 | .932685 | 1.27 | .780203 | 4.77 | .219797 | 55 |
| 6 | .713098 | 3.50 | .932609 | 1.27 | .780489 | 4.77 | .219511 | 54 |
| 7 | .713308 | 3.48 | .932533 | 1.27 | .780775 | 4.75 | .219225 | 53 |
| 8 | .713517 | 3.48 | .932457 | 1.28 | .781060 | 4.77 | .218940 | 52 |
| 9 | .713726 | 3.48 | .932380 | 1.27 | .781346 | 4.75 | .218654 | 51 |
| 10 | .713935 | 3.48 | .932304 | 1.27 | .781631 | 4.75 | .218369 | 50 |
| 11 | 9.714144 | 3.47 | 9.932228 | 1.28 | 9.781916 | 4.75 | 10.218084 | 49 |
| 12 | .714352 | 3.48 | .932151 | 1.27 | .782201 | 4.75 | .217799 | 48 |
| 13 | .714561 | 3.47 | .932075 | 1.28 | .782486 | 4.75 | .217514 | 47 |
| 14 | .714769 | 3.48 | .931998 | 1.28 | .782771 | 4.75 | .217229 | 46 |
| 15 | .714978 | 3.47 | .931921 | 1.27 | .783056 | 4.75 | .216944 | 45 |
| 16 | .715186 | 3.47 | .931845 | 1.28 | .783341 | 4.75 | .216659 | 44 |
| 17 | .715394 | 3.47 | .931768 | 1.28 | .783626 | 4.73 | .216374 | 43 |
| 18 | .715602 | 3.45 | .931691 | 1.28 | .783910 | 4.75 | .216090 | 42 |
| 19 | .715809 | 3.47 | .931614 | 1.28 | .784195 | 4.73 | .215805 | 41 |
| 20 | .716017 | 3.45 | .931537 | 1.28 | .784479 | 4.75 | .215521 | 40 |
| 21 | 9.716224 | 3.47 | 9.931460 | 1.28 | 9.784764 | 4.73 | 10.215236 | 39 |
| 22 | .716432 | 3.45 | .931383 | 1.28 | .785048 | 4.73 | .214952 | 38 |
| 23 | .716639 | 3.45 | .931306 | 1.28 | .785332 | 4.73 | .214668 | 37 |
| 24 | .716846 | 3.45 | .931229 | 1.28 | .785616 | 4.73 | .214384 | 36 |
| 25 | .717053 | 3.43 | .931152 | 1.28 | .785900 | 4.73 | .214100 | 35 |
| 26 | .717259 | 3.45 | .931075 | 1.28 | .786184 | 4.73 | .213816 | 34 |
| 27 | .717466 | 3.45 | .930998 | 1.28 | .786468 | 4.73 | .213532 | 33 |
| 28 | .717673 | 3.43 | .930921 | 1.30 | .786752 | 4.73 | .213248 | 32 |
| 29 | .717879 | 3.43 | .930843 | 1.28 | .787036 | 4.72 | .212964 | 31 |
| 30 | .718085 | 3.43 | .930766 | 1.30 | .787319 | 4.73 | .212681 | 30 |
| 31 | 9.718291 | 3.43 | 9.930688 | 1.28 | 9.787603 | 4.72 | 10.212397 | 29 |
| 32 | .718497 | 3.43 | .930611 | 1.30 | .787886 | 4.73 | .212114 | 28 |
| 33 | .718703 | 3.43 | .930533 | 1.28 | .788170 | 4.72 | .211830 | 27 |
| 34 | .718909 | 3.42 | .930456 | 1.30 | .788453 | 4.72 | .211547 | 26 |
| 35 | .719114 | 3.43 | .930378 | 1.30 | .788736 | 4.72 | .211264 | 25 |
| 36 | .719320 | 3.42 | .930300 | 1.28 | .789019 | 4.72 | .210981 | 24 |
| 37 | .719525 | 3.42 | .930223 | 1.30 | .789302 | 4.72 | .210698 | 23 |
| 38 | .719730 | 3.42 | .930145 | 1.30 | .789585 | 4.72 | .210415 | 22 |
| 39 | .719935 | 3.42 | .930067 | 1.30 | .789868 | 4.72 | .210132 | 21 |
| 40 | .720140 | 3.42 | .929989 | 1.30 | .790151 | 4.72 | .209849 | 20 |
| 41 | 9.720345 | 3.40 | 9.929911 | 1.30 | 9.790434 | 4.70 | 10.209566 | 19 |
| 42 | .720549 | 3.42 | .929833 | 1.30 | .790716 | 4.72 | .209284 | 18 |
| 43 | .720754 | 3.40 | .929755 | 1.30 | .790999 | 4.70 | .209001 | 17 |
| 44 | .720958 | 3.40 | .929677 | 1.30 | .791281 | 4.70 | .208719 | 16 |
| 45 | .721162 | 3.40 | .929599 | 1.30 | .791563 | 4.72 | .208437 | 15 |
| 46 | .721366 | 3.40 | .929521 | 1.32 | .791846 | 4.70 | .208154 | 14 |
| 47 | .721570 | 3.40 | .929442 | 1.30 | .792128 | 4.70 | .207872 | 13 |
| 48 | .721774 | 3.40 | .929364 | 1.30 | .792410 | 4.70 | .207590 | 12 |
| 49 | .721978 | 3.38 | .929286 | 1.32 | .792692 | 4.70 | .207308 | 11 |
| 50 | .722181 | 3.40 | .929207 | 1.30 | .792974 | 4.70 | .207026 | 10 |
| 51 | 9.722385 | 3.38 | 9.929129 | 1.32 | 9.793256 | 4.70 | 10.206744 | 9 |
| 52 | .722588 | 3.38 | .929050 | 1.30 | .793538 | 4.68 | .206462 | 8 |
| 53 | .722791 | 3.38 | .928972 | 1.32 | .793819 | 4.70 | .206181 | 7 |
| 54 | .722994 | 3.38 | .928893 | 1.30 | .794101 | 4.70 | .205899 | 6 |
| 55 | .723197 | 3.38 | .928815 | 1.32 | .794383 | 4.68 | .205617 | 5 |
| 56 | .723400 | 3.38 | .928736 | 1.32 | .794664 | 4.70 | .205336 | 4 |
| 57 | .723603 | 3.37 | .928657 | 1.32 | .794946 | 4.68 | .205054 | 3 |
| 58 | .723805 | 3.37 | .928578 | 1.32 | .795227 | 4.68 | .204773 | 2 |
| 59 | .724007 | 3.38 | .928499 | 1.32 | .795508 | 4.68 | .204492 | 1 |
| 60 | 9.724210 | | 9.928420 | | 9.795789 | | 10.204211 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.724210 | 3.37 | 9.928420 | 1.30 | 9.795789 | 4.68 | 10.204211 | 60 |
| 1 | .724412 | 3.37 | .928342 | 1.32 | .796070 | 4.68 | .203930 | 59 |
| 2 | .724614 | 3.37 | .928263 | 1.33 | .796351 | 4.68 | .203649 | 58 |
| 3 | .724816 | 3.35 | .928183 | 1.32 | .796632 | 4.68 | .203368 | 57 |
| 4 | .725017 | 3.37 | .928104 | 1.32 | .796913 | 4.68 | .203087 | 56 |
| 5 | .725219 | 3.35 | .928025 | 1.32 | .797194 | 4.67 | .202806 | 55 |
| 6 | .725420 | 3.37 | .927946 | 1.32 | .797474 | 4.68 | .202526 | 54 |
| 7 | .725622 | 3.35 | .927867 | 1.33 | .797755 | 4.68 | .202245 | 53 |
| 8 | .725823 | 3.35 | .927787 | 1.32 | .798036 | 4.67 | .201964 | 52 |
| 9 | .726024 | 3.35 | .927708 | 1.32 | .798316 | 4.67 | .201684 | 51 |
| 10 | .726225 | 3.35 | .927629 | 1.33 | .798596 | 4.68 | .201404 | 50 |
| 11 | 9.726426 | 3.33 | 9.927549 | 1.32 | 9.798877 | 4.67 | 10.201123 | 49 |
| 12 | .726626 | 3.35 | .927470 | 1.33 | .799157 | 4.67 | .200843 | 48 |
| 13 | .726827 | 3.33 | .927390 | 1.33 | .799437 | 4.67 | .200563 | 47 |
| 14 | .727027 | 3.35 | .927310 | 1.32 | .799717 | 4.67 | .200283 | 46 |
| 15 | .727228 | 3.33 | .927231 | 1.33 | .799997 | 4.67 | .200003 | 45 |
| 16 | .727428 | 3.33 | .927151 | 1.33 | .800277 | 4.67 | .199723 | 44 |
| 17 | .727628 | 3.33 | .927071 | 1.33 | .800557 | 4.65 | .199443 | 43 |
| 18 | .727828 | 3.32 | .926991 | 1.33 | .800836 | 4.67 | .199164 | 42 |
| 19 | .728027 | 3.33 | .926911 | 1.33 | .801116 | 4.67 | .198884 | 41 |
| 20 | .728227 | 3.33 | .926831 | 1.33 | .801396 | 4.65 | .198604 | 40 |
| 21 | 9.728427 | 3.32 | 9.926751 | 1.33 | 9.801675 | 4.67 | 10.198325 | 39 |
| 22 | .728626 | 3.32 | .926671 | 1.33 | .801955 | 4.65 | .198045 | 38 |
| 23 | .728825 | 3.32 | .926591 | 1.33 | .802234 | 4.65 | .197766 | 37 |
| 24 | .729024 | 3.32 | .926511 | 1.33 | .802513 | 4.65 | .197487 | 36 |
| 25 | .729223 | 3.32 | .926431 | 1.33 | .802792 | 4.67 | .197208 | 35 |
| 26 | .729422 | 3.32 | .926351 | 1.35 | .803072 | 4.65 | .196928 | 34 |
| 27 | .729621 | 3.32 | .926270 | 1.33 | .803351 | 4.65 | .196649 | 33 |
| 28 | .729820 | 3.30 | .926190 | 1.33 | .803630 | 4.65 | .196370 | 32 |
| 29 | .730018 | 3.32 | .926110 | 1.35 | .803909 | 4.63 | .196091 | 31 |
| 30 | .730217 | 3.30 | .926029 | 1.33 | .804187 | 4.65 | .195813 | 30 |
| 31 | 9.730415 | 3.30 | 9.925949 | 1.35 | 9.804466 | 4.65 | 10.195534 | 29 |
| 32 | .730613 | 3.30 | .925868 | 1.33 | .804745 | 4.63 | .195255 | 28 |
| 33 | .730811 | 3.30 | .925788 | 1.35 | .805023 | 4.65 | .194977 | 27 |
| 34 | .731009 | 3.28 | .925707 | 1.35 | .805302 | 4.63 | .194698 | 26 |
| 35 | .731206 | 3.30 | .925626 | 1.35 | .805580 | 4.65 | .194420 | 25 |
| 36 | .731404 | 3.30 | .925545 | 1.33 | .805859 | 4.63 | .194141 | 24 |
| 37 | .731602 | 3.28 | .925465 | 1.35 | .806137 | 4.63 | .193863 | 23 |
| 38 | .731799 | 3.28 | .925384 | 1.35 | .806415 | 4.63 | .193585 | 22 |
| 39 | .731996 | 3.28 | .925303 | 1.35 | .806693 | 4.63 | .193307 | 21 |
| 40 | .732193 | 3.28 | .925222 | 1.35 | .806971 | 4.63 | .193029 | 20 |
| 41 | 9.732390 | 3.28 | 9.925141 | 1.35 | 9.807249 | 4.63 | 10.192751 | 19 |
| 42 | .732587 | 3.28 | .925060 | 1.35 | .807527 | 4.63 | .192473 | 18 |
| 43 | .732784 | 3.27 | .924979 | 1.37 | .807805 | 4.63 | .192195 | 17 |
| 44 | .732980 | 3.28 | .924897 | 1.35 | .808083 | 4.63 | .191917 | 16 |
| 45 | .733177 | 3.27 | .924816 | 1.35 | .808361 | 4.62 | .191639 | 15 |
| 46 | .733373 | 3.27 | .924735 | 1.35 | .808638 | 4.63 | .191362 | 14 |
| 47 | .733569 | 3.27 | .924654 | 1.37 | .808916 | 4.62 | .191084 | 13 |
| 48 | .733765 | 3.27 | .924572 | 1.35 | .809193 | 4.63 | .190807 | 12 |
| 49 | .733961 | 3.27 | .924491 | 1.37 | .809471 | 4.62 | .190529 | 11 |
| 50 | .734157 | 3.27 | .924409 | 1.35 | .809748 | 4.62 | .190252 | 10 |
| 51 | 9.734353 | 3.27 | 9.924328 | 1.37 | 9.810025 | 4.62 | 10.189975 | 9 |
| 52 | .734549 | 3.25 | .924246 | 1.37 | .810302 | 4.63 | .189698 | 8 |
| 53 | .734744 | 3.25 | .924164 | 1.35 | .810580 | 4.62 | .189420 | 7 |
| 54 | .734939 | 3.27 | .924083 | 1.37 | .810857 | 4.62 | .189143 | 6 |
| 55 | .735135 | 3.25 | .924001 | 1.37 | .811134 | 4.60 | .188866 | 5 |
| 56 | .735330 | 3.25 | .923919 | 1.37 | .811410 | 4.62 | .188590 | 4 |
| 57 | .735525 | 3.23 | .923837 | 1.37 | .811687 | 4.62 | .188313 | 3 |
| 58 | .735719 | 3.25 | .923755 | 1.37 | .811964 | 4.62 | .188036 | 2 |
| 59 | .735914 | 3.25 | .923673 | 1.37 | .812241 | 4.60 | .187759 | 1 |
| 60 | 9.736109 | | 9.923591 | | 9.812517 | | 10.187483 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.736109 | 3.23 | 9.923591 | 1.37 | 9.812517 | 4.62 | 10.187483 | 60 |
| 1 | .736303 | 3.25 | .923509 | 1.37 | .812794 | 4.60 | .187206 | 59 |
| 2 | .736498 | 3.23 | .923427 | 1.37 | .813070 | 4.62 | .186930 | 58 |
| 3 | .736692 | 3.23 | .923345 | 1.37 | .813347 | 4.60 | .186653 | 57 |
| 4 | .736886 | 3.23 | .923263 | 1.37 | .813623 | 4.60 | .186377 | 56 |
| 5 | .737080 | 3.23 | .923181 | 1.38 | .813899 | 4.62 | .186101 | 55 |
| 6 | .737274 | 3.22 | .923098 | 1.37 | .814176 | 4.60 | .185824 | 54 |
| 7 | .737467 | 3.23 | .923016 | 1.38 | .814452 | 4.60 | .185548 | 53 |
| 8 | .737661 | 3.23 | .922933 | 1.37 | .814728 | 4.60 | .185272 | 52 |
| 9 | .737855 | 3.22 | .922851 | 1.38 | .815004 | 4.60 | .184996 | 51 |
| 10 | .738048 | 3.22 | .922768 | 1.37 | .815280 | 4.58 | .184720 | 50 |
| 11 | 9.738241 | 3.22 | 9.922686 | 1.38 | 9.815555 | 4.60 | 10.184445 | 49 |
| 12 | .738434 | 3.22 | .922603 | 1.38 | .815831 | 4.60 | .184169 | 48 |
| 13 | .738627 | 3.22 | .922520 | 1.37 | .816107 | 4.58 | .183893 | 47 |
| 14 | .738820 | 3.22 | .922438 | 1.38 | .816382 | 4.60 | .183618 | 46 |
| 15 | .739013 | 3.22 | .922355 | 1.38 | .816658 | 4.58 | .183342 | 45 |
| 16 | .739206 | 3.20 | .922272 | 1.38 | .816933 | 4.60 | .183067 | 44 |
| 17 | .739398 | 3.20 | .922189 | 1.38 | .817209 | 4.58 | .182791 | 43 |
| 18 | .739590 | 3.22 | .922106 | 1.38 | .817484 | 4.58 | .182516 | 42 |
| 19 | .739783 | 3.20 | .922023 | 1.38 | .817759 | 4.60 | .182241 | 41 |
| 20 | .739975 | 3.20 | .921940 | 1.38 | .818035 | 4.58 | .181965 | 40 |
| 21 | 9.740167 | 3.20 | 9.921857 | 1.38 | 9.818310 | 4.58 | 10.181690 | 39 |
| 22 | .740359 | 3.18 | .921774 | 1.38 | .818585 | 4.58 | .181415 | 38 |
| 23 | .740550 | 3.20 | .921691 | 1.40 | .818860 | 4.58 | .181140 | 37 |
| 24 | .740742 | 3.20 | .921607 | 1.38 | .819135 | 4.58 | .180865 | 36 |
| 25 | .740934 | 3.18 | .921524 | 1.38 | .819410 | 4.57 | .180590 | 35 |
| 26 | .741125 | 3.18 | .921441 | 1.40 | .819684 | 4.58 | .180316 | 34 |
| 27 | .741316 | 3.20 | .921357 | 1.38 | .819959 | 4.58 | .180041 | 33 |
| 28 | .741508 | 3.18 | .921274 | 1.40 | .820234 | 4.57 | .179766 | 32 |
| 29 | .741699 | 3.17 | .921190 | 1.38 | .820508 | 4.58 | .179492 | 31 |
| 30 | .741889 | 3.18 | .921107 | 1.40 | .820783 | 4.57 | .179217 | 30 |
| 31 | 9.742080 | 3.18 | 9.921023 | 1.40 | 9.821057 | 4.58 | 10.178943 | 29 |
| 32 | .742271 | 3.18 | .920939 | 1.38 | .821332 | 4.57 | .178668 | 28 |
| 33 | .742462 | 3.17 | .920856 | 1.40 | .821606 | 4.57 | .178394 | 27 |
| 34 | .742652 | 3.17 | .920772 | 1.40 | .821880 | 4.57 | .178120 | 26 |
| 35 | .742842 | 3.18 | .920688 | 1.40 | .822154 | 4.58 | .177846 | 25 |
| 36 | .743033 | 3.17 | .920604 | 1.40 | .822429 | 4.57 | .177571 | 24 |
| 37 | .743223 | 3.17 | .920520 | 1.40 | .822703 | 4.57 | .177297 | 23 |
| 38 | .743413 | 3.15 | .920436 | 1.40 | .822977 | 4.57 | .177023 | 22 |
| 39 | .743602 | 3.17 | .920352 | 1.40 | .823251 | 4.55 | .176749 | 21 |
| 40 | .743792 | 3.17 | .920268 | 1.40 | .823524 | 4.57 | .176476 | 20 |
| 41 | 9.743982 | 3.15 | 9.920184 | 1.42 | 9.823798 | 4.57 | 10.176202 | 19 |
| 42 | .744171 | 3.17 | .920099 | 1.40 | .824072 | 4.55 | .175928 | 18 |
| 43 | .744361 | 3.15 | .920015 | 1.40 | .824345 | 4.57 | .175655 | 17 |
| 44 | .744550 | 3.15 | .919931 | 1.42 | .824619 | 4.57 | .175381 | 16 |
| 45 | .744739 | 3.15 | .919846 | 1.40 | .824893 | 4.55 | .175107 | 15 |
| 46 | .744928 | 3.15 | .919762 | 1.42 | .825166 | 4.55 | .174834 | 14 |
| 47 | .745117 | 3.15 | .919677 | 1.40 | .825439 | 4.57 | .174561 | 13 |
| 48 | .745306 | 3.13 | .919593 | 1.42 | .825713 | 4.55 | .174287 | 12 |
| 49 | .745494 | 3.15 | .919508 | 1.40 | .825986 | 4.55 | .174014 | 11 |
| 50 | .745683 | 3.13 | .919424 | 1.42 | .826259 | 4.55 | .173741 | 10 |
| 51 | 9.745871 | 3.15 | 9.919339 | 1.42 | 9.826532 | 4.55 | 10.173468 | 9 |
| 52 | .746060 | 3.13 | .919254 | 1.42 | .826805 | 4.55 | .173195 | 8 |
| 53 | .746248 | 3.13 | .919169 | 1.40 | .827078 | 4.55 | .172922 | 7 |
| 54 | .746436 | 3.13 | .919085 | 1.42 | .827351 | 4.55 | .172649 | 6 |
| 55 | .746624 | 3.13 | .919000 | 1.42 | .827624 | 4.55 | .172376 | 5 |
| 56 | .746812 | 3.12 | .918915 | 1.42 | .827897 | 4.55 | .172103 | 4 |
| 57 | .746999 | 3.13 | .918830 | 1.42 | .828170 | 4.53 | .171830 | 3 |
| 58 | .747187 | 3.12 | .918745 | 1.43 | .828442 | 4.55 | .171558 | 2 |
| 59 | .747374 | 3.13 | .918659 | 1.42 | .828715 | 4.53 | .171285 | 1 |
| 60 | 9.747562 | | 9.918574 | | 9.828987 | | 10.171013 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.747562 | 3.12 | 9.918574 | 1.42 | 9.828987 | 4.55 | 10.171013 | 60 |
| 1 | .747749 | 3.12 | .918489 | 1.42 | .829260 | 4.53 | .170740 | 59 |
| 2 | .747936 | 3.12 | .918404 | 1.43 | .829532 | 4.55 | .170468 | 58 |
| 3 | .748123 | 3.12 | .918318 | 1.42 | .829805 | 4.53 | .170195 | 57 |
| 4 | .748310 | 3.12 | .918233 | 1.43 | .830077 | 4.53 | .169923 | 56 |
| 5 | .748497 | 3.10 | .918147 | 1.42 | .830349 | 4.53 | .169651 | 55 |
| 6 | .748683 | 3.12 | .918062 | 1.43 | .830621 | 4.53 | .169379 | 54 |
| 7 | .748870 | 3.10 | .917976 | 1.42 | .830893 | 4.53 | .169107 | 53 |
| 8 | .749056 | 3.12 | .917891 | 1.43 | .831165 | 4.53 | .168835 | 52 |
| 9 | .749243 | 3.10 | .917805 | 1.43 | .831437 | 4.53 | .168563 | 51 |
| 10 | .749429 | 3.10 | .917719 | 1.42 | .831709 | 4.53 | .168291 | 50 |
| 11 | 9.749615 | 3.10 | 9.917634 | 1.43 | 9.831981 | 4.53 | 10.168019 | 49 |
| 12 | .749801 | 3.10 | .917548 | 1.43 | .832253 | 4.53 | .167747 | 48 |
| 13 | .749987 | 3.08 | .917462 | 1.43 | .832525 | 4.52 | .167475 | 47 |
| 14 | .750172 | 3.10 | .917376 | 1.43 | .832796 | 4.53 | .167204 | 46 |
| 15 | .750358 | 3.08 | .917290 | 1.43 | .833068 | 4.52 | .166932 | 45 |
| 16 | .750543 | 3.10 | .917204 | 1.43 | .833339 | 4.53 | .166661 | 44 |
| 17 | .750729 | 3.08 | .917118 | 1.43 | .833611 | 4.52 | .166389 | 43 |
| 18 | .750914 | 3.08 | .917032 | 1.43 | .833882 | 4.53 | .166118 | 42 |
| 19 | .751099 | 3.08 | .916946 | 1.45 | .834154 | 4.52 | .165846 | 41 |
| 20 | .751284 | 3.08 | .916859 | 1.43 | .834425 | 4.52 | .165575 | 40 |
| 21 | 9.751469 | 3.08 | 9.916773 | 1.43 | 9.834696 | 4.52 | 10.165304 | 39 |
| 22 | .751654 | 3.08 | .916687 | 1.45 | .834967 | 4.52 | .165033 | 38 |
| 23 | .751839 | 3.07 | .916600 | 1.43 | .835238 | 4.52 | .164762 | 37 |
| 24 | .752023 | 3.08 | .916514 | 1.45 | .835509 | 4.52 | .164491 | 36 |
| 25 | .752208 | 3.07 | .916427 | 1.43 | .835780 | 4.52 | .164220 | 35 |
| 26 | .752392 | 3.07 | .916341 | 1.45 | .836051 | 4.52 | .163949 | 34 |
| 27 | .752576 | 3.07 | .916254 | 1.45 | .836322 | 4.52 | .163678 | 33 |
| 28 | .752760 | 3.07 | .916167 | 1.43 | .836593 | 4.52 | .163407 | 32 |
| 29 | .752944 | 3.07 | .916081 | 1.45 | .836864 | 4.50 | .163136 | 31 |
| 30 | .753128 | 3.07 | .915994 | 1.45 | .837134 | 4.52 | .162866 | 30 |
| 31 | 9.753312 | 3.05 | 9.915907 | 1.45 | 9.837405 | 4.50 | 10.162595 | 29 |
| 32 | .753495 | 3.07 | .915820 | 1.45 | .837675 | 4.52 | .162325 | 28 |
| 33 | .753679 | 3.07 | .915733 | 1.45 | .837946 | 4.50 | .162054 | 27 |
| 34 | .753862 | 3.07 | .915646 | 1.45 | .838216 | 4.52 | .161784 | 26 |
| 35 | .754046 | 3.05 | .915559 | 1.45 | .838487 | 4.50 | .161513 | 25 |
| 36 | 754229 | 3.05 | .915472 | 1.45 | .838757 | 4.50 | .161243 | 24 |
| 37 | .754412 | 3.05 | .915385 | 1.47 | .839027 | 4.50 | .160973 | 23 |
| 38 | .754595 | 3.05 | .915297 | 1.45 | .839297 | 4.52 | .160703 | 22 |
| 39 | .754778 | 3.03 | .915210 | 1.45 | .839568 | 4.50 | .160432 | 21 |
| 40 | .754960 | 3.05 | .915123 | 1.47 | .839838 | 4.50 | .160162 | 20 |
| 41 | 9.755143 | 3.05 | 9.915035 | 1.45 | 9.840108 | 4.50 | 10.159892 | 19 |
| 42 | .755326 | 3.03 | .914948 | 1.47 | .840378 | 4.50 | .159622 | 18 |
| 43 | .755508 | 3.03 | .914860 | 1.45 | .840648 | 4.48 | .159352 | 17 |
| 44 | .755690 | 3.03 | .914773 | 1.47 | .840917 | 4.50 | .159083 | 16 |
| 45 | .755872 | 3.03 | .914685 | 1.45 | .841187 | 4.50 | .158813 | 15 |
| 46 | .756054 | 3.03 | .914598 | 1.47 | .841457 | 4.50 | .158543 | 14 |
| 47 | .756236 | 3.03 | .914510 | 1.47 | .841727 | 4.48 | .158273 | 13 |
| 48 | .756418 | 3.03 | .914422 | 1.47 | .841996 | 4.50 | .158004 | 12 |
| 49 | .756600 | 3.03 | .914334 | 1.47 | .842266 | 4.48 | .157734 | 11 |
| 50 | .756782 | 3.02 | .914246 | 1.47 | .842535 | 4.50 | .157465 | 10 |
| 51 | 9.756963 | 3.02 | 9.914158 | 1.47 | 9.842805 | 4.48 | 10.157195 | 9 |
| 52 | .757144 | 3 03 | .914070 | 1.47 | .843074 | 4.48 | 156926 | 8 |
| 53 | .757326 | 3.02 | .913982 | 1.47 | .843343 | 4.48 | .156657 | 7 |
| 54 | .757507 | 3.02 | .913894 | 1.47 | .843612 | 4.50 | .156388 | 6 |
| 55 | .757688 | 3 02 | .913806 | 1.47 | .843882 | 4.48 | .156118 | 5 |
| 56 | .757869 | 3.02 | .913718 | 1.47 | .844151 | 4.48 | .155849 | 4 |
| 57 | .758050 | 3.00 | .913630 | 1.48 | .844420 | 4.48 | .155580 | 3 |
| 58 | .758230 | 3.02 | 913541 | 1.47 | .844689 | 4.48 | .155311 | 2 |
| 59 | .758411 | 3.00 | .913453 | 1.47 | .844958 | 4.48 | .155042 | 1 |
| 60 | 9.758591 | | 9.913365 | | 9.845227 | | 10.154773 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.758591 | 3.02 | 9.913365 | 1.48 | 9.845227 | 4.48 | 10.154773 | 60 |
| 1 | .758772 | 3.00 | .913276 | 1.48 | .845496 | 4.47 | .154504 | 59 |
| 2 | .758952 | 3.00 | .913187 | 1.47 | .845764 | 4.48 | .154236 | 58 |
| 3 | .759132 | 3.00 | .913099 | 1.48 | .846033 | 4.48 | .153967 | 57 |
| 4 | .759312 | 3.00 | .913010 | 1.47 | .846302 | 4.47 | .153698 | 56 |
| 5 | .759492 | 3.00 | .912922 | 1.48 | .846570 | 4.48 | .153430 | 55 |
| 6 | .759672 | 3.00 | .912833 | 1.48 | .846839 | 4.48 | .153161 | 54 |
| 7 | .759852 | 2.98 | .912744 | 1.48 | .847108 | 4.47 | .152892 | 53 |
| 8 | .760031 | 3.00 | .912655 | 1.48 | .847376 | 4.47 | .152624 | 52 |
| 9 | .760211 | 2.98 | .912566 | 1.48 | .847644 | 4.48 | .152356 | 51 |
| 10 | .760390 | 2.98 | .912477 | 1.48 | .847913 | 4.47 | .152087 | 50 |
| 11 | 9.760569 | 2.98 | 9.912388 | 1.43 | 9.848181 | 4.47 | 10.151819 | 49 |
| 12 | .760748 | 2.98 | .912299 | 1.48 | .848449 | 4.47 | .151551 | 48 |
| 13 | .760927 | 2.98 | .912210 | 1.48 | .848717 | 4.48 | .151283 | 47 |
| 14 | .761106 | 2.98 | .912121 | 1.50 | .848986 | 4.47 | .151014 | 46 |
| 15 | .761285 | 2.98 | .912031 | 1.48 | .849254 | 4.47 | .150746 | 45 |
| 16 | .761464 | 2.97 | .911942 | 1.48 | .849522 | 4.47 | .150478 | 44 |
| 17 | .761642 | 2.98 | .911853 | 1.50 | .849790 | 4.45 | .150210 | 43 |
| 18 | .761821 | 2.97 | .911763 | 1.48 | .850057 | 4.47 | .149943 | 42 |
| 19 | .761999 | 2.97 | .911674 | 1.50 | .850325 | 4.47 | .149675 | 41 |
| 20 | .762177 | 2.98 | .911584 | 1.48 | .850593 | 4.47 | .149407 | 40 |
| 21 | 9.762356 | 2.97 | 9.911495 | 1.50 | 9.850861 | 4.47 | 10.149139 | 39 |
| 22 | .762534 | 2.97 | .911405 | 1.50 | .851129 | 4.45 | .148871 | 38 |
| 23 | .762712 | 2.95 | .911315 | 1.48 | .851396 | 4.47 | .148604 | 37 |
| 24 | .762889 | 2.97 | .911226 | 1.50 | .851664 | 4.45 | .148336 | 36 |
| 25 | .763067 | 2.97 | .911136 | 1.50 | .851931 | 4.47 | .148069 | 35 |
| 26 | .763245 | 2.95 | .911046 | 1.50 | .852199 | 4.45 | .147801 | 34 |
| 27 | .763422 | 2.97 | .910956 | 1.50 | .852466 | 4.45 | .147534 | 33 |
| 28 | .763600 | 2.95 | .910866 | 1.50 | .852733 | 4.47 | .147267 | 32 |
| 29 | .763777 | 2.95 | .910776 | 1.50 | .853001 | 4.45 | .146999 | 31 |
| 30 | .763954 | 2.95 | .910686 | 1.50 | .853268 | 4.45 | .146732 | 30 |
| 31 | 9.764131 | 2.95 | 9.910596 | 1.50 | 9.853535 | 4.45 | 10.146465 | 29 |
| 32 | .764308 | 2.95 | .910506 | 1.52 | .853802 | 4.45 | .146198 | 28 |
| 33 | .764485 | 2.95 | .910415 | 1.50 | .854069 | 4.45 | .145931 | 27 |
| 34 | .764662 | 2.93 | .910325 | 1.50 | .854336 | 4.45 | .145664 | 26 |
| 35 | .764838 | 2.95 | .910235 | 1.52 | .854603 | 4.45 | .145397 | 25 |
| 36 | .765015 | 2.93 | .910144 | 1.50 | .854870 | 4.45 | .145130 | 24 |
| 37 | .765191 | 2.93 | .910054 | 1.52 | .855137 | 4.45 | .144863 | 23 |
| 38 | .765367 | 2.95 | .909963 | 1.50 | .855404 | 4.45 | .144596 | 22 |
| 39 | .765544 | 2.93 | .909873 | 1.52 | .855671 | 4.45 | .144329 | 21 |
| 40 | .765720 | 2.93 | .909782 | 1.52 | .855938 | 4.43 | .144062 | 20 |
| 41 | 9.765896 | 2.93 | 9.909691 | 1.50 | 9.856204 | 4.45 | 10.143796 | 19 |
| 42 | .766072 | 2.92 | .909601 | 1.52 | .856471 | 4.43 | .143529 | 18 |
| 43 | .766247 | 2.93 | .909510 | 1.52 | .856737 | 4.45 | .143263 | 17 |
| 44 | .766423 | 2.92 | .909419 | 1.52 | .857004 | 4.43 | .142996 | 16 |
| 45 | .766598 | 2.93 | .909328 | 1.52 | .857270 | 4.45 | .142730 | 15 |
| 46 | .766774 | 2.92 | .909237 | 1.52 | .857537 | 4.43 | .142463 | 14 |
| 47 | .766949 | 2.92 | .909146 | 1.52 | .857803 | 4.43 | .142197 | 13 |
| 48 | .767124 | 2.93 | .909055 | 1.52 | .858069 | 4.45 | .141931 | 12 |
| 49 | .767300 | 2.92 | .908964 | 1.52 | .858336 | 4.43 | .141664 | 11 |
| 50 | .767475 | 2.90 | .908873 | 1.53 | .858602 | 4.43 | .141398 | 10 |
| 51 | 9.767649 | 2.92 | 9.908781 | 1.52 | 9.858868 | 4.43 | 10.141132 | 9 |
| 52 | .767824 | 2.92 | .908690 | 1.52 | .859134 | 4.43 | .140866 | 8 |
| 53 | .767999 | 2.90 | .908599 | 1.53 | .859400 | 4.43 | .140600 | 7 |
| 54 | .768173 | 2.92 | .908507 | 1.52 | .859666 | 4.43 | .140334 | 6 |
| 55 | .768348 | 2.90 | .908416 | 1.53 | .859932 | 4.43 | .140068 | 5 |
| 56 | .768522 | 2.92 | .908324 | 1.52 | .860198 | 4.43 | .139802 | 4 |
| 57 | .768697 | 2.90 | .908233 | 1.53 | .860464 | 4.43 | .139536 | 3 |
| 58 | .768871 | 2.90 | .908141 | 1.53 | .860730 | 4.42 | .139270 | 2 |
| 59 | .769045 | 2.90 | .908049 | 1.52 | .860995 | 4.43 | .139005 | 1 |
| 60 | 9.769219 | | 9.907958 | | 9.861261 | | 10.138739 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.769219 | 2.90 | 9.907958 | 1.53 | 9.861261 | 4.43 | 10.138739 | 60 |
| 1 | .769393 | 2.88 | .907866 | 1.53 | .861527 | 4.42 | .138473 | 59 |
| 2 | .769566 | 2.90 | .907774 | 1.53 | .861792 | 4.43 | .138208 | 58 |
| 3 | .769740 | 2.88 | .907682 | 1.53 | .862058 | 4.42 | .137942 | 57 |
| 4 | .769913 | 2.90 | .907590 | 1.53 | .862323 | 4.43 | .137677 | 56 |
| 5 | .770087 | 2.88 | .907498 | 1.53 | .862589 | 4.42 | .137411 | 55 |
| 6 | .770260 | 2.88 | .907406 | 1.53 | .862854 | 4.42 | .137146 | 54 |
| 7 | .770433 | 2.88 | .907314 | 1.53 | .863119 | 4.43 | .136881 | 53 |
| 8 | .770606 | 2.88 | .907222 | 1.55 | .863385 | 4.42 | .136615 | 52 |
| 9 | .770779 | 2.88 | .907129 | 1.53 | .863650 | 4.42 | .136350 | 51 |
| 10 | .770952 | 2.88 | .907037 | 1.53 | .863915 | 4.42 | .136085 | 50 |
| 11 | 9.771125 | 2.88 | 9.906945 | 1.55 | 9.864180 | 4.42 | 10.135820 | 49 |
| 12 | .771298 | 2.87 | .906852 | 1.53 | .864445 | 4.42 | .135555 | 48 |
| 13 | .771470 | 2.88 | .906760 | 1.55 | .864710 | 4.42 | .135290 | 47 |
| 14 | .771643 | 2.87 | .906667 | 1.53 | .864975 | 4.42 | .135025 | 46 |
| 15 | .771815 | 2.87 | .906575 | 1.55 | .865240 | 4.42 | .134760 | 45 |
| 16 | .771987 | 2.87 | .906482 | 1.55 | .865505 | 4.42 | .134495 | 44 |
| 17 | .772159 | 2.87 | .906389 | 1.55 | .865770 | 4.42 | .134230 | 43 |
| 18 | .772331 | 2.87 | .906296 | 1.53 | .866035 | 4.42 | .133965 | 42 |
| 19 | .772503 | 2.87 | .906204 | 1.55 | .866300 | 4.40 | .133700 | 41 |
| 20 | .772675 | 2.87 | .906111 | 1.55 | .866564 | 4.42 | .133436 | 40 |
| 21 | 9.772847 | 2.85 | 9.906018 | 1.55 | 9.866829 | 4.42 | 10.133171 | 39 |
| 22 | .773018 | 2.87 | .905925 | 1.55 | .867094 | 4.40 | .132906 | 38 |
| 23 | .773190 | 2.85 | .905832 | 1.55 | .867358 | 4.42 | .132642 | 37 |
| 24 | .773361 | 2.87 | .905739 | 1.57 | .867623 | 4.40 | .132377 | 36 |
| 25 | .773533 | 2.85 | .905645 | 1.55 | .867887 | 4.42 | .132113 | 35 |
| 26 | .773704 | 2.85 | .905552 | 1.55 | .868152 | 4.40 | .131848 | 34 |
| 27 | .773875 | 2.85 | .905459 | 1.55 | .868416 | 4.40 | .131584 | 33 |
| 28 | .774046 | 2.85 | .905366 | 1.57 | .868680 | 4.42 | .131320 | 32 |
| 29 | .774217 | 2.85 | .905272 | 1.55 | .868945 | 4.40 | .131055 | 31 |
| 30 | .774388 | 2.83 | .905179 | 1.57 | .869209 | 4.40 | .130791 | 30 |
| 31 | 9.774558 | 2.85 | 9.905085 | 1.55 | 9.869473 | 4.40 | 10.130527 | 29 |
| 32 | .774729 | 2.83 | .904992 | 1.57 | .869737 | 4.40 | .130263 | 28 |
| 33 | .774899 | 2.85 | .904898 | 1.57 | .870001 | 4.40 | .129999 | 27 |
| 34 | .775070 | 2.83 | .904804 | 1.55 | .870265 | 4.40 | .129735 | 26 |
| 35 | .775240 | 2.83 | .904711 | 1.57 | .870529 | 4.40 | .129471 | 25 |
| 36 | .775410 | 2.83 | .904617 | 1.57 | .870793 | 4.40 | .129207 | 24 |
| 37 | .775580 | 2.83 | .904523 | 1.57 | .871057 | 4.40 | .128943 | 23 |
| 38 | .775750 | 2.83 | .904429 | 1.57 | .871321 | 4.40 | .128679 | 22 |
| 39 | .775920 | 2.83 | .904335 | 1.57 | .871585 | 4.40 | .128415 | 21 |
| 40 | .776090 | 2.82 | .904241 | 1.57 | .871849 | 4.38 | .128151 | 20 |
| 41 | 9.776259 | 2.83 | 9.904147 | 1.57 | 9.872112 | 4.40 | 10.127888 | 19 |
| 42 | .776429 | 2.82 | .904053 | 1.57 | .872376 | 4.40 | .127624 | 18 |
| 43 | .776598 | 2.83 | .903959 | 1.58 | .872640 | 4.38 | .127360 | 17 |
| 44 | .776768 | 2.82 | .903864 | 1.57 | .872903 | 4.40 | .127097 | 16 |
| 45 | .776937 | 2.82 | .903770 | 1.57 | .873167 | 4.38 | .126833 | 15 |
| 46 | .777106 | 2.82 | .903676 | 1.58 | .873430 | 4.40 | .126570 | 14 |
| 47 | .777275 | 2.82 | .903581 | 1.57 | .873694 | 4.38 | .126306 | 13 |
| 48 | .777444 | 2.82 | .903487 | 1.58 | .873957 | 4.38 | .126043 | 12 |
| 49 | .777613 | 2.80 | .903392 | 1.57 | .874220 | 4.40 | .125780 | 11 |
| 50 | .777781 | 2.82 | .903298 | 1.58 | .874484 | 4.38 | .125516 | 10 |
| 51 | 9.777950 | 2.82 | 9.903203 | 1.58 | 9.874747 | 4.38 | 10.125253 | 9 |
| 52 | .778119 | 2.80 | .903108 | 1.57 | .875010 | 4.38 | .124990 | 8 |
| 53 | .778287 | 2.80 | .903014 | 1.58 | .875273 | 4.40 | .124727 | 7 |
| 54 | .778455 | 2.82 | .902919 | 1.58 | .875537 | 4.38 | .124463 | 6 |
| 55 | .778624 | 2.80 | .902824 | 1.58 | .875800 | 4.38 | .124200 | 5 |
| 56 | .778792 | 2.80 | .902729 | 1.58 | .876063 | 4.38 | .123937 | 4 |
| 57 | .778960 | 2.80 | .902634 | 1.58 | .876326 | 4.38 | .123674 | 3 |
| 58 | .779128 | 2.78 | .902539 | 1.58 | .876589 | 4.38 | .123411 | 2 |
| 59 | .779295 | 2.80 | .902444 | 1.58 | .876852 | 4.37 | .123148 | 1 |
| 60 | 9.779463 | | 9.902349 | | 9.877114 | | 10.122886 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.779463 | 2.80 | 9.902349 | 1.60 | 9.877114 | 4.38 | 10.122886 | 60 |
| 1 | .779631 | 2.78 | .902253 | 1.58 | .877377 | 4.38 | .122623 | 59 |
| 2 | .779798 | 2.80 | .902158 | 1.58 | .877640 | 4.38 | .122360 | 58 |
| 3 | .779966 | 2.78 | .902063 | 1.60 | .877903 | 4.37 | .122097 | 57 |
| 4 | .780133 | 2.78 | .901967 | 1.58 | .878165 | 4.38 | .121835 | 56 |
| 5 | .780300 | 2.78 | .901872 | 1.60 | .878428 | 4.38 | .121572 | 55 |
| 6 | .780467 | 2.78 | .901776 | 1.58 | .878691 | 4.37 | .121309 | 54 |
| 7 | .780634 | 2.78 | .901681 | 1.60 | .878953 | 4.38 | .121047 | 53 |
| 8 | .780801 | 2.78 | .901585 | 1.58 | .879216 | 4.37 | .120784 | 52 |
| 9 | .780968 | 2.77 | .901490 | 1.60 | .879478 | 4.38 | .120522 | 51 |
| 10 | .781134 | 2.78 | .901394 | 1.60 | .879741 | 4.37 | .120259 | 50 |
| 11 | 9.781301 | 2.78 | 9.901298 | 1.60 | 9.880003 | 4.37 | 10.119997 | 49 |
| 12 | .781468 | 2.77 | .901202 | 1.60 | .880265 | 4.38 | .119735 | 48 |
| 13 | .781634 | 2.77 | .901106 | 1.60 | .880528 | 4.37 | .119472 | 47 |
| 14 | .781800 | 2.77 | .901010 | 1.60 | .880790 | 4.37 | .119210 | 46 |
| 15 | .781966 | 2.77 | .900914 | 1.60 | .881052 | 4.37 | .118948 | 45 |
| 16 | .782132 | 2.77 | .900818 | 1.60 | .881314 | 4.38 | .118686 | 44 |
| 17 | .782298 | 2.77 | .900722 | 1.60 | .881577 | 4.37 | .118423 | 43 |
| 18 | .782464 | 2.77 | .900626 | 1.62 | .881839 | 4.37 | .118161 | 42 |
| 19 | .782630 | 2.77 | .900529 | 1.60 | .882101 | 4.37 | .117899 | 41 |
| 20 | .782796 | 2.75 | .900433 | 1.60 | .882363 | 4.37 | .117637 | 40 |
| 21 | 9.782961 | 2.77 | 9.900337 | 1.62 | 9.882625 | 4.37 | 10.117375 | 39 |
| 22 | .783127 | 2.75 | .900240 | 1.60 | .882887 | 4.35 | .117113 | 38 |
| 23 | .783292 | 2.77 | .900144 | 1.62 | .883148 | 4.37 | .116852 | 37 |
| 24 | .783458 | 2.75 | .900047 | 1.60 | .883410 | 4.37 | .116590 | 36 |
| 25 | .783623 | 2.75 | .899951 | 1.62 | .883672 | 4.37 | .116328 | 35 |
| 26 | .783788 | 2.75 | .899854 | 1.62 | .883934 | 4.37 | .116066 | 34 |
| 27 | .783953 | 2.75 | .899757 | 1.62 | .884196 | 4.35 | .115804 | 33 |
| 28 | .784118 | 2.73 | .899660 | 1.60 | .884457 | 4.37 | .115543 | 32 |
| 29 | .784282 | 2.75 | .899564 | 1.62 | .884719 | 4.35 | .115281 | 31 |
| 30 | .784447 | 2.75 | .899467 | 1.62 | .884980 | 4.37 | .115020 | 30 |
| 31 | 9.784612 | 2.73 | 9.899370 | 1.62 | 9.885242 | 4.37 | 10.114758 | 29 |
| 32 | .784776 | 2.75 | .899273 | 1.62 | .885504 | 4.35 | .114496 | 28 |
| 33 | .784941 | 2.73 | .899176 | 1.63 | .885765 | 4.35 | .114235 | 27 |
| 34 | .785105 | 2.73 | .899078 | 1.62 | .886026 | 4.37 | .113974 | 26 |
| 35 | .785269 | 2.73 | .898981 | 1.62 | .886288 | 4.35 | .113712 | 25 |
| 36 | .785433 | 2.73 | .898884 | 1.62 | .886549 | 4.37 | .113451 | 24 |
| 37 | .785597 | 2.73 | .898787 | 1.63 | .886811 | 4.35 | .113189 | 23 |
| 38 | .785761 | 2.73 | .898689 | 1.62 | .887072 | 4.35 | .112928 | 22 |
| 39 | .785925 | 2.73 | .898592 | 1.63 | .887333 | 4.35 | .112667 | 21 |
| 40 | .786089 | 2.72 | .898494 | 1.62 | .887594 | 4.35 | .112406 | 20 |
| 41 | 9.786252 | 2.73 | 9.898397 | 1.63 | 9.887855 | 4.35 | 10.112145 | 19 |
| 42 | .786416 | 2.72 | .898299 | 1.62 | .888116 | 4.37 | .111884 | 18 |
| 43 | .786579 | 2.72 | .898202 | 1.63 | .888378 | 4.35 | .111622 | 17 |
| 44 | .786742 | 2.73 | .898104 | 1.63 | .888639 | 4.35 | .111361 | 16 |
| 45 | .786906 | 2.72 | .898006 | 1.63 | 888900 | 4.35 | .111100 | 15 |
| 46 | .787069 | 2.72 | .897908 | 1.63 | .889161 | 4.33 | .110839 | 14 |
| 47 | .787232 | 2.72 | .897810 | 1.63 | .889421 | 4.35 | .110579 | 13 |
| 48 | .787395 | 2.70 | .897712 | 1.63 | .889682 | 4.35 | .110318 | 12 |
| 49 | .787557 | 2.72 | .897614 | 1.63 | .889943 | 4.35 | .110057 | 11 |
| 50 | .787720 | 2.72 | .897516 | 1.63 | .890204 | 4.35 | .109796 | 10 |
| 51 | 9.787883 | 2.70 | 9.897418 | 1.63 | 9.890465 | 4.33 | 10.109535 | 9 |
| 52 | .788045 | 2.72 | .897320 | 1.63 | .890725 | 4.35 | .109275 | 8 |
| 53 | .788208 | 2.70 | .897222 | 1.65 | .890986 | 4.35 | .109014 | 7 |
| 54 | .788370 | 2.70 | .897123 | 1.63 | .891247 | 4.33 | .108753 | 6 |
| 55 | .788532 | 2.70 | .897025 | 1.65 | .891507 | 4.35 | .108493 | 5 |
| 56 | .788694 | 2.70 | .896926 | 1.63 | .891768 | 4.33 | .108232 | 4 |
| 57 | .788856 | 2.70 | .896828 | 1.65 | .892028 | 4.35 | .107972 | 3 |
| 58 | .789018 | 2.70 | .896729 | 1.63 | .892289 | 4.33 | .107711 | 2 |
| 59 | .789180 | 2.70 | .896631 | 1.65 | .892549 | 4.35 | .107451 | 1 |
| 60 | 9.789342 | | 9.896532 | | 9.892810 | | 10.107190 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.789342 | 2.70 | 9.896532 | 1.65 | 9.892810 | 4.33 | 10.107190 | 60 |
| 1 | .789504 | 2.68 | .896433 | 1.63 | .893070 | 4.35 | .106930 | 59 |
| 2 | .789665 | 2.70 | .896335 | 1.65 | .893331 | 4.33 | .106669 | 58 |
| 3 | .789827 | 2.68 | .896236 | 1.65 | .893591 | 4.33 | .106409 | 57 |
| 4 | .789988 | 2.68 | .896137 | 1.65 | .893851 | 4.33 | .106149 | 56 |
| 5 | .790149 | 2.68 | .896038 | 1.65 | .894111 | 4.35 | .105889 | 55 |
| 6 | .790310 | 2.68 | .895939 | 1.65 | .894372 | 4.33 | .105628 | 54 |
| 7 | .790471 | 2.68 | .895840 | 1.65 | .894632 | 4.33 | .105368 | 53 |
| 8 | .790632 | 2.68 | .895741 | 1.67 | .894892 | 4.33 | .105108 | 52 |
| 9 | .790793 | 2.68 | .895641 | 1.65 | .895152 | 4.33 | .104848 | 51 |
| 10 | .790954 | 2.68 | .895542 | 1.65 | .895412 | 4.33 | .104588 | 50 |
| 11 | 9.791115 | 2.67 | 9.895443 | 1.67 | 9.895672 | 4.33 | 10.104328 | 49 |
| 12 | .791275 | 2.68 | .895343 | 1.65 | .895932 | 4.33 | .104068 | 48 |
| 13 | .791436 | 2.67 | .895244 | 1.65 | .896192 | 4.33 | .103808 | 47 |
| 14 | .791596 | 2.68 | .895145 | 1.67 | .896452 | 4.33 | .103548 | 46 |
| 15 | .791757 | 2.67 | .895045 | 1.67 | .896712 | 4.32 | .103288 | 45 |
| 16 | .791917 | 2.67 | .894945 | 1.65 | .896971 | 4.33 | .103029 | 44 |
| 17 | .792077 | 2.67 | .894846 | 1.67 | .897231 | 4.33 | .102769 | 43 |
| 18 | .792237 | 2.67 | .894746 | 1.67 | .897491 | 4.33 | .102509 | 42 |
| 19 | .792397 | 2.67 | .894646 | 1.67 | .897751 | 4.32 | .102249 | 41 |
| 20 | .792557 | 2.65 | .894546 | 1.67 | .898010 | 4.33 | .101990 | 40 |
| 21 | 9.792716 | 2.67 | 9.894446 | 1.67 | 9.898270 | 4.33 | 10.101730 | 39 |
| 22 | .792876 | 2.65 | .894346 | 1.67 | .898530 | 4.32 | .101470 | 38 |
| 23 | .793035 | 2.67 | .894246 | 1.67 | .898789 | 4.33 | .101211 | 37 |
| 24 | .793195 | 2.65 | .894146 | 1.67 | .899049 | 4.32 | .100951 | 36 |
| 25 | .793354 | 2.67 | .894046 | 1.67 | .899308 | 4.33 | .100692 | 35 |
| 26 | .793514 | 2.65 | .893946 | 1.67 | .899568 | 4.32 | .100432 | 34 |
| 27 | .793673 | 2.65 | .893846 | 1.68 | .899827 | 4.33 | .100173 | 33 |
| 28 | .793832 | 2.65 | .893745 | 1.67 | .900087 | 4.32 | .099913 | 32 |
| 29 | .793991 | 2.65 | .893645 | 1.68 | .900346 | 4.32 | .099654 | 31 |
| 30 | .794150 | 2.63 | .893544 | 1.67 | .900605 | 4.32 | .099395 | 30 |
| 31 | 9.794308 | 2.65 | 9.893444 | 1.68 | 9.900864 | 4.33 | 10.099136 | 29 |
| 32 | .794467 | 2.65 | .893343 | 1.67 | .901124 | 4.32 | .098876 | 28 |
| 33 | .794626 | 2.63 | .893243 | 1.68 | .901383 | 4.32 | .098617 | 27 |
| 34 | .794784 | 2.63 | .893142 | 1.68 | .901642 | 4.32 | .098358 | 26 |
| 35 | .794942 | 2.65 | .893041 | 1.68 | .901901 | 4.32 | .098099 | 25 |
| 36 | .795101 | 2.63 | .892940 | 1.68 | .902160 | 4.33 | .097840 | 24 |
| 37 | .795259 | 2.63 | .892839 | 1.67 | .902420 | 4.32 | .097580 | 23 |
| 38 | .795417 | 2.63 | .892739 | 1.68 | .902679 | 4.22 | .097321 | 22 |
| 39 | .795575 | 2.63 | .892638 | 1.70 | .902938 | 4.32 | .097062 | 21 |
| 40 | .795733 | 2.63 | .892536 | 1.68 | .903197 | 4.32 | .096803 | 20 |
| 41 | 9.795891 | 2.63 | 9.892435 | 1.68 | 9.903456 | 4.30 | 10.096544 | 19 |
| 42 | .796049 | 2.62 | .892334 | 1.68 | .903714 | 4.32 | .096286 | 18 |
| 43 | .796206 | 2.63 | .892233 | 1.68 | .903973 | 4.32 | .096027 | 17 |
| 44 | .796364 | 2.62 | .892132 | 1.70 | .904232 | 4.32 | .095768 | 16 |
| 45 | .796521 | 2.63 | .892030 | 1.68 | .904491 | 4.32 | .095509 | 15 |
| 46 | .796679 | 2.62 | .891929 | 1.70 | .904750 | 4.30 | .095250 | 14 |
| 47 | .796836 | 2.62 | .891827 | 1.68 | .905008 | 4.32 | .094992 | 13 |
| 48 | .796993 | 2.62 | .891726 | 1.70 | .905267 | 4.32 | .094733 | 12 |
| 49 | .797150 | 2.62 | .891624 | 1.68 | .905526 | 4.32 | .094474 | 11 |
| 50 | .797307 | 2.62 | .891523 | 1.70 | .905785 | 4.30 | .094215 | 10 |
| 51 | 9.797464 | 2.62 | 9.891421 | 1.70 | 9.906043 | 4.32 | 10.093957 | 9 |
| 52 | .797621 | 2.60 | .891319 | 1.70 | .906302 | 4.30 | .093698 | 8 |
| 53 | .797777 | 2.62 | .891217 | 1.70 | .906560 | 4.32 | .093440 | 7 |
| 54 | .797934 | 2.62 | .891115 | 1.70 | .906819 | 4.30 | .093181 | 6 |
| 55 | .798091 | 2.60 | .891013 | 1.70 | .907077 | 4.32 | .092923 | 5 |
| 56 | .798247 | 2.60 | .890911 | 1.70 | .907336 | 4.30 | .092664 | 4 |
| 57 | .798403 | 2.62 | .890809 | 1.70 | .907594 | 4.22 | .092406 | 3 |
| 58 | .798560 | 2.60 | .890707 | 1.70 | .907853 | 4.30 | .092147 | 2 |
| 59 | .798716 | 2.60 | .890605 | 1.70 | .908111 | 4.30 | .091889 | 1 |
| 60 | 9.798872 | | 9.890503 | | 9.908369 | | 10.091631 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.798872 | 2.60 | 9.890503 | 1.72 | 9.908369 | 4.32 | 10.091631 | 60 |
| 1 | .799028 | 2.60 | .890400 | 1.70 | .908628 | 4.30 | .091372 | 59 |
| 2 | .799184 | 2.58 | .890298 | 1.72 | .908886 | 4.30 | .091114 | 58 |
| 3 | .799339 | 2.60 | .890195 | 1.70 | .909144 | 4.30 | .090856 | 57 |
| 4 | .799495 | 2.60 | .890093 | 1.72 | .909402 | 4.30 | .090598 | 56 |
| 5 | .799651 | 2.58 | .889990 | 1.70 | .909660 | 4.30 | .090340 | 55 |
| 6 | .799806 | 2.60 | .889888 | 1.72 | .909918 | 4.32 | .090082 | 54 |
| 7 | .799962 | 2.58 | .889785 | 1.72 | .910177 | 4.30 | .089823 | 53 |
| 8 | .800117 | 2.58 | .889682 | 1.72 | .910435 | 4.30 | .089565 | 52 |
| 9 | .800272 | 2.58 | .889579 | 1.70 | .910693 | 4.30 | .089307 | 51 |
| 10 | .800427 | 2.58 | .889477 | 1.72 | .910951 | 4.30 | .089049 | 50 |
| 11 | 9.800582 | 2.58 | 9.889374 | 1.72 | 9.911209 | 4.30 | 10.088791 | 49 |
| 12 | .800737 | 2.58 | .889271 | 1.72 | .911467 | 4.30 | .088533 | 48 |
| 13 | .800892 | 2.58 | .889168 | 1.73 | .911725 | 4.28 | .088275 | 47 |
| 14 | .801047 | 2.57 | .889064 | 1.72 | .911982 | 4.30 | .088018 | 46 |
| 15 | .801201 | 2.58 | .888961 | 1.72 | .912240 | 4.30 | .087760 | 45 |
| 16 | .801356 | 2.58 | .888858 | 1.72 | .912498 | 4.30 | .087502 | 44 |
| 17 | .801511 | 2.57 | .888755 | 1.73 | .912756 | 4.30 | .087244 | 43 |
| 18 | .801665 | 2.57 | .888651 | 1.72 | .913014 | 4.28 | .086986 | 42 |
| 19 | .801819 | 2.57 | .888548 | 1.73 | .913271 | 4.30 | .086729 | 41 |
| 20 | .801973 | 2.58 | .888444 | 1.72 | .913529 | 4.30 | .086471 | 40 |
| 21 | 9.802128 | 2.57 | 9.888341 | 1.73 | 9.913787 | 4.28 | 10.086213 | 39 |
| 22 | .802282 | 2.57 | .888237 | 1.72 | .914044 | 4.30 | .085956 | 38 |
| 23 | .802436 | 2.55 | .888134 | 1.73 | .914302 | 4.30 | .085698 | 37 |
| 24 | .802589 | 2.57 | .888030 | 1.73 | .914560 | 4.28 | .085440 | 36 |
| 25 | .802743 | 2.57 | .887926 | 1.73 | .914817 | 4.30 | .085183 | 35 |
| 26 | .802897 | 2.55 | .887822 | 1.73 | .915075 | 4.28 | .084925 | 34 |
| 27 | .803050 | 2.57 | .887718 | 1.73 | .915332 | 4.30 | .084668 | 33 |
| 28 | .803204 | 2.55 | .887614 | 1.73 | .915590 | 4.28 | .084410 | 32 |
| 29 | .803357 | 2.57 | .887510 | 1.73 | .915847 | 4.28 | .084153 | 31 |
| 30 | .803511 | 2.55 | .887406 | 1.73 | .916104 | 4.30 | .083896 | 30 |
| 31 | 9.803664 | 2.55 | 9.887302 | 1.73 | 9.916362 | 4.28 | 10.083638 | 29 |
| 32 | .803817 | 2.55 | .887198 | 1.75 | .916619 | 4.30 | .083381 | 28 |
| 33 | .803970 | 2.55 | .887093 | 1.73 | .916877 | 4.28 | .083123 | 27 |
| 34 | .804123 | 2.55 | .886989 | 1.73 | .917134 | 4.28 | .082866 | 26 |
| 35 | .804276 | 2.55 | .886885 | 1.75 | .917391 | 4.28 | .082609 | 25 |
| 36 | .804428 | 2.55 | .886780 | 1.73 | .917648 | 4.30 | .082352 | 24 |
| 37 | .804581 | 2.55 | .886676 | 1.75 | .917906 | 4.28 | .082094 | 23 |
| 38 | .804734 | 2.53 | .886571 | 1.75 | .918163 | 4.28 | .081837 | 22 |
| 39 | .804886 | 2.55 | .886466 | 1.73 | .918420 | 4.28 | .081580 | 21 |
| 40 | .805039 | 2.53 | .886362 | 1.75 | .918677 | 4.28 | .081323 | 20 |
| 41 | 9.805191 | 2.53 | 9.886257 | 1.75 | 9.918934 | 4.28 | 10.081066 | 19 |
| 42 | .805343 | 2.53 | .886152 | 1.75 | .919191 | 4.28 | .080809 | 18 |
| 43 | .805495 | 2.53 | .886047 | 1.75 | .919448 | 4.28 | .080552 | 17 |
| 44 | .805647 | 2.53 | .885942 | 1.75 | .919705 | 4.28 | .080295 | 16 |
| 45 | .805799 | 2.53 | .885837 | 1.75 | .919962 | 4.28 | .080038 | 15 |
| 46 | .805951 | 2.53 | .885732 | 1.75 | .920219 | 4.28 | .079781 | 14 |
| 47 | .806103 | 2.52 | .885627 | 1.75 | .920476 | 4.28 | .079524 | 13 |
| 48 | .806254 | 2.53 | .885522 | 1.77 | .920733 | 4.28 | .079267 | 12 |
| 49 | .806406 | 2.52 | .885416 | 1.75 | .920990 | 4.28 | .079010 | 11 |
| 50 | .806557 | 2.53 | .885311 | 1.77 | .921247 | 4.27 | .078753 | 10 |
| 51 | 9.806709 | 2.52 | 9.885205 | 1.75 | 9.921503 | 4.28 | 10.078497 | 9 |
| 52 | .806860 | 2.52 | .885100 | 1.77 | .921760 | 4.28 | .078240 | 8 |
| 53 | .807011 | 2.53 | .884994 | 1.75 | .922017 | 4.28 | .077983 | 7 |
| 54 | .807163 | 2.52 | .884889 | 1.77 | .922274 | 4.27 | .077726 | 6 |
| 55 | .807314 | 2.52 | .884783 | 1.77 | .922530 | 4.28 | .077470 | 5 |
| 56 | .807465 | 2.50 | .884677 | 1.75 | .922787 | 4.28 | .077213 | 4 |
| 57 | .807615 | 2.52 | .884572 | 1.77 | .923044 | 4.27 | .076956 | 3 |
| 58 | .807766 | 2.52 | .884466 | 1.77 | .923300 | 4.28 | .076700 | 2 |
| 59 | .807917 | 2.50 | .884360 | 1.77 | .923557 | 4.28 | .076443 | 1 |
| 60 | 9.808067 | | 9.884254 | | 9.923814 | | 10.076186 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.808067 | 2.52 | 9.884254 | 1.77 | 9.923814 | 4.27 | 10.076186 | 60 |
| 1 | .808218 | 2.50 | .884148 | 1.77 | .924070 | 4.28 | .075930 | 59 |
| 2 | .808368 | 2.52 | .884042 | 1.77 | .924327 | 4.27 | .075673 | 58 |
| 3 | .808519 | 2.50 | .883936 | 1.78 | .924583 | 4.28 | .075417 | 57 |
| 4 | .808669 | 2.50 | .883829 | 1.77 | .924840 | 4.27 | .075160 | 56 |
| 5 | .808819 | 2.50 | .883723 | 1.77 | .925096 | 4.27 | .074904 | 55 |
| 6 | .808969 | 2.50 | .883617 | 1.78 | .925352 | 4.28 | .074648 | 54 |
| 7 | .809119 | 2.50 | .883510 | 1.77 | .925609 | 4.27 | .074391 | 53 |
| 8 | .809269 | 2.50 | .883404 | 1.78 | .925865 | 4.28 | .074135 | 52 |
| 9 | .809419 | 2.50 | .883297 | 1.77 | .926122 | 4.27 | .073878 | 51 |
| 10 | .809569 | 2.48 | .883191 | 1.78 | .926378 | 4.27 | .073622 | 50 |
| 11 | 9.809718 | 2.50 | 9.883084 | 1.78 | 9.926634 | 4.27 | 10.073366 | 49 |
| 12 | .809868 | 2.48 | .882977 | 1.77 | .926890 | 4.28 | .073110 | 48 |
| 13 | .810017 | 2.50 | .882871 | 1.78 | .927147 | 4.27 | .072853 | 47 |
| 14 | .810167 | 2.48 | .882764 | 1.78 | .927403 | 4.27 | .072597 | 46 |
| 15 | .810316 | 2.48 | .882657 | 1.78 | .927659 | 4.27 | .072341 | 45 |
| 16 | .810465 | 2.48 | .882550 | 1.78 | .927915 | 4.27 | .072085 | 44 |
| 17 | .810614 | 2.48 | .882443 | 1.78 | .928171 | 4.27 | .071829 | 43 |
| 18 | .810763 | 2.48 | .882336 | 1.78 | .928427 | 4.28 | .071573 | 42 |
| 19 | .810912 | 2.48 | .882229 | 1.80 | .928684 | 4.27 | .071316 | 41 |
| 20 | .811061 | 2.48 | .882121 | 1.78 | .928940 | 4.27 | .071060 | 40 |
| 21 | 9.811210 | 2.47 | 9.882014 | 1.78 | 9.929196 | 4.27 | 10.070804 | 39 |
| 22 | .811358 | 2.48 | .881907 | 1.80 | .929452 | 4.27 | .070548 | 38 |
| 23 | .811507 | 2.47 | .881799 | 1.78 | .929708 | 4.27 | .070292 | 37 |
| 24 | .811655 | 2.48 | .881692 | 1.80 | .929964 | 4.27 | .070036 | 36 |
| 25 | .811804 | 2.47 | .881584 | 1.78 | .930220 | 4.25 | .069780 | 35 |
| 26 | .811952 | 2.47 | .881477 | 1.80 | .930475 | 4.27 | .069525 | 34 |
| 27 | .812100 | 2.47 | .881369 | 1.80 | .930731 | 4.27 | .069269 | 33 |
| 28 | .812248 | 2.47 | .881261 | 1.80 | .930987 | 4.27 | .069013 | 32 |
| 29 | .812396 | 2.47 | .881153 | 1.78 | .931243 | 4.27 | .068757 | 31 |
| 30 | .812544 | 2.47 | .881046 | 1.80 | .931499 | 4.27 | .068501 | 30 |
| 31 | 9.812692 | 2.47 | 9.880938 | 1.80 | 9.931755 | 4.25 | 10.068245 | 29 |
| 32 | .812840 | 2.47 | .880830 | 1.80 | .932010 | 4.27 | .067990 | 28 |
| 33 | .812988 | 2.45 | .880722 | 1.82 | .932266 | 4.27 | .067734 | 27 |
| 34 | .813135 | 2.47 | .880613 | 1.80 | .932522 | 4.27 | .067478 | 26 |
| 35 | .813283 | 2.45 | .880505 | 1.80 | .932778 | 4.25 | .067222 | 25 |
| 36 | .813430 | 2.47 | .880397 | 1.80 | .933033 | 4.27 | .066967 | 24 |
| 37 | .813578 | 2.45 | .880289 | 1.82 | .933289 | 4.27 | .066711 | 23 |
| 38 | .813725 | 2.45 | .880180 | 1.80 | .933545 | 4.25 | .066455 | 22 |
| 39 | .813872 | 2.45 | .880072 | 1.82 | .933800 | 4.27 | .066200 | 21 |
| 40 | .814019 | 2.45 | .879963 | 1.80 | .934056 | 4.25 | .065944 | 20 |
| 41 | 9.814166 | 2.45 | 9.879855 | 1.82 | 9.934311 | 4.27 | 10.065689 | 19 |
| 42 | .814313 | 2.45 | .879746 | 1.82 | .934567 | 4.25 | .065433 | 18 |
| 43 | .814460 | 2.45 | .879637 | 1.80 | .934822 | 4.27 | .065178 | 17 |
| 44 | .814607 | 2.43 | .879529 | 1.82 | .935078 | 4.25 | .064922 | 16 |
| 45 | .814753 | 2.45 | .879420 | 1.82 | .935333 | 4.27 | .064667 | 15 |
| 46 | .814900 | 2.43 | .879311 | 1.82 | .935589 | 4.25 | .064411 | 14 |
| 47 | .815046 | 2.45 | .879202 | 1.82 | .935844 | 4.27 | .064156 | 13 |
| 48 | .815193 | 2.43 | .879093 | 1.82 | .936100 | 4.25 | .063900 | 12 |
| 49 | .815339 | 2.43 | .878984 | 1.82 | .936355 | 4.27 | .063645 | 11 |
| 50 | .815485 | 2.45 | .878875 | 1.82 | .936611 | 4.25 | .063389 | 10 |
| 51 | 9.815632 | 2.43 | 9.878766 | 1.83 | 9.936866 | 4.25 | 10.063134 | 9 |
| 52 | .815778 | 2.43 | .878656 | 1.82 | .937121 | 4.27 | .062879 | 8 |
| 53 | .815924 | 2.42 | .878547 | 1.82 | .937377 | 4.25 | .062623 | 7 |
| 54 | .816069 | 2.43 | .878438 | 1.83 | .937632 | 4.25 | .062368 | 6 |
| 55 | .816215 | 2.43 | .878328 | 1.82 | .937887 | 4.25 | .062113 | 5 |
| 56 | .816361 | 2.43 | .878219 | 1.83 | .938142 | 4.27 | .061858 | 4 |
| 57 | .816507 | 2.42 | .878109 | 1.83 | .938398 | 4.25 | .061602 | 3 |
| 58 | .816652 | 2.43 | .877999 | 1.82 | .938653 | 4.25 | .061347 | 2 |
| 59 | .816798 | 2.42 | .877890 | 1.83 | .938908 | 4.25 | .061092 | 1 |
| 60 | 9.816943 | | 9.877780 | | 9.939163 | | 10.060837 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.816943 | 2.42 | 9.877780 | 1.83 | 9.939163 | 4.25 | 10.060837 | 60 |
| 1 | .817088 | 2.42 | .877670 | 1.83 | .939418 | 4.25 | .060582 | 59 |
| 2 | .817233 | 2.43 | .877560 | 1.83 | .939673 | 4.25 | .060327 | 58 |
| 3 | .817379 | 2.42 | .877450 | 1.83 | .939928 | 4.25 | .060072 | 57 |
| 4 | .817524 | 2.40 | .877340 | 1.83 | .940183 | 4.27 | .059817 | 56 |
| 5 | .817668 | 2.42 | .877230 | 1.83 | .940439 | 4.25 | .059561 | 55 |
| 6 | .817813 | 2.42 | .877120 | 1.83 | .940694 | 4.25 | .059306 | 54 |
| 7 | .817958 | 2.42 | .877010 | 1.85 | .940949 | 4.25 | .059051 | 53 |
| 8 | .818103 | 2.40 | .876899 | 1.83 | .941204 | 4.25 | .058796 | 52 |
| 9 | .818247 | 2.42 | .876789 | 1.85 | .941459 | 4.23 | .058541 | 51 |
| 10 | .818392 | 2.40 | .876678 | 1.83 | .941713 | 4.25 | .058287 | 50 |
| 11 | 9.818536 | 2.42 | 9.876568 | 1.85 | 9.941968 | 4.25 | 10.058032 | 49 |
| 12 | .818681 | 2.40 | .876457 | 1.83 | .942223 | 4.25 | .057777 | 48 |
| 13 | .818825 | 2.40 | .876347 | 1.85 | .942478 | 4.25 | .057522 | 47 |
| 14 | .818969 | 2.40 | .876236 | 1.85 | .942733 | 4.25 | .057267 | 46 |
| 15 | .819113 | 2.40 | .876125 | 1.85 | .942988 | 4.25 | .057012 | 45 |
| 16 | .819257 | 2.40 | .876014 | 1.83 | .943243 | 4.25 | .056757 | 44 |
| 17 | .819401 | 2.40 | .875904 | 1.85 | .943498 | 4.23 | .056502 | 43 |
| 18 | .819545 | 2.40 | .875793 | 1.85 | .943752 | 4.25 | .056248 | 42 |
| 19 | .819689 | 2.38 | .875682 | 1.85 | .944007 | 4.25 | .055993 | 41 |
| 20 | .819832 | 2.40 | .875571 | 1.87 | .944262 | 4.25 | .055738 | 40 |
| 21 | 9.819976 | 2.40 | 9.875459 | 1.85 | 9.944517 | 4.23 | 10.055483 | 39 |
| 22 | .820120 | 2.38 | .875348 | 1.85 | .944771 | 4.25 | .055229 | 38 |
| 23 | .820263 | 2.38 | .875237 | 1.85 | .945026 | 4.25 | .054974 | 37 |
| 24 | .820406 | 2.40 | .875126 | 1.87 | .945281 | 4.23 | .054719 | 36 |
| 25 | .820550 | 2.38 | .875014 | 1.85 | .945535 | 4.25 | .054465 | 35 |
| 26 | .820693 | 2.38 | .874903 | 1.87 | .945790 | 4.25 | .054210 | 34 |
| 27 | .820836 | 2.38 | .874791 | 1.85 | .946045 | 4.23 | .053955 | 33 |
| 28 | .820979 | 2.38 | .874680 | 1.87 | .946299 | 4.25 | .053701 | 32 |
| 29 | .821122 | 2.38 | .874568 | 1.87 | .946554 | 4.23 | .053446 | 31 |
| 30 | .821265 | 2.37 | .874456 | 1.87 | .946808 | 4.25 | .053192 | 30 |
| 31 | 9.821407 | 2.38 | 9.874344 | 1.87 | 9.947063 | 4.25 | 10.052937 | 29 |
| 32 | .821550 | 2.38 | .874232 | 1.85 | .947318 | 4.23 | .052682 | 28 |
| 33 | .821693 | 2.37 | .874121 | 1.87 | .947572 | 4.25 | .052428 | 27 |
| 34 | .821835 | 2.37 | .874009 | 1.88 | .947827 | 4.23 | .052173 | 26 |
| 35 | .821977 | 2.38 | .873896 | 1.87 | .948081 | 4.23 | .051919 | 25 |
| 36 | .822120 | 2.37 | .873784 | 1.87 | .948335 | 4.25 | .051665 | 24 |
| 37 | .822262 | 2.37 | .873672 | 1.87 | .948590 | 4.23 | .051410 | 23 |
| 38 | .822404 | 2.37 | .873560 | 1.87 | .948844 | 4.25 | .051156 | 22 |
| 39 | .822546 | 2.37 | .873448 | 1.88 | .949099 | 4.23 | .050901 | 21 |
| 40 | .822688 | 2.37 | .873335 | 1.87 | .949353 | 4.25 | .050647 | 20 |
| 41 | 9.822830 | 2.37 | 9.873223 | 1.88 | 9.949608 | 4.23 | 10.050392 | 19 |
| 42 | .822972 | 2.37 | .873110 | 1.87 | .949862 | 4.23 | .050138 | 18 |
| 43 | .823114 | 2.35 | .872998 | 1.88 | .950116 | 4.25 | .049884 | 17 |
| 44 | .823255 | 2.37 | .872885 | 1.88 | .950371 | 4.23 | .049629 | 16 |
| 45 | .823397 | 2.37 | .872772 | 1.88 | .950625 | 4.23 | .049375 | 15 |
| 46 | .823539 | 2.35 | .872659 | 1.87 | .950879 | 4.23 | .049121 | 14 |
| 47 | .823680 | 2.35 | .872547 | 1.88 | .951133 | 4.25 | .048867 | 13 |
| 48 | .823821 | 2.37 | .872434 | 1.88 | .951388 | 4.23 | .048612 | 12 |
| 49 | .823963 | 2.35 | .872321 | 1.88 | .951642 | 4.23 | .048358 | 11 |
| 50 | .824104 | 2.35 | .872208 | 1.88 | .951896 | 4.23 | .048104 | 10 |
| 51 | 9.824245 | 2.35 | 9.872095 | 1.90 | 9.952150 | 4.25 | 10.047850 | 9 |
| 52 | .824386 | 2.35 | .871981 | 1.88 | .952405 | 4.23 | .047595 | 8 |
| 53 | .824527 | 2.35 | .871868 | 1.88 | .952659 | 4.23 | .047341 | 7 |
| 54 | 824668 | 2.33 | .871755 | 1.90 | .952913 | 4.23 | .047087 | 6 |
| 55 | .824808 | 2.35 | .871641 | 1.88 | .953167 | 4.23 | .046833 | 5 |
| 56 | .824949 | 2.35 | .871528 | 1.90 | .953421 | 4.23 | .046579 | 4 |
| 57 | .825090 | 2.33 | .871414 | 1.88 | .953675 | 4.23 | .046325 | 3 |
| 58 | .825230 | 2.35 | .871301 | 1.90 | .953929 | 4.23 | .046071 | 2 |
| 59 | .825371 | 2.33 | .871187 | 1.90 | .954183 | 4.23 | .045817 | 1 |
| 60 | 9.825511 | | 9.871073 | | 9.954437 | | 10.045563 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.825511 | 2.33 | 9.871073 | 1.88 | 9.954437 | 4.23 | 10.045563 | 60 |
| 1 | .825651 | 2.33 | .870960 | 1.90 | .954691 | 4.25 | .045309 | 59 |
| 2 | .825791 | 2.33 | .870846 | 1.90 | .954946 | 4.23 | .045054 | 58 |
| 3 | .825931 | 2.33 | .870732 | 1.90 | .955200 | 4.23 | .044800 | 57 |
| 4 | .826071 | 2.33 | .870618 | 1.90 | .955454 | 4.23 | .044546 | 56 |
| 5 | .826211 | 2.33 | .870504 | 1.90 | .955708 | 4.22 | .044292 | 55 |
| 6 | .826351 | 2.33 | .870390 | 1.90 | .955961 | 4.23 | .044039 | 54 |
| 7 | .826491 | 2.33 | .870276 | 1.92 | .956215 | 4.23 | .043785 | 53 |
| 8 | .826631 | 2.32 | .870161 | 1.90 | .956469 | 4.23 | .043531 | 52 |
| 9 | .826770 | 2.33 | .870047 | 1.90 | .956723 | 4.23 | .043277 | 51 |
| 10 | .826910 | 2.32 | .869933 | 1.92 | .956977 | 4.23 | .043023 | 50 |
| 11 | 9.827049 | 2.33 | 9.869818 | 1.90 | 9.957231 | 4.23 | 10.042769 | 49 |
| 12 | .827189 | 2.32 | .869704 | 1.92 | .957485 | 4.23 | .042515 | 48 |
| 13 | .827328 | 2.32 | .869589 | 1.92 | .957739 | 4.23 | .042261 | 47 |
| 14 | .827467 | 2.32 | .869474 | 1.90 | .957993 | 4.23 | .042007 | 46 |
| 15 | .827606 | 2.32 | .869360 | 1.92 | .958247 | 4.22 | .041753 | 45 |
| 16 | .827745 | 2.32 | .869245 | 1.92 | .958500 | 4.23 | .041500 | 44 |
| 17 | .827884 | 2.32 | .869130 | 1.92 | .958754 | 4.23 | .041246 | 43 |
| 18 | .828023 | 2.32 | .869015 | 1.92 | .959008 | 4.23 | .040992 | 42 |
| 19 | .828162 | 2.32 | .868900 | 1.92 | .959262 | 4.23 | .040738 | 41 |
| 20 | .828301 | 2.30 | .868785 | 1.92 | .959516 | 4.22 | .040484 | 40 |
| 21 | 9.828439 | 2.32 | 9.868670 | 1.92 | 9.959769 | 4.23 | 10.040231 | 39 |
| 22 | .828578 | 2.30 | .868555 | 1.92 | .960023 | 4.23 | .039977 | 38 |
| 23 | .828716 | 2.32 | .868440 | 1.93 | .960277 | 4.22 | .039723 | 37 |
| 24 | .828855 | 2.30 | .868324 | 1.92 | .960530 | 4.23 | .039470 | 36 |
| 25 | .828993 | 2.30 | .868209 | 1.93 | .960784 | 4.23 | .039216 | 35 |
| 26 | .829131 | 2.30 | .868093 | 1.92 | .961038 | 4.23 | .038962 | 34 |
| 27 | .829269 | 2.30 | .867978 | 1.93 | .961292 | 4.22 | .038708 | 33 |
| 28 | .829407 | 2.30 | .867862 | 1.92 | .961545 | 4.23 | .038455 | 32 |
| 29 | .829545 | 2.30 | .867747 | 1.93 | .961799 | 4.22 | .038201 | 31 |
| 30 | .829683 | 2.30 | .867631 | 1.93 | .962052 | 4.23 | .037948 | 30 |
| 31 | 9.829821 | 2.30 | 9.867515 | 1.93 | 9.962306 | 4.23 | 10.037694 | 29 |
| 32 | .829959 | 2.30 | .867399 | 1.93 | .962560 | 4.22 | .037440 | 28 |
| 33 | .830097 | 2.28 | .867283 | 1.93 | .962813 | 4.23 | .037187 | 27 |
| 34 | .830234 | 2.30 | .867167 | 1.93 | .963067 | 4.22 | .036933 | 26 |
| 35 | .830372 | 2.28 | .867051 | 1.93 | .963320 | 4.23 | .036680 | 25 |
| 36 | .830509 | 2.28 | .866935 | 1.93 | .963574 | 4.23 | .036426 | 24 |
| 37 | .830646 | 2.30 | .866819 | 1.93 | .963828 | 4.22 | .036172 | 23 |
| 38 | .830784 | 2.28 | .866703 | 1.95 | .964081 | 4.23 | .035919 | 22 |
| 39 | .830921 | 2.28 | .866586 | 1.93 | .964335 | 4.22 | .035665 | 21 |
| 40 | .831058 | 2.28 | .866470 | 1.95 | .964588 | 4.23 | .035412 | 20 |
| 41 | 9.831195 | 2.28 | 9.866353 | 1.93 | 9.964842 | 4.22 | 10.035158 | 19 |
| 42 | .831332 | 2.28 | .866237 | 1.95 | .965095 | 4.23 | .034905 | 18 |
| 43 | .831469 | 2.28 | .866120 | 1.93 | .965349 | 4.22 | .034651 | 17 |
| 44 | .831606 | 2.27 | .866004 | 1.95 | .965602 | 4.22 | .034398 | 16 |
| 45 | .831742 | 2.28 | .865887 | 1.95 | .965855 | 4.23 | .034145 | 15 |
| 46 | .831879 | 2.27 | .865770 | 1.95 | .966109 | 4.22 | .033891 | 14 |
| 47 | .832015 | 2.28 | .865653 | 1.95 | .966362 | 4.23 | .033638 | 13 |
| 48 | .832152 | 2.27 | .865536 | 1.95 | .966616 | 4.22 | .033384 | 12 |
| 49 | .832288 | 2.28 | .865419 | 1.95 | .966869 | 4.23 | .033131 | 11 |
| 50 | .832425 | 2.27 | .865302 | 1.95 | .967123 | 4.22 | .032877 | 10 |
| 51 | 9.832561 | 2.27 | 9.865185 | 1.95 | 9.967376 | 4.22 | 10.032624 | 9 |
| 52 | .832697 | 2.27 | .865068 | 1.97 | .967629 | 4.23 | .032371 | 8 |
| 53 | .832833 | 2.27 | .864950 | 1.95 | .967883 | 4.22 | .032117 | 7 |
| 54 | .832969 | 2.27 | .864833 | 1.95 | .968136 | 4.22 | .031864 | 6 |
| 55 | .833105 | 2.27 | .864716 | 1.97 | .968389 | 4.23 | .031611 | 5 |
| 56 | .833241 | 2.27 | .864598 | 1.95 | .968643 | 4.22 | .031357 | 4 |
| 57 | .833377 | 2.25 | .864481 | 1.97 | .968896 | 4.22 | .031104 | 3 |
| 58 | .833512 | 2.27 | .864363 | 1.97 | .969140 | 4.23 | .030851 | 2 |
| 59 | .833648 | 2.25 | .864245 | 1.97 | .969403 | 4.22 | .030597 | 1 |
| 60 | 9.833783 | | 9.864127 | | 9.969656 | | 10.030344 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.833783 | 2.27 | 9.864127 | 1.95 | 9.969656 | 4.22 | 10.030344 | 60 |
| 1 | .833919 | 2.25 | .864010 | 1.97 | .969909 | 4.22 | .030091 | 59 |
| 2 | .834054 | 2.25 | .863892 | 1.97 | .970162 | 4.23 | .029838 | 58 |
| 3 | .834189 | 2.27 | .863774 | 1.97 | .970416 | 4.22 | .029584 | 57 |
| 4 | .834325 | 2.25 | .863656 | 1.97 | .970669 | 4.22 | .029331 | 56 |
| 5 | .834460 | 2.25 | .863538 | 1.98 | .970922 | 4.22 | .029078 | 55 |
| 6 | .834595 | 2.25 | .863419 | 1.97 | .971175 | 4.23 | .028825 | 54 |
| 7 | .834730 | 2.25 | .863301 | 1.97 | .971429 | 4.22 | .028571 | 53 |
| 8 | .834865 | 2.23 | .863183 | 1.98 | .971682 | 4.22 | .028318 | 52 |
| 9 | .834999 | 2.25 | .863064 | 1.97 | .971935 | 4.22 | .028065 | 51 |
| 10 | .835134 | 2.25 | .862946 | 1.98 | .972188 | 4.22 | .027812 | 50 |
| 11 | 9.835269 | 2.23 | 9.862827 | 1.97 | 9.972441 | 4.23 | 10.027559 | 49 |
| 12 | .835403 | 2.25 | .862709 | 1.98 | .972695 | 4.22 | .027305 | 48 |
| 13 | .835538 | 2.23 | .862590 | 1.98 | .972948 | 4.22 | .027052 | 47 |
| 14 | .835672 | 2.25 | .862471 | 1.97 | .973201 | 4.22 | .026799 | 46 |
| 15 | .835807 | 2.23 | .862353 | 1.98 | .973454 | 4.22 | .026546 | 45 |
| 16 | .835941 | 2.23 | .862234 | 1.98 | .973707 | 4.22 | .026293 | 44 |
| 17 | .836075 | 2.23 | .862115 | 1.98 | .973960 | 4.22 | .026040 | 43 |
| 18 | .836209 | 2.23 | .861996 | 1.98 | .974213 | 4.22 | .025787 | 42 |
| 19 | .836343 | 2.23 | .861877 | 1.98 | .974466 | 4.23 | .025534 | 41 |
| 20 | .836477 | 2.23 | .861758 | 2.00 | .974720 | 4.22 | .025280 | 40 |
| 21 | 9.836611 | 2.23 | 9.861638 | 1.98 | 9.974973 | 4.22 | 10.025027 | 39 |
| 22 | .836745 | 2.22 | .861519 | 1.98 | .975226 | 4.22 | .024774 | 38 |
| 23 | .836878 | 2.23 | .861400 | 2.00 | .975479 | 4.22 | .024521 | 37 |
| 24 | .837012 | 2.23 | .861280 | 1.98 | .975732 | 4.22 | .024268 | 36 |
| 25 | .837146 | 2.22 | .861161 | 2.00 | .975985 | 4.22 | .024015 | 35 |
| 26 | .837279 | 2.22 | .861041 | 1.98 | .976238 | 4.22 | .023762 | 34 |
| 27 | .837412 | 2.23 | .860922 | 2.00 | .976491 | 4.22 | .023509 | 33 |
| 28 | .837546 | 2.22 | .860802 | 2.00 | .976744 | 4.22 | .023256 | 32 |
| 29 | .837679 | 2.22 | .860682 | 2.00 | .976997 | 4.22 | .023003 | 31 |
| 30 | .837812 | 2.22 | .860562 | 2.00 | .977250 | 4.22 | .022750 | 30 |
| 31 | 9.837945 | 2.22 | 9.860442 | 2.00 | 9.977503 | 4.22 | 10.022497 | 29 |
| 32 | .838078 | 2.22 | .860322 | 2.00 | .977756 | 4.22 | .022244 | 28 |
| 33 | .838211 | 2.22 | .860202 | 2.00 | .978009 | 4.22 | .021991 | 27 |
| 34 | .838344 | 2.22 | .860082 | 2.00 | .978262 | 4.22 | .021738 | 26 |
| 35 | .838477 | 2.22 | .859962 | 2.00 | .978515 | 4.22 | .021485 | 25 |
| 36 | .838610 | 2.20 | .859842 | 2.02 | .978768 | 4.22 | .021232 | 24 |
| 37 | .838742 | 2.22 | .859721 | 2.00 | .979021 | 4.22 | .020979 | 23 |
| 38 | .838875 | 2.20 | .859601 | 2.02 | .979274 | 4.22 | .020726 | 22 |
| 39 | .839007 | 2.22 | .859480 | 2.00 | .979527 | 4.22 | .020473 | 21 |
| 40 | .839140 | 2.20 | .859360 | 2.02 | .979780 | 4.22 | .020220 | 20 |
| 41 | 9.839272 | 2.20 | 9.859239 | 2.00 | 9.980033 | 4.22 | 10.019967 | 19 |
| 42 | .839404 | 2.20 | .859119 | 2.02 | .980286 | 4.20 | .019714 | 18 |
| 43 | .839536 | 2.20 | .858998 | 2.02 | .980538 | 4.22 | .019462 | 17 |
| 44 | .839668 | 2.20 | .858877 | 2.02 | .980791 | 4.22 | .019209 | 16 |
| 45 | .839800 | 2.20 | .858756 | 2.02 | .981044 | 4.22 | .018956 | 15 |
| 46 | .839932 | 2.20 | .858635 | 2.02 | .981297 | 4.22 | .018703 | 14 |
| 47 | .840064 | 2.20 | .858514 | 2.02 | .981550 | 4.22 | .018450 | 13 |
| 48 | .840196 | 2.20 | .858393 | 2.02 | .981803 | 4.22 | .018197 | 12 |
| 49 | .840328 | 2.18 | .858272 | 2.02 | .982056 | 4.22 | .017944 | 11 |
| 50 | .840459 | 2.20 | .858151 | 2.03 | .982309 | 4.22 | .017691 | 10 |
| 51 | 9.840591 | 2.18 | 9.858029 | 2.02 | 9.982562 | 4.20 | 10.017438 | 9 |
| 52 | .840722 | 2.20 | .857908 | 2.03 | .982814 | 4.22 | .017186 | 8 |
| 53 | .840854 | 2.18 | .857786 | 2.02 | .983067 | 4.22 | .016933 | 7 |
| 54 | .840985 | 2.18 | .857665 | 2.03 | .983320 | 4.22 | .016680 | 6 |
| 55 | .841116 | 2.18 | .857543 | 2.02 | .983573 | 4.22 | .016427 | 5 |
| 56 | .841247 | 2.18 | .857422 | 2.03 | .983826 | 4.22 | .016174 | 4 |
| 57 | .841378 | 2.18 | .857300 | 2.03 | .984079 | 4.22 | .015921 | 3 |
| 58 | .841509 | 2.18 | .857178 | 2.03 | .984332 | 4.20 | .015668 | 2 |
| 59 | .841640 | 2.18 | .857056 | 2.03 | .984584 | 4.22 | .015416 | 1 |
| 60 | 9.841771 | | 9.856934 | | 9.984837 | | 10.015163 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

| ′ | Sine. | D. 1″. | Cosine. | D. 1″. | Tang. | D. 1″. | Cotang. | ′ |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.841771 | 2.18 | 9.856934 | 2.03 | 9.984837 | 4.22 | 10.015163 | 60 |
| 1 | .841902 | 2.18 | .856812 | 2.03 | .985090 | 4.22 | .014910 | 59 |
| 2 | .842033 | 2.17 | .856690 | 2.03 | .985343 | 4.22 | .014657 | 58 |
| 3 | .842163 | 2.18 | .856568 | 2.03 | .985596 | 4.20 | .014404 | 57 |
| 4 | .842294 | 2.17 | .856446 | 2.05 | .985848 | 4.22 | .014152 | 56 |
| 5 | .842424 | 2.18 | .856323 | 2.03 | .986101 | 4.22 | .013899 | 55 |
| 6 | .842555 | 2.17 | .856201 | 2.05 | .986354 | 4.22 | .013646 | 54 |
| 7 | .842685 | 2.17 | .856078 | 2.03 | .986607 | 4.22 | .013393 | 53 |
| 8 | .842815 | 2.18 | .855956 | 2.05 | .986860 | 4.20 | .013140 | 52 |
| 9 | .842946 | 2.17 | .855833 | 2.03 | .987112 | 4.22 | .012888 | 51 |
| 10 | .843076 | 2.17 | .855711 | 2.05 | .987365 | 4.22 | .012635 | 50 |
| 11 | 9.843206 | 2.17 | 9.855588 | 2.05 | 9.987618 | 4.22 | 10.012382 | 49 |
| 12 | .843336 | 2.17 | .855465 | 2.05 | .987871 | 4.20 | .012129 | 48 |
| 13 | .843466 | 2.15 | .855342 | 2.05 | .988123 | 4.22 | .011877 | 47 |
| 14 | .843595 | 2.17 | .855219 | 2.05 | .988376 | 4.22 | .011624 | 46 |
| 15 | .843725 | 2.17 | .855096 | 2.05 | .988629 | 4.22 | .011371 | 45 |
| 16 | .843855 | 2.15 | .854973 | 2.05 | .988882 | 4.20 | .011118 | 44 |
| 17 | .843984 | 2.17 | .854850 | 2.05 | .989134 | 4.22 | .010866 | 43 |
| 18 | .844114 | 2.15 | .854727 | 2.07 | .989387 | 4.22 | .010613 | 42 |
| 19 | .844243 | 2.15 | .854603 | 2.05 | .989640 | 4.22 | .010360 | 41 |
| 20 | .844372 | 2.17 | .854480 | 2.07 | .989893 | 4.20 | .010107 | 40 |
| 21 | 9.844502 | 2.15 | 9.854356 | 2.05 | 9.990145 | 4.22 | 10.009855 | 39 |
| 22 | .844631 | 2.15 | .854233 | 2.07 | .990398 | 4.22 | .009602 | 38 |
| 23 | .844760 | 2.15 | .854109 | 2.05 | .990651 | 4.20 | .009349 | 37 |
| 24 | .844889 | 2.15 | .853986 | 2.07 | .990903 | 4.22 | .009097 | 36 |
| 25 | .845018 | 2.15 | .853862 | 2.07 | .991156 | 4.22 | .008844 | 35 |
| 26 | .845147 | 2.15 | .853738 | 2.07 | .991409 | 4.22 | .008591 | 34 |
| 27 | .845276 | 2.15 | .853614 | 2.07 | .991662 | 4.20 | .008338 | 33 |
| 28 | .845405 | 2.13 | .853490 | 2.07 | .991914 | 4.22 | .008086 | 32 |
| 29 | .845533 | 2.15 | .853366 | 2.07 | .992167 | 4.22 | .007833 | 31 |
| 30 | .845662 | 2.13 | .853242 | 2.07 | .992420 | 4.20 | .007580 | 30 |
| 31 | 9.845790 | 2.15 | 9.853118 | 2.07 | 9.992672 | 4.22 | 10.007328 | 29 |
| 32 | .845919 | 2.13 | .852994 | 2.08 | .992925 | 4.22 | .007075 | 28 |
| 33 | .846047 | 2.13 | .852869 | 2.07 | .993178 | 4.22 | .006822 | 27 |
| 34 | .846175 | 2.15 | .852745 | 2.08 | .993431 | 4.20 | .006569 | 26 |
| 35 | .846304 | 2.13 | .852620 | 2.07 | .993683 | 4.22 | .006317 | 25 |
| 36 | .846432 | 2.13 | .852496 | 2.08 | .993936 | 4.22 | .006064 | 24 |
| 37 | .846560 | 2.13 | .852371 | 2.07 | .994189 | 4.20 | .005811 | 23 |
| 38 | .846688 | 2.13 | .852247 | 2.08 | .994441 | 4.22 | .005559 | 22 |
| 39 | .846816 | 2.13 | .852122 | 2.08 | .994694 | 4.22 | .005306 | 21 |
| 40 | .846944 | 2.12 | .851997 | 2.08 | .994947 | 4.20 | .005053 | 20 |
| 41 | 9.847071 | 2.13 | 9.851872 | 2.08 | 9.995199 | 4.22 | 10.004801 | 19 |
| 42 | .847199 | 2.13 | .851747 | 2.08 | .995452 | 4.22 | .004548 | 18 |
| 43 | .847327 | 2.12 | .851622 | 2.08 | .995705 | 4.20 | .004295 | 17 |
| 44 | .847454 | 2.13 | .851497 | 2.08 | .995957 | 4.22 | .004043 | 16 |
| 45 | .847582 | 2.12 | .851372 | 2.10 | .996210 | 4.22 | .003790 | 15 |
| 46 | .847709 | 2.12 | .851246 | 2.08 | .996463 | 4.20 | .003537 | 14 |
| 47 | .847836 | 2.13 | .851121 | 2.08 | .996715 | 4.22 | .003285 | 13 |
| 48 | .847964 | 2.12 | .850996 | 2.10 | .996968 | 4.22 | .003032 | 12 |
| 49 | .848091 | 2.12 | .850870 | 2.08 | .997221 | 4.20 | .002779 | 11 |
| 50 | .848218 | 2.12 | .850745 | 2.10 | .997473 | 4.22 | .002527 | 10 |
| 51 | 9.848345 | 2.12 | 9.850619 | 2.10 | 9.997726 | 4.22 | 10.002274 | 9 |
| 52 | .848472 | 2.12 | .850493 | 2.08 | .997979 | 4.20 | .002021 | 8 |
| 53 | .848599 | 2.12 | .850368 | 2.10 | .998231 | 4.22 | .001769 | 7 |
| 54 | .848726 | 2.10 | .850242 | 2.10 | .998484 | 4.22 | .001516 | 6 |
| 55 | .848852 | 2.12 | .850116 | 2.10 | .998737 | 4.20 | .001263 | 5 |
| 56 | .848979 | 2.12 | .849990 | 2.10 | .998989 | 4.22 | .001011 | 4 |
| 57 | .849106 | 2.10 | .849864 | 2.10 | .999242 | 4.22 | .000758 | 3 |
| 58 | .849232 | 2.12 | .849738 | 2.12 | .999495 | 4.20 | .000505 | 2 |
| 59 | .849359 | 2.10 | .849611 | 2.10 | .999747 | 4,22 | .000253 | 1 |
| 60 | 9.849485 | | 9 849485 | | 10.000000 | | 10.000000 | 0 |
| ′ | Cosine. | D. 1″. | Sine. | D. 1″. | Cotang. | D. 1″. | Tang. | ′ |

# TABLE XXVI.—LOGARITHMIC VERSED SINES.

| 0° | | | | | | 1° | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ″ | ′ | Vers. | q − 2l | | Ex. sec. | ″ | ′ | Vers. | q − 2l | | Ex. sec. |
| | | | 9.070 | | | | | | 9.070 | | |
| 0 | 0 | Inf. neg. | 120 | 120 | Inf. neg. | 3600 | 0 | 6.182714 | 109 | 175 | 6.182780 |
| 60 | 1 | 2.626422 | 120 | 120 | 2.626422 | 3660 | 1 | .197071 | 108 | 177 | .197139 |
| 120 | 2 | 3.228482 | 120 | 120 | 3.228482 | 3720 | 2 | .211194 | 108 | 179 | .211264 |
| 180 | 3 | .580665 | 120 | 120 | .580665 | 3780 | 3 | .225091 | 108 | 181 | .225164 |
| 240 | 4 | 3.830542 | 120 | 120 | 3.830542 | 3840 | 4 | .238770 | 107 | 182 | .238845 |
| 300 | 5 | 4.024362 | 120 | 120 | 4.024363 | 3900 | 5 | .252236 | 107 | 184 | .252314 |
| 360 | 6 | .182725 | 120 | 120 | .182725 | 3960 | 6 | .265497 | 106 | 186 | .265577 |
| 420 | 7 | .316618 | 120 | 120 | .316619 | 4020 | 7 | .278558 | 106 | 188 | .278641 |
| 480 | 8 | .432602 | 120 | 121 | .432603 | 4080 | 8 | .291426 | 106 | 191 | .291511 |
| 540 | 9 | .534907 | 119 | 121 | .534908 | 4140 | 9 | .304106 | 105 | 193 | .304193 |
| 600 | 10 | .626422 | 119 | 121 | .626424 | 4200 | 10 | .316603 | 105 | 195 | .316693 |
| 660 | 11 | 4.709207 | 119 | 122 | 4.709209 | 4260 | 11 | 6.328923 | 104 | 197 | 6.329016 |
| 720 | 12 | .784784 | 119 | 122 | .784787 | 4320 | 12 | .341071 | 104 | 199 | .341167 |
| 780 | 13 | .854308 | 119 | 122 | .854312 | 4380 | 13 | .353052 | 103 | 201 | .353150 |
| 840 | 14 | .918678 | 119 | 123 | .918681 | 4440 | 14 | .364869 | 103 | 204 | .364970 |
| 900 | 15 | 4.978604 | 119 | 123 | 4.978608 | 4500 | 15 | .376528 | 103 | 206 | .376631 |
| 960 | 16 | 5.034661 | 119 | 124 | 5.034666 | 4560 | 16 | .388032 | 102 | 208 | .388138 |
| 1020 | 17 | .087319 | 119 | 124 | .087325 | 4620 | 17 | .399386 | 102 | 211 | .399494 |
| 1080 | 18 | .136966 | 119 | 125 | .136972 | 4680 | 18 | .410593 | 101 | 213 | .410705 |
| 1140 | 19 | .183928 | 119 | 125 | .183935 | 4740 | 19 | .421657 | 101 | 215 | .421772 |
| 1200 | 20 | .228481 | 119 | 126 | .228488 | 4800 | 20 | .432583 | 100 | 218 | .432700 |
| 1260 | 21 | 5.270859 | 118 | 126 | 5.270868 | 4860 | 21 | 6.443372 | 100 | 220 | 6.443493 |
| 1320 | 22 | .311266 | 118 | 127 | .311275 | 4920 | 22 | .454029 | 099 | 223 | .454153 |
| 1380 | 23 | .349876 | 118 | 128 | .349886 | 4980 | 23 | .464557 | 099 | 225 | .464684 |
| 1440 | 24 | .386843 | 118 | 129 | .386854 | 5040 | 24 | .474959 | 098 | 228 | .475089 |
| 1500 | 25 | .422300 | 118 | 129 | .422312 | 5100 | 25 | .485238 | 098 | 230 | .485371 |
| 1560 | 26 | .456367 | 118 | 130 | .456379 | 5160 | 26 | .495396 | 097 | 233 | .495532 |
| 1620 | 27 | .489148 | 118 | 131 | .489161 | 5220 | 27 | .505438 | 097 | 236 | .505577 |
| 1680 | 28 | .520736 | 117 | 132 | .520750 | 5280 | 28 | .515364 | 096 | 238 | .515506 |
| 1740 | 29 | .551216 | 117 | 133 | .551231 | 5340 | 29 | .525178 | 095 | 241 | .525324 |
| 1800 | 30 | .580662 | 117 | 134 | .580679 | 5400 | 30 | .534882 | 095 | 244 | .535031 |
| 1860 | 31 | 5.609143 | 117 | 134 | 5.609160 | 5460 | 31 | 6.544480 | 094 | 247 | 6.544632 |
| 1920 | 32 | .636719 | 117 | 135 | .636738 | 5520 | 32 | .553972 | 094 | 249 | .554128 |
| 1980 | 33 | .663447 | 116 | 136 | .663467 | 5580 | 33 | .563362 | 093 | 252 | .563521 |
| 2040 | 34 | .689377 | 116 | 137 | .689398 | 5640 | 34 | .572651 | 093 | 255 | .572813 |
| 2100 | 35 | .714555 | 116 | 138 | .714577 | 5700 | 35 | .581842 | 092 | 258 | .582008 |
| 2160 | 36 | .739023 | 116 | 140 | .739047 | 5760 | 36 | .590936 | 092 | 261 | .591106 |
| 2220 | 37 | .762821 | 116 | 141 | .762847 | 5820 | 37 | .599937 | 091 | 264 | .600110 |
| 2280 | 38 | .785985 | 115 | 142 | .786012 | 5880 | 38 | .608845 | 090 | 267 | .609021 |
| 2340 | 39 | .808547 | 115 | 143 | .808575 | 5940 | 39 | .617663 | 090 | 270 | .617843 |
| 2400 | 40 | .830537 | 115 | 144 | .830567 | 6000 | 40 | .626392 | 089 | 273 | .626575 |
| 2460 | 41 | 5.851985 | 115 | 145 | 5.852016 | 6060 | 41 | 6.635034 | 089 | 276 | 6.635221 |
| 2520 | 42 | .872915 | 114 | 147 | .872948 | 6120 | 42 | .643591 | 088 | 279 | .643782 |
| 2580 | 43 | .893353 | 114 | 148 | .893387 | 6180 | 43 | .652064 | 087 | 282 | .652259 |
| 2640 | 44 | .913322 | 114 | 149 | .913357 | 6240 | 44 | .660456 | 087 | 285 | .660655 |
| 2700 | 45 | .932841 | 114 | 151 | .932878 | 6300 | 45 | .668767 | 086 | 289 | .668970 |
| 2760 | 46 | .951931 | 113 | 152 | .951970 | 6360 | 46 | .677000 | 085 | 292 | .677206 |
| 2820 | 47 | .970611 | 113 | 154 | .970652 | 6420 | 47 | .685155 | 085 | 295 | .685365 |
| 2880 | 48 | 5.988898 | 113 | 155 | 5.988940 | 6480 | 48 | .693234 | 084 | 298 | .693448 |
| 2940 | 49 | 6.006807 | 112 | 157 | 6.006851 | 6540 | 49 | .701239 | 083 | 302 | .701457 |
| 3000 | 50 | .024355 | 112 | 158 | .024401 | 6600 | 50 | .709171 | 083 | 305 | .709393 |
| 3060 | 51 | 6.041555 | 112 | 160 | 6.041602 | 6660 | 51 | 6.717030 | 082 | 308 | 6.717257 |
| 3120 | 52 | .058421 | 111 | 161 | .058470 | 6720 | 52 | .724820 | 081 | 312 | .725050 |
| 3180 | 53 | .074965 | 111 | 163 | .075017 | 6780 | 53 | .732540 | 081 | 315 | .732775 |
| 3240 | 54 | .091201 | 111 | 164 | .091254 | 6840 | 54 | .740192 | 080 | 319 | .740431 |
| 3300 | 55 | .107138 | 110 | 166 | .107194 | 6900 | 55 | .747777 | 079 | 322 | .748020 |
| 3360 | 56 | .122789 | 110 | 168 | .122846 | 6960 | 56 | .755297 | 079 | 326 | .755544 |
| 3420 | 57 | .138162 | 110 | 169 | .138222 | 7020 | 57 | .762752 | 078 | 329 | .763004 |
| 3480 | 58 | .153268 | 109 | 171 | .153330 | 7080 | 58 | .770144 | 077 | 333 | .770400 |
| 3540 | 59 | .168116 | 109 | 173 | .168180 | 7140 | 59 | .777473 | 076 | 337 | .777733 |
| 3600 | 60 | 6.182714 | 109 | 175 | 6.182780 | 7200 | 60 | 6.784741 | 076 | 340 | 6.785005 |
| ″ | ′ | | | | | ″ | ′ | | | | |

| 2° | | | | | | 3° | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| " | ' | Vers. | q − 2l | | Ex. sec. | " | ' | Vers. | q − 2l | | Ex. sec. |
| | | | 9.070 | | | | | | 9.070* | | |
| 7200 | 0 | 6.784741 | 076 | 340 | 6.785005 | 10800 | 0 | 7.136868 | 021 | 616 | 7.137464 |
| 7260 | 1 | .791948 | 075 | 344 | .792217 | 10860 | 1 | .141679 | 019 | 622 | .142281 |
| 7320 | 2 | .799096 | 074 | 348 | .799370 | 10920 | 2 | .146464 | 018 | 627 | .147072 |
| 7380 | 3 | .806186 | 073 | 351 | .806464 | 10980 | 3 | .151222 | 017 | 633 | .151837 |
| 7440 | 4 | .813219 | 073 | 355 | .813501 | 11040 | 4 | .155954 | 016 | 638 | .156577 |
| 7500 | 5 | .820194 | 072 | 359 | .820482 | 11100 | 5 | .160661 | 015 | 644 | .161290 |
| 7560 | 6 | .827115 | 071 | 363 | .827406 | 11160 | 6 | .165342 | 014 | 650 | .165978 |
| 7620 | 7 | .833980 | 070 | 367 | .834277 | 11220 | 7 | .169998 | 013 | 655 | .170641 |
| 7680 | 8 | .840792 | 070 | 371 | .841093 | 11280 | 8 | .174630 | 011 | 661 | .175279 |
| 7740 | 9 | .847551 | 069 | 375 | .847857 | 11340 | 9 | .179236 | 010 | 667 | .179893 |
| 7800 | 10 | .854257 | 068 | 379 | .854568 | 11400 | 10 | .183819 | 009 | 673 | .184483 |
| 7860 | 11 | 6.860912 | 067 | 383 | 6.861228 | 11460 | 11 | 7.188377 | 008 | 679 | 7.189048 |
| 7920 | 12 | .867517 | 066 | 387 | .867837 | 11520 | 12 | .192912 | 007 | 685 | .193589 |
| 7980 | 13 | .874071 | 066 | 391 | .874396 | 11580 | 13 | .197423 | 006 | 690 | .198108 |
| 8040 | 14 | .880577 | 065 | 395 | .880907 | 11640 | 14 | .201910 | 004 | 696 | .202602 |
| 8100 | 15 | .887034 | 064 | 399 | .887369 | 11700 | 15 | .206375 | 003 | 702 | .207074 |
| 8160 | 16 | .893443 | 063 | 403 | .893783 | 11760 | 16 | .210817 | 002 | 708 | .211523 |
| 8220 | 17 | .899806 | 062 | 407 | .900151 | 11820 | 17 | .215236 | 001 | 714 | .215949 |
| 8280 | 18 | .906122 | 061 | 411 | .906472 | 11880 | 18 | 219633 | ◆00 | 720 | .220353 |
| 8340 | 19 | .912393 | 061 | 416 | .912748 | 11940 | 19 | .224007 | 998 | 727 | .224735 |
| 8400 | 20 | .918618 | 060 | 420 | .918979 | 12000 | 20 | .228360 | 997 | 733 | .229095 |
| 8460 | 21 | 6.924800 | 059 | 424 | 6.925165 | 12060 | 21 | 7.232691 | 996 | 739 | 7.233433 |
| 8520 | 22 | .930937 | 058 | 429 | .931308 | 12120 | 22 | .237000 | 995 | 745 | .237750 |
| 8580 | 23 | .937032 | 057 | 433 | .937408 | 12180 | 23 | .241288 | 994 | 751 | .242046 |
| 8640 | 24 | .943084 | 056 | 437 | .943465 | 12240 | 24 | .245555 | 992 | 757 | .246320 |
| 8700 | 25 | .949094 | 055 | 442 | .949480 | 12300 | 25 | .249801 | 991 | 764 | .250574 |
| 8760 | 26 | .955063 | 054 | 446 | .955455 | 12360 | 26 | .254027 | 990 | 770 | .254807 |
| 8820 | 27 | .960991 | 054 | 451 | .961388 | 12420 | 27 | .258232 | 989 | 776 | .259019 |
| 8880 | 28 | .966879 | 053 | 455 | .967281 | 12480 | 28 | .262416 | 987 | 783 | .263212 |
| 8940 | 29 | .972727 | 052 | 460 | .973135 | 12540 | 29 | .266581 | 986 | 789 | .267384 |
| 9000 | 30 | .978536 | 051 | 464 | .978949 | 12600 | 30 | .270726 | 985 | 795 | .271537 |
| 9060 | 31 | 6.984306 | 050 | 469 | 6.984725 | 12660 | 31 | 7.274851 | 983 | 802 | 7.275669 |
| 9120 | 32 | .990039 | 049 | 474 | .990463 | 12720 | 32 | .278956 | 982 | 808 | .279783 |
| 9180 | 33 | 6.995733 | 048 | 478 | 6.996164 | 13780 | 33 | .283043 | 981 | 815 | .283877 |
| 9240 | 34 | 7.001391 | 047 | 483 | 7.001827 | 12840 | 34 | .287110 | 980 | 821 | .287952 |
| 9300 | 35 | .007012 | 046 | 488 | .007454 | 12900 | 35 | .291158 | 978 | 828 | .292007 |
| 9360 | 36 | .012597 | 045 | 493 | .013044 | 12960 | 36 | .295187 | 977 | 835 | .296045 |
| 9420 | 37 | .018146 | 044 | 497 | .018599 | 13020 | 37 | .299197 | 976 | 841 | .300063 |
| 9480 | 38 | .023660 | 043 | 502 | .024119 | 13080 | 38 | .303190 | 974 | 848 | .304063 |
| 9540 | 39 | .029139 | 042 | 507 | .029604 | 13140 | 39 | .307164 | 973 | 855 | .308045 |
| 9600 | 40 | .034584 | 041 | 512 | .035054 | 13200 | 40 | .311119 | 972 | 861 | .312009 |
| 9660 | 41 | 7.039995 | 040 | 517 | 7.040471 | 13260 | 41 | 7.315057 | 970 | 868 | 7.315955 |
| 9720 | 42 | .045372 | 039 | 522 | .045854 | 13320 | 42 | .318977 | 969 | 875 | .319883 |
| 9780 | 43 | .050716 | 038 | 527 | .051204 | 13380 | 43 | .322880 | 967 | 882 | .323794 |
| 9840 | 44 | .056028 | 037 | 532 | .056522 | 13440 | 44 | .326765 | 966 | 889 | .327687 |
| 9900 | 45 | .061307 | 036 | 537 | .061807 | 13500 | 45 | .330632 | 965 | 896 | .331563 |
| 9960 | 46 | .066554 | 035 | 542 | .067061 | 13560 | 46 | .334483 | 963 | 902 | .335422 |
| 10020 | 47 | .071770 | 034 | 547 | .072282 | 13620 | 47 | .338316 | 962 | 908 | .339263 |
| 10080 | 48 | .076954 | 033 | 552 | .077473 | 13680 | 48 | .342133 | 961 | 916 | .343089 |
| 10140 | 49 | .082108 | 032 | 557 | .082633 | 13740 | 49 | .345933 | 959 | 923 | .346897 |
| 10200 | 50 | .087232 | 031 | 562 | .087763 | 13800 | 50 | .349716 | 958 | 930 | .350689 |
| 10260 | 51 | 7.092325 | 030 | 568 | 7.092862 | 13860 | 51 | 7.353483 | 956 | 938 | 7.354464 |
| 10320 | 52 | .097389 | 029 | 573 | .097932 | 13920 | 52 | .357233 | 955 | 945 | .358223 |
| 10380 | 53 | .102423 | 028 | 578 | .102973 | 13980 | 53 | .360968 | 953 | 952 | .361966 |
| 10440 | 54 | .107428 | 027 | 584 | .107985 | 14040 | 54 | .364686 | 952 | 959 | .365693 |
| 10500 | 55 | .112405 | 026 | 589 | .112968 | 14100 | 55 | .368389 | 951 | 966 | .369404 |
| 10560 | 56 | .117353 | 025 | 594 | .117922 | 14160 | 56 | .372076 | 949 | 973 | .373100 |
| 10620 | 57 | .122273 | 024 | 600 | .122849 | 14220 | 57 | .375747 | 948 | 981 | .376780 |
| 10680 | 58 | .127165 | 023 | 605 | .127748 | 14280 | 58 | .379403 | 946 | 988 | .380444 |
| 10740 | 59 | .132030 | 022 | 611 | .132619 | 14340 | 59 | .383043 | 945 | 995 | .384094 |
| 10800 | 60 | 7.136868 | 021 | 616 | 7.137464 | 14400 | 60 | 7.386668 | 943 | ◆03 | 7.387728 |
| " | ' | | | | | " | ' | | 9.069* | 9.071* | |

# TABLE XXVI.—LOGARITHMIC VERSED SINES

| 4° | | | | | 5° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 7.386668 | 60.17 | 7.387728 | 60.32 | 0 | 7.580389 | 48.15 | 7.582045 | 48.33 |
| 1 | .390278 | 59.93 | .391347 | 60.07 | 1 | .583278 | 47.98 | .584945 | 48.17 |
| 2 | .393874 | 59.67 | .394951 | 59.82 | 2 | .586157 | 47.82 | .587835 | 48.00 |
| 3 | .397454 | 59.43 | .398540 | 59.57 | 3 | .589026 | 47.67 | .590715 | 47.87 |
| 4 | .401020 | 59.18 | .402114 | 59.33 | 4 | .591886 | 47.52 | .593587 | 47.70 |
| 5 | .404571 | 58.93 | .405674 | 59.10 | 5 | .594737 | 47.35 | .596449 | 47.53 |
| 6 | .408107 | 58.70 | .409220 | 58.85 | 6 | .597578 | 47.20 | .599301 | 47.38 |
| 7 | .411629 | 58.47 | .412751 | 58.62 | 7 | .600410 | 47.05 | .602144 | 47.25 |
| 8 | .415137 | 58.23 | .416268 | 58.38 | 8 | .603233 | 46.90 | .604979 | 47.08 |
| 9 | .418631 | 58.00 | .419771 | 58.15 | 9 | .606047 | 47.73 | .607804 | 46.92 |
| 10 | .422111 | 57.77 | .423260 | 57.92 | 10 | .608851 | 46.60 | .610619 | 46.78 |
| 11 | 7.425577 | 57.53 | 7.426735 | 57.70 | 11 | 7.611647 | 46.43 | 7.613426 | 46.63 |
| 12 | .429029 | 57.30 | .430197 | 57.45 | 12 | .614433 | 46.30 | .616224 | 46.48 |
| 13 | .432467 | 57.08 | .433644 | 57.25 | 13 | .617211 | 46.15 | .619013 | 46.35 |
| 14 | .435892 | 56.85 | .437079 | 57.00 | 14 | .619980 | 45.98 | .621794 | 46.18 |
| 15 | .439303 | 56.63 | .440499 | 56.80 | 15 | .622739 | 45.87 | .624565 | 46.05 |
| 16 | .442701 | 56.42 | .443907 | 56.57 | 16 | .625491 | 45.70 | .627328 | 45.90 |
| 17 | .446086 | 56.20 | .447301 | 56.35 | 17 | .628233 | 45.57 | .630082 | 45.75 |
| 18 | .449458 | 55.97 | .450682 | 56.13 | 18 | .630967 | 45.42 | .632827 | 45.62 |
| 19 | .452816 | 55.77 | .454050 | 55.92 | 19 | .633692 | 45.28 | .635564 | 45.48 |
| 20 | .456162 | 55.55 | .457405 | 55.72 | 20 | .636409 | 45.13 | .638293 | 45.33 |
| 21 | 7.459495 | 55.33 | 7.460748 | 55.48 | 21 | 7.639117 | 44.98 | 7.641013 | 45.18 |
| 22 | .462815 | 55.12 | .464077 | 55.28 | 22 | .641816 | 44.87 | .643724 | 45.07 |
| 23 | .466122 | 54.92 | .467394 | 55.08 | 23 | .644508 | 44.72 | .646428 | 44.90 |
| 24 | .469417 | 54.70 | .470699 | 54.87 | 24 | .647191 | 44.57 | .649122 | 44.78 |
| 25 | .472699 | 54.50 | .473991 | 54.65 | 25 | .649865 | 44.45 | .651809 | 44.65 |
| 26 | .475969 | 54.28 | .477270 | 54.47 | 26 | .652532 | 44.30 | .654488 | 44.50 |
| 27 | .479226 | 54.10 | .480538 | 54.25 | 27 | .655190 | 44.17 | .657158 | 44.37 |
| 28 | .482472 | 53.88 | .483793 | 54.05 | 28 | .657840 | 44.05 | .659820 | 44.23 |
| 29 | .485705 | 53.70 | .487036 | 53.85 | 29 | .660483 | 43.90 | .662474 | 44.12 |
| 30 | .488927 | 53.48 | .490267 | 53.67 | 30 | .663117 | 43.77 | .665121 | 43.97 |
| 31 | 7.492136 | 53.28 | 7.493487 | 53.45 | 31 | 7.665743 | 43.63 | 7.667759 | 43.83 |
| 32 | .495333 | 53.10 | .496694 | 53.27 | 32 | .668361 | 43.50 | .670389 | 43.73 |
| 33 | .498519 | 52.90 | .499890 | 53.07 | 33 | .670971 | 43.38 | .673012 | 43.57 |
| 34 | .501693 | 52.72 | .503074 | 52.88 | 34 | .673574 | 43.23 | .675626 | 43.45 |
| 35 | .504856 | 52.52 | .506247 | 52.68 | 35 | .676168 | 43.12 | .678233 | 43.33 |
| 36 | .508007 | 52.33 | .509408 | 52.50 | 36 | .678755 | 42.98 | .680833 | 43.18 |
| 37 | .511147 | 52.13 | .512558 | 52.32 | 37 | .681334 | 42.87 | .683424 | 43.07 |
| 38 | .514275 | 51.95 | .515697 | 52.12 | 38 | .683906 | 42.73 | .686008 | 42.95 |
| 39 | .517392 | 51.77 | .518824 | 51.93 | 39 | .686470 | 42.60 | .688585 | 42.82 |
| 40 | .520498 | 51.58 | .521940 | 51.77 | 40 | .689026 | 42.48 | .691154 | 42.68 |
| 41 | 7.523593 | 51.40 | 7.525046 | 51.57 | 41 | 7.691575 | 42.35 | 7.693715 | 42.57 |
| 42 | 526677 | 51.22 | .528140 | 51.38 | 42 | .694116 | 42.23 | .696269 | 42.43 |
| 43 | .529750 | 51.03 | .531223 | 51.22 | 43 | .696650 | 42.12 | .698815 | 42.33 |
| 44 | .532812 | 50.85 | .534296 | 51.02 | 44 | .699177 | 41.98 | .701355 | 42.20 |
| 45 | .535863 | 50.68 | .537357 | 50.85 | 45 | .701696 | 41.87 | .703887 | 42.07 |
| 46 | .538904 | 50.50 | .540408 | 50.68 | 46 | .704208 | 41.73 | .706411 | 41.97 |
| 47 | .541934 | 50.32 | .543449 | 50.50 | 47 | .706712 | 41.63 | .708929 | 41.83 |
| 48 | .544953 | 50.15 | .546479 | 50.33 | 48 | .709210 | 41.50 | .711439 | 41.72 |
| 49 | .547962 | 49.98 | .549499 | 50.15 | 49 | .711700 | 41.38 | .713942 | 41.60 |
| 50 | .550961 | 49.80 | .552508 | 49.98 | 50 | .714183 | 41.27 | .716438 | 41.48 |
| 51 | 7.553949 | 49.63 | 7.555507 | 49.80 | 51 | 7.716659 | 41.15 | 7.718927 | 41.37 |
| 52 | .556927 | 49.43 | .558495 | 49.65 | 52 | .719128 | 41.03 | .721409 | 41.25 |
| 53 | .559895 | 49.28 | .561474 | 49.47 | 53 | .721590 | 40.92 | .723884 | 41.13 |
| 54 | .562852 | 49.13 | .564442 | 49.32 | 54 | .724045 | 40.80 | .726352 | 41.02 |
| 55 | .565800 | 48.95 | .567401 | 49.13 | 55 | .726493 | 40.68 | .728813 | 40.90 |
| 56 | .568737 | 48.80 | .570349 | 48.98 | 56 | .728934 | 40.57 | .731267 | 40.78 |
| 57 | .571665 | 48.63 | .573288 | 48.82 | 57 | .731368 | 40.47 | .733714 | 40.68 |
| 58 | .574583 | 48.47 | .576217 | 48.65 | 58 | .733796 | 40.33 | .736155 | 40.57 |
| 59 | .577491 | 48.30 | .579136 | 48.48 | 59 | .736216 | 40.23 | .738589 | 40.45 |
| 60 | 7.580389 | 48.15 | 7.582045 | 48.33 | 60 | 7.738630 | 40.13 | 7.741016 | 40.33 |

| | 6° | | | | | 7° | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 7.738630 | 40.13 | 7.741016 | 40.33 | 0 | 7.872381 | 34.38 | 7.875630 | 34.63 |
| 1 | .741038 | 40.00 | .743436 | 40.23 | 1 | .874444 | 34.30 | .877708 | 34.57 |
| 2 | .743438 | 39.90 | .745850 | 40.13 | 2 | .876502 | 34.22 | .879782 | 34.48 |
| 3 | .745832 | 39.78 | .748258 | 40.00 | 3 | .878555 | 34.13 | .881851 | 34.40 |
| 4 | .748219 | 39.68 | .750658 | 39.90 | 4 | .880603 | 34.07 | .883915 | 34.32 |
| 5 | .750600 | 39.57 | .753052 | 39.80 | 5 | .882647 | 33.98 | .885974 | 34.25 |
| 6 | .752974 | 39.47 | .755440 | 39.68 | 6 | .884686 | 33.90 | .888029 | 34.15 |
| 7 | .755342 | 39.35 | .757821 | 39.58 | 7 | .886720 | 33.82 | .890078 | 34.08 |
| 8 | .757703 | 39.25 | .760196 | 39.48 | 8 | .888749 | 33.73 | .892123 | 34.02 |
| 9 | .760058 | 39.13 | .762565 | 39.37 | 9 | .890773 | 33.67 | .894164 | 33.92 |
| 10 | .762406 | 39.05 | .764927 | 39.25 | 10 | .892793 | 33.58 | .896199 | 33.85 |
| 11 | 7.764749 | 38.92 | 7.767282 | 39.17 | 11 | 7.894808 | 33.50 | 7.898230 | 33.77 |
| 12 | .767084 | 38.83 | .769632 | 39.05 | 12 | .896818 | 33.43 | .900256 | 33.70 |
| 13 | .769414 | 38.72 | .771975 | 38.95 | 13 | .898824 | 33.35 | .902278 | 33.62 |
| 14 | .771737 | 38.62 | .774312 | 38.85 | 14 | .900825 | 33.27 | .904295 | 33.53 |
| 15 | .774054 | 38.52 | .776643 | 38.75 | 15 | .902821 | 33.20 | .906307 | 33.47 |
| 16 | .776365 | 38.42 | .778968 | 38.63 | 16 | .904813 | 33.12 | .908315 | 33.40 |
| 17 | .778670 | 38.30 | .781286 | 38.55 | 17 | .906800 | 33.05 | .910319 | 33.30 |
| 18 | .780968 | 38.22 | .783599 | 38.43 | 18 | .908783 | 32.97 | .912317 | 33.25 |
| 19 | .783261 | 38.10 | .785905 | 38.35 | 19 | .910761 | 32.90 | .914312 | 33.17 |
| 20 | .785547 | 38.02 | .788206 | 38.23 | 20 | .912735 | 32.82 | .916302 | 33.08 |
| 21 | 7.787828 | 37.90 | 7.790500 | 38.15 | 21 | 7.914704 | 32.73 | 7.918287 | 33.02 |
| 22 | .790102 | 37.82 | .792789 | 38.03 | 22 | .916668 | 32.68 | .920268 | 32.95 |
| 23 | .792371 | 37.70 | .795071 | 37.95 | 23 | .918629 | 32.58 | .922245 | 32.87 |
| 24 | .794633 | 37.62 | .797348 | 37.85 | 24 | .920584 | 32.53 | .924217 | 32.78 |
| 25 | .796890 | 37.52 | .799619 | 37.75 | 25 | .922536 | 32.45 | .926184 | 32.73 |
| 26 | .799141 | 37.40 | .801884 | 37.65 | 26 | .924483 | 32.37 | .928148 | 32.65 |
| 27 | .801385 | 37.33 | .804143 | 37.57 | 27 | .926425 | 32.32 | .930107 | 32.58 |
| 28 | .803625 | 37.22 | .806397 | 37.45 | 28 | .928364 | 32.22 | .932062 | 32.50 |
| 29 | .805858 | 37.13 | .808644 | 37.37 | 29 | .930297 | 32.17 | .934012 | 32.43 |
| 30 | .808086 | 37.03 | .810886 | 37.28 | 30 | .932227 | 32.08 | .935958 | 32.37 |
| 31 | 7.810308 | 36.93 | 7.813123 | 37.17 | 31 | 7.934152 | 32.02 | 7.937900 | 32.30 |
| 32 | .812524 | 36.83 | .815353 | 37.08 | 32 | .936073 | 31.95 | .939838 | 32.23 |
| 33 | .814734 | 36.75 | .817578 | 37.00 | 33 | .937990 | 31.88 | .941772 | 32.15 |
| 34 | .816939 | 36.67 | .819798 | 36.90 | 34 | .939903 | 31.80 | .943701 | 32.08 |
| 35 | .819139 | 36.55 | .822012 | 36.80 | 35 | .941811 | 31.73 | .945626 | 32.02 |
| 36 | .821332 | 36.48 | .824220 | 36.72 | 36 | .943715 | 31.67 | .947547 | 31.95 |
| 37 | .823521 | 36.37 | .826423 | 36.62 | 37 | .945615 | 31.60 | .949464 | 31.87 |
| 38 | .825703 | 36.28 | .828620 | 36.53 | 38 | .947511 | 31.52 | .951376 | 31.82 |
| 39 | .827880 | 36.20 | .830812 | 36.45 | 39 | .949402 | 31.47 | .953285 | 31.73 |
| 40 | .830052 | 36.10 | .832999 | 36.35 | 40 | .951290 | 31.38 | .955189 | 31.68 |
| 41 | 7.832218 | 36.02 | 7.835180 | 36.27 | 41 | 7.953173 | 31.32 | 7.957090 | 31.60 |
| 42 | .834379 | 35.93 | .837356 | 36.17 | 42 | .955052 | 31.27 | .958986 | 31.53 |
| 43 | .836535 | 35.83 | .839526 | 36.08 | 43 | .956928 | 31.18 | .960878 | 31.48 |
| 44 | .838685 | 35.75 | .841691 | 36.00 | 44 | .958799 | 31.12 | .962767 | 31.40 |
| 45 | .840830 | 35.65 | .843851 | 35.90 | 45 | .960666 | 31.05 | .964651 | 31.35 |
| 46 | .842969 | 35.58 | .846005 | 35.83 | 46 | .962529 | 30.98 | .966531 | 31.28 |
| 47 | .845104 | 35.48 | .848155 | 35.73 | 47 | .964388 | 30.92 | .968408 | 31.20 |
| 48 | .847233 | 35.40 | .850299 | 35.63 | 48 | .966243 | 30.85 | .970280 | 31.13 |
| 49 | .849357 | 35.30 | .852437 | 35.57 | 49 | .968094 | 30.78 | .972148 | 31.08 |
| 50 | .851475 | 35.23 | .854571 | 35.48 | 50 | .969941 | 30.73 | .974013 | 31.02 |
| 51 | 7.853589 | 35.13 | 7.856700 | 35.38 | 51 | 7.971785 | 30.65 | 7.975874 | 30.93 |
| 52 | .855697 | 35.05 | .858823 | 35.32 | 52 | .973624 | 30.58 | .977730 | 30.88 |
| 53 | .857800 | 34.97 | .860942 | 35.22 | 53 | .975459 | 30.53 | .979583 | 30.82 |
| 54 | .859898 | 34.88 | .863055 | 35.13 | 54 | .977291 | 30.45 | .981432 | 30.75 |
| 55 | .861991 | 34.80 | .865163 | 35.05 | 55 | .979118 | 30.40 | .983277 | 30.70 |
| 56 | .864079 | 34.72 | .867266 | 34.98 | 56 | .980942 | 30.33 | .985119 | 30.62 |
| 57 | .866162 | 34.63 | .869365 | 34.88 | 57 | .982762 | 30.27 | .986956 | 30.57 |
| 58 | .868240 | 34.55 | .871458 | 34.80 | 58 | .984578 | 30.22 | .988790 | 30.50 |
| 59 | .870313 | 34.47 | .873546 | 34.73 | 59 | .986391 | 30.13 | .990620 | 30.42 |
| 60 | 7.872381 | 34.38 | 7.875630 | 34.63 | 60 | 7.988199 | 30.08 | 7.992446 | 30.38 |

| 8° | | | | | 9° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 7.988199 | 30.08 | 7.992446 | 30.38 | 0 | 8.090317 | 26.72 | 8.095697 | 27.05 |
| 1 | .990004 | 30.02 | .994269 | 30.32 | 1 | .091920 | 26.68 | .097320 | 27.02 |
| 2 | .991805 | 29.95 | .996088 | 30.25 | 2 | .093521 | 26.63 | .098941 | 26.97 |
| 3 | .993602 | 29.88 | .997903 | 30.18 | 3 | .095119 | 26.58 | .100559 | 26.92 |
| 4 | .995395 | 29.83 | 7.999714 | 30.13 | 4 | .096714 | 26.52 | .102174 | 26.87 |
| 5 | .997185 | 29.77 | 8.001522 | 30.07 | 5 | .098305 | 26.48 | .103786 | 26.82 |
| 6 | 7.998971 | 29.72 | .003326 | 30.00 | 6 | .099894 | 26.43 | .105395 | 26.77 |
| 7 | 8.000754 | 29.63 | .005126 | 29.95 | 7 | .101480 | 26.40 | .107001 | 26.73 |
| 8 | .002532 | 29.60 | .006923 | 29.88 | 8 | .103064 | 26.33 | .108605 | 26.67 |
| 9 | .004308 | 29.52 | .008716 | 29.83 | 9 | .104644 | 26.28 | .110205 | 26.63 |
| 10 | .006079 | 29.47 | .010506 | 29.73 | 10 | .106221 | 26.25 | .111803 | 26.58 |
| 11 | 8.007847 | 29.40 | 8.012292 | 29.70 | 11 | 8.107796 | 26.18 | 8.113398 | 26.53 |
| 12 | .009611 | 29.35 | .014074 | 29.65 | 12 | .109367 | 26.15 | .114990 | 26.48 |
| 13 | .011372 | 29.28 | .015853 | 29.58 | 13 | .110936 | 26.10 | .116579 | 26.45 |
| 14 | .013129 | 29.22 | .017628 | 29.53 | 14 | .112502 | 26.05 | .118166 | 26.38 |
| 15 | .014882 | 29.17 | .019400 | 29.47 | 15 | .114065 | 26.00 | .119749 | 26.35 |
| 16 | .016632 | 29.10 | .021168 | 29.42 | 16 | .115625 | 25.95 | .121330 | 26.30 |
| 17 | .018378 | 29.05 | .022933 | 29.35 | 17 | .117182 | 25.92 | .122908 | 26.25 |
| 18 | .020121 | 29.00 | .024694 | 29.30 | 18 | .118737 | 25.87 | .124483 | 26.22 |
| 19 | .021861 | 28.93 | .026452 | 29.23 | 19 | .120289 | 25.82 | .126056 | 26.17 |
| 20 | .023597 | 28.87 | .028206 | 29.18 | 20 | .121838 | 25.77 | .127626 | 26.12 |
| 21 | 8.025329 | 28.82 | 8.029957 | 29.13 | 21 | 8.123384 | 25.72 | 8.129193 | 26.07 |
| 22 | .027058 | 28.75 | .031705 | 29.07 | 22 | .124927 | 25.68 | .130757 | 26.02 |
| 23 | .028783 | 28.70 | .033449 | 29.00 | 23 | .126468 | 25.65 | .132318 | 25.98 |
| 24 | .030505 | 28.65 | .035189 | 28.97 | 24 | .128006 | 25.58 | .133877 | 25.93 |
| 25 | .032224 | 28.58 | .036927 | 28.90 | 25 | .129541 | 25.55 | .135433 | 25.90 |
| 26 | .033939 | 28.53 | .038661 | 28.83 | 26 | .131074 | 25.50 | .136987 | 25.85 |
| 27 | .035651 | 28.47 | .040391 | 28.78 | 27 | .132604 | 25.45 | .138538 | 25.80 |
| 28 | .037359 | 28.42 | .042118 | 28.73 | 28 | .134131 | 25.40 | .140086 | 25.75 |
| 29 | .039064 | 28.37 | .043842 | 28.68 | 29 | .135655 | 25.37 | .141631 | 25.72 |
| 30 | .040766 | 28.30 | .045563 | 28.62 | 30 | .137177 | 25.32 | .143174 | 25.67 |
| 31 | 8.042464 | 28.25 | 8.047280 | 28.57 | 31 | 8.138696 | 25.27 | 8.144714 | 25.63 |
| 32 | .044159 | 28.20 | .048994 | 28.50 | 32 | .140212 | 25.23 | .146252 | 25.58 |
| 33 | .045851 | 28.13 | .050704 | 28.47 | 33 | .141726 | 25.18 | .147787 | 25.53 |
| 34 | .047539 | 28.08 | .052412 | 28.40 | 34 | .143237 | 25.13 | .149319 | 25.50 |
| 35 | .049224 | 28.03 | .054116 | 28.35 | 35 | .144745 | 25.10 | .150849 | 25.45 |
| 36 | .050906 | 27.98 | .055817 | 28.28 | 36 | .146251 | 25.05 | .152376 | 25.40 |
| 37 | .052585 | 27.92 | .057514 | 28.25 | 37 | .147754 | 25.02 | .153900 | 25.37 |
| 38 | .054260 | 27.87 | .059209 | 28.18 | 38 | .149255 | 24.95 | .155422 | 25.33 |
| 39 | .055932 | 27.82 | .060900 | 28.13 | 39 | .150752 | 24.93 | .156942 | 25.27 |
| 40 | .057601 | 27.75 | .062588 | 28.08 | 40 | .152248 | 24.88 | .158458 | 25.25 |
| 41 | 8.059266 | 27.72 | 8.064273 | 28.03 | 41 | 8.153741 | 24.83 | 8.159973 | 25.18 |
| 42 | .060929 | 27.65 | .065955 | 27.97 | 42 | .155231 | 24.78 | .161484 | 25.17 |
| 43 | .062588 | 27.60 | .067633 | 27.93 | 43 | .156718 | 24.75 | .162994 | 25.10 |
| 44 | .064244 | 27.55 | .069309 | 27.87 | 44 | .158203 | 24.72 | .164500 | 25.07 |
| 45 | .065897 | 27.48 | .070981 | 27.82 | 45 | .159686 | 24.67 | .166004 | 25.03 |
| 46 | .067546 | 27.45 | .072650 | 27.77 | 46 | .161166 | 24.62 | .167506 | 24.98 |
| 47 | .069193 | 27.38 | .074316 | 27.72 | 47 | .162643 | 24.58 | .169005 | 24.95 |
| 48 | .070836 | 27.33 | .075979 | 27.67 | 48 | .164118 | 24.53 | .170502 | 24.90 |
| 49 | .072476 | 27.30 | .077639 | 27.60 | 49 | .165590 | 24.50 | .171996 | 24.87 |
| 50 | .074114 | 27.23 | .079295 | 27.57 | 50 | .167060 | 24.45 | .173488 | 24.82 |
| 51 | 8.075748 | 27.18 | 8.080949 | 27.52 | 51 | 8.168527 | 24.42 | 8.174977 | 24.78 |
| 52 | .077379 | 27.13 | .082600 | 27.45 | 52 | .169992 | 24.37 | .176464 | 24.73 |
| 53 | .079007 | 27.07 | .084247 | 27.42 | 53 | .171454 | 24.33 | .177948 | 24.70 |
| 54 | .080631 | 27.03 | .085892 | 27.37 | 54 | .172914 | 24.30 | .179430 | 24.65 |
| 55 | .082253 | 26.98 | .087534 | 27.30 | 55 | .174372 | 24.25 | .180909 | 24.62 |
| 56 | .083872 | 26.93 | .089172 | 27.27 | 56 | .175827 | 24.20 | .182386 | 24.58 |
| 57 | .085488 | 26.87 | .090808 | 27.20 | 57 | .177279 | 24.17 | .183861 | 24.53 |
| 58 | .087100 | 26.83 | .092440 | 27.17 | 58 | .178729 | 24.13 | .185333 | 24.50 |
| 59 | .088710 | 26.78 | .094070 | 27.12 | 59 | .180177 | 24.08 | .186803 | 24.47 |
| 60 | 8.090317 | 26.72 | 8.095697 | 27.05 | 60 | 8.181622 | 24.05 | 8.188271 | 24.42 |

| 10° | | | | | 11° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 8.181622 | 24.05 | 8.188271 | 24.42 | 0 | 8.264176 | 21.85 | 8.272229 | 22.27 |
| 1 | .183065 | 24.00 | .189736 | 24.37 | 1 | .265487 | 21.82 | .273565 | 22.22 |
| 2 | .184505 | 23.97 | .191198 | 24.35 | 2 | .266796 | 21.78 | .274898 | 22.20 |
| 3 | .185943 | 23.93 | .192659 | 24.30 | 3 | .268103 | 21.75 | .276230 | 22.17 |
| 4 | .187379 | 23.88 | .194117 | 24.25 | 4 | .269408 | 21.72 | .277560 | 22.13 |
| 5 | .188812 | 23.85 | .195572 | 24.22 | 5 | .270711 | 21.68 | .278888 | 22.08 |
| 6 | .190243 | 23.80 | .197025 | 24.18 | 6 | .272012 | 21.65 | .280213 | 22.07 |
| 7 | .191671 | 23.77 | .198476 | 24.15 | 7 | .273311 | 21.62 | .281537 | 22.03 |
| 8 | .193097 | 23.73 | .199925 | 24.10 | 8 | .274608 | 21.58 | .282859 | 22.00 |
| 9 | .194521 | 23.68 | .201371 | 24.07 | 9 | .275903 | 21.57 | .284179 | 21.98 |
| 10 | .195942 | 23.65 | .202815 | 24.03 | 10 | .277197 | 21.52 | .285498 | 21.93 |
| 11 | 8.197361 | 23.62 | 8.204257 | 23.98 | 11 | 8.278488 | 21.48 | 8.286814 | 21.90 |
| 12 | .198778 | 23.57 | .205696 | 23.95 | 12 | .279777 | 21.47 | .288128 | 21.88 |
| 13 | .200192 | 23.53 | .207133 | 23.92 | 13 | .281065 | 21.42 | .289441 | 21.83 |
| 14 | .201604 | 23.50 | .208568 | 23.88 | 14 | .282350 | 21.40 | .290751 | 21.82 |
| 15 | .203014 | 23.45 | .210001 | 23.83 | 15 | .283634 | 21.37 | .292060 | 21.78 |
| 16 | .204421 | 23.42 | .211431 | 23.80 | 16 | .284916 | 21.33 | .293367 | 21.75 |
| 17 | .205826 | 23.38 | .212859 | 23.77 | 17 | .286196 | 21.28 | .294672 | 21.72 |
| 18 | .207229 | 23.35 | .214285 | 23.72 | 18 | .287473 | 21.27 | .295975 | 21.68 |
| 19 | .208630 | 23.30 | .215708 | 23.70 | 19 | .288749 | 21.25 | .297276 | 21.67 |
| 20 | .210028 | 23.27 | .217130 | 23.65 | 20 | .290024 | 21.20 | .298576 | 21.62 |
| 21 | 8.211424 | 23.23 | 8.218549 | 23.62 | 21 | 8.291296 | 21.17 | 8.299873 | 21.60 |
| 22 | .212818 | 23.18 | .219966 | 23.57 | 22 | .292566 | 21.15 | .301169 | 21.57 |
| 23 | .214209 | 23.17 | .221380 | 23.55 | 23 | .293835 | 21.10 | .302463 | 21.53 |
| 24 | .215599 | 23.12 | .222793 | 23.50 | 24 | .295101 | 21.08 | .303755 | 21.50 |
| 25 | .216986 | 23.08 | .224203 | 23.47 | 25 | .296366 | 21.05 | .305045 | 21.48 |
| 26 | .218371 | 23.03 | .225611 | 23.43 | 26 | .297629 | 21.02 | .306334 | 21.43 |
| 27 | .219753 | 23.00 | .227017 | 23.40 | 27 | .298890 | 20.98 | .307620 | 21.42 |
| 28 | .221133 | 22.98 | .228421 | 23.35 | 28 | .300149 | 20.95 | .308905 | 21.38 |
| 29 | .222512 | 22.93 | .229822 | 23.32 | 29 | .301406 | 20 93 | .310188 | 21.35 |
| 30 | .223888 | 22.88 | .231221 | 23.30 | 30 | .302662 | 20.90 | .311469 | 21.33 |
| 31 | 8.225261 | 22.87 | 8.232619 | 23.25 | 31 | 8.303916 | 20.85 | 8.312749 | 21.28 |
| 32 | .226633 | 22.82 | .234014 | 23.22 | 32 | .305167 | 20.85 | .314026 | 21.27 |
| 33 | .228002 | 22.78 | .235407 | 23.17 | 33 | .306418 | 20.80 | .315302 | 21.23 |
| 34 | .229369 | 23.77 | .236797 | 23.15 | 34 | .307666 | 20.77 | .316576 | 21.22 |
| 35 | .230735 | 22.70 | .238186 | 23.10 | 35 | .308912 | 20.75 | .317849 | 21 17 |
| 36 | .232097 | 22.68 | .239572 | 23.08 | 36 | .310157 | 20.72 | .319119 | 21.15 |
| 37 | .233458 | 22.65 | .240957 | 23.03 | 37 | .311400 | 20.68 | .320388 | 21.12 |
| 38 | .234817 | 22.60 | .242339 | 23.00 | 38 | .312641 | 20.65 | .321655 | 21.08 |
| 39 | .236173 | 22.57 | .243719 | 22.97 | 39 | .313880 | 20.62 | .322920 | 21.05 |
| 40 | .237527 | 22.55 | .245097 | 22.93 | 40 | .315117 | 20.60 | .324183 | 21.03 |
| 41 | 8.238880 | 22.50 | 8.246473 | 22.90 | 41 | 8.316353 | 20.57 | 8.325445 | 21.00 |
| 42 | .240230 | 22.47 | .247847 | 22.87 | 42 | .317587 | 20.53 | .326705 | 20.98 |
| 43 | .241578 | 22.43 | .249219 | 22.83 | 43 | .318819 | 20.50 | .327964 | 20.93 |
| 44 | .242924 | 22.38 | .250589 | 22.80 | 44 | .320049 | 20.48 | .329220 | 20.92 |
| 45 | .244267 | 22.37 | .251957 | 22.75 | 45 | .321278 | 20.45 | .330475 | 20.88 |
| 46 | .245609 | 22.32 | .253322 | 22.73 | 46 | .322505 | 20.42 | .331728 | 20.87 |
| 47 | .246948 | 22.30 | .254686 | 22.68 | 47 | .323730 | 20.38 | .332980 | 20.82 |
| 48 | .248286 | 22.25 | .256047 | 22.67 | 48 | .324953 | 20.37 | .334229 | 20.80 |
| 49 | .249621 | 22.23 | .257407 | 22.62 | 49 | .326175 | 20.33 | .335477 | 20.78 |
| 50 | .250955 | 22.18 | .258764 | 22.60 | 50 | .327395 | 20.30 | .336724 | 20.73 |
| 51 | 8.252286 | 22.15 | 8.260120 | 22.55 | 51 | 8.328613 | 20 27 | 8.337968 | 20.72 |
| 52 | .253615 | 22.12 | .261473 | 22.53 | 52 | .329829 | 20.25 | .339211 | 20.70 |
| 53 | .254942 | 22.10 | .262825 | 22.48 | 53 | .331044 | 20.22 | .340453 | 20.65 |
| 54 | .256268 | 22.05 | .264174 | 22.47 | 54 | .332257 | 20.18 | .341692 | 20.63 |
| 55 | .257591 | 22 02 | .265522 | 22.42 | 55 | .333468 | 20.17 | .342930 | 20.60 |
| 56 | .258912 | 21.98 | .266867 | 22.40 | 56 | .334678 | 20.13 | .344166 | 20.58 |
| 57 | .260231 | 21.95 | .268211 | 22.35 | 57 | .335886 | 20.10 | .345401 | 20.55 |
| 58 | .261548 | 21.92 | .269552 | 22 33 | 58 | .337092 | 20.07 | .346634 | 20.52 |
| 59 | .262863 | 21.88 | .270892 | 22 28 | 59 | .338296 | 20.05 | .347865 | 20.50 |
| 60 | 8.264176 | 21.85 | 8.272229 | 22.27 | 60 | 8.339499 | 20.02 | 8.349095 | 20.47 |

| 12° | | | | | 13° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 8.339499 | 20.02 | 8.349095 | 20.47 | 0 | 8.408748 | 18.47 | 8.420024 | 18.95 |
| 1 | .340700 | 20.00 | .350323 | 20.43 | 1 | .409856 | 18.43 | .421161 | 18.93 |
| 2 | .341900 | 19.95 | .351549 | 20.42 | 2 | .410962 | 18.42 | .422297 | 18.90 |
| 3 | .343097 | 19.95 | .352774 | 20.38 | 3 | .412067 | 18.40 | .423431 | 18.88 |
| 4 | .344294 | 19.90 | .353997 | 20.35 | 4 | .413171 | 18.38 | .424564 | 18.87 |
| 5 | .345488 | 19.88 | .355218 | 20.33 | 5 | .414274 | 18.35 | .425696 | 18.83 |
| 6 | .346681 | 19.85 | .356438 | 20.30 | 6 | .415375 | 18.32 | .426826 | 18.82 |
| 7 | .347872 | 19.82 | .357656 | 20.28 | 7 | .416474 | 18.30 | .427955 | 18.80 |
| 8 | .349061 | 19.80 | .358873 | 20.25 | 8 | .417572 | 18.28 | .429083 | 18.77 |
| 9 | .350249 | 19.77 | .360088 | 20.22 | 9 | .418669 | 18.25 | .430209 | 18.75 |
| 10 | .351435 | 19.75 | .361301 | 20.20 | 10 | .419764 | 18.23 | .431334 | 18.73 |
| 11 | 8.352620 | 19.72 | 8.362513 | 20.18 | 11 | 8.420858 | 18.22 | 8.432458 | 18.70 |
| 12 | .353803 | 19.68 | .363724 | 20.13 | 12 | .421951 | 18.18 | .433580 | 18.67 |
| 13 | .354984 | 19.67 | .364932 | 20.12 | 13 | .423042 | 18.17 | .434700 | 18.67 |
| 14 | .356164 | 19.63 | .366139 | 20.10 | 14 | .424132 | 18.13 | .435820 | 18.63 |
| 15 | .357342 | 19.60 | .367345 | 20.07 | 15 | .425220 | 18.12 | .436938 | 18.62 |
| 16 | .358518 | 19.58 | .368549 | 20.03 | 16 | .426307 | 18.10 | .438055 | 18.58 |
| 17 | .359693 | 19.55 | .369751 | 20.02 | 17 | .427393 | 18.07 | .439170 | 18.57 |
| 18 | .360866 | 19.53 | .370952 | 19.98 | 18 | .428477 | 18.05 | .440284 | 18.55 |
| 19 | .362038 | 19.50 | .372151 | 19.95 | 19 | .429560 | 18.02 | .441397 | 18.53 |
| 20 | .363208 | 19.48 | .373348 | 19.95 | 20 | .430641 | 18.02 | .442509 | 18.50 |
| 21 | 8.364377 | 19.43 | 8.374545 | 19.90 | 21 | 8.431722 | 17.97 | 8.443619 | 18.47 |
| 22 | .365543 | 19.43 | .375739 | 19.88 | 22 | .432800 | 17.97 | .444727 | 18.47 |
| 23 | .366709 | 19.38 | .376932 | 19.85 | 23 | .433878 | 17.93 | .445835 | 18.43 |
| 24 | .367872 | 19.37 | .378123 | 19.83 | 24 | .434954 | 17.92 | .446941 | 18.42 |
| 25 | .369034 | 19.35 | .379313 | 19.82 | 25 | .436029 | 17.88 | .448046 | 18.38 |
| 26 | .370195 | 19.32 | .380502 | 19.78 | 26 | .437102 | 17.87 | .449149 | 18.38 |
| 27 | .371354 | 19.28 | .381689 | 19.75 | 27 | .438174 | 17.85 | .450252 | 18.35 |
| 28 | .372511 | 19.27 | .382874 | 19.73 | 28 | .439245 | 17.82 | .451353 | 18.32 |
| 29 | .373667 | 19.25 | .384058 | 19.70 | 29 | .440314 | 17.80 | .452452 | 18.32 |
| 30 | .374822 | 19.20 | .385240 | 19.68 | 30 | .441382 | 17.78 | .453551 | 18.28 |
| 31 | 8.375974 | 19.18 | 8.386421 | 19.65 | 31 | 8.442449 | 17.75 | 8.454648 | 18.25 |
| 32 | .377125 | 19.17 | .387600 | 19.63 | 32 | .443514 | 17.73 | .455743 | 18.25 |
| 33 | .378275 | 19.13 | .388778 | 19.60 | 33 | .444578 | 17.72 | .456838 | 18.22 |
| 34 | .379423 | 19.12 | .389954 | 19.58 | 34 | .445641 | 17.68 | .457931 | 18.20 |
| 35 | .380570 | 19.08 | .391129 | 19.55 | 35 | .446702 | 17.68 | .459023 | 18.18 |
| 36 | .381715 | 19.05 | .392302 | 19.53 | 36 | .447763 | 17.63 | .460114 | 18.15 |
| 37 | .382858 | 19.03 | .393474 | 19.50 | 37 | .448821 | 17.63 | .461203 | 18.13 |
| 38 | .384000 | 19.02 | .394644 | 19.48 | 38 | .449879 | 17.62 | .462291 | 18.12 |
| 39 | .385141 | 18.98 | .395813 | 19.45 | 39 | .450935 | 17.58 | .463378 | 18.10 |
| 40 | .386280 | 18.95 | .396980 | 19.43 | 40 | .451990 | 17.55 | .464464 | 18.07 |
| 41 | 8.387417 | 18.93 | 8.398146 | 19.42 | 41 | 8.453043 | 17.55 | 8.465548 | 18.05 |
| 42 | .388553 | 18.92 | .399311 | 19.38 | 42 | .454096 | 17.52 | .466631 | 18.03 |
| 43 | .389688 | 18.88 | .400474 | 19.35 | 43 | .455147 | 17.48 | .467713 | 18.00 |
| 44 | .390821 | 18.85 | .401635 | 19.33 | 44 | .456196 | 17.48 | .468793 | 18.00 |
| 45 | .391952 | 18.83 | .402795 | 19.32 | 45 | .457245 | 17.45 | .469873 | 17.97 |
| 46 | .393082 | 18.82 | .403954 | 19.28 | 46 | .458292 | 17.43 | .470951 | 17.95 |
| 47 | .394211 | 18.78 | .405111 | 19.27 | 47 | .459338 | 17.40 | .472028 | 17.92 |
| 48 | .395338 | 18.75 | .406267 | 19.23 | 48 | .460382 | 17.40 | .473103 | 17.90 |
| 49 | .396463 | 18.73 | .407421 | 19.22 | 49 | .461426 | 17.37 | .474177 | 17.90 |
| 50 | .397587 | 18.72 | .408574 | 19.18 | 50 | .462468 | 17.35 | .475251 | 17.85 |
| 51 | 8.398710 | 18.68 | 8.409725 | 19.17 | 51 | 8.463509 | 17.32 | 8.476322 | 17.85 |
| 52 | .399831 | 18.67 | .410875 | 19.13 | 52 | .464548 | 17.30 | .477393 | 17.83 |
| 53 | .400951 | 18.63 | .412023 | 19.13 | 53 | .465586 | 17.28 | .478463 | 17.80 |
| 54 | .402069 | 18.62 | .413171 | 19.08 | 54 | .466623 | 17.27 | .479531 | 17.78 |
| 55 | .403186 | 18.58 | .414316 | 19.08 | 55 | .467659 | 17.23 | .480598 | 17.77 |
| 56 | .404301 | 18.57 | .415461 | 19.03 | 56 | .468693 | 17.23 | .481664 | 17.73 |
| 57 | .405415 | 18.53 | .416603 | 19.03 | 57 | .469727 | 17.20 | .482728 | 17.73 |
| 58 | .406527 | 18.52 | .417745 | 19.00 | 58 | .470759 | 17.17 | .483792 | 17.70 |
| 59 | .407638 | 18.50 | .418885 | 18.98 | 59 | .471789 | 17.17 | .484854 | 17.68 |
| 60 | 8.408748 | 18.47 | 8.420024 | 18.95 | 60 | 8.472819 | 17.13 | 8.485915 | 17.67 |

| ′ | 14° Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | 15° Vers. | D. 1″. | Ex. sec. | D. 1″. |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 8.472819 | 17.13 | 8.485915 | 17.67 | 0 | 8.532425 | 15.98 | 8.547482 | 16.53 |
| 1 | .473847 | 17.12 | .486975 | 17.63 | 1 | .533384 | 15.97 | .548474 | 16.53 |
| 2 | .474874 | 17.10 | .488033 | 17.63 | 2 | .534342 | 15.95 | .549466 | 16.52 |
| 3 | .475900 | 17.08 | .489091 | 17.60 | 3 | .535299 | 15.93 | .550457 | 16.50 |
| 4 | .476925 | 17.05 | .490147 | 17.58 | 4 | .536255 | 15.92 | .551447 | 16.48 |
| 5 | .477948 | 17.03 | .491202 | 17.57 | 5 | .537210 | 15.88 | .552436 | 16.47 |
| 6 | .478970 | 17.02 | .492256 | 17.53 | 6 | .538163 | 15.88 | .553424 | 16.43 |
| 7 | .479991 | 17.00 | .493308 | 17.53 | 7 | .539116 | 15.87 | .554410 | 16.43 |
| 8 | .481011 | 16.97 | .494360 | 17.50 | 8 | .540068 | 15.83 | .555396 | 16.42 |
| 9 | .482029 | 16.95 | .495410 | 17.48 | 9 | .541018 | 15.83 | .556381 | 16.38 |
| 10 | .483046 | 16.93 | .496459 | 17.47 | 10 | .541968 | 15.80 | .557364 | 16.38 |
| 11 | 8.484062 | 16.92 | 8.497507 | 17.45 | 11 | 8.542916 | 15.78 | 8.558347 | 16.37 |
| 12 | .485077 | 16.90 | .498554 | 17.43 | 12 | .543863 | 15.78 | .559329 | 16.33 |
| 13 | .486091 | 16.87 | .499600 | 17.40 | 13 | .544810 | 15.75 | .560309 | 16.33 |
| 14 | .487103 | 16.87 | .500644 | 17.38 | 14 | .545755 | 15.73 | .561289 | 16.30 |
| 15 | .488115 | 16.83 | .501687 | 17.38 | 15 | .546699 | 15.72 | .562267 | 16.30 |
| 16 | .489125 | 16.82 | .502730 | 17.35 | 16 | .547642 | 15.70 | .563245 | 16.28 |
| 17 | .490134 | 16.78 | .503771 | 17.32 | 17 | .548584 | 15.68 | .564222 | 16.25 |
| 18 | .491141 | 16.78 | .504810 | 17.32 | 18 | .549525 | 15.67 | .565197 | 16.25 |
| 19 | .492148 | 16.75 | .505849 | 17.30 | 19 | .550465 | 15.65 | .566172 | 16.22 |
| 20 | .493153 | 16.73 | .506887 | 17.27 | 20 | .551404 | 15.63 | .567145 | 16.22 |
| 21 | 8.494157 | 16.72 | 8.507923 | 17.25 | 21 | 8.552342 | 15.62 | 8.568118 | 16.20 |
| 22 | .495160 | 16.70 | .508958 | 17.25 | 22 | .553279 | 15.60 | .569090 | 16.17 |
| 23 | .496162 | 16.67 | .509993 | 17.22 | 23 | .554215 | 15.58 | .570060 | 16.17 |
| 24 | .497162 | 16.67 | .511026 | 17.18 | 24 | .555150 | 15.57 | .571030 | 16.15 |
| 25 | .498162 | 16.63 | .512057 | 17.18 | 25 | .556084 | 15.55 | .571999 | 16.12 |
| 26 | .499160 | 16.62 | .513088 | 17.17 | 26 | .557017 | 15.53 | .572966 | 16.12 |
| 27 | .500157 | 16.60 | .514118 | 17.13 | 27 | .557949 | 15.50 | .573933 | 16.10 |
| 28 | .501153 | 16.58 | .515146 | 17.13 | 28 | .558879 | 15.50 | .574899 | 16.08 |
| 29 | .502148 | 16.57 | .516174 | 17.10 | 29 | .559809 | 15.48 | .575864 | 16.05 |
| 30 | .503142 | 16.53 | .517200 | 17.08 | 30 | .560738 | 15.47 | .576827 | 16.05 |
| 31 | 8.504134 | 16.52 | 8.518225 | 17.07 | 31 | 8.561666 | 15.43 | 8.577790 | 16.03 |
| 32 | .505125 | 16.52 | .519249 | 17.05 | 32 | .562592 | 15.43 | .578752 | 16.02 |
| 33 | .506116 | 16.48 | .520272 | 17.03 | 33 | .563518 | 15.42 | .579713 | 16.00 |
| 34 | .507105 | 16.47 | .521294 | 17.02 | 34 | .564443 | 15.40 | .580673 | 15.98 |
| 35 | .508092 | 16.47 | .522315 | 16.98 | 35 | .565367 | 15.37 | .581632 | 15.97 |
| 36 | .509079 | 16.43 | .523334 | 16.98 | 36 | .566289 | 15.37 | .582590 | 15.95 |
| 37 | .510065 | 16.40 | .524353 | 16.95 | 37 | .567211 | 15.35 | .583547 | 15.93 |
| 38 | .511049 | 16.40 | .525370 | 16.95 | 38 | .568132 | 15.33 | .584503 | 15.92 |
| 39 | .512033 | 16.37 | .526387 | 16.92 | 39 | .569052 | 15.30 | .585458 | 15.90 |
| 40 | .513015 | 16.35 | .527402 | 16.90 | 40 | .569970 | 15.30 | .586412 | 15.88 |
| 41 | 8.513996 | 16.33 | 8.528416 | 16.88 | 41 | 8.570888 | 15.28 | 8.587365 | 15.88 |
| 42 | .514976 | 16.32 | .529429 | 16.87 | 42 | .571805 | 15.27 | .588318 | 15.85 |
| 43 | .515955 | 16.28 | .530441 | 16.85 | 43 | .572721 | 15.25 | .589269 | 15.83 |
| 44 | .516932 | 16.28 | .531452 | 16.83 | 44 | .573636 | 15.22 | .590219 | 15.83 |
| 45 | .517909 | 16.25 | .532462 | 16.82 | 45 | .574549 | 15.22 | .591169 | 15.80 |
| 46 | .518884 | 16.25 | .533471 | 16.78 | 46 | .575462 | 15.20 | .592117 | 15.80 |
| 47 | .519859 | 16.22 | .534478 | 16.78 | 47 | .576374 | 15.18 | .593065 | 15.78 |
| 48 | .520832 | 16.20 | .535485 | 16.75 | 48 | .577285 | 15.17 | .594012 | 15.75 |
| 49 | .521804 | 16.18 | .536490 | 16.75 | 49 | .578195 | 15.15 | .594957 | 15.75 |
| 50 | .522775 | 16.17 | .537495 | 16.72 | 50 | .579104 | 15.13 | .595902 | 15.73 |
| 51 | 8.523745 | 16.15 | 8.538498 | 16.72 | 51 | 8.580012 | 15.12 | 8.596846 | 15.72 |
| 52 | .524714 | 16.13 | .539501 | 16.68 | 52 | .580919 | 15.10 | .597789 | 15.70 |
| 53 | .525682 | 16.10 | .540502 | 16.67 | 53 | .581825 | 15.08 | .598731 | 15.68 |
| 54 | .526648 | 16.10 | .541502 | 16.65 | 54 | .582730 | 15.07 | .599672 | 15.67 |
| 55 | .527614 | 16.07 | .542501 | 16.63 | 55 | .583634 | 15.05 | .600612 | 15.65 |
| 56 | .528578 | 16.07 | .543499 | 16.63 | 56 | .584537 | 15.05 | .601551 | 15.65 |
| 57 | .529542 | 16.03 | .544497 | 16.60 | 57 | .585440 | 15.02 | .602490 | 15.62 |
| 58 | .530504 | 16.02 | .545493 | 16.58 | 58 | .586341 | 15.00 | .603427 | 15.60 |
| 59 | .531465 | 16.00 | .546488 | 16.57 | 59 | .587241 | 15.00 | .604363 | 15.60 |
| 60 | 8.532425 | 15.98 | 8.547482 | 16.53 | 60 | 8.588141 | 14.97 | 8.605299 | 15.58 |

| | 16° | | | | | 17° | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 8.588141 | 14.97 | 8.605299 | 15.58 | 0 | 8.640434 | 14.08 | 8.659838 | 14.72 |
| 1 | .589039 | 14.95 | .606234 | 15.55 | 1 | .641279 | 14.07 | .660721 | 14.72 |
| 2 | .589936 | 14.95 | .607167 | 15.55 | 2 | .642123 | 14.05 | .661604 | 14.70 |
| 3 | .590833 | 14.93 | .608100 | 15.53 | 3 | .642966 | 14.05 | .662486 | 14.68 |
| 4 | .591729 | 14.90 | .609032 | 15.52 | 4 | .643809 | 14.02 | .663367 | 14.68 |
| 5 | .592623 | 14.90 | .609963 | 15.50 | 5 | .644650 | 14.02 | .664248 | 14.65 |
| 6 | .593517 | 14.88 | .610893 | 15.50 | 6 | .645491 | 14.00 | .665127 | 14.65 |
| 7 | .594410 | 14.87 | .611823 | 15.47 | 7 | .646331 | 13.98 | .666006 | 14.63 |
| 8 | .595302 | 14.83 | .612751 | 15.45 | 8 | .647170 | 13.97 | .666884 | 14.62 |
| 9 | .596192 | 14.83 | .613678 | 15.45 | 9 | .648008 | 13.95 | .667761 | 14.60 |
| 10 | .597082 | 14.82 | .614605 | 15.43 | 10 | .648845 | 13.95 | .668637 | 14.60 |
| 11 | 8.597971 | 14.82 | 8.615531 | 15.42 | 11 | 8.649682 | 13.93 | 8.669513 | 14.58 |
| 12 | .598860 | 14.78 | .616456 | 15.38 | 12 | .650518 | 13.92 | .670388 | 14.57 |
| 13 | .599747 | 14.77 | .617379 | 15.38 | 13 | .651353 | 13.90 | .671262 | 14.55 |
| 14 | .600633 | 14.75 | .618302 | 15.38 | 14 | .652187 | 13.88 | .672135 | 14.55 |
| 15 | .601518 | 14.75 | .619225 | 15.35 | 15 | .653020 | 13.87 | .673008 | 14.52 |
| 16 | .602403 | 14.72 | .620146 | 15.33 | 16 | .653852 | 13.87 | .673879 | 14.52 |
| 17 | .603286 | 14.72 | .621066 | 15.33 | 17 | .654684 | 13.85 | .674750 | 14.50 |
| 18 | .604169 | 14.70 | .621986 | 15.30 | 18 | .655515 | 13.83 | .675620 | 14.50 |
| 19 | .605051 | 14.67 | .622904 | 15.30 | 19 | .656345 | 13.82 | .676490 | 14.47 |
| 20 | .605931 | 14.67 | .623822 | 15.28 | 20 | .657174 | 13.82 | .677358 | 14.47 |
| 21 | 8.606811 | 14.65 | 8.624739 | 15.27 | 21 | 8.658003 | 13.78 | 8.678226 | 14.45 |
| 22 | .607690 | 14.63 | .625655 | 15.25 | 22 | .658830 | 13.78 | .679093 | 14.45 |
| 23 | .608568 | 14.62 | .626570 | 15.23 | 23 | .659657 | 13.77 | .679960 | 14.42 |
| 24 | .609445 | 14.60 | .627484 | 15.23 | 24 | .660483 | 13.75 | .680825 | 14.42 |
| 25 | .610321 | 14.60 | .628398 | 15.20 | 25 | .661308 | 13.73 | .681690 | 14.40 |
| 26 | .611197 | 14.57 | .629310 | 15.20 | 26 | .662132 | 13.73 | .682554 | 14.38 |
| 27 | .612071 | 14.57 | .630222 | 15.18 | 27 | .662956 | 13.72 | .683417 | 14.38 |
| 28 | .612945 | 14.53 | .631133 | 15.17 | 28 | .663779 | 13.70 | .684280 | 14.35 |
| 29 | .613817 | 14.53 | .632043 | 15.15 | 29 | .664601 | 13.68 | .685141 | 14.35 |
| 30 | .614689 | 14.52 | .632952 | 15.13 | 30 | .665422 | 13.67 | .686002 | 14.35 |
| 31 | 8.615560 | 14.50 | 8.633860 | 15.13 | 31 | 8.666242 | 13.67 | 8.686863 | 14.32 |
| 32 | .616430 | 14.48 | .634768 | 15.10 | 32 | .667062 | 13.65 | .687722 | 14.32 |
| 33 | .617299 | 14.47 | .635674 | 15.10 | 33 | .667881 | 13.63 | .688581 | 14.30 |
| 34 | .618167 | 14.45 | .636580 | 15.08 | 34 | .668699 | 13.62 | .689439 | 14.28 |
| 35 | .619034 | 14.45 | .637485 | 15.07 | 35 | .669516 | 13.60 | .690296 | 14.28 |
| 36 | .619901 | 14.42 | .638389 | 15.05 | 36 | .670332 | 13.60 | .691153 | 14.25 |
| 37 | .620766 | 14.42 | .639292 | 15.05 | 37 | .671148 | 13.58 | .692008 | 14.25 |
| 38 | .621631 | 14.40 | .640195 | 15.02 | 38 | .671963 | 13.57 | .692863 | 14.25 |
| 39 | .622495 | 14.38 | .641096 | 15.02 | 39 | .672777 | 13.55 | .693718 | 14.22 |
| 40 | .623358 | 14.37 | .641997 | 15.00 | 40 | .673590 | 13.55 | .694571 | 14.22 |
| 41 | 8.624220 | 14.35 | 8.642897 | 14.98 | 41 | 8.674403 | 13.53 | 8.695424 | 14.20 |
| 42 | .625081 | 14.33 | .643796 | 14.97 | 42 | .675215 | 13.52 | .696276 | 14.18 |
| 43 | .625941 | 14.33 | .644694 | 14.95 | 43 | .676026 | 13.50 | .697127 | 14.18 |
| 44 | .626801 | 14.30 | .645591 | 14.95 | 44 | .676836 | 13.48 | .697978 | 14.17 |
| 45 | .627659 | 14.30 | .646488 | 14.93 | 45 | .677645 | 13.48 | .698828 | 14.15 |
| 46 | .628517 | 14.28 | .647384 | 14.92 | 46 | .678454 | 13.47 | .699677 | 14.13 |
| 47 | .629374 | 14.27 | .648279 | 14.90 | 47 | .679262 | 13.45 | .700525 | 14.13 |
| 48 | .630230 | 14.25 | .649173 | 14.88 | 48 | .680069 | 13.43 | .701373 | 14.12 |
| 49 | .631085 | 14.23 | .650066 | 14.87 | 49 | .680875 | 13.43 | .702220 | 14.10 |
| 50 | .631939 | 14.22 | .650958 | 14.87 | 50 | .681681 | 13.42 | .703066 | 14.10 |
| 51 | 8.632792 | 14.22 | 8.651850 | 14.85 | 51 | 8.682486 | 13.40 | 8.703912 | 14.07 |
| 52 | .633645 | 14.18 | .652741 | 14.83 | 52 | .683290 | 13.38 | .704756 | 14.07 |
| 53 | .634496 | 14.18 | .653631 | 14.82 | 53 | .684093 | 13.38 | .705600 | 14.07 |
| 54 | .635347 | 14.17 | .654520 | 14.80 | 54 | .684896 | 13.35 | .706444 | 14.03 |
| 55 | .636197 | 14.15 | .655408 | 14.80 | 55 | .685697 | 13.35 | .707286 | 14.03 |
| 56 | .637046 | 14.13 | .656296 | 14.77 | 56 | .686498 | 13.35 | .708128 | 14.02 |
| 57 | .637894 | 14.13 | .657182 | 14.77 | 57 | .687299 | 13.32 | .708969 | 14.02 |
| 58 | .638742 | 14.10 | .658068 | 14.77 | 58 | .688098 | 13.32 | .709810 | 14.00 |
| 59 | .639588 | 14.10 | .658954 | 14.73 | 59 | .688897 | 13.30 | .710650 | 13.98 |
| 60 | 8.640434 | 14.08 | 8.659838 | 14.72 | 60 | 8.689695 | 13.28 | 8.711489 | 13.97 |

| 18° | | | | | 19° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 8.689695 | 13.28 | 8.711489 | 13.97 | 0 | 8.736248 | 12.58 | 8.760578 | 13.30 |
| 1 | .690492 | 13.28 | .712327 | 13.95 | 1 | .737003 | 12.57 | .761376 | 13.30 |
| 2 | .691289 | 13.25 | .713164 | 13.95 | 2 | .737757 | 12.55 | .762174 | 13.28 |
| 3 | .692084 | 13.25 | .714001 | 13.95 | 3 | .738510 | 12.55 | .762971 | 13.27 |
| 4 | .692879 | 13.25 | .714838 | 13.92 | 4 | .739263 | 12.53 | .763767 | 13.27 |
| 5 | .693674 | 13.22 | .715673 | 13.92 | 5 | .740015 | 12.52 | .764563 | 13.25 |
| 6 | .694467 | 13.22 | .716508 | 13.90 | 6 | .740766 | 12.50 | .765358 | 13.23 |
| 7 | .695260 | 13.20 | .717342 | 13.88 | 7 | .741516 | 12.50 | .766152 | 13.23 |
| 8 | .696052 | 13.18 | .718175 | 13.88 | 8 | .742266 | 12.50 | .766946 | 13.22 |
| 9 | .696843 | 13.18 | .719008 | 13.87 | 9 | .743016 | 12.47 | .767739 | 13.20 |
| 10 | .697634 | 13.17 | .719840 | 13.85 | 10 | .743764 | 12.47 | .768531 | 13.20 |
| 11 | 8.698424 | 13.15 | 8.720671 | 13.85 | 11 | 8.744512 | 12.45 | 8.769323 | 13.18 |
| 12 | .699213 | 13.13 | .721502 | 13.83 | 12 | .745259 | 12.43 | .770114 | 13.18 |
| 13 | .700001 | 13.13 | .722332 | 13.82 | 13 | .746006 | 12.45 | .770905 | 13.17 |
| 14 | .700789 | 13.12 | .723161 | 13.80 | 14 | .746752 | 12.42 | .771695 | 13.15 |
| 15 | .701576 | 13.10 | .723989 | 13.80 | 15 | .747497 | 12.42 | .772484 | 13.15 |
| 16 | .702362 | 13.08 | .724817 | 13.78 | 16 | .748242 | 12.40 | .773273 | 13.13 |
| 17 | .703147 | 13.08 | .725644 | 13.78 | 17 | .748986 | 12.38 | .774061 | 13.13 |
| 18 | .703932 | 13.07 | .726471 | 13.77 | 18 | .749729 | 12.38 | .774849 | 13.12 |
| 19 | .704716 | 13.05 | .727297 | 13.75 | 19 | .750472 | 12.37 | .775636 | 13.10 |
| 20 | .705499 | 13.05 | .728122 | 13.73 | 20 | .751214 | 12.35 | .776422 | 13.08 |
| 21 | 8.706282 | 13.02 | 8.728946 | 13.73 | 21 | 8.751955 | 12.35 | 8.777207 | 13.10 |
| 22 | .707063 | 13.02 | .729770 | 13.72 | 22 | .752696 | 12.33 | .777993 | 13.07 |
| 23 | .707844 | 13.02 | .730593 | 13.70 | 23 | .753436 | 12.32 | .778777 | 13.07 |
| 24 | .708625 | 12.98 | .731415 | 13.70 | 24 | .754175 | 12.32 | .779561 | 13.05 |
| 25 | .709404 | 12.98 | .732237 | 13.68 | 25 | .754914 | 12.30 | .780344 | 13.05 |
| 26 | .710183 | 12.98 | .733058 | 13.67 | 26 | .755652 | 12.28 | .781127 | 13.03 |
| 27 | .710961 | 12.95 | .733878 | 13.67 | 27 | .756389 | 12.28 | .781909 | 13.02 |
| 28 | .711739 | 12.95 | .734698 | 13.65 | 28 | .757126 | 12.27 | .782690 | 13.02 |
| 29 | .712516 | 12.93 | .735517 | 13.63 | 29 | .757862 | 12.27 | .783471 | 13.00 |
| 30 | .713292 | 12.92 | .736335 | 13.63 | 30 | .758598 | 12.25 | .784251 | 13.00 |
| 31 | 8.714067 | 12.92 | 8.737153 | 13.62 | 31 | 8.759333 | 12.23 | 8.785031 | 12.98 |
| 32 | .714842 | 12.90 | .737970 | 13.60 | 32 | .760067 | 12.23 | .785810 | 12.97 |
| 33 | .715616 | 12.88 | .738786 | 13.60 | 33 | .760801 | 12.22 | .786588 | 12.97 |
| 34 | .716389 | 12.87 | .739602 | 13.58 | 34 | .761534 | 12.20 | .787366 | 12.97 |
| 35 | .717161 | 12.87 | .740417 | 13.57 | 35 | .762266 | 12.20 | .788144 | 12.93 |
| 36 | .717933 | 12.85 | .741231 | 13.57 | 36 | .762998 | 12.18 | .788920 | 12.93 |
| 37 | .718704 | 12.85 | .742045 | 13.55 | 37 | .763729 | 12.17 | .789696 | 12.93 |
| 38 | .719475 | 12.82 | .742858 | 13.53 | 38 | .764459 | 12.17 | .790472 | 12.92 |
| 39 | .720244 | 12.82 | .743670 | 13.53 | 39 | .765189 | 12.15 | .791247 | 12.90 |
| 40 | .721013 | 12.82 | .744482 | 13.52 | 40 | .765918 | 12.15 | .792021 | 12.90 |
| 41 | 8.721782 | 12.78 | 8.745293 | 13.50 | 41 | 8.766647 | 12.12 | 8.792795 | 12.88 |
| 42 | .722549 | 12.78 | .746103 | 13.50 | 42 | .767374 | 12.12 | .793568 | 12.87 |
| 43 | .723316 | 12.78 | .746913 | 13.48 | 43 | .768102 | 12.10 | .794340 | 12.87 |
| 44 | .724083 | 12.75 | .747722 | 13.47 | 44 | .768828 | 12.10 | .795112 | 12.87 |
| 45 | .724848 | 12.75 | .748530 | 13.47 | 45 | .769554 | 12.10 | .795884 | 12.83 |
| 46 | .725613 | 12.73 | .749338 | 13.45 | 46 | .770280 | 12.08 | .796654 | 12.85 |
| 47 | .726377 | 12.72 | .750145 | 13.43 | 47 | .771005 | 12.07 | .797425 | 12.82 |
| 48 | .727140 | 12.72 | .750951 | 13.43 | 48 | .771729 | 12.05 | .798194 | 12.82 |
| 49 | .727903 | 12.70 | .751757 | 13.42 | 49 | .772452 | 12.05 | .798963 | 12.82 |
| 50 | .728665 | 12.70 | .752562 | 13.42 | 50 | .773175 | 12.05 | .799732 | 12.80 |
| 51 | 8.729427 | 12.67 | 8.753367 | 13.40 | 51 | 8.773898 | 12.02 | 8.800500 | 12.78 |
| 52 | .730187 | 12.67 | .754171 | 13.38 | 52 | .774619 | 12.02 | .801267 | 12.78 |
| 53 | .730947 | 12.67 | .754974 | 13.37 | 53 | .775340 | 12.02 | .802034 | 12.77 |
| 54 | .731707 | 12.63 | .755776 | 13.37 | 54 | .776061 | 12.00 | .802800 | 12.75 |
| 55 | .732465 | 12.63 | .756578 | 13.37 | 55 | .776781 | 11.98 | .803565 | 12.75 |
| 56 | .733223 | 12.63 | .757380 | 13.33 | 56 | .777500 | 11.97 | .804330 | 12.75 |
| 57 | .733981 | 12.60 | .758180 | 13.33 | 57 | .778218 | 11.97 | .805095 | 12.73 |
| 58 | .734737 | 12.60 | .758980 | 13.33 | 58 | .778936 | 11.97 | .805859 | 12.72 |
| 59 | .735493 | 12.58 | .759780 | 13.30 | 59 | .779654 | 11.93 | .806622 | 12.72 |
| 60 | 8.736248 | 12.58 | 8.760578 | 13.30 | 60 | 8.780370 | 11.95 | 8.807385 | 12.70 |

| 20° | | | | | 21° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 8.780370 | 11.95 | 8.807385 | 12.70 | 0 | 8.822296 | 11.35 | 8.852144 | 12.17 |
| 1 | .781087 | 11.92 | .808147 | 12.68 | 1 | .822977 | 11.35 | .852874 | 12.17 |
| 2 | .781802 | 11.92 | .808908 | 12.68 | 2 | .823658 | 11.33 | .853604 | 12.13 |
| 3 | .782517 | 11.90 | .809669 | 12.68 | 3 | .824338 | 11.33 | .854332 | 12.15 |
| 4 | .783231 | 11.90 | .810430 | 12.67 | 4 | .825018 | 11.32 | .855061 | 12.13 |
| 5 | .783945 | 11.88 | .811190 | 12.65 | 5 | .825697 | 11.32 | .855789 | 12.12 |
| 6 | .784658 | 11.88 | .811949 | 12.65 | 6 | .826376 | 11.30 | .856516 | 12.12 |
| 7 | .785371 | 11.87 | .812708 | 12.63 | 7 | .827054 | 11.28 | .857243 | 12.10 |
| 8 | .786083 | 11.85 | .813466 | 12.63 | 8 | .827731 | 11.28 | .857969 | 12.10 |
| 9 | .786794 | 11.85 | .814224 | 12.62 | 9 | .828408 | 11.28 | .858695 | 12.08 |
| 10 | .787505 | 11.83 | .814981 | 12.60 | 10 | .829085 | 11.27 | .859420 | 12.08 |
| 11 | 8.788215 | 11.82 | 8.815737 | 12.60 | 11 | 8.829761 | 11.25 | 8.860145 | 12.07 |
| 12 | .788924 | 11.82 | .816493 | 12.60 | 12 | .830436 | 11.25 | .860869 | 12.07 |
| 13 | .789633 | 11.82 | .817249 | 12.58 | 13 | .831111 | 11.23 | .861593 | 12.05 |
| 14 | .790342 | 11.78 | .818004 | 12.57 | 14 | .831785 | 11.23 | .862316 | 12.05 |
| 15 | .791049 | 11.78 | .818758 | 12.57 | 15 | .832459 | 11.22 | .863039 | 12.03 |
| 16 | .791756 | 11.78 | .819512 | 12.55 | 16 | .833132 | 11.20 | .863761 | 12.03 |
| 17 | .792463 | 11.77 | .820265 | 12.55 | 17 | .833804 | 11.20 | .864483 | 12.02 |
| 18 | .793169 | 11.75 | .821018 | 12.53 | 18 | .834476 | 11.20 | .865204 | 12.02 |
| 19 | .793874 | 11.75 | .821770 | 12.52 | 19 | .835148 | 11.18 | .865925 | 12.02 |
| 20 | .794579 | 11.73 | .822521 | 12.52 | 20 | .835819 | 11.17 | .866646 | 11.98 |
| 21 | 8.795283 | 11.73 | 8.823272 | 12.52 | 21 | 8.836489 | 11.17 | 8.867365 | 12.00 |
| 22 | .795987 | 11.72 | .824023 | 12.50 | 22 | .837159 | 11.17 | .868085 | 11.98 |
| 23 | .796690 | 11.70 | .824773 | 12.48 | 23 | .837829 | 11.15 | .868804 | 11.97 |
| 24 | .797392 | 11.70 | .825522 | 12.48 | 24 | .838498 | 11.13 | .869522 | 11.97 |
| 25 | .798094 | 11.68 | .826271 | 12.47 | 25 | .839166 | 11.13 | .870240 | 11.95 |
| 26 | .798795 | 11.68 | .827019 | 12.47 | 26 | .839834 | 11.12 | .870957 | 11.95 |
| 27 | .799496 | 11.67 | .827767 | 12.45 | 27 | .840501 | 11.12 | .871674 | 11.93 |
| 28 | .800196 | 11.67 | .828514 | 12.45 | 28 | .841168 | 11.10 | .872390 | 11.93 |
| 29 | .800896 | 11.63 | .829261 | 12.43 | 29 | .841834 | 11.10 | .873106 | 11.93 |
| 30 | .801594 | 11.65 | .830007 | 12.42 | 30 | .842500 | 11.08 | .873822 | 11.92 |
| 31 | 8.802293 | 11.63 | 8.830752 | 12.42 | 31 | 8.843165 | 11.07 | 8.874537 | 11.90 |
| 32 | .802991 | 11.62 | .831497 | 12.42 | 32 | .843829 | 11.07 | .875251 | 11.90 |
| 33 | .803688 | 11.60 | .832242 | 12.40 | 33 | .844493 | 11.07 | .875965 | 11.88 |
| 34 | .804384 | 11.60 | .832986 | 12.38 | 34 | .845157 | 11.05 | .876678 | 11.88 |
| 35 | .805080 | 11.60 | .833729 | 12.38 | 35 | .845820 | 11.05 | .877391 | 11.88 |
| 36 | .805776 | 11.58 | .834472 | 12.38 | 36 | .846483 | 11.03 | .878104 | 11.87 |
| 37 | .806471 | 11.57 | .835215 | 12.37 | 37 | .847145 | 11.02 | .878816 | 11.87 |
| 38 | .807165 | 11.57 | .835957 | 12.35 | 38 | .847806 | 11.02 | .879528 | 11.85 |
| 39 | .807859 | 11.55 | .836698 | 12.35 | 39 | .848467 | 11.00 | .880239 | 11.83 |
| 40 | .808552 | 11.53 | .837439 | 12.33 | 40 | .849127 | 11.00 | .880949 | 11.83 |
| 41 | 8.809244 | 11.53 | 8.838179 | 12.33 | 41 | 8.849787 | 11.00 | 8.881659 | 11.83 |
| 42 | .809936 | 11.53 | .838919 | 12.32 | 42 | .850447 | 10.98 | .882369 | 11.82 |
| 43 | .810628 | 11.52 | .839658 | 12.30 | 43 | .851106 | 10.97 | .883078 | 11.82 |
| 44 | .811319 | 11.50 | .840396 | 12.32 | 44 | .851764 | 10.97 | .883787 | 11.80 |
| 45 | .812009 | 11.50 | .841135 | 12.28 | 45 | .852422 | 10.95 | .884495 | 11.80 |
| 46 | .812699 | 11.48 | .841872 | 12.28 | 46 | .853079 | 10.95 | .885203 | 11.78 |
| 47 | .813388 | 11.48 | .842609 | 12.28 | 47 | .853736 | 10.93 | .885910 | 11.78 |
| 48 | .814077 | 11.47 | .843346 | 12.27 | 48 | .854392 | 10.93 | .886617 | 11.77 |
| 49 | .814765 | 11.45 | .844082 | 12.25 | 49 | .855048 | 10.92 | .887323 | 11.77 |
| 50 | .815452 | 11.45 | .844817 | 12.25 | 50 | .855703 | 10.92 | .888029 | 11.75 |
| 51 | 8.816139 | 11.43 | 8.845552 | 12.25 | 51 | 8.856358 | 10.90 | 8.888734 | 11.75 |
| 52 | .816825 | 11.43 | .846287 | 12.23 | 52 | .857012 | 10.90 | .889439 | 11.75 |
| 53 | .817511 | 11.42 | .847021 | 12.22 | 53 | .857666 | 10.88 | .890144 | 11.73 |
| 54 | .818196 | 11.42 | .847754 | 12.22 | 54 | .858319 | 10.88 | .890848 | 11.72 |
| 55 | .818881 | 11.40 | .848487 | 12.22 | 55 | .858972 | 10.87 | .891551 | 11.72 |
| 56 | .819565 | 11.40 | .849220 | 12.20 | 56 | .859624 | 10.87 | .892254 | 11.72 |
| 57 | .820249 | 11.38 | .849952 | 12.18 | 57 | .860276 | 10.85 | .892957 | 11.70 |
| 58 | .820932 | 11.37 | .850683 | 12.18 | 58 | .860927 | 10.85 | .893659 | 11.70 |
| 59 | .821614 | 11.37 | .851414 | 12.17 | 59 | .861578 | 10.83 | .894361 | 11.68 |
| 60 | 8.822296 | 11.35 | 8.852144 | 12.17 | 60 | 8.862228 | 10.82 | 8.895062 | 11.68 |

| 22° | | | | | 23° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 8.862228 | 10.82 | 8.895062 | 11.68 | 0 | 8.900341 | 10.33 | 8.936315 | 11.23 |
| 1 | .862877 | 10.83 | .895763 | 11.67 | 1 | .900961 | 10.35 | .936989 | 11.23 |
| 2 | .863527 | 10.80 | .896463 | 11.67 | 2 | .901582 | 10.32 | .937663 | 11.22 |
| 3 | .864175 | 10.80 | .897163 | 11.65 | 3 | .902201 | 10.33 | .938336 | 11.22 |
| 4 | .864823 | 10.80 | .897862 | 11.65 | 4 | .902821 | 10.32 | .939009 | 11.22 |
| 5 | .865471 | 10.78 | .898561 | 11.63 | 5 | .903440 | 10.30 | .939682 | 11.20 |
| 6 | .866118 | 10.78 | .899259 | 11.63 | 6 | .904058 | 10.30 | .940354 | 11.20 |
| 7 | .866765 | 10.77 | .899957 | 11.63 | 7 | .904676 | 10.28 | .941026 | 11.20 |
| 8 | .867411 | 10.77 | .900655 | 11.62 | 8 | .905293 | 10.28 | .941698 | 11.18 |
| 9 | .868057 | 10.75 | .901352 | 11.60 | 9 | .905910 | 10.28 | .942369 | 11.17 |
| 10 | .868702 | 10.73 | .902048 | 11.62 | 10 | .906527 | 10.27 | .943039 | 11.18 |
| 11 | 8.869346 | 10.75 | 8.902745 | 11.58 | 11 | 8.907143 | 10.27 | 8.943710 | 11.15 |
| 12 | .869991 | 10.72 | .903440 | 11.60 | 12 | .907759 | 10.25 | .944379 | 11.17 |
| 13 | .870634 | 10.72 | .904136 | 11.57 | 13 | .908374 | 10.25 | .945049 | 11.15 |
| 14 | .871277 | 10.72 | .904830 | 11.58 | 14 | .908989 | 10.23 | .945718 | 11.13 |
| 15 | .871920 | 10.70 | .905525 | 11.57 | 15 | .909603 | 10.23 | .946386 | 11.13 |
| 16 | .872562 | 10.70 | .906219 | 11.55 | 16 | .910217 | 10.22 | .947054 | 11.13 |
| 17 | .873204 | 10.68 | .906912 | 11.55 | 17 | .910830 | 10.22 | .947722 | 11.12 |
| 18 | .873845 | 10.68 | .907605 | 11.53 | 18 | .911443 | 10.22 | .948389 | 11.12 |
| 19 | .874486 | 10.67 | .908298 | 11.53 | 19 | .912056 | 10.20 | .949056 | 11.12 |
| 20 | .875126 | 10.67 | .908990 | 11.52 | 20 | .912668 | 10.18 | .949723 | 11.10 |
| 21 | 8.875766 | 10.65 | 8.909681 | 11.52 | 21 | 8.913279 | 10.20 | 8.950389 | 11.10 |
| 22 | .876405 | 10.65 | .910372 | 11.52 | 22 | .913891 | 10.17 | .951055 | 11.08 |
| 23 | .877044 | 10.63 | .911063 | 11.52 | 23 | .914501 | 10.17 | .951720 | 11.08 |
| 24 | .877682 | 10.63 | .911754 | 11.48 | 24 | .915111 | 10.17 | .952385 | 11.07 |
| 25 | .878320 | 10.62 | .912443 | 11.50 | 25 | .915721 | 10.17 | .953049 | 11.07 |
| 26 | .878957 | 10.62 | .913133 | 11.48 | 26 | .916331 | 10.15 | .953713 | 11.07 |
| 27 | .879594 | 10.60 | .913822 | 11.47 | 27 | .916940 | 10.13 | .954377 | 11.05 |
| 28 | .880230 | 10.60 | .914510 | 11.47 | 28 | .917548 | 10.13 | .955040 | 11.05 |
| 29 | .880866 | 10.58 | .915198 | 11.47 | 29 | .918156 | 10.13 | .955703 | 11.05 |
| 30 | .881501 | 10.58 | .915886 | 11.45 | 30 | .918764 | 10.12 | .956366 | 11.03 |
| 31 | 8.882136 | 10.58 | 8.916573 | 11.45 | 31 | 8.919371 | 10.10 | 8.957028 | 11.03 |
| 32 | .882771 | 10.57 | .917260 | 11.43 | 32 | .919977 | 10.12 | .957690 | 11.02 |
| 33 | .883405 | 10.55 | .917946 | 11.43 | 33 | .920584 | 10.10 | .958351 | 11.02 |
| 34 | .884038 | 10.55 | .918632 | 11.43 | 34 | .921190 | 10.08 | .959012 | 11.00 |
| 35 | .884671 | 10.53 | .919318 | 11.42 | 35 | .921795 | 10.08 | .959672 | 11.00 |
| 36 | .885303 | 10.53 | .920003 | 11.40 | 36 | .922400 | 10.07 | .960332 | 11.00 |
| 37 | .885935 | 10.53 | .920687 | 11.42 | 37 | .923004 | 10.07 | .960992 | 10.98 |
| 38 | .886567 | 10.52 | .921372 | 11.38 | 38 | .923608 | 10.07 | .961651 | 10.98 |
| 39 | .887198 | 10.52 | .922055 | 11.40 | 39 | .924212 | 10.05 | .962310 | 10.98 |
| 40 | .887829 | 10.50 | .922739 | 11.37 | 40 | .924815 | 10.05 | .962969 | 10.97 |
| 41 | 8.888459 | 10.48 | 8.923421 | 11.38 | 41 | 8.925418 | 10.03 | 8.963627 | 10.97 |
| 42 | .889088 | 10.48 | .924104 | 11.37 | 42 | .926020 | 10.03 | .964285 | 10.95 |
| 43 | .889717 | 10.48 | .924786 | 11.35 | 43 | .926622 | 10.03 | .964942 | 10.95 |
| 44 | .890346 | 10.47 | .925467 | 11.37 | 44 | .927224 | 10.02 | .965599 | 10.95 |
| 45 | .890974 | 10.47 | .926149 | 11.33 | 45 | .927825 | 10.00 | .966256 | 10.93 |
| 46 | .891602 | 10.45 | .926829 | 11.35 | 46 | .928425 | 10.00 | .966912 | 10.93 |
| 47 | .892229 | 10.45 | .927510 | 11.32 | 47 | .929025 | 10.00 | .967568 | 10.92 |
| 48 | .892856 | 10.43 | .928189 | 11.33 | 48 | .929625 | 9.98 | .968223 | 10.92 |
| 49 | .893482 | 10.43 | .928869 | 11.32 | 49 | .930224 | 9.98 | .968878 | 10.92 |
| 50 | .894108 | 10.42 | .929548 | 11.30 | 50 | .930823 | 9.97 | .969533 | 10.90 |
| 51 | 8.894733 | 10.42 | 8.930226 | 11.32 | 51 | 8.931421 | 9.97 | 8.970187 | 10.90 |
| 52 | .895358 | 10.42 | .930905 | 11.28 | 52 | .932019 | 9.97 | .970841 | 10.88 |
| 53 | .895983 | 10.40 | .931582 | 11.30 | 53 | .932617 | 9.95 | .971494 | 10.88 |
| 54 | .896607 | 10.38 | .932260 | 11.27 | 54 | .933214 | 9.95 | .972147 | 10.88 |
| 55 | .897230 | 10.38 | .932936 | 11.28 | 55 | .933811 | 9.93 | .972800 | 10.87 |
| 56 | .897853 | 10.38 | .933613 | 11.27 | 56 | .934407 | 9.93 | .973452 | 10.87 |
| 57 | .898476 | 10.37 | .934289 | 11.27 | 57 | .935003 | 9.92 | .974104 | 10.87 |
| 58 | .899098 | 10.35 | .934965 | 11.25 | 58 | .935598 | 9.92 | .974756 | 10.85 |
| 59 | .899719 | 10.37 | .935640 | 11.25 | 59 | .936193 | 9.92 | .975407 | 10.85 |
| 60 | 8.900341 | 10.33 | 8.936315 | 11.23 | 60 | 8.936788 | 9.90 | 8.976058 | 10.83 |

## TABLE XXVI.—LOGARITHMIC VERSED SINES

| 24° | | | | | 25° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 8.936788 | 9.90 | 8.976058 | 10.83 | 0 | 8.971703 | 9.50 | 9.014428 | 10.47 |
| 1 | .937382 | 9.90 | .976708 | 10.83 | 1 | .972273 | 9.48 | .015056 | 10.48 |
| 2 | .937976 | 9.88 | .977358 | 10.83 | 2 | .972842 | 9.48 | .015685 | 10.45 |
| 3 | .938569 | 9.88 | .978008 | 10.82 | 3 | .973411 | 9.48 | .016312 | 10.47 |
| 4 | .939162 | 9.87 | .978657 | 10.82 | 4 | .973980 | 9.47 | .016940 | 10.45 |
| 5 | .939754 | 9.87 | .979306 | 10.80 | 5 | .974548 | 9.47 | .017567 | 10.45 |
| 6 | .940346 | 9.87 | .979954 | 10.80 | 6 | .975116 | 9.45 | .018194 | 10.45 |
| 7 | .940938 | 9.85 | .980602 | 10.80 | 7 | .975683 | 9.45 | .018821 | 10.43 |
| 8 | .941529 | 9.85 | .981250 | 10.80 | 8 | .976250 | 9.43 | .019447 | 10.43 |
| 9 | .942120 | 9.83 | .981898 | 10.78 | 9 | .976816 | 9.43 | .020073 | 10.42 |
| 10 | .942710 | 9.83 | .982545 | 10.77 | 10 | .977382 | 9.43 | .020698 | 10.42 |
| 11 | 8.943300 | 9.82 | 8.983191 | 10.77 | 11 | 8.977948 | 9.43 | 9.021323 | 10.42 |
| 12 | .943889 | 9.83 | .983837 | 10.77 | 12 | .978514 | 9.42 | .021948 | 10.40 |
| 13 | .944479 | 9.80 | .984483 | 10.77 | 13 | .979079 | 9.40 | .022572 | 10.42 |
| 14 | .945067 | 9.80 | .985129 | 10.75 | 14 | .979643 | 9.40 | .023197 | 10.38 |
| 15 | .945655 | 9.80 | .985774 | 10.75 | 15 | .980207 | 9.40 | .023820 | 10.40 |
| 16 | .946243 | 9.80 | .986419 | 10.73 | 16 | .980771 | 9.40 | .024444 | 10.38 |
| 17 | .946831 | 9.78 | .987063 | 10.73 | 17 | .981335 | 9.38 | .025067 | 10.38 |
| 18 | .947418 | 9.77 | .987707 | 10.73 | 18 | .981898 | 9.37 | .025690 | 10.37 |
| 19 | .948004 | 9.77 | .988351 | 10.72 | 19 | .982460 | 9.38 | .026312 | 10.37 |
| 20 | .948590 | 9.77 | .988994 | 10.72 | 20 | .983023 | 9.37 | .026934 | 10.37 |
| 21 | 8.949176 | 9.75 | 8.989637 | 10.70 | 21 | 8.983585 | 9.35 | 9.027556 | 10.35 |
| 22 | .949761 | 9.75 | .990279 | 10.72 | 22 | .984146 | 9.35 | .028177 | 10.35 |
| 23 | .950346 | 9.75 | .990922 | 10.68 | 23 | .984707 | 9.35 | .028798 | 10.35 |
| 24 | .950931 | 9.73 | .991563 | 10.70 | 24 | .985268 | 9.33 | .029419 | 10.33 |
| 25 | .951515 | 9.73 | .992205 | 10.68 | 25 | .985828 | 9.33 | .030039 | 10.33 |
| 26 | .952099 | 9.72 | .992846 | 10.68 | 26 | .986388 | 9.33 | .030659 | 10.33 |
| 27 | .952682 | 9.72 | .993487 | 10.67 | 27 | .986948 | 9.32 | .031279 | 10.33 |
| 28 | .953265 | 9.70 | .994127 | 10.67 | 28 | .987507 | 9.32 | .031899 | 10 32 |
| 29 | .953847 | 9.70 | .994767 | 10.65 | 29 | .988066 | 9.32 | .032518 | 10.30 |
| 30 | .954429 | 9.70 | .995406 | 10.67 | 30 | .988625 | 9.30 | .033136 | 10.28 |
| 31 | 8.955011 | 9.68 | 8.996046 | 10.65 | 31 | 8.989183 | 9.28 | 9.033755 | 10.30 |
| 32 | .955592 | 9.68 | .996685 | 10.63 | 32 | .989740 | 9.30 | .034373 | 10.30 |
| 33 | .956173 | 9.67 | .997323 | 10.63 | 33 | .990298 | 9.28 | .034991 | 10.28 |
| 34 | .956753 | 9.68 | .997961 | 10.63 | 34 | .990855 | 9.27 | .035608 | 10.28 |
| 35 | .957334 | 9.65 | .998599 | 10.62 | 35 | .991411 | 9.28 | .036225 | 10.28 |
| 36 | .957913 | 9.65 | .999236 | 10.62 | 36 | .991968 | 9.25 | .036842 | 10.27 |
| 37 | .958492 | 9.65 | 8.999873 | 10.62 | 37 | .992523 | 9.27 | .037458 | 10.27 |
| 38 | .959071 | 9.65 | 9.000510 | 10.60 | 38 | .993079 | 9.25 | .038074 | 10.27 |
| 39 | .959650 | 9.63 | .001146 | 10.62 | 39 | .993634 | 9.25 | .038690 | 10.25 |
| 40 | .960228 | 9.62 | .001783 | 10.58 | 40 | .994189 | 9.23 | .039305 | 10.25 |
| 41 | 8.960805 | 9.62 | 9.002418 | 10.58 | 41 | 8.994743 | 9.23 | 9.039920 | 10.25 |
| 42 | .961382 | 9.62 | .003053 | 10.58 | 42 | .995297 | 9.23 | .040535 | 10.25 |
| 43 | .961959 | 9.60 | .003688 | 10.58 | 43 | .995851 | 9.22 | .041150 | 10.23 |
| 44 | .962535 | 9.60 | .004323 | 10.57 | 44 | .996404 | 9.22 | .041764 | 10.23 |
| 45 | .963111 | 9.60 | .004957 | 10.57 | 45 | .996957 | 9.20 | .042378 | 10.22 |
| 46 | .963687 | 9.58 | .005591 | 10.55 | 46 | .997509 | 9.22 | .042991 | 10.22 |
| 47 | .964262 | 9.58 | .006224 | 10.57 | 47 | .998062 | 9.18 | .043604 | 10.22 |
| 48 | .964837 | 9.57 | .006858 | 10.53 | 48 | .998613 | 9.20 | .044217 | 10.22 |
| 49 | .965411 | 9.57 | .007490 | 10.55 | 49 | .999165 | 9.18 | .044830 | 10.20 |
| 50 | .965985 | 9.57 | .008123 | 10.53 | 50 | 8.999716 | 9.17 | .045442 | 10.20 |
| 51 | 8.966559 | 9.55 | 9.008755 | 10.53 | 51 | 9.000266 | 9.18 | 9.046054 | 10.18 |
| 52 | .967132 | 9.55 | .009387 | 10.52 | 52 | .000817 | 9.17 | .046665 | 10.18 |
| 53 | .967705 | 9.53 | .010018 | 10.52 | 53 | .001367 | 9 15 | .047276 | 10.18 |
| 54 | .968277 | 9.53 | .010649 | 10.52 | 54 | .001916 | 9.17 | .047887 | 10.18 |
| 55 | .968849 | 9.53 | .011280 | 10.50 | 55 | .002466 | 9.13 | .048498 | 10.17 |
| 56 | .969421 | 9.52 | .011910 | 10.50 | 56 | .003014 | 9.15 | .049108 | 10.17 |
| 57 | .969992 | 9.52 | .012540 | 10.50 | 57 | .003563 | 9.13 | .049718 | 10.17 |
| 58 | .970563 | 9.50 | .013170 | 10.48 | 58 | .004111 | 9.13 | .050328 | 10.15 |
| 59 | .971133 | 9.50 | .013799 | 10.48 | 59 | .004659 | 9.12 | .050937 | 10.15 |
| 60 | 8.971703 | 9.50 | 9.014428 | 10.47 | 60 | 9.005206 | 9.12 | 9.051546 | 10.15 |

| 26° | | | | | 27° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.005206 | 9.12 | 9.051546 | 10.15 | 0 | 9.037401 | 8.77 | 9.087520 | 9.83 |
| 1 | .005753 | 9.12 | .052155 | 10.13 | 1 | .037927 | 8.75 | .088110 | 9.83 |
| 2 | .006300 | 9.10 | .052763 | 10.13 | 2 | .038452 | 8.77 | .088700 | 9.83 |
| 3 | .006846 | 9.10 | .053371 | 10.13 | 3 | .038978 | 8.75 | .089290 | 9.83 |
| 4 | .007392 | 9.10 | .053979 | 10.12 | 4 | .039503 | 8.73 | .089880 | 9.82 |
| 5 | .007938 | 9.08 | .054586 | 10.12 | 5 | .040027 | 8.75 | .090469 | 9.82 |
| 6 | .008483 | 9.08 | .055193 | 10.12 | 6 | .040552 | 8.73 | .091058 | 9.82 |
| 7 | .009028 | 9.07 | .055800 | 10.10 | 7 | .041076 | 8.72 | .091647 | 9.80 |
| 8 | .009572 | 9.07 | .056406 | 10.10 | 8 | .041599 | 8.73 | .092235 | 9.80 |
| 9 | .010116 | 9.07 | .057012 | 10.10 | 9 | .042123 | 8.72 | .092823 | 9.80 |
| 10 | .010660 | 9.05 | .057618 | 10.10 | 10 | .042646 | 8.70 | .093411 | 9.78 |
| 11 | 9.011203 | 9.05 | 9.058224 | 10.08 | 11 | 9.043168 | 8.72 | 9.093998 | 9.80 |
| 12 | .011746 | 9.05 | .058829 | 10.08 | 12 | .043691 | 8.70 | .094586 | 9.78 |
| 13 | .012289 | 9.03 | .059434 | 10.07 | 13 | .044213 | 8.70 | .095173 | 9.77 |
| 14 | .012831 | 9.03 | .060038 | 10.08 | 14 | .044735 | 8.68 | .095759 | 9.78 |
| 15 | .013373 | 9.03 | .060643 | 10.07 | 15 | .045256 | 8.68 | .096346 | 9.77 |
| 16 | .013915 | 9.02 | .061247 | 10.05 | 16 | .045777 | 8.68 | .096932 | 9.77 |
| 17 | .014456 | 9.02 | .061850 | 10.07 | 17 | .046298 | 8.67 | .097518 | 9.75 |
| 18 | .014997 | 9.02 | .062454 | 10.05 | 18 | .046818 | 8.67 | .098103 | 9.77 |
| 19 | .015538 | 9.00 | .063057 | 10.03 | 19 | .047338 | 8.67 | .098689 | 9.75 |
| 20 | .016078 | 9.00 | .063659 | 10.05 | 20 | .047858 | 8.65 | .099274 | 9.73 |
| 21 | 9.016618 | 8.98 | 9.064262 | 10.03 | 21 | 9.048377 | 8.65 | 9.099858 | 9.75 |
| 22 | .017157 | 9.00 | .064864 | 10.03 | 22 | .048896 | 8.65 | .100443 | 9.73 |
| 23 | .017697 | 8.97 | .065466 | 10.02 | 23 | .049415 | 8.63 | .101027 | 9.73 |
| 24 | .018235 | 8.98 | .066067 | 10.02 | 24 | .049933 | 8.63 | .101611 | 9.72 |
| 25 | .018774 | 8.97 | .066668 | 10.02 | 25 | .050451 | 8.63 | .102194 | 9.73 |
| 26 | .019312 | 8.97 | .067269 | 10.02 | 26 | .050969 | 8.63 | .102778 | 9.72 |
| 27 | .019850 | 8.95 | .067870 | 10.00 | 27 | .051487 | 8.62 | .103361 | 9.70 |
| 28 | .020387 | 8.95 | .068470 | 10.00 | 28 | .052004 | 8.60 | .103943 | 9.72 |
| 29 | .020924 | 8.95 | .069070 | 10.00 | 29 | .052520 | 8.62 | .104526 | 9.70 |
| 30 | .021461 | 8.93 | .069670 | 9.98 | 30 | .053037 | 8.60 | .105108 | 9.70 |
| 31 | 9.021997 | 8.93 | 9.070269 | 9.98 | 31 | 9.053553 | 8.60 | 9.105690 | 9.68 |
| 32 | .022533 | 8.93 | .070868 | 9.98 | 32 | .054069 | 8.58 | .106271 | 9.70 |
| 33 | .023069 | 8.92 | .071467 | 9.97 | 33 | .054584 | 8.58 | .106853 | 9.68 |
| 34 | .023604 | 8.92 | .072065 | 9.97 | 34 | .055099 | 8.58 | .107434 | 9.68 |
| 35 | .024139 | 8.90 | .072663 | 9.97 | 35 | .055614 | 8.58 | .108015 | 9.67 |
| 36 | .024673 | 8.92 | .073261 | 9.97 | 36 | .056129 | 8.57 | .108595 | 9.67 |
| 37 | .025208 | 8.90 | .073859 | 9.95 | 37 | .056643 | 8.57 | .109175 | 9.67 |
| 38 | .025742 | 8.88 | .074456 | 9.95 | 38 | .057157 | 8.55 | .109755 | 9.67 |
| 39 | .026275 | 8.88 | .075053 | 9.93 | 39 | .057670 | 8.55 | .110335 | 9.65 |
| 40 | .026808 | 8.88 | .075649 | 9.95 | 40 | .058183 | 8.55 | .110914 | 9.67 |
| 41 | 9.027341 | 8.88 | 9.076246 | 9.93 | 41 | 9.058696 | 8.55 | 9.111494 | 9.63 |
| 42 | .027874 | 8.87 | .076842 | 9.92 | 42 | .059209 | 8.53 | .112072 | 9.65 |
| 43 | .028406 | 8.87 | .077437 | 9.93 | 43 | .059721 | 8.53 | .112651 | 9.63 |
| 44 | .028938 | 8.85 | .078033 | 9.92 | 44 | .060233 | 8.53 | .113229 | 9.63 |
| 45 | .029469 | 8.85 | .078628 | 9.92 | 45 | .060745 | 8.52 | .113807 | 9.63 |
| 46 | .030000 | 8.85 | .079223 | 9.90 | 46 | .061256 | 8.52 | .114385 | 9.63 |
| 47 | .030531 | 8.85 | .079817 | 9.92 | 47 | .061767 | 8.50 | .114963 | 9.62 |
| 48 | .031062 | 8.83 | .080412 | 9.90 | 48 | .062277 | 8.52 | .115540 | 9.62 |
| 49 | .031592 | 8.83 | .081006 | 9.88 | 49 | .062788 | 8.50 | .116117 | 9.60 |
| 50 | .032122 | 8.82 | .081599 | 9.90 | 50 | .063298 | 8.48 | .116693 | 9.62 |
| 51 | 9.032651 | 8.82 | 9.082193 | 9.88 | 51 | 9.063807 | 8.50 | 9.117270 | 9.60 |
| 52 | .033180 | 8.82 | .082786 | 9.87 | 52 | .064317 | 8.48 | .117846 | 9.60 |
| 53 | .033709 | 8.80 | .083378 | 9.88 | 53 | .064826 | 8.48 | .118422 | 9.58 |
| 54 | .034237 | 8.80 | .083971 | 9.87 | 54 | .065335 | 8.47 | .118997 | 9.60 |
| 55 | .034765 | 8.80 | .084563 | 9.87 | 55 | .065843 | 8.47 | .119573 | 9.58 |
| 56 | .035293 | 8.78 | .085155 | 9.87 | 56 | .066351 | 8.47 | .120148 | 9.58 |
| 57 | .035820 | 8.78 | .085747 | 9.85 | 57 | .066859 | 8.45 | .120723 | 9.57 |
| 58 | .036347 | 8.78 | .086338 | 9.85 | 58 | .067366 | 8.47 | .121297 | 9.57 |
| 59 | .036874 | 8.78 | .086929 | 9.85 | 59 | .067874 | 8.43 | .121871 | 9.57 |
| 60 | 9.037401 | 8.77 | 9.087520 | 9.83 | 60 | 9.068380 | 8.45 | 9.122445 | 9.57 |

| 28° | | | | | 29° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.068380 | 8.45 | 9.122445 | 9.57 | 0 | 9.098229 | 8.15 | 9.156410 | 9.30 |
| 1 | .068887 | 8.43 | .123019 | 9.57 | 1 | .098718 | 8.13 | .156968 | 9.32 |
| 2 | .069393 | 8.43 | .123593 | 9.55 | 2 | .099206 | 8.12 | .157527 | 9.28 |
| 3 | .069899 | 8.43 | .124166 | 9.55 | 3 | .099693 | 8.13 | .158084 | 9.30 |
| 4 | .070405 | 8.42 | .124739 | 9.53 | 4 | .100181 | 8.12 | .158642 | 9.30 |
| 5 | .070910 | 8.42 | .125311 | 9.55 | 5 | .100668 | 8.12 | .159200 | 9.28 |
| 6 | .071415 | 8.40 | .125884 | 9.53 | 6 | .101155 | 8.12 | .159757 | 9.28 |
| 7 | .071919 | 8.42 | .126456 | 9.53 | 7 | .101642 | 8.10 | .160314 | 9.27 |
| 8 | .072424 | 8.40 | .127028 | 9.52 | 8 | .102128 | 8.10 | .160870 | 9.28 |
| 9 | .072928 | 8.40 | .127599 | 9.53 | 9 | .102614 | 8.10 | .161427 | 9.27 |
| 10 | .073432 | 8.38 | .128171 | 9.52 | 10 | .103100 | 8.08 | .161983 | 9.27 |
| 11 | 9.073935 | 8.38 | 9.128742 | 9.52 | 11 | 9.103585 | 8.08 | 9.162539 | 9.27 |
| 12 | .074438 | 8.38 | .129313 | 9.50 | 12 | .104070 | 8.08 | .163095 | 9.25 |
| 13 | .074941 | 8.37 | .129883 | 9.50 | 13 | .104555 | 8.08 | .163650 | 9.25 |
| 14 | .075443 | 8.38 | .130453 | 9.50 | 14 | .105040 | 8.07 | .164205 | 9.25 |
| 15 | .075946 | 8.35 | .131023 | 9.50 | 15 | .105524 | 8.07 | .164760 | 9.25 |
| 16 | .076447 | 8.37 | .131593 | 9.50 | 16 | .106008 | 8.05 | .165315 | 9.25 |
| 17 | .076949 | 8.35 | .132163 | 9.48 | 17 | .106491 | 8.07 | .165870 | 9.23 |
| 18 | .077450 | 8.35 | .132732 | 9.48 | 18 | .106975 | 8.05 | .166424 | 9.23 |
| 19 | .077951 | 8.35 | .133301 | 9.48 | 19 | .107458 | 8.05 | .166978 | 9.23 |
| 20 | .078452 | 8.33 | .133870 | 9.47 | 20 | .107941 | 8.03 | .167532 | 9.22 |
| 21 | 9.078952 | 8.33 | 9.134438 | 9.47 | 21 | 9.108423 | 8.05 | 9.168085 | 9.23 |
| 22 | .079452 | 8.33 | .135006 | 9.47 | 22 | .108906 | 8.03 | .168639 | 9.22 |
| 23 | .079952 | 8.32 | .135574 | 9.47 | 23 | .109388 | 8.02 | .169192 | 9.22 |
| 24 | .080451 | 8.32 | .136142 | 9.45 | 24 | .109869 | 8.03 | .169745 | 9.20 |
| 25 | .080950 | 8.32 | .136709 | 9.47 | 25 | .110351 | 8.02 | .170297 | 9.22 |
| 26 | .081449 | 8.32 | .137277 | 9.45 | 26 | .110832 | 8.02 | .170850 | 9.20 |
| 27 | .081948 | 8.30 | .137844 | 9.43 | 27 | .111313 | 8.00 | .171402 | 9.20 |
| 28 | .082446 | 8.30 | .138410 | 9.45 | 28 | .111793 | 8.00 | .171954 | 9.18 |
| 29 | .082944 | 8.28 | .138977 | 9.43 | 29 | .112273 | 8.00 | .172505 | 9.20 |
| 30 | .083441 | 8.30 | .139543 | 9.43 | 30 | .112753 | 8.00 | .173057 | 9.18 |
| 31 | 9.083939 | 8.28 | 9.140109 | 9.42 | 31 | 9.113233 | 8.00 | 9.173608 | 9.18 |
| 32 | .084436 | 8.27 | .140674 | 9.43 | 32 | .113713 | 7.98 | .174159 | 9.18 |
| 33 | .084932 | 8.28 | .141240 | 9.42 | 33 | .114192 | 7.98 | .174710 | 9.17 |
| 34 | .085429 | 8.27 | .141805 | 9.42 | 34 | .114671 | 7.97 | .175260 | 9.17 |
| 35 | .085925 | 8.25 | .142370 | 9.40 | 35 | .115149 | 7.97 | .175810 | 9.17 |
| 36 | .086420 | 8.27 | .142934 | 9.42 | 36 | .115627 | 7.97 | .176360 | 9.17 |
| 37 | .086916 | 8.25 | .143499 | 9.40 | 37 | .116105 | 7.97 | .176910 | 9.17 |
| 38 | .087411 | 8.25 | .144063 | 9.40 | 38 | .116583 | 7.97 | .177460 | 9.15 |
| 39 | .087906 | 8.23 | .144627 | 9.38 | 39 | .117061 | 7.95 | .178009 | 9.15 |
| 40 | .088400 | 8.25 | .145190 | 9.40 | 40 | .117538 | 7.95 | .178558 | 9.15 |
| 41 | 9.088895 | 8.23 | 9.145754 | 9.38 | 41 | 9.118015 | 7.93 | 9.179107 | 9.15 |
| 42 | .089389 | 8.22 | .146317 | 9.38 | 42 | .118491 | 7.95 | .179656 | 9.13 |
| 43 | .089882 | 8.23 | .146880 | 9.37 | 43 | .118968 | 7.93 | .180204 | 9.13 |
| 44 | .090376 | 8.22 | .147442 | 9.38 | 44 | .119444 | 7.92 | .180752 | 9.13 |
| 45 | .090869 | 8.22 | .148005 | 9.37 | 45 | .119919 | 7.90 | .181300 | 9.13 |
| 46 | .091362 | 8.20 | .148567 | 9.37 | 46 | .120395 | 7.92 | .181848 | 9.12 |
| 47 | .091854 | 8.20 | .149129 | 9.35 | 47 | .120870 | 7.92 | .182395 | 9.13 |
| 48 | .092346 | 8.20 | .149690 | 9.35 | 48 | .121345 | 7.92 | .182943 | 9.12 |
| 49 | .092838 | 8.20 | .150251 | 9.37 | 49 | .121820 | 7.90 | .183490 | 9.10 |
| 50 | .093330 | 8.18 | .150813 | 9.33 | 50 | .122294 | 7.90 | .184036 | 9.12 |
| 51 | 9.093821 | 8.18 | 9.151373 | 9.35 | 51 | 9.122768 | 7.90 | 9.184583 | 9.10 |
| 52 | .094312 | 8.18 | .151934 | 9.33 | 52 | .123242 | 7.88 | .185129 | 9.10 |
| 53 | 094803 | 8.17 | .152494 | 9.35 | 53 | .123715 | 7.90 | .185675 | 9.10 |
| 54 | .095293 | 8.17 | .153055 | 9.32 | 54 | .124189 | 7.88 | .186221 | 9.10 |
| 55 | .095783 | 8.17 | .153614 | 9.33 | 55 | .124662 | 7.87 | .186767 | 9.08 |
| 56 | .096273 | 8.17 | .154174 | 9.32 | 56 | .125134 | 7.88 | .187312 | 9.10 |
| 57 | .096763 | 8.15 | .154733 | 9.33 | 57 | .125607 | 7.87 | .187858 | 9.08 |
| 58 | .097252 | 8.15 | .155293 | 9.30 | 58 | .126079 | 7.87 | .188403 | 9.07 |
| 59 | .097741 | 8.13 | .155851 | 9.32 | 59 | .126551 | 7.85 | .188947 | 9.08 |
| 60 | 9.098229 | 8.15 | 9.156410 | 9.30 | 60 | 9.127022 | 7.87 | 9.189492 | 9.07 |

| 30° | | | | | 31° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.127022 | 7.87 | 9.189492 | 9.07 | 0 | 9.154828 | 7.58 | 9.221762 | 8.85 |
| 1 | .127494 | 7.85 | .190036 | 9.07 | 1 | .155283 | 7.58 | .222293 | 8.87 |
| 2 | .127965 | 7.85 | .190580 | 9.07 | 2 | .155738 | 7.58 | .222825 | 8.83 |
| 3 | .128436 | 7.83 | .191124 | 9.07 | 3 | .156193 | 7.58 | .223355 | 8.85 |
| 4 | .128906 | 7.83 | .191668 | 9.05 | 4 | .156648 | 7.57 | .223886 | 8.85 |
| 5 | .129376 | 7.83 | .192211 | 9.05 | 5 | .157102 | 7.57 | .224417 | 8.83 |
| 6 | .129846 | 7.83 | .192754 | 9.05 | 6 | .157556 | 7.57 | .224947 | 8.83 |
| 7 | .130316 | 7.82 | .193297 | 9.05 | 7 | .158010 | 7.57 | .225477 | 8.83 |
| 8 | .130785 | 7.83 | .193840 | 9.03 | 8 | .158464 | 7.55 | .226007 | 8.83 |
| 9 | .131255 | 7.82 | .194382 | 9.05 | 9 | .158917 | 7.55 | .226537 | 8.82 |
| 10 | .131724 | 7.80 | .194925 | 9.03 | 10 | .159370 | 7.55 | .227066 | 8.82 |
| 11 | 9.132192 | 7.80 | 9.195467 | 9.03 | 11 | 9.159823 | 7.55 | 9.227595 | 8.83 |
| 12 | .132660 | 7.82 | .196009 | 9.02 | 12 | .160276 | 7.53 | .228125 | 8.80 |
| 13 | .133129 | 7.78 | .196550 | 9.03 | 13 | .160728 | 7.53 | .228653 | 8.82 |
| 14 | .133596 | 7.80 | .197092 | 9.02 | 14 | .161180 | 7.53 | .229182 | 8.82 |
| 15 | .134064 | 7.78 | .197633 | 9.02 | 15 | .161632 | 7.52 | .229711 | 8.80 |
| 16 | .134531 | 7.78 | .198174 | 9.02 | 16 | .162083 | 7.53 | .230239 | 8.80 |
| 17 | .134998 | 7.78 | .198715 | 9.00 | 17 | .162535 | 7.52 | .230767 | 8.80 |
| 18 | .135465 | 7.77 | .199255 | 9.00 | 18 | .162986 | 7.52 | .231295 | 8.78 |
| 19 | .135931 | 7.77 | .199795 | 9.00 | 19 | .163437 | 7.50 | .231822 | 8.80 |
| 20 | .136397 | 7.77 | .200335 | 9.00 | 20 | .163887 | 7.52 | .232350 | 8.78 |
| 21 | 9.136863 | 7.77 | 9.200875 | 9.00 | 21 | 9.164338 | 7.50 | 9.232877 | 8.78 |
| 22 | .137329 | 7.75 | .201415 | 8.98 | 22 | .164788 | 7.48 | .233404 | 8.78 |
| 23 | .137794 | 7.77 | .201954 | 9.00 | 23 | .165237 | 7.50 | .233931 | 8.78 |
| 24 | .138260 | 7.73 | .202494 | 8.97 | 24 | .165687 | 7.48 | .234458 | 8.77 |
| 25 | .138724 | 7.75 | .203032 | 8.98 | 25 | .166136 | 7.48 | .234984 | 8.77 |
| 26 | .139189 | 7.73 | .203571 | 8.98 | 26 | .166585 | 7.48 | .235510 | 8.77 |
| 27 | .139653 | 7.73 | .204110 | 8.97 | 27 | .167034 | 7.48 | .236036 | 8.77 |
| 28 | .140117 | 7.73 | .204648 | 8.97 | 28 | .167483 | 7.47 | .236562 | 8.77 |
| 29 | .140581 | 7.73 | .205186 | 8.97 | 29 | .167931 | 7.47 | .237088 | 8.75 |
| 30 | .141045 | 7.72 | .205724 | 8.97 | 30 | .168379 | 7.47 | .237613 | 8.77 |
| 31 | 9.141508 | 7.72 | 9.206262 | 8.95 | 31 | 9.168827 | 7.47 | 9.238139 | 8.75 |
| 32 | .141971 | 7.72 | .206799 | 8.97 | 32 | .169275 | 7.45 | .238664 | 8.75 |
| 33 | .142434 | 7.70 | .207337 | 8.95 | 33 | .169722 | 7.45 | .239189 | 8.73 |
| 34 | .142896 | 7.70 | .207874 | 8.93 | 34 | .170169 | 7.45 | .239713 | 8.75 |
| 35 | .143358 | 7.70 | .208410 | 8.95 | 35 | .170616 | 7.43 | .240238 | 8.73 |
| 36 | .143820 | 7.70 | .208947 | 8.93 | 36 | .171062 | 7.45 | .240762 | 8.73 |
| 37 | .144282 | 7.68 | .209483 | 8.95 | 37 | .171509 | 7.43 | .241286 | 8.73 |
| 38 | .144743 | 7.68 | .210020 | 8.93 | 38 | .171955 | 7.42 | .241810 | 8.72 |
| 39 | .145204 | 7.68 | .210556 | 8.92 | 39 | .172400 | 7.43 | .242333 | 8.73 |
| 40 | .145665 | 7.68 | .211091 | 8.93 | 40 | .172846 | 7.42 | .242857 | 8.72 |
| 41 | 9.146126 | 7.67 | 9.211627 | 8.92 | 41 | 9.173291 | 7.42 | 9.243380 | 8.72 |
| 42 | .146586 | 7.67 | .212162 | 8.92 | 42 | .173736 | 7.42 | .243903 | 8.72 |
| 43 | .147046 | 7.67 | .212697 | 8.92 | 43 | .174181 | 7.42 | .244426 | 8.72 |
| 44 | .147506 | 7.67 | .213232 | 8.92 | 44 | .174626 | 7.40 | .244949 | 8.70 |
| 45 | .147966 | 7.65 | .213767 | 8.90 | 45 | .175070 | 7.40 | .245471 | 8.72 |
| 46 | .148425 | 7.65 | .214301 | 8.92 | 46 | .175514 | 7.40 | .245994 | 8.70 |
| 47 | .148884 | 7.65 | .214836 | 8.90 | 47 | .175958 | 7.40 | .246516 | 8.70 |
| 48 | .149343 | 7.63 | .215370 | 8.90 | 48 | .176402 | 7.38 | .247038 | 8.68 |
| 49 | .149801 | 7.63 | .215904 | 8.88 | 49 | .176845 | 7.38 | .247559 | 8.70 |
| 50 | .150259 | 7.63 | .216437 | 8.90 | 50 | .177288 | 7.38 | .248081 | 8.68 |
| 51 | 9.150717 | 7.63 | 9.216971 | 8.88 | 51 | 9.177731 | 7.38 | 9.248602 | 8.68 |
| 52 | .151175 | 7.63 | .217504 | 8.88 | 52 | .178174 | 7.37 | .249123 | 8.68 |
| 53 | .151633 | 7.62 | .218037 | 8.88 | 53 | .178616 | 7.37 | .249644 | 8.68 |
| 54 | .152090 | 7.62 | .218570 | 8.87 | 54 | .179058 | 7.37 | .250165 | 8.68 |
| 55 | .152547 | 7.60 | .219102 | 8.88 | 55 | .179500 | 7.37 | .250686 | 8.67 |
| 56 | .153003 | 7.62 | .219635 | 8.87 | 56 | .179942 | 7.35 | .251206 | 8.67 |
| 57 | .153460 | 7.60 | .220167 | 8.87 | 57 | .180383 | 7.37 | .251726 | 8.67 |
| 58 | 153916 | 7.60 | .220699 | 8.87 | 58 | .180825 | 7.33 | .252246 | 8.67 |
| 59 | .154372 | 7.60 | .221231 | 8.85 | 59 | .181265 | 7.35 | .252766 | 8.67 |
| 60 | 9.154828 | 7.58 | 9.221762 | 8.85 | 60 | 9.181706 | 7.35 | 9.253286 | 8.65 |

| 32° | | | | | 33° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.181706 | 7.35 | 9.253286 | 8.65 | 0 | 9.207714 | 7.10 | 9.284122 | 8.48 |
| 1 | .182147 | 7.33 | .253805 | 8.65 | 1 | .208140 | 7.10 | .284631 | 8.47 |
| 2 | .182587 | 7.33 | .254324 | 8.65 | 2 | .208566 | 7.10 | .285139 | 8.47 |
| 3 | .183027 | 7.32 | .254843 | 8.65 | 3 | .208992 | 7.10 | .285647 | 8.47 |
| 4 | .183466 | 7.33 | .255362 | 8.65 | 4 | .209418 | 7.08 | .286155 | 8.47 |
| 5 | .183906 | 7.32 | .255881 | 8.63 | 5 | .209843 | 7.08 | .286663 | 8.45 |
| 6 | .184345 | 7.32 | .256399 | 8.65 | 6 | .210268 | 7.08 | .287170 | 8.47 |
| 7 | .184784 | 7.32 | .256918 | 8.63 | 7 | .210693 | 7.08 | .287678 | 8.45 |
| 8 | .185223 | 7.32 | .257436 | 8.63 | 8 | .211118 | 7.08 | .288185 | 8.45 |
| 9 | .185662 | 7.30 | .257954 | 8.62 | 9 | .211543 | 7.07 | .288692 | 8.45 |
| 10 | .186100 | 7.30 | .258471 | 8.63 | 10 | .211967 | 7.07 | .289199 | 8 43 |
| 11 | 9.186538 | 7.30 | 9.258989 | 8.62 | 11 | 9.212391 | 7.07 | 9.289705 | 8.45 |
| 12 | .186976 | 7.28 | .259506 | 8.62 | 12 | .212815 | 7.07 | .290212 | 8.43 |
| 13 | .187413 | 7.30 | .260023 | 8.62 | 13 | .213239 | 7.05 | .290718 | 8.43 |
| 14 | .187851 | 7.28 | .260540 | 8.62 | 14 | .213662 | 7.05 | .291224 | 8.43 |
| 15 | .188288 | 7.27 | .261057 | 8.62 | 15 | .214085 | 7.05 | .291730 | 8.43 |
| 16 | .188724 | 7.28 | .261574 | 8.60 | 16 | .214508 | 7.05 | .292236 | 8.43 |
| 17 | .189161 | 7.27 | .262090 | 8.60 | 17 | .214931 | 7.05 | .292742 | 8.42 |
| 18 | .189597 | 7.28 | .262606 | 8.60 | 18 | .215354 | 7.03 | .293247 | 8.43 |
| 19 | .190034 | 7.25 | .263122 | 8.60 | 19 | .215776 | 7.03 | .293753 | 8.42 |
| 20 | .190469 | 7.27 | .263638 | 8.60 | 20 | .216198 | 7.03 | .294258 | 8.42 |
| 21 | 9.190905 | 7.27 | 9.264154 | 8.58 | 21 | 9.216620 | 7.03 | 9.294763 | 8.42 |
| 22 | .191341 | 7.25 | .264669 | 8.58 | 22 | .217042 | 7.02 | .295268 | 8.40 |
| 23 | .191776 | 7.25 | .265184 | 8.60 | 23 | .217463 | 7.02 | .295772 | 8.42 |
| 24 | .192211 | 7.23 | .265700 | 8.57 | 24 | .217884 | 7.02 | .296277 | 8.40 |
| 25 | .192645 | 7.25 | .266214 | 8.58 | 25 | .218305 | 7.02 | .296781 | 8.40 |
| 26 | .193080 | 7.23 | .266729 | 8.58 | 26 | .218726 | 7.00 | .297285 | 8.40 |
| 27 | .193514 | 7.23 | .267244 | 8.57 | 27 | .219146 | 7.02 | .297789 | 8.40 |
| 28 | .193948 | 7.23 | .267758 | 8.57 | 28 | .219567 | 7.00 | .298293 | 8.40 |
| 29 | .194382 | 7.22 | .268272 | 8.57 | 29 | .219987 | 7.00 | .298797 | 8.38 |
| 30 | .194815 | 7.23 | .268786 | 8.57 | 30 | .220407 | 6.98 | .299300 | 8.38 |
| 31 | 9.195249 | 7.22 | 9.269300 | 8.57 | 31 | 9.220826 | 7.00 | 9.299803 | 8.40 |
| 32 | .195682 | 7.22 | .269814 | 8.55 | 32 | .221246 | 6.98 | .300307 | 8.37 |
| 33 | .196115 | 7.20 | .270327 | 8.55 | 33 | .221665 | 6.98 | .300809 | 8.38 |
| 34 | .196547 | 7.22 | .270840 | 8.57 | 34 | .222084 | 6.98 | .301312 | 8.38 |
| 35 | .196980 | 7.20 | .271354 | 8.53 | 35 | .222503 | 6.97 | .301815 | 8.37 |
| 36 | .197412 | 7.20 | .271866 | 8.55 | 36 | .222921 | 6.98 | .302317 | 8.38 |
| 37 | .197844 | 7.18 | .272379 | 8.55 | 37 | .223340 | 6.97 | .302820 | 8.37 |
| 38 | .198275 | 7.20 | .272892 | 8.53 | 38 | .223758 | 6.97 | .303322 | 8.37 |
| 39 | .198707 | 7.18 | .273404 | 8.53 | 39 | .224176 | 6.95 | .303824 | 8.35 |
| 40 | .199138 | 7.18 | .273916 | 8.53 | 40 | .224593 | 6.97 | .304325 | 8.37 |
| 41 | 9.199569 | 7.18 | 9.274428 | 8.53 | 41 | 9.225011 | 6.95 | 9.304827 | 8.35 |
| 42 | .200000 | 7.17 | .274940 | 8.53 | 42 | .225428 | 6.95 | .305328 | 8.37 |
| 43 | .200430 | 7.18 | .275452 | 8.52 | 43 | .225845 | 6.95 | .305830 | 8.35 |
| 44 | .200861 | 7.17 | .275963 | 8.52 | 44 | .226262 | 6.93 | .306331 | 8.35 |
| 45 | .201291 | 7.15 | .276474 | 8.53 | 45 | .226678 | 6.95 | .306832 | 8.35 |
| 46 | .201720 | 7.17 | .276986 | 8.50 | 46 | .227095 | 6.93 | .307333 | 8.33 |
| 47 | .202150 | 7.15 | .277496 | 8.52 | 47 | .227511 | 6.93 | .307833 | 8.35 |
| 48 | .202579 | 7.15 | .278007 | 8.52 | 48 | .227927 | 6.92 | .308334 | 8.33 |
| 49 | .203008 | 7.15 | .278518 | 8.50 | 49 | .228342 | 6.93 | .308834 | 8.33 |
| 50 | .203437 | 7.15 | .279028 | 8.50 | 50 | .228758 | 6.92 | .309334 | 8.33 |
| 51 | 9.203866 | 7.13 | 9.279538 | 8.50 | 51 | 9.229173 | 6.92 | 9.309834 | 8.33 |
| 52 | .204294 | 7.15 | .280048 | 8.50 | 52 | .229588 | 6.92 | .310334 | 8.33 |
| 53 | .204723 | 7.13 | .280558 | 8.50 | 53 | .230003 | 6.92 | .310834 | 8.32 |
| 54 | .205151 | 7.12 | .281068 | 8.48 | 54 | .230418 | 6.90 | .311333 | 8.32 |
| 55 | .205578 | 7.13 | .281577 | 8.50 | 55 | .230832 | 6.90 | .311832 | 8.32 |
| 56 | .206006 | 7.13 | .282087 | 8.48 | 56 | .231246 | 6.90 | .312331 | 8.32 |
| 57 | .206433 | 7.12 | .282596 | 8.48 | 57 | .231660 | 6.90 | .312830 | 8.32 |
| 58 | .206860 | 7.12 | .283105 | 8.48 | 58 | .232074 | 6.88 | .313329 | 8.32 |
| 59 | .207287 | 7.12 | .283614 | 8.47 | 59 | .232487 | 6.90 | .313828 | 8.30 |
| 60 | 9.207714 | 7.10 | 9.284122 | 8.48 | 60 | 9.232901 | 6.88 | 9.314326 | 8.32 |

| 34° | | | | | 35° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.232901 | 6.88 | 9.314326 | 8.32 | 0 | 9.257314 | 6.67 | 9.343949 | 8.15 |
| 1 | .233314 | 6.88 | .314825 | 8.30 | 1 | .257714 | 6.68 | .344438 | 8.15 |
| 2 | .233727 | 6.87 | .315323 | 8.30 | 2 | .258115 | 6.67 | .344927 | 8.15 |
| 3 | .234139 | 6.88 | .315821 | 8.30 | 3 | .258515 | 6.67 | .345416 | 8.13 |
| 4 | .234552 | 6.87 | .316319 | 8.30 | 4 | .258915 | 6.65 | .345904 | 8.15 |
| 5 | .234964 | 6.87 | .316817 | 8.28 | 5 | .259314 | 6.67 | .346393 | 8.13 |
| 6 | .235376 | 6.87 | .317314 | 8.28 | 6 | .259714 | 6.65 | .346881 | 8.13 |
| 7 | .235788 | 6.85 | .317811 | 8.30 | 7 | .260113 | 6.65 | .347369 | 8.13 |
| 8 | .236199 | 6.87 | .318309 | 8.28 | 8 | .260512 | 6.65 | .347857 | 8.13 |
| 9 | .236611 | 6.85 | .318806 | 8.28 | 9 | .260911 | 6.65 | .348345 | 8.13 |
| 10 | .237022 | 6.85 | .319303 | 8.27 | 10 | .261310 | 6.65 | .348833 | 8.13 |
| 11 | 9.237433 | 6.85 | 9.319799 | 8.28 | 11 | 9.261709 | 6.63 | 9.349321 | 8.12 |
| 12 | .237844 | 6.83 | .320296 | 8.27 | 12 | .262107 | 6.63 | .349808 | 8.12 |
| 13 | .238254 | 6.85 | .320792 | 8.28 | 13 | .262505 | 6.63 | .350295 | 8.12 |
| 14 | .238665 | 6.83 | .321289 | 8.27 | 14 | .262903 | 6.63 | .350782 | 8.12 |
| 15 | .239075 | 6.83 | .321785 | 8.27 | 15 | .263301 | 6.62 | .351269 | 8.12 |
| 16 | .239485 | 6.82 | .322281 | 8.25 | 16 | .263698 | 6.63 | .351756 | 8.12 |
| 17 | .239894 | 6.83 | .322776 | 8.27 | 17 | .264096 | 6.62 | .352243 | 8.12 |
| 18 | .240304 | 6.82 | .323272 | 8.27 | 18 | .264493 | 6.62 | .352730 | 8.10 |
| 19 | .240713 | 6.82 | .323768 | 8.25 | 19 | .264890 | 6.62 | .353216 | 8.10 |
| 20 | .241122 | 6.82 | .324263 | 8.25 | 20 | .265287 | 6.60 | .353702 | 8.10 |
| 21 | 9.241531 | 6.82 | 9.324758 | 8.25 | 21 | 9.265683 | 6.62 | 9.354188 | 8.10 |
| 22 | .241940 | 6.82 | .325253 | 8.25 | 22 | .266080 | 6.60 | .354674 | 8.10 |
| 23 | .242348 | 6.80 | .325748 | 8.25 | 23 | .266476 | 6.60 | .355160 | 8.10 |
| 24 | .242756 | 6.80 | .326243 | 8.23 | 24 | .266872 | 6.58 | .355646 | 8.08 |
| 25 | .243164 | 6.80 | .326737 | 8.25 | 25 | .267267 | 6.60 | .356131 | 8.10 |
| 26 | .243572 | 6.80 | .327232 | 8.23 | 26 | .267663 | 6.58 | .356617 | 8.08 |
| 27 | .243980 | 6.78 | .327726 | 8.23 | 27 | .268058 | 6.58 | .357102 | 8.08 |
| 28 | .244387 | 6.78 | .328220 | 8.23 | 28 | .268453 | 6.58 | .357587 | 8.08 |
| 29 | .244794 | 6.78 | .328714 | 8.22 | 29 | .268848 | 6.58 | .358072 | 8.08 |
| 30 | .245201 | 6.78 | .329207 | 8.23 | 30 | .269243 | 6.58 | .358557 | 8.08 |
| 31 | 9.245608 | 6.77 | 9.329701 | 8.23 | 31 | 9.269638 | 6.57 | 9.359042 | 8.07 |
| 32 | .246014 | 6.78 | .330195 | 8.22 | 32 | .270032 | 6.57 | .359526 | 8.08 |
| 33 | .246421 | 6.77 | .330688 | 8.22 | 33 | .270426 | 6.57 | .360011 | 8.07 |
| 34 | .246827 | 6.77 | .331181 | 8.22 | 34 | .270820 | 6.57 | .360495 | 8.07 |
| 35 | .247233 | 6.77 | .331674 | 8.22 | 35 | .271214 | 6.57 | .360979 | 8.07 |
| 36 | .247639 | 6.75 | .332167 | 8.20 | 36 | .271608 | 6.55 | .361463 | 8.07 |
| 37 | .248044 | 6.75 | .332659 | 8.22 | 37 | .272001 | 6.55 | .361947 | 8.07 |
| 38 | .248449 | 6.75 | .333152 | 8.20 | 38 | .272394 | 6.55 | .362431 | 8.05 |
| 39 | .248854 | 6.75 | .333644 | 8.22 | 39 | .272787 | 6.55 | .362914 | 8.07 |
| 40 | .249259 | 6.75 | .334137 | 8.20 | 40 | .273180 | 6.53 | .363398 | 8.05 |
| 41 | 9.249664 | 6.73 | 9.334629 | 8.20 | 41 | 9.273572 | 6.55 | 9.363881 | 8.05 |
| 42 | .250068 | 6.75 | .335121 | 8.18 | 42 | .273965 | 6.53 | .364364 | 8.05 |
| 43 | .250473 | 6.73 | .335612 | 8.20 | 43 | .274357 | 6.53 | .364847 | 8.05 |
| 44 | .250877 | 6.73 | .336104 | 8.18 | 44 | .274749 | 6.53 | .365330 | 8.05 |
| 45 | .251281 | 6.72 | .336595 | 8.20 | 45 | .275141 | 6.52 | .365813 | 8.03 |
| 46 | .251684 | 6.73 | .337087 | 8.18 | 46 | .275532 | 6.53 | .366295 | 8.05 |
| 47 | .252088 | 6.72 | .337578 | 8.18 | 47 | .275924 | 6.52 | .366778 | 8.03 |
| 48 | .252491 | 6.72 | .338069 | 8.18 | 48 | .276315 | 6.52 | .367260 | 8.03 |
| 49 | .252894 | 6.72 | .338560 | 8.17 | 49 | .276706 | 6.52 | .367742 | 8.03 |
| 50 | .253297 | 6.70 | .339050 | 8.18 | 50 | 277097 | 6.52 | .368224 | 8.03 |
| 51 | 9.253699 | 6.72 | 9.339541 | 8.17 | 51 | 9.277488 | 6.50 | 9.368706 | 8.03 |
| 52 | .254102 | 6.70 | .340031 | 8.18 | 52 | .277878 | 6.50 | .369188 | 8.03 |
| 53 | .254504 | 6.70 | .340522 | 8.17 | 53 | .278268 | 6.50 | .369670 | 8.02 |
| 54 | .254906 | 6.70 | .341012 | 8.17 | 54 | .278658 | 6.50 | .370151 | 8.02 |
| 55 | .255308 | 6.68 | .341502 | 8.15 | 55 | .279048 | 6.50 | .370632 | 8.03 |
| 56 | .255709 | 6.70 | .341991 | 8.17 | 56 | .279438 | 6.48 | .371114 | 8.02 |
| 57 | .256111 | 6.68 | .342481 | 8.17 | 57 | .279827 | 6.50 | .371595 | 8.02 |
| 58 | .256512 | 6.68 | .342971 | 8.15 | 58 | .280217 | 6.48 | .372076 | 8.00 |
| 59 | .256913 | 6.68 | .343460 | 8.15 | 59 | .280606 | 6.48 | .372556 | 8.02 |
| 60 | 9.257314 | 6.67 | 9.343949 | 8.15 | 60 | 9.280995 | 6.47 | 9.373037 | 8.02 |

| 36° | | | | | 37° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.280995 | 6.47 | 9.373037 | 8.02 | 0 | 9.303983 | 6.28 | 9.401634 | 7.88 |
| 1 | .281383 | 6.48 | .373518 | 8.00 | 1 | .304360 | 6.30 | .402107 | 7.88 |
| 2 | .281772 | 6.47 | .373998 | 8.00 | 2 | .304738 | 6.28 | .402580 | 7.87 |
| 3 | .282160 | 6.47 | .374478 | 8.00 | 3 | .305115 | 6.28 | .403052 | 7.87 |
| 4 | .282548 | 6.47 | .374958 | 8.00 | 4 | .305492 | 6.27 | .403524 | 7.88 |
| 5 | .282936 | 6.47 | .375438 | 8.00 | 5 | .305868 | 6.28 | .403997 | 7.88 |
| 6 | .283324 | 6.47 | .375918 | 8.00 | 6 | .306245 | 6.27 | .404469 | 7.87 |
| 7 | .283712 | 6.45 | .376398 | 7.98 | 7 | .306621 | 6.28 | .404941 | 7.87 |
| 8 | .284099 | 6.45 | .376877 | 8.00 | 8 | .306998 | 6.27 | .405412 | 7.87 |
| 9 | .284486 | 6.45 | .377357 | 7.98 | 9 | .307374 | 6.25 | .405884 | 7.87 |
| 10 | .284873 | 6.45 | .377836 | 7.98 | 10 | .307749 | 6.27 | .406356 | 7.85 |
| 11 | 9.285260 | 6.45 | 9.378315 | 7.98 | 11 | 9.308125 | 6.27 | 9.406827 | 7.85 |
| 12 | .285647 | 6.43 | .378794 | 7.98 | 12 | .308501 | 6.25 | .407298 | 7.87 |
| 13 | .286033 | 6.43 | .379273 | 7.98 | 13 | .308876 | 6.25 | .407770 | 7.85 |
| 14 | .286419 | 6.43 | .379752 | 7.98 | 14 | .309251 | 6.25 | .408241 | 7.85 |
| 15 | .286805 | 6.43 | .380231 | 7.97 | 15 | .309626 | 6.25 | .408712 | 7.85 |
| 16 | .287191 | 6.43 | .380709 | 7.98 | 16 | .310001 | 6.23 | .409183 | 7.83 |
| 17 | .287577 | 6.42 | .381188 | 7.97 | 17 | .310375 | 6.25 | .409653 | 7.85 |
| 18 | .287962 | 6.40 | .381666 | 7.97 | 18 | .310750 | 6.23 | .410124 | 7.83 |
| 19 | .288348 | 6.42 | .382144 | 7.97 | 19 | .311124 | 6.23 | .410594 | 7.85 |
| 20 | .288733 | 6.42 | .382622 | 7.97 | 20 | .311498 | 6.23 | .411065 | 7.83 |
| 21 | 9.289118 | 6.40 | 9.383100 | 7.95 | 21 | 9.311872 | 6.22 | 9.411535 | 7.83 |
| 22 | .289502 | 6.42 | .383577 | 7.97 | 22 | .312245 | 6.23 | .412005 | 7.83 |
| 23 | .289887 | 6.40 | .384055 | 7.95 | 23 | .312619 | 6.22 | .412475 | 7.83 |
| 24 | .290271 | 6.40 | .384532 | 7.97 | 24 | .312992 | 6.22 | .412945 | 7.83 |
| 25 | .290655 | 6.40 | .385010 | 7.95 | 25 | .313365 | 6.22 | .413415 | 7.82 |
| 26 | .291039 | 6.40 | .385487 | 7.95 | 26 | .313738 | 6.22 | .413884 | 7.83 |
| 27 | .291423 | 6.40 | .385964 | 7.95 | 27 | .314111 | 6.22 | .414354 | 7.82 |
| 28 | .291807 | 6.38 | .386441 | 7.95 | 28 | .314484 | 6.20 | .414823 | 7.83 |
| 29 | .292190 | 6.38 | .386918 | 7.93 | 29 | .314856 | 6.20 | .415293 | 7.82 |
| 30 | .292573 | 6.38 | .387394 | 7.95 | 30 | .315228 | 6.20 | .415762 | 7.82 |
| 31 | 9.292956 | 6.38 | 9.387871 | 7.93 | 31 | 9.315600 | 6.20 | 9.416231 | 7.82 |
| 32 | .293339 | 6.38 | .388347 | 7.95 | 32 | .315972 | 6.20 | .416700 | 7.80 |
| 33 | .293722 | 6.37 | .388824 | 7.93 | 33 | .316344 | 6.20 | .417168 | 7.82 |
| 34 | .294104 | 6.37 | .389300 | 7.93 | 34 | .316716 | 6.18 | .417637 | 7.82 |
| 35 | .294486 | 6.37 | .389776 | 7.93 | 35 | .317087 | 6.18 | .418106 | 7.80 |
| 36 | .294868 | 6.37 | .390252 | 7.92 | 36 | .317458 | 6.18 | .418574 | 7.80 |
| 37 | .295250 | 6.37 | .390727 | 7.93 | 37 | .317829 | 6.18 | .419042 | 7.82 |
| 38 | .295632 | 6.37 | .391203 | 7.92 | 38 | .318200 | 6.18 | .419511 | 7.80 |
| 39 | .296014 | 6.35 | .391678 | 7.93 | 39 | .318571 | 6.17 | .419979 | 7.80 |
| 40 | .296395 | 6.35 | .392154 | 7.92 | 40 | .318941 | 6.17 | .420447 | 7.80 |
| 41 | 9.296776 | 6.35 | 9.392629 | 7.92 | 41 | 9.319311 | 6.18 | 9.420915 | 7.78 |
| 42 | .297157 | 6.35 | .393104 | 7.92 | 42 | .319682 | 6.15 | .421382 | 7.80 |
| 43 | .297538 | 6.33 | .393579 | 7.92 | 43 | .320051 | 6.17 | .421850 | 7.78 |
| 44 | .297918 | 6.35 | .394054 | 7.92 | 44 | .320421 | 6.17 | .422317 | 7.80 |
| 45 | .298299 | 6.33 | .394529 | 7.90 | 45 | .320791 | 6.15 | .422785 | 7.78 |
| 46 | .298679 | 6.33 | .395003 | 7.92 | 46 | .321160 | 6.17 | .423252 | 7.78 |
| 47 | .299059 | 6.33 | .395478 | 7.90 | 47 | .321530 | 6.15 | .423719 | 7.78 |
| 48 | .299439 | 6.33 | .395952 | 7.90 | 48 | .321899 | 6.13 | .424186 | 7.78 |
| 49 | .299819 | 6.32 | .396426 | 7.90 | 49 | .322267 | 6.15 | .424653 | 7.78 |
| 50 | .300198 | 6.32 | .396900 | 7.90 | 50 | .322636 | 6.15 | .425120 | 7.78 |
| 51 | 9.300577 | 6.33 | 9.397374 | 7.90 | 51 | 9.323005 | 6.13 | 9.425587 | 7.77 |
| 52 | .300957 | 6.30 | .397848 | 7.90 | 52 | .323373 | 6.13 | .426053 | 7.78 |
| 53 | .301335 | 6.32 | .398322 | 7.88 | 53 | .323741 | 6.13 | .426520 | 7.77 |
| 54 | .301714 | 6.32 | .398795 | 7.90 | 54 | .324109 | 6.13 | .426986 | 7.77 |
| 55 | .302093 | 6.30 | .399269 | 7.88 | 55 | .324477 | 6.13 | .427452 | 7.77 |
| 56 | .302471 | 6.30 | .399742 | 7.88 | 56 | .324845 | 6.12 | .427918 | 7.77 |
| 57 | .302849 | 6.30 | .400215 | 7.88 | 57 | .325212 | 6.13 | .428384 | 7.77 |
| 58 | .303227 | 6.30 | .400688 | 7.88 | 58 | .325580 | 6.12 | .428850 | 7.77 |
| 59 | .303605 | 6.30 | .401161 | 7.88 | 59 | .325947 | 6.12 | .429316 | 7.77 |
| 60 | 9.303983 | 6.28 | 9.401634 | 7.88 | 60 | 9.326314 | 6.12 | 9.429782 | 7.75 |

| 38° | | | | | 39° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.326314 | 6.12 | 9.429782 | 7.75 | 0 | 9.348021 | 5.93 | 9.457518 | 7.65 |
| 1 | .326681 | 6.10 | .430247 | 7.77 | 1 | .348377 | 5.95 | .457977 | 7.65 |
| 2 | .327047 | 6.12 | .430713 | 7.75 | 2 | .348734 | 5.93 | .458436 | 7.65 |
| 3 | .327414 | 6.10 | .431178 | 7.75 | 3 | .349090 | 5.93 | .458895 | 7.63 |
| 4 | .327780 | 6.10 | .431643 | 7.75 | 4 | .349446 | 5.93 | .459353 | 7.65 |
| 5 | .328146 | 6.10 | .432108 | 7.75 | 5 | .349802 | 5.93 | .459812 | 7.63 |
| 6 | .328512 | 6.10 | .432573 | 7.75 | 6 | .350158 | 5.93 | .460270 | 7.65 |
| 7 | .328878 | 6.08 | .433038 | 7.75 | 7 | .350514 | 5.92 | .460729 | 7.63 |
| 8 | .329243 | 6.10 | .433503 | 7.73 | 8 | .350869 | 5.93 | .461187 | 7.63 |
| 9 | .329609 | 6.08 | .433967 | 7.75 | 9 | .351225 | 5.92 | .461645 | 7.63 |
| 10 | .329974 | 6.08 | .434432 | 7.73 | 10 | .351580 | 5.92 | .462103 | 7.63 |
| 11 | 9.330339 | 6.08 | 9.434896 | 7.75 | 11 | 9.351935 | 5.92 | 9.462561 | 7.63 |
| 12 | .330704 | 6.08 | .435361 | 7.73 | 12 | .352290 | 5.90 | .463019 | 7.63 |
| 13 | .331069 | 6.07 | .435825 | 7.73 | 13 | .352644 | 5.92 | .463477 | 7.62 |
| 14 | .331433 | 6.08 | .436289 | 7.73 | 14 | .352999 | 5.90 | .463934 | 7.63 |
| 15 | .331798 | 6.07 | .436753 | 7.73 | 15 | .353353 | 5.90 | .464392 | 7.62 |
| 16 | .332162 | 6.07 | .437217 | 7.72 | 16 | .353707 | 5.92 | .464849 | 7.63 |
| 17 | .332526 | 6.07 | .437680 | 7.73 | 17 | .354062 | 5.88 | .465307 | 7.62 |
| 18 | .332890 | 6.07 | .438144 | 7.73 | 18 | .354415 | 5.90 | .465764 | 7.62 |
| 19 | .333254 | 6.05 | .438608 | 7.72 | 19 | .354769 | 5.90 | .466221 | 7.62 |
| 20 | .333617 | 6.07 | .439071 | 7.72 | 20 | .355123 | 5.88 | .466678 | 7.62 |
| 21 | 9.333981 | 6.05 | 9.439534 | 7.72 | 21 | 9.355476 | 5.88 | 9.467135 | 7.62 |
| 22 | .334344 | 6.05 | .439997 | 7.72 | 22 | .355829 | 5.88 | .467592 | 7.62 |
| 23 | .334707 | 6.05 | .440460 | 7.72 | 23 | .356182 | 5.88 | .468049 | 7.62 |
| 24 | .335070 | 6.03 | .440923 | 7.72 | 24 | .356535 | 5.88 | .468506 | 7.60 |
| 25 | .335432 | 6.05 | .441386 | 7.72 | 25 | .356888 | 5.88 | .468962 | 7.60 |
| 26 | .335795 | 6.03 | .441849 | 7.72 | 26 | .357241 | 5.87 | .469418 | 7.62 |
| 27 | .336157 | 6.03 | .442312 | 7.70 | 27 | .357593 | 5.87 | .469875 | 7.60 |
| 28 | .336519 | 6.03 | .442774 | 7.72 | 28 | .357945 | 5.87 | .470331 | 7.60 |
| 29 | .336881 | 6.03 | .443237 | 7.70 | 29 | .358297 | 5.87 | ,470787 | 7.60 |
| 30 | .337243 | 6.03 | .443699 | 7.70 | 30 | .358649 | 5.87 | .471243 | 7.60 |
| 31 | 9.337605 | 6.02 | 9.444161 | 7.70 | 31 | 9.359001 | 5.87 | 9.471699 | 7.60 |
| 32 | .337966 | 6.03 | .444623 | 7.70 | 32 | .359353 | 5.85 | .472155 | 7.60 |
| 33 | .338328 | 6.02 | .445085 | 7.70 | 33 | .359704 | 5.87 | .472611 | 7.60 |
| 34 | .338689 | 6.02 | .445547 | 7.70 | 34 | .360056 | 5.85 | .473067 | 7.58 |
| 35 | .339050 | 6.02 | .446009 | 7.68 | 35 | .360407 | 5.85 | .473522 | 7.60 |
| 36 | .339411 | 6.00 | .446470 | 7.70 | 36 | .360758 | 5.83 | .473978 | 7.58 |
| 37 | .339771 | 6.02 | .446932 | 7.68 | 37 | .361108 | 5.85 | .474433 | 7.58 |
| 38 | .340132 | 6.00 | .447393 | 7.70 | 38 | .361459 | 5.85 | .474888 | 7.58 |
| 39 | .340492 | 6.00 | .447855 | 7.68 | 39 | .361810 | 5.83 | .475343 | 7.58 |
| 40 | 340852 | 6.00 | .448316 | 7.68 | 40 | .362160 | 5.83 | .475798 | 7.58 |
| 41 | 9.341212 | 6.00 | 9.448777 | 7.68 | 41 | 9.362510 | 5.83 | 9.476253 | 7.58 |
| 42 | .341572 | 6.00 | .449238 | 7.68 | 42 | .362860 | 5.83 | .476708 | 7.58 |
| 43 | .341932 | 5.98 | .449699 | 7.68 | 43 | .363210 | 5.83 | .477163 | 7.58 |
| 44 | .342291 | 6.00 | .450160 | 7.67 | 44 | .363560 | 5.82 | .477618 | 7.57 |
| 45 | .342651 | 5.98 | .450620 | 7 68 | 45 | .363909 | 5.83 | .478072 | 7.58 |
| 46 | .343010 | 5.98 | .451081 | 7.67 | 46 | .364259 | 5.82 | .478527 | 7.57 |
| 47 | .343369 | 5.98 | .451541 | 7.68 | 47 | .364608 | 5.82 | .478981 | 7.57 |
| 48 | .343728 | 5.97 | .452002 | 7.67 | 48 | .364957 | 5.82 | .479435 | 7.58 |
| 49 | .344086 | 5.98 | .452462 | 7.67 | 49 | .365306 | 5.82 | .479890 | 7.57 |
| 50 | .344445 | 5.97 | .452922 | 7.67 | 50 | .365655 | 5.80 | .480344 | 7.57 |
| 51 | 9.344803 | 5.97 | 9.453382 | 7.67 | 51 | 9.366003 | 5.82 | 9.480798 | 7.57 |
| 52 | .345161 | 5.97 | .453842 | 7.67 | 52 | .366352 | 5.80 | .481252 | 7.55 |
| 53 | .345519 | 5.97 | .454302 | 7.67 | 53 | .366700 | 5.80 | .481705 | 7.57 |
| 54 | .345877 | 5.97 | .454762 | 7.65 | 54 | .367048 | 5.80 | .482159 | 7.57 |
| 55 | .346235 | 5.95 | .455221 | 7.67 | 55 | .367396 | 5.80 | .482613 | 7.55 |
| 56 | .346592 | 5.97 | .455681 | 7.65 | 56 | .367744 | 5.78 | .483066 | 7.57 |
| 57 | .346950 | 5.95 | .456140 | 7.67 | 57 | .368091 | 5.80 | .483520 | 7.55 |
| 58 | .347307 | 5.95 | .456600 | 7.65 | 58 | .368439 | 5.78 | .483973 | 7.55 |
| 59 | .347664 | 5.95 | .457059 | 7.65 | 59 | .368786 | 5.78 | .484426 | 7.55 |
| 60 | 9.348021 | 5.93 | 9.457518 | 7.65 | 60 | 9.369133 | 5.78 | 9.484879 | 7.55 |

| 40° | | | | | 41° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.369133 | 5.78 | 9.484879 | 7.55 | 0 | 9.389681 | 5.62 | 9.511901 | 7.45 |
| 1 | .369480 | 5.78 | .485332 | 7.55 | 1 | .390018 | 5.63 | .512348 | 7.47 |
| 2 | .369827 | 5.78 | .485785 | 7.55 | 2 | .390356 | 5.63 | .512796 | 7.45 |
| 3 | .370174 | 5.77 | .486238 | 7.55 | 3 | .390694 | 5.62 | .513243 | 7.47 |
| 4 | .370520 | 5.78 | .486691 | 7.55 | 4 | .391031 | 5.62 | .513691 | 7.45 |
| 5 | .370867 | 5.77 | .487144 | 7.53 | 5 | .391368 | 5.62 | .514138 | 7.45 |
| 6 | .371213 | 5.77 | .487596 | 7.55 | 6 | .391705 | 5.62 | .514585 | 7.47 |
| 7 | .371559 | 5.77 | .488049 | 7.53 | 7 | .392042 | 5.62 | .515033 | 7.45 |
| 8 | .371905 | 5.77 | .488501 | 7.53 | 8 | .392379 | 5.62 | .515480 | 7.45 |
| 9 | .372251 | 5.75 | .488953 | 7.55 | 9 | .392716 | 5.60 | .515927 | 7.45 |
| 10 | .372596 | 5.77 | .489406 | 7.53 | 10 | .393052 | 5.60 | .516374 | 7.43 |
| 11 | 9.372942 | 5.75 | 9.489858 | 7.53 | 11 | 9.393388 | 5.60 | 9.516820 | 7.45 |
| 12 | .373287 | 5.75 | .490310 | 7.53 | 12 | .393724 | 5.62 | .517267 | 7.45 |
| 13 | .373632 | 5.75 | .490762 | 7.53 | 13 | .394061 | 5.58 | .517714 | 7.43 |
| 14 | .373977 | 5.75 | .491214 | 7.52 | 14 | .394396 | 5.60 | .518160 | 7.45 |
| 15 | .374322 | 5.75 | .491665 | 7.53 | 15 | .394732 | 5.60 | .518607 | 7.43 |
| 16 | .374667 | 5.73 | .492117 | 7.53 | 16 | .395068 | 5.58 | .519053 | 7.45 |
| 17 | .375011 | 5.75 | .492569 | 7.52 | 17 | .395403 | 5.58 | .519500 | 7.43 |
| 18 | .375356 | 5.73 | .493020 | 7.52 | 18 | .395738 | 5.60 | .519946 | 7.43 |
| 19 | .375700 | 5.73 | .493471 | 7.53 | 19 | .396074 | 5.58 | .520392 | 7.43 |
| 20 | .376044 | 5.73 | .493923 | 7.52 | 20 | .396409 | 5.57 | .520838 | 7.43 |
| 21 | 9.376388 | 5.73 | 9.494374 | 7.52 | 21 | 9.396743 | 5.58 | 9.521284 | 7.43 |
| 22 | .376732 | 5.72 | .494825 | 7.52 | 21 | .397078 | 5.58 | .521730 | 7.43 |
| 23 | .377075 | 5.73 | .495276 | 7.52 | 23 | .397413 | 5.57 | .522176 | 7.42 |
| 24 | .377419 | 5.72 | .495727 | 7.52 | 24 | .397747 | 5.57 | .522621 | 7.43 |
| 25 | .377762 | 5.72 | .496178 | 7.50 | 25 | .398081 | 5.57 | .523067 | 7.43 |
| 26 | .378105 | 5.72 | .496628 | 7.52 | 26 | .398415 | 5.57 | .523513 | 7.42 |
| 27 | .378448 | 5.72 | .497079 | 7.52 | 27 | .398749 | 5.57 | .523958 | 7.43 |
| 28 | .378791 | 5.70 | .497530 | 7.50 | 28 | .399083 | 5.57 | .524404 | 7.42 |
| 29 | .379133 | 5.72 | .497980 | 7.52 | 29 | .399417 | 5.55 | .524849 | 7.42 |
| 30 | .379476 | 5.70 | .498430 | 7.50 | 30 | .399750 | 5.57 | .525294 | 7.42 |
| 31 | 9.379818 | 5.72 | 9.498881 | 7.48 | 31 | 9.400084 | 5.55 | 9.525739 | 7.42 |
| 32 | .380161 | 5.70 | .499331 | 7.52 | 32 | .400417 | 5.55 | .526184 | 7.42 |
| 33 | .380503 | 5.70 | .499781 | 7.50 | 33 | .400750 | 5.55 | .526629 | 7.42 |
| 34 | .380845 | 5.68 | .500231 | 7.50 | 34 | .401083 | 5.55 | .527074 | 7.42 |
| 35 | .381186 | 5.70 | .500681 | 7.50 | 35 | .401416 | 5.53 | .527519 | 7.42 |
| 36 | .381528 | 5.68 | .501131 | 7.50 | 36 | .401748 | 5.55 | .527964 | 7.42 |
| 37 | .381869 | 5.70 | .501581 | 7.48 | 37 | .402081 | 5.53 | .528409 | 7.40 |
| 38 | .382211 | 5.68 | .502030 | 7.50 | 38 | .402413 | 5.53 | .528853 | 7.42 |
| 39 | .382552 | 5.68 | .502480 | 7.48 | 39 | .402745 | 5.53 | .529298 | 7.40 |
| 40 | .382893 | 5.68 | .502929 | 7.50 | 40 | .403077 | 5.53 | .529742 | 7.42 |
| 41 | 9.383234 | 5.67 | 9.503379 | 7.48 | 41 | 9.403409 | 5.53 | 9.530187 | 7.40 |
| 42 | .383574 | 5.68 | .503828 | 7.48 | 42 | .403741 | 5.53 | .530631 | 7.40 |
| 43 | .383915 | 5.67 | .504277 | 7.48 | 43 | .404073 | 5.52 | .531075 | 7.40 |
| 44 | .384255 | 5.67 | .504726 | 7.48 | 44 | .404404 | 5.53 | .531519 | 7.40 |
| 45 | .384595 | 5.67 | .505175 | 7.48 | 45 | .404736 | 5.52 | .531963 | 7.40 |
| 46 | .384935 | 5.67 | .505624 | 7.48 | 46 | .405067 | 5.52 | .532407 | 7.40 |
| 47 | .385275 | 5.67 | .506073 | 7.48 | 47 | .405398 | 5.52 | .532851 | 7.40 |
| 48 | .385615 | 5.67 | .506522 | 7.48 | 48 | .405729 | 5.50 | .533295 | 7.40 |
| 49 | .385955 | 5.65 | .506971 | 7.47 | 49 | .406059 | 5.52 | .533739 | 7.38 |
| 50 | .386294 | 5.67 | .507419 | 7.48 | 50 | .406390 | 5.52 | .534182 | 7.40 |
| 51 | 9.386634 | 5.65 | 9.507868 | 7.47 | 51 | 9.406721 | 5.50 | 9.534626 | 7.40 |
| 52 | .386973 | 5.65 | .508316 | 7.48 | 52 | .407051 | 5.50 | .535070 | 7.38 |
| 53 | .387312 | 5.65 | .508765 | 7.47 | 53 | .407381 | 5.50 | .535513 | 7.38 |
| 54 | .387651 | 5.63 | .509213 | 7.47 | 54 | .407711 | 5.50 | .535956 | 7.40 |
| 55 | .387989 | 5.65 | .509661 | 7.47 | 55 | .408041 | 5.50 | .536400 | 7.38 |
| 56 | .388328 | 5.63 | .510109 | 7.47 | 56 | .408371 | 5.48 | .536843 | 7.38 |
| 57 | .388666 | 5.65 | .510557 | 7.47 | 57 | .408700 | 5.50 | .537286 | 7.38 |
| 58 | .389005 | 5.63 | .511005 | 7.47 | 58 | .409030 | 5.48 | .537729 | 7.38 |
| 59 | .389343 | 5.63 | .511453 | 7.47 | 59 | .409359 | 5.48 | .538172 | 7.33 |
| 60 | 9.389681 | 5.62 | 9.511901 | 7.45 | 60 | 9.409688 | 5.48 | 9.538615 | 7.38 |

| | 42° | | | | | 43° | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.409688 | 5.48 | 9.538615 | 7.38 | 0 | 9.429181 | 5.35 | 9.565053 | 7.32 |
| 1 | .410017 | 5.48 | .539058 | 7.37 | 1 | .429502 | 5.33 | .565492 | 7.30 |
| 2 | .410346 | 5.48 | .539500 | 7.38 | 2 | .429822 | 5.33 | .565930 | 7.32 |
| 3 | .410675 | 5.48 | .539943 | 7.38 | 3 | .430142 | 5.35 | .566369 | 7.30 |
| 4 | .411004 | 5.47 | .540386 | 7.37 | 4 | .430463 | 5.33 | .566807 | 7.30 |
| 5 | .411332 | 5.47 | .540828 | 7.38 | 5 | .430783 | 5.33 | .567245 | 7.30 |
| 6 | .411660 | 5.48 | .541271 | 7.37 | 6 | .431103 | 5.32 | .567683 | 7.30 |
| 7 | .411989 | 5.47 | .541713 | 7.37 | 7 | .431422 | 5.33 | .568121 | 7.30 |
| 8 | .412317 | 5.45 | .542155 | 7.37 | 8 | .431742 | 5.33 | .568559 | 7.30 |
| 9 | .412644 | 5.47 | .542597 | 7.38 | 9 | .432062 | 5.32 | .568997 | 7.30 |
| 10 | .412972 | 5.47 | .543040 | 7.37 | 10 | .432381 | 5.32 | .569435 | 7.30 |
| 11 | 9.413300 | 5.45 | 9.543482 | 7.37 | 11 | 9.432700 | 5.33 | 9.569873 | 7.30 |
| 12 | .413627 | 5.47 | .543924 | 7.37 | 12 | .433020 | 5.32 | .570311 | 7.28 |
| 13 | .413955 | 5.45 | .544366 | 7.35 | 13 | .433339 | 5.30 | .570748 | 7.30 |
| 14 | .414282 | 5.45 | .544807 | 7.37 | 14 | .433657 | 5.32 | .571186 | 7.30 |
| 15 | .414609 | 5.45 | .545249 | 7.37 | 15 | .433976 | 5.32 | .571624 | 7.28 |
| 16 | .414936 | 5.45 | .545691 | 7.35 | 16 | .434295 | 5.30 | .572061 | 7.28 |
| 17 | .415263 | 5.43 | .546132 | 7.37 | 17 | .434613 | 5.32 | .572498 | 7.30 |
| 18 | .415589 | 5.45 | .546574 | 7.35 | 18 | .434932 | 5.30 | .572936 | 7.28 |
| 19 | .415916 | 5.43 | .547015 | 7.37 | 19 | .435250 | 5.30 | .573373 | 7.28 |
| 20 | .416242 | 5.43 | .547457 | 7.35 | 20 | .435568 | 5.30 | .573810 | 7.28 |
| 21 | 9.416568 | 5.43 | 9.547898 | 7.35 | 21 | 9.435886 | 5.30 | 9.574247 | 7.30 |
| 22 | .416894 | 5.43 | .548339 | 7 37 | 22 | .436204 | 5.28 | .574685 | 7.28 |
| 23 | .417220 | 5.43 | .548781 | 7.35 | 23 | .436521 | 5.30 | .575122 | 7.27 |
| 24 | .417546 | 5.42 | .549222 | 7.35 | 24 | .436839 | 5.28 | .575558 | 7.30 |
| 25 | .417871 | 5.43 | .549663 | 7.35 | 25 | .437156 | 5.28 | .575995 | 7.28 |
| 26 | .418197 | 5.42 | .550104 | 7.33 | 26 | .437473 | 5.30 | .576432 | 7.28 |
| 27 | .418522 | 5.43 | .550544 | 7.35 | 27 | .437791 | 5.27 | .576869 | 7.28 |
| 28 | .418848 | 5.42 | .550985 | 7.35 | 28 | .438107 | 5.28 | .577306 | 7.27 |
| 29 | .419173 | 5.42 | .551426 | 7.35 | 29 | .438424 | 5.28 | .577742 | 7.28 |
| 30 | .419498 | 5.40 | .551867 | 7.33 | 30 | .438741 | 5.28 | .578179 | 7.27 |
| 31 | 9.419822 | 5.42 | 9.552307 | 7.35 | 31 | 9.439058 | 5.27 | 9.578615 | 7.28 |
| 32 | .420147 | 5.40 | .552748 | 7.33 | 32 | .439374 | 5.27 | .579052 | 7.27 |
| 33 | .420471 | 5.42 | .553188 | 7.35 | 33 | .439690 | 5.28 | .579488 | 7.27 |
| 34 | .420796 | 5.40 | .553629 | 7.33 | 34 | .440007 | 5.27 | .579924 | 7.28 |
| 35 | .421120 | 5.40 | .554069 | 7.33 | 35 | .440323 | 5.27 | .580361 | 7.27 |
| 36 | .421444 | 5.40 | .554509 | 7.33 | 36 | .440639 | 5.25 | .580797 | 7.27 |
| 37 | .421768 | 5.40 | .554949 | 7.33 | 37 | .440954 | 5.27 | .581233 | 7.27 |
| 38 | .422092 | 5.40 | .555389 | 7.33 | 38 | .441270 | 5.25 | .581669 | 7.27 |
| 39 | .422416 | 5.38 | .555829 | 7.33 | 39 | .441585 | 5.27 | .582105 | 7.27 |
| 40 | .422739 | 5.40 | .556269 | 7.33 | 40 | .441901 | 5.25 | .582541 | 7.27 |
| 41 | 9.423063 | 5.38 | 9.556709 | 7.33 | 41 | 9.442216 | 5.25 | 9.582977 | 7.27 |
| 42 | .423386 | 5.38 | .557149 | 7.33 | 42 | .442531 | 5.25 | .583413 | 7.2[illegible] |
| 43 | .423709 | 5.38 | .557589 | 7.32 | 43 | .442846 | 5.25 | .583848 | 7.27 |
| 44 | .424032 | 5.38 | .558028 | 7.33 | 44 | .443161 | 5.25 | .584284 | 7.27 |
| 45 | .424355 | 5.37 | .558468 | 7.32 | 45 | .443476 | 5.23 | .584720 | 7.25 |
| 46 | .424677 | 5.38 | .558907 | 7.33 | 46 | .443790 | 5.25 | .585155 | 7.27 |
| 47 | .425000 | 5.37 | .559347 | 7.32 | 47 | .444105 | 5.23 | .585591 | 7.25 |
| 48 | .425322 | 5.38 | .559786 | 7.33 | 48 | .444419 | 5.23 | .586026 | 7.27 |
| 49 | .425645 | 5.37 | .560226 | 7.32 | 49 | .444733 | 5.23 | .586462 | 7.25 |
| 50 | .425967 | 5.37 | .560665 | 7.32 | 50 | .445047 | 5.23 | .586897 | 7.25 |
| 51 | 9.426289 | 5.37 | 9.561104 | 7.32 | 51 | 9.445361 | 5.23 | 9.587332 | 7.25 |
| 52 | .426611 | 5.37 | .561543 | 7.32 | 52 | .445675 | 5.23 | .587767 | 7.27 |
| 53 | .426933 | 5.35 | .561982 | 7.32 | 53 | .445989 | 5.22 | .58[illegible] | 7.25 |
| 54 | .427254 | 5.37 | .562421 | 7.32 | 54 | .446302 | 5.23 | .588638 | 7.25 |
| 55 | .427576 | 5.35 | .562860 | 7.32 | 55 | .446616 | 5.22 | .589073 | 7.25 |
| 56 | .427897 | 5.35 | .563299 | 7.32 | 56 | .446929 | 5.22 | .589508 | 7.23 |
| 57 | .428218 | 5.35 | .563738 | 7.30 | 57 | .447242 | 5.22 | .589942 | 7.25 |
| 58 | .428539 | 5.35 | .564176 | 7.32 | 58 | .447555 | 5.22 | .590377 | 7.25 |
| 59 | .428860 | 5.35 | .564615 | 7.30 | 59 | .447868 | 5.22 | .590812 | 7.25 |
| 60 | 9.429181 | 5.33 | 9.565053 | 7.32 | 60 | 9.448181 | 5.20 | 9.591247 | 7.23 |

| 44° | | | | | 45° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.448181 | 5.20 | 9.591247 | 7.23 | 0 | 9.466709 | 5.08 | 9.617224 | 7.20 |
| 1 | .448493 | 5.22 | .591681 | 7.25 | 1 | .467014 | 5.08 | .617656 | 7.18 |
| 2 | .448806 | 5.20 | .592116 | 7.25 | 2 | .467319 | 5.08 | .618087 | 7.18 |
| 3 | .449118 | 5.22 | .592551 | 7.23 | 3 | .467624 | 5.07 | .618518 | 7.18 |
| 4 | .449431 | 5.20 | .592985 | 7.23 | 4 | .467928 | 5.08 | .618949 | 7.18 |
| 5 | .449743 | 5.20 | .593419 | 7.25 | 5 | .468233 | 5.07 | .619380 | 7.18 |
| 6 | .450055 | 5.18 | .593854 | 7.23 | 6 | .468537 | 5.07 | .619811 | 7.18 |
| 7 | .450366 | 5.20 | .594288 | 7.23 | 7 | .468841 | 5.07 | .620242 | 7.18 |
| 8 | .450678 | 5.20 | .594722 | 7.23 | 8 | .469145 | 5.07 | .620673 | 7.18 |
| 9 | .450990 | 5.18 | .595156 | 7.25 | 9 | .469449 | 5.07 | .621104 | 7.18 |
| 10 | .451301 | 5.18 | .595591 | 7.23 | 10 | .469753 | 5.07 | .621535 | 7.18 |
| 11 | 9.451612 | 5.20 | 9.596025 | 7.23 | 11 | 9.470057 | 5.05 | 9.621966 | 7.17 |
| 12 | .451924 | 5.18 | .596459 | 7.23 | 12 | .470360 | 5.07 | .622396 | 7.18 |
| 13 | .452235 | 5.18 | .596893 | 7.22 | 13 | .470664 | 5.05 | .622827 | 7.18 |
| 14 | .452546 | 5.17 | .597326 | 7.23 | 14 | .470967 | 5.05 | .623258 | 7.17 |
| 15 | .452856 | 5.17 | .597760 | 7.23 | 15 | .471270 | 5.05 | .623688 | 7.18 |
| 16 | .453167 | 5.18 | .598194 | 7.23 | 16 | .471573 | 5.05 | .624119 | 7.17 |
| 17 | .453478 | 5.17 | .598628 | 7.22 | 17 | .471876 | 5.05 | .624549 | 7.18 |
| 18 | .453788 | 5.17 | .599061 | 7.23 | 18 | .472179 | 5.05 | .624980 | 7.17 |
| 19 | .454098 | 5.17 | .599495 | 7.22 | 19 | .472482 | 5.03 | .625410 | 7.18 |
| 20 | .454408 | 5.17 | .599928 | 7.23 | 20 | .472784 | 5.05 | .625841 | 7.17 |
| 21 | 9.454718 | 5.17 | 9.600362 | 7.22 | 21 | 9.473087 | 5.03 | 9.626271 | 7.17 |
| 22 | .455028 | 5.17 | .600795 | 7.23 | 22 | .473389 | 5.03 | .626701 | 7.17 |
| 23 | .455338 | 5.17 | .601229 | 7.22 | 23 | .473691 | 5.03 | .627131 | 7.17 |
| 24 | .455648 | 5.15 | .601662 | 7.22 | 24 | .473993 | 5.03 | .627561 | 7.17 |
| 25 | .455957 | 5.17 | .602095 | 7.22 | 25 | .474295 | 5.03 | .627991 | 7.17 |
| 26 | .456267 | 5.15 | .602528 | 7.23 | 26 | .474597 | 5.03 | .628421 | 7.17 |
| 27 | .456576 | 5.15 | .602962 | 7.22 | 27 | .474899 | 5.02 | .628851 | 7.17 |
| 28 | .456885 | 5.15 | .603395 | 7.22 | 28 | .475200 | 5.03 | .629281 | 7.17 |
| 29 | .457194 | 5.15 | .603828 | 7.22 | 29 | .475502 | 5.02 | .629711 | 7.17 |
| 30 | .457503 | 5.13 | .604261 | 7.22 | 30 | .475803 | 5.02 | .630141 | 7.17 |
| 31 | 9.457811 | 5.15 | 9.604694 | 7.20 | 31 | 9.476104 | 5.02 | 9.630571 | 7.17 |
| 32 | .458120 | 5.15 | .605126 | 7.22 | 32 | .476405 | 5.02 | .631001 | 7.15 |
| 33 | .458429 | 5.13 | .605559 | 7.22 | 33 | .476706 | 5.02 | .631430 | 7.17 |
| 34 | .458737 | 5.13 | .605992 | 7.22 | 34 | .477007 | 5.02 | .631860 | 7.17 |
| 35 | .459045 | 5.13 | .606425 | 7.20 | 35 | .477308 | 5.00 | .632290 | 7.15 |
| 36 | .459353 | 5.13 | .606857 | 7.22 | 36 | .477608 | 5.02 | .632719 | 7.17 |
| 37 | .459661 | 5.13 | .607290 | 7.20 | 37 | .477909 | 5.00 | .633149 | 7.15 |
| 38 | .459969 | 5.13 | .607722 | 7.22 | 38 | .478209 | 5.00 | .633578 | 7.17 |
| 39 | .460277 | 5.12 | .608155 | 7.20 | 39 | .478509 | 5.00 | .634008 | 7.15 |
| 40 | .460584 | 5.13 | .608587 | 7.22 | 40 | .478809 | 5.00 | .634437 | 7.15 |
| 41 | 9.460892 | 5.12 | 9.609020 | 7.20 | 41 | 9.479109 | 5.00 | 9.634866 | 7.17 |
| 42 | .461199 | 5.12 | .609452 | 7.20 | 42 | .479409 | 5.00 | .635296 | 7.15 |
| 43 | .461506 | 5.12 | .609884 | 7.20 | 43 | .479709 | 5.00 | .635725 | 7.15 |
| 44 | .461813 | 5.12 | .610316 | 7.22 | 44 | .480009 | 4.98 | .636154 | 7.15 |
| 45 | .462120 | 5.12 | .610749 | 7.20 | 45 | .480308 | 5.00 | .636583 | 7.15 |
| 46 | .462427 | 5.12 | .611181 | 7.20 | 46 | .480608 | 4.98 | .637012 | 7.15 |
| 47 | .462734 | 5.10 | .611613 | 7.20 | 47 | .480907 | 4.98 | .637441 | 7.15 |
| 48 | .463040 | 5.12 | .612045 | 7.20 | 48 | .481206 | 4.98 | .637870 | 7.15 |
| 49 | .463347 | 5.10 | .612477 | 7.18 | 49 | .481505 | 4.98 | .638299 | 7.15 |
| 50 | .463653 | 5.10 | .612908 | 7.20 | 50 | .481804 | 4.98 | .638728 | 7.15 |
| 51 | 9.463959 | 5.10 | 9.613340 | 7.20 | 51 | 9.482103 | 4.97 | 9.639157 | 7.15 |
| 52 | .464265 | 5.10 | .613772 | 7.20 | 52 | .482401 | 4.98 | .639586 | 7.15 |
| 53 | .464571 | 5.10 | .614204 | 7.18 | 53 | .482700 | 4.97 | .640015 | 7.13 |
| 54 | .464877 | 5.10 | .614635 | 7.20 | 54 | .482998 | 4.97 | .640443 | 7.15 |
| 55 | .465183 | 5.08 | .615067 | 7.20 | 55 | .483296 | 4.98 | .640872 | 7.15 |
| 56 | .465488 | 5.10 | .615499 | 7.18 | 56 | .483595 | 4.97 | .641301 | 7.13 |
| 57 | .465794 | 5.08 | .615930 | 7.20 | 57 | .483893 | 4.97 | .641729 | 7.15 |
| 58 | .466099 | 5.08 | .616362 | 7.18 | 58 | .484191 | 4.95 | .642158 | 7.13 |
| 59 | .466404 | 5.08 | .616793 | 7.18 | 59 | .484488 | 4.97 | .642586 | 7.15 |
| 60 | 9.466709 | 5.08 | 9.617224 | 7.20 | 60 | 9.484786 | 4.97 | 9.643015 | 7.13 |

| 46° | | | | | 47° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.484786 | 4.97 | 9.643015 | 7.13 | 0 | 9.502429 | 4.85 | 9.668646 | 7.10 |
| 1 | .485084 | 4.95 | .643443 | 7.15 | 1 | .502720 | 4.83 | .669072 | 7.10 |
| 2 | .485381 | 4.95 | .643872 | 7.13 | 2 | .503010 | 4.83 | .669498 | 7.10 |
| 3 | .485678 | 4.97 | .644300 | 7.13 | 3 | .503300 | 4.85 | .669924 | 7.10 |
| 4 | .485976 | 4.95 | .644728 | 7.13 | 4 | .503591 | 4.83 | .670350 | 7.10 |
| 5 | .486273 | 4.95 | .645156 | 7.15 | 5 | .503881 | 4.83 | .670776 | 7.08 |
| 6 | .486570 | 4.93 | .645585 | 7.13 | 6 | .504171 | 4.82 | .671201 | 7.10 |
| 7 | .486866 | 4.95 | .646013 | 7.13 | 7 | .504460 | 4.83 | .671627 | 7.10 |
| 8 | .487163 | 4.95 | .646441 | 7.13 | 8 | .504750 | 4.83 | .672053 | 7.10 |
| 9 | .487460 | 4.93 | .646869 | 7.13 | 9 | .505040 | 4.82 | .672479 | 7.08 |
| 10 | .487756 | 4.95 | .647297 | 7.13 | 10 | .505329 | 4.82 | .672904 | 7.10 |
| 11 | 9.488053 | 4.93 | 9.647725 | 7.13 | 11 | 9.505618 | 4.83 | 9.673330 | 7.10 |
| 12 | .488349 | 4.93 | .648153 | 7.13 | 12 | .505908 | 4.82 | .673756 | 7.08 |
| 13 | .488645 | 4.93 | .648581 | 7.13 | 13 | .506197 | 4.82 | .674181 | 7.10 |
| 14 | .488941 | 4.93 | .649009 | 7.12 | 14 | .506486 | 4.82 | .674607 | 7.08 |
| 15 | .489237 | 4.93 | .649436 | 7.13 | 15 | .506775 | 4.80 | .675032 | 7.10 |
| 16 | .489533 | 4.92 | .649864 | 7.13 | 16 | .507063 | 4.82 | .675458 | 7.08 |
| 17 | .489828 | 4.93 | .650292 | 7.13 | 17 | .507352 | 4.80 | .675883 | 7.10 |
| 18 | .490124 | 4.92 | .650720 | 7.12 | 18 | .507640 | 4.82 | .676309 | 7.08 |
| 19 | .490419 | 4.92 | .651147 | 7.13 | 19 | .507929 | 4.80 | .676734 | 7.08 |
| 20 | .490714 | 4.93 | .651575 | 7.12 | 20 | .508217 | 4.80 | .677159 | 7.08 |
| 21 | 9.491010 | 4.92 | 9.652002 | 7.13 | 21 | 9.508505 | 4.80 | 9.677584 | 7.10 |
| 22 | .491305 | 4.92 | .652430 | 7.12 | 22 | .508793 | 4.80 | .678010 | 7.08 |
| 23 | .491600 | 4.90 | .652857 | 7.13 | 23 | .509081 | 4.80 | .678435 | 7.08 |
| 24 | .491894 | 4.92 | .653285 | 7.12 | 24 | .509369 | 4.80 | .678860 | 7.08 |
| 25 | .492189 | 4.92 | .653712 | 7.13 | 25 | .509657 | 4.80 | .679285 | 7.08 |
| 26 | .492484 | 4.90 | .654140 | 7.12 | 26 | .509945 | 4.78 | .679710 | 7.10 |
| 27 | .492778 | 4.90 | .654567 | 7.12 | 27 | .510232 | 4.80 | .680136 | 7.08 |
| 28 | .493072 | 4.92 | .654994 | 7.12 | 28 | .510520 | 4.78 | .680561 | 7.08 |
| 29 | .493367 | 4.90 | .655421 | 7.13 | 29 | .510807 | 4.78 | .680986 | 7.08 |
| 30 | .493661 | 4.90 | .655849 | 7.12 | 30 | .511094 | 4.78 | .681411 | 7.08 |
| 31 | 9.493955 | 4.90 | 9.656276 | 7.12 | 31 | 9.511381 | 4.78 | 9.681836 | 7.07 |
| 32 | .494249 | 4.88 | .656703 | 7.12 | 32 | .511668 | 4.78 | .682260 | 7.08 |
| 33 | .494542 | 4.90 | .657130 | 7.12 | 33 | .511955 | 4.77 | .682685 | 7.08 |
| 34 | .494836 | 4.90 | .657557 | 7.12 | 34 | .512241 | 4.78 | .683110 | 7.08 |
| 35 | .495130 | 4.88 | .657984 | 7.12 | 35 | .512528 | 4.78 | .683535 | 7.08 |
| 36 | .495423 | 4.88 | .658411 | 7.12 | 36 | .512815 | 4.77 | .683960 | 7.08 |
| 37 | .495716 | 4.88 | .658838 | 7.12 | 37 | .513101 | 4.77 | .684385 | 7.07 |
| 38 | .496009 | 4.88 | .659265 | 7.10 | 38 | .513387 | 4.77 | .684809 | 7.08 |
| 39 | .496302 | 4.88 | .659691 | 7.12 | 39 | .513673 | 4.77 | .685234 | 7.08 |
| 40 | .496595 | 4.88 | .660118 | 7.12 | 40 | .513959 | 4.77 | .685659 | 7.07 |
| 41 | 9.496888 | 4.88 | 9.660545 | 7.12 | 41 | 9.514245 | 4.77 | 9.686083 | 7.08 |
| 42 | .497181 | 4.87 | .660972 | 7.10 | 42 | .514531 | 4.77 | .686508 | 7.08 |
| 43 | .497473 | 4.88 | .661398 | 7.12 | 43 | .514817 | 4.75 | .686933 | 7.07 |
| 44 | .497766 | 4.87 | .661825 | 7.12 | 44 | .515102 | 4.77 | .687357 | 7.08 |
| 45 | .498058 | 4.87 | .662252 | 7.10 | 45 | .515388 | 4.75 | .687782 | 7.07 |
| 46 | .498350 | 4.88 | .662678 | 7.12 | 46 | .515673 | 4.77 | .688206 | 7.08 |
| 47 | .498643 | 4.87 | .663105 | 7.10 | 47 | .515959 | 4.75 | .688631 | 7.07 |
| 48 | .498935 | 4.85 | .663531 | 7.12 | 48 | .516244 | 4.75 | .689055 | 7.07 |
| 49 | .499226 | 4.87 | .663958 | 7.10 | 49 | .516529 | 4.75 | .689479 | 7.08 |
| 50 | .499518 | 4.87 | .664384 | 7.10 | 50 | .516814 | 4.73 | .689904 | 7.07 |
| 51 | 9.499810 | 4.85 | 9.664810 | 7.12 | 51 | 9.517098 | 4.75 | 9.690328 | 7.07 |
| 52 | .500101 | 4.87 | .665237 | 7.10 | 52 | .517383 | 4.75 | .690752 | 7.08 |
| 53 | .500393 | 4.85 | .665663 | 7.10 | 53 | .517668 | 4.73 | .691177 | 7.07 |
| 54 | .500684 | 4.85 | .666089 | 7.10 | 54 | .517952 | 4.73 | .691601 | 7.07 |
| 55 | .500975 | 4.85 | .666515 | 7.12 | 55 | .518236 | 4.75 | .692025 | 7.07 |
| 56 | .501266 | 4.85 | .666942 | 7.10 | 56 | .518521 | 4.73 | .692449 | 7.07 |
| 57 | .501557 | 4.85 | .667368 | 7.10 | 57 | .518805 | 4.73 | .692873 | 7.08 |
| 58 | .501848 | 4.85 | .667794 | 7.10 | 58 | .519089 | 4.73 | .693298 | 7.07 |
| 59 | .502139 | 4.83 | .668220 | 7.10 | 59 | .519373 | 4.73 | .693722 | 7.07 |
| 60 | 9.502429 | 4.85 | 9.668646 | 7.10 | 60 | 9.519657 | 4.72 | 9.694146 | 7.07 |

| 48° | | | | | 49° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.519657 | 4.72 | 9.694146 | 7.07 | 0 | 9.536484 | 4.62 | 9.719541 | 7.05 |
| 1 | .519940 | 4.73 | .694570 | 7.07 | 1 | .536761 | 4.62 | .719964 | 7.03 |
| 2 | .520224 | 4.72 | .694994 | 7.07 | 2 | .537038 | 4.62 | .720386 | 7.05 |
| 3 | .520507 | 4.73 | .695418 | 7.07 | 3 | .537315 | 4.62 | .720809 | 7.03 |
| 4 | .520791 | 4.72 | .695842 | 7.07 | 4 | .537592 | 4.62 | .721231 | 7.03 |
| 5 | .521074 | 4.72 | .696266 | 7.05 | 5 | .537869 | 4.60 | .721653 | 7.05 |
| 6 | .521357 | 4.72 | .696689 | 7.07 | 6 | .538145 | 4.62 | .722076 | 7.03 |
| 7 | .521640 | 4.72 | .697113 | 7.07 | 7 | .538422 | 4.60 | .722498 | 7.05 |
| 8 | .521923 | 4.72 | .697537 | 7.07 | 8 | .538698 | 4.60 | .722921 | 7.03 |
| 9 | .522206 | 4.70 | .697961 | 7.07 | 9 | .538974 | 4.62 | .723343 | 7.03 |
| 10 | .522488 | 4.72 | .698385 | 7.07 | 10 | .539251 | 4.60 | .723765 | 7.05 |
| 11 | 9.522771 | 4.72 | 9.698809 | 7.05 | 11 | 9.539527 | 4.60 | 9.724188 | 7.03 |
| 12 | .523054 | 4.70 | .699232 | 7.07 | 12 | .539803 | 4.60 | .724610 | 7.03 |
| 13 | .523336 | 4.70 | .699656 | 7.07 | 13 | .540079 | 4.58 | .725032 | 7.03 |
| 14 | .523618 | 4.70 | .700080 | 7.05 | 14 | .540354 | 4.60 | .725454 | 7.05 |
| 15 | .523900 | 4.70 | .700503 | 7.07 | 15 | .540630 | 4.60 | .725877 | 7.03 |
| 16 | .524182 | 4.70 | .700927 | 7.05 | 16 | .540906 | 4.58 | .726299 | 7.03 |
| 17 | .524464 | 4.70 | .701350 | 7.07 | 17 | .541181 | 4.58 | .726721 | 7.03 |
| 18 | .524746 | 4.70 | .701774 | 7.07 | 18 | .541456 | 4.60 | .727143 | 7.03 |
| 19 | .525028 | 4.68 | .702198 | 7.05 | 19 | .541732 | 4.58 | .727565 | 7.05 |
| 20 | .525309 | 4.70 | .702621 | 7.07 | 20 | .542007 | 4.58 | .727988 | 7.03 |
| 21 | 9.525591 | 4.68 | 9.703045 | 7.05 | 21 | 9.542282 | 4.58 | 9.728410 | 7.03 |
| 22 | .525872 | 4.68 | .703468 | 7.05 | 22 | .542557 | 4.58 | .728832 | 7.03 |
| 23 | .526153 | 4.70 | .703891 | 7.07 | 23 | .542832 | 4.57 | .729254 | 7.03 |
| 24 | .526435 | 4.68 | .704315 | 7.05 | 24 | .543106 | 4.58 | .729676 | 7.03 |
| 25 | .526716 | 4.68 | .704738 | 7.07 | 25 | .543381 | 4.57 | .730098 | 7.03 |
| 26 | .526997 | 4.67 | .705162 | 7.05 | 26 | .543655 | 4.58 | .730520 | 7.03 |
| 27 | .527277 | 4.68 | .705585 | 7.05 | 27 | .543930 | 4.57 | .730942 | 7.03 |
| 28 | .527558 | 4.68 | .706008 | 7.05 | 28 | .544204 | 4.57 | .731364 | 7.03 |
| 29 | .527839 | 4.67 | .706431 | 7.07 | 29 | .544478 | 4.57 | .731786 | 7.03 |
| 30 | .528119 | 4.68 | .706855 | 7.05 | 30 | .544752 | 4.57 | .732208 | 7.03 |
| 31 | 9.528400 | 4.67 | 9.707278 | 7.05 | 31 | 9.545026 | 4.57 | 9.732630 | 7.03 |
| 32 | .528680 | 4.67 | .707701 | 7.05 | 32 | .545300 | 4.57 | .733052 | 7.03 |
| 33 | .528960 | 4.67 | .708124 | 7.05 | 33 | .545574 | 4.57 | .733474 | 7.03 |
| 34 | .529240 | 4.67 | .708547 | 7.07 | 34 | .545848 | 4.55 | .733896 | 7.02 |
| 35 | .529520 | 4.67 | .708971 | 7.05 | 35 | .546121 | 4.57 | .734317 | 7.03 |
| 36 | .529800 | 4.67 | .709394 | 7.05 | 36 | .546395 | 4.55 | .734739 | 7.03 |
| 37 | .530080 | 4.65 | .709817 | 7.05 | 37 | .546668 | 4.55 | .735161 | 7.03 |
| 38 | .530359 | 4.67 | .710240 | 7.05 | 38 | .546941 | 4.55 | .735583 | 7.03 |
| 39 | .530639 | 4.65 | .710663 | 7.05 | 39 | .547214 | 4.55 | .736005 | 7.03 |
| 40 | .530918 | 4.67 | .711086 | 7.05 | 40 | .547487 | 4.55 | .736427 | 7.02 |
| 41 | 9.531198 | 4.65 | 9.711509 | 7.05 | 41 | 9.547760 | 4.55 | 9.736848 | 7.03 |
| 42 | .531477 | 4.65 | .711932 | 7.05 | 42 | .548033 | 4.55 | .737270 | 7.03 |
| 43 | .531756 | 4.65 | .712355 | 7.05 | 43 | .548306 | 4.55 | .737692 | 7.03 |
| 44 | .532035 | 4.65 | .712778 | 7.03 | 44 | .548579 | 4.53 | .738114 | 7.02 |
| 45 | .532314 | 4.63 | .713200 | 7.05 | 45 | .548851 | 4.55 | .738535 | 7.03 |
| 46 | .532592 | 4.65 | .713623 | 7.05 | 46 | .549124 | 4.53 | .738957 | 7.03 |
| 47 | .532871 | 4.65 | .714046 | 7.05 | 47 | .549396 | 4.53 | .739379 | 7.02 |
| 48 | .533150 | 4.63 | .714469 | 7.05 | 48 | .549668 | 4.53 | .739800 | 7.03 |
| 49 | .533428 | 4.63 | .714892 | 7.05 | 49 | .549940 | 4.53 | .740222 | 7.03 |
| 50 | .533706 | 4.65 | .715315 | 7.03 | 50 | .550212 | 4.53 | .740644 | 7.02 |
| 51 | 9.533985 | 4.63 | 9.715737 | 7.05 | 51 | 9.550484 | 4.53 | 9.741065 | 7.03 |
| 52 | .534263 | 4.63 | .716160 | 7.05 | 52 | .550756 | 4.53 | .741487 | 7.02 |
| 53 | .534541 | 4.63 | .716583 | 7.03 | 53 | .551028 | 4.52 | .741908 | 7.03 |
| 54 | .534819 | 4.63 | .717005 | 7.05 | 54 | .551299 | 4.53 | .742330 | 7.02 |
| 55 | .535097 | 4.62 | .717428 | 7.05 | 55 | .551571 | 4.52 | .742751 | 7.03 |
| 56 | .535374 | 4.63 | .717851 | 7.03 | 56 | .551842 | 4.52 | .743173 | 7.03 |
| 57 | .535652 | 4.62 | .718273 | 7.05 | 57 | .552113 | 4.52 | .743595 | 7.02 |
| 58 | .535929 | 4.63 | .718696 | 7.03 | 58 | .552384 | 4.53 | .744016 | 7.03 |
| 59 | .536207 | 4.62 | .719118 | 7.05 | 59 | .552656 | 4.52 | .744438 | 7.02 |
| 60 | 9.536484 | 4.62 | 9.719541 | 7.05 | 60 | 9.552927 | 4.50 | 9.744859 | 7.02 |

| 50° | | | | |
|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.552927 | 4.50 | 9.744859 | 7.02 |
| 1 | .553197 | 4.52 | .745280 | 7.03 |
| 2 | .553468 | 4.52 | .745702 | 7.02 |
| 3 | .553739 | 4.50 | .746123 | 7.03 |
| 4 | .554009 | 4.52 | .746545 | 7.02 |
| 5 | .554280 | 4.50 | .746966 | 7.03 |
| 6 | .554550 | 4.50 | .747388 | 7.02 |
| 7 | .554820 | 4.52 | .747809 | 7.02 |
| 8 | .555091 | 4.50 | .748230 | 7.03 |
| 9 | .555361 | 4.50 | .748652 | 7.02 |
| 10 | .555631 | 4.48 | .749073 | 7.02 |
| 11 | 9.555900 | 4.50 | 9.749494 | 7.03 |
| 12 | .556170 | 4.50 | .749916 | 7.02 |
| 13 | .556440 | 4.48 | .750337 | 7.02 |
| 14 | .556709 | 4.50 | .750758 | 7.03 |
| 15 | .556979 | 4.48 | .751180 | 7.02 |
| 16 | .557248 | 4.48 | .751601 | 7.02 |
| 17 | .557517 | 4.48 | .752022 | 7.02 |
| 18 | .557786 | 4.48 | .752443 | 7.03 |
| 19 | .558055 | 4.48 | .752865 | 7.02 |
| 20 | .558324 | 4.48 | .753286 | 7.02 |
| 21 | 9.558593 | 4.48 | 9.753707 | 7.02 |
| 22 | .558862 | 4.48 | .754128 | 7.02 |
| 23 | .559131 | 4.47 | .754549 | 7.03 |
| 24 | .559399 | 4.47 | .754971 | 7.02 |
| 25 | .559667 | 4.48 | .755392 | 7.02 |
| 26 | .559936 | 4.47 | .755813 | 7.02 |
| 27 | .560204 | 4.47 | .756234 | 7.02 |
| 28 | .560472 | 4.47 | .756655 | 7.02 |
| 29 | .560740 | 4.47 | .757076 | 7.03 |
| 30 | .561008 | 4.47 | .757498 | 7.02 |
| 31 | 9.561276 | 4.47 | 9.757919 | 7.02 |
| 32 | .561544 | 4.45 | .758340 | 7.02 |
| 33 | .561811 | 4.47 | .758761 | 7.02 |
| 34 | .562079 | 4.45 | .759182 | 7.02 |
| 35 | .562346 | 4.45 | .759603 | 7.02 |
| 36 | .562613 | 4.47 | .760024 | 7.02 |
| 37 | .562881 | 4.45 | .760445 | 7.02 |
| 38 | .563148 | 4.45 | .760866 | 7.02 |
| 39 | .563415 | 4.45 | .761287 | 7.02 |
| 40 | .563682 | 4.43 | .761708 | 7.02 |
| 41 | 9.563948 | 4.45 | 9.762129 | 7.02 |
| 42 | .564215 | 4.45 | .762550 | 7.02 |
| 43 | .564482 | 4.43 | .762971 | 7.02 |
| 44 | .564748 | 4.45 | .763392 | 7.02 |
| 45 | .565015 | 4.43 | .763813 | 7.02 |
| 46 | .565281 | 4.43 | .764234 | 7.02 |
| 47 | .565547 | 4.43 | .764655 | 7.02 |
| 48 | .565813 | 4.43 | .765076 | 7.02 |
| 49 | .566079 | 4.43 | .765497 | 7.02 |
| 50 | .566345 | 4.43 | .765918 | 7.02 |
| 51 | 9.566611 | 4.43 | 9.766339 | 7.02 |
| 52 | .566877 | 4.42 | .766760 | 7.02 |
| 53 | .567142 | 4.43 | .767181 | 7.02 |
| 54 | .567408 | 4.42 | .767602 | 7.00 |
| 55 | .567673 | 4.42 | .768022 | 7.02 |
| 56 | .567938 | 4.43 | .768443 | 7.02 |
| 57 | .568204 | 4.42 | .768864 | 7.02 |
| 58 | .568469 | 4.42 | .769285 | 7.02 |
| 59 | .568734 | 4.42 | .769706 | 7.02 |
| 60 | 9.568999 | 4.42 | 9.770127 | 7.02 |

| 51° | | | | |
|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.568999 | 4.42 | 9.770127 | 7.02 |
| 1 | .569264 | 4.40 | .770548 | 7.02 |
| 2 | .569528 | 4.42 | .770969 | 7.00 |
| 3 | .569793 | 4.40 | .771389 | 7.02 |
| 4 | .570057 | 4.42 | .771810 | 7.02 |
| 5 | .570322 | 4.40 | .772231 | 7.02 |
| 6 | .570586 | 4.40 | .772652 | 7.02 |
| 7 | .570850 | 4.40 | .773073 | 7.02 |
| 8 | .571114 | 4.40 | .773494 | 7.00 |
| 9 | .571378 | 4.40 | .773914 | 7.02 |
| 10 | .571642 | 4.40 | .774335 | 7.02 |
| 11 | 9.571906 | 4.40 | 9.774756 | 7.02 |
| 12 | .572170 | 4.40 | .775177 | 7.02 |
| 13 | .572434 | 4.38 | .775598 | 7.00 |
| 14 | .572697 | 4.38 | .776018 | 7.02 |
| 15 | .572960 | 4.40 | .776439 | 7.02 |
| 16 | .573224 | 4.38 | .776860 | 7.02 |
| 17 | .573487 | 4.38 | .777281 | 7.02 |
| 18 | .573750 | 4.38 | .777702 | 7.00 |
| 19 | .574013 | 4.38 | .778122 | 7.02 |
| 20 | .574276 | 4.38 | .778543 | 7.02 |
| 21 | 9.574539 | 4.38 | 9.778964 | 7.02 |
| 22 | .574802 | 4.37 | .779385 | 7.00 |
| 23 | .575064 | 4.38 | .779805 | 7.02 |
| 24 | .575327 | 4.37 | .780226 | 7.02 |
| 25 | .575589 | 4.38 | .780647 | 7.02 |
| 26 | .575852 | 4.37 | .781068 | 7.00 |
| 27 | .576114 | 4.37 | .781488 | 7.02 |
| 28 | .576376 | 4.37 | .781909 | 7.02 |
| 29 | .576638 | 4.37 | .782330 | 7.02 |
| 30 | .576900 | 4.37 | .782751 | 7.00 |
| 31 | 9.577162 | 4.37 | 9.783171 | 7.02 |
| 32 | .577424 | 4.35 | .783592 | 7.02 |
| 33 | .577685 | 4.37 | .784013 | 7.00 |
| 34 | .577947 | 4.35 | .784433 | 7.02 |
| 35 | .578208 | 4.37 | .784854 | 7.02 |
| 36 | .578470 | 4.35 | .785275 | 7.02 |
| 37 | .578731 | 4.35 | .785696 | 7.00 |
| 38 | .578992 | 4.35 | .786116 | 7.02 |
| 39 | .579253 | 4.35 | .786537 | 7.02 |
| 40 | .579514 | 4.35 | .786958 | 7.00 |
| 41 | 9.579775 | 4.35 | 9.787378 | 7.02 |
| 42 | .580036 | 4.35 | .787799 | 7.02 |
| 43 | .580297 | 4.33 | .788220 | 7.02 |
| 44 | .580557 | 4.35 | .788641 | 7.00 |
| 45 | .580818 | 4.33 | .789061 | 7.02 |
| 46 | .581078 | 4.35 | .789482 | 7.02 |
| 47 | .581339 | 4.33 | .789903 | 7.00 |
| 48 | .581599 | 4.33 | .790323 | 7.02 |
| 49 | .581859 | 4.33 | .790744 | 7.02 |
| 50 | .582119 | 4.33 | .791165 | 7.02 |
| 51 | 9.582379 | 4.33 | 9.791586 | 7.00 |
| 52 | .582639 | 4.32 | .792006 | 7.02 |
| 53 | .582898 | 4.33 | .792427 | 7.02 |
| 54 | .583158 | 4.33 | .792848 | 7.00 |
| 55 | .583418 | 4.32 | .793268 | 7.02 |
| 56 | .583677 | 4.32 | .793689 | 7.02 |
| 57 | .583936 | 4.33 | .794110 | 7.02 |
| 58 | .584196 | 4.32 | .794531 | 7.00 |
| 59 | .584455 | 4.32 | .794951 | 7.02 |
| 60 | 9.584714 | 4.32 | 9.795372 | 7.02 |

# TABLE XXVI.—LOGARITHMIC VERSED SINES

| 52° | | | | | 53° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.584714 | 4.32 | 9.795372 | 7.02 | 0 | 9.600085 | 4.22 | 9.820622 | 7.02 |
| 1 | .584973 | 4.32 | .795793 | 7.00 | 1 | .600338 | 4.22 | .821043 | 7.02 |
| 2 | .585232 | 4.32 | .796213 | 7.02 | 2 | .600591 | 4.23 | .821464 | 7.02 |
| 3 | .585491 | 4.30 | .796634 | 7.02 | 3 | .600845 | 4.22 | .821885 | 7.02 |
| 4 | .585749 | 4.32 | .797055 | 7.02 | 4 | .601098 | 4.22 | .822306 | 7.02 |
| 5 | .586008 | 4.30 | .797476 | 7.00 | 5 | .601351 | 4.20 | .822727 | 7.02 |
| 6 | .586266 | 4.32 | .797896 | 7.02 | 6 | .601603 | 4.22 | .823148 | 7.02 |
| 7 | .586525 | 4.30 | .798317 | 7.02 | 7 | .601856 | 4.22 | .823569 | 7.02 |
| 8 | .586783 | 4.30 | .798738 | 7.00 | 8 | .602109 | 4.22 | .823990 | 7.02 |
| 9 | .587041 | 4.30 | .799158 | 7.02 | 9 | .602362 | 4.20 | .824411 | 7.03 |
| 10 | .587299 | 4.30 | .799579 | 7.02 | 10 | .602614 | 4.20 | .824833 | 7.02 |
| 11 | 9.587557 | 4.30 | 9.800000 | 7.02 | 11 | 9.602866 | 4.22 | 9.825254 | 7.02 |
| 12 | .587815 | 4.30 | .800421 | 7.00 | 12 | .603119 | 4.20 | .825675 | 7.02 |
| 13 | .588073 | 4.30 | .800841 | 7.02 | 13 | .603371 | 4.20 | .826096 | 7.02 |
| 14 | .588331 | 4.28 | .801262 | 7.02 | 14 | .603623 | 4.20 | .826517 | 7.02 |
| 15 | .588588 | 4.28 | .801683 | 7.02 | 15 | .603875 | 4.20 | .826938 | 7.03 |
| 16 | .588846 | 4.28 | .802104 | 7.00 | 16 | .604127 | 4.20 | .827360 | 7.02 |
| 17 | .589103 | 4.30 | .802524 | 7.02 | 17 | .604379 | 4.20 | .827781 | 7.02 |
| 18 | .589361 | 4.28 | .802945 | 7.02 | 18 | .604631 | 4.20 | .828202 | 7.02 |
| 19 | .589618 | 4.28 | .803366 | 7.02 | 19 | .604883 | 4.18 | .828623 | 7.02 |
| 20 | .589875 | 4.28 | .803787 | 7.00 | 20 | .605134 | 4.20 | .829044 | 7.03 |
| 21 | 9.590132 | 4.28 | 9.804207 | 7.02 | 21 | 9.605386 | 4.18 | 9.829466 | 7.02 |
| 22 | .590389 | 4.28 | .804628 | 7.02 | 22 | .605637 | 4.18 | .829887 | 7.02 |
| 23 | .590646 | 4.28 | .805049 | 7.02 | 23 | .605888 | 4.20 | .830308 | 7.02 |
| 24 | .590903 | 4.28 | .805470 | 7.02 | 24 | .606140 | 4.18 | .830729 | 7.03 |
| 25 | .591160 | 4.27 | .805891 | 7.00 | 25 | .606391 | 4.18 | .831151 | 7.02 |
| 26 | .591416 | 4.28 | .806311 | 7.02 | 26 | .606642 | 4.18 | .831572 | 7.02 |
| 27 | .591673 | 4.27 | .806732 | 7.02 | 27 | .606893 | 4.18 | .831993 | 7.03 |
| 28 | .591929 | 4.27 | .807153 | 7.02 | 28 | .607144 | 4.17 | .832415 | 7.02 |
| 29 | .592185 | 4.28 | .807574 | 7.02 | 29 | .607394 | 4.18 | .832836 | 7.02 |
| 30 | .592442 | 4.27 | .807995 | 7.00 | 30 | .607645 | 4.18 | .833257 | 7.03 |
| 31 | 9.592698 | 4.27 | 9.808415 | 7.02 | 31 | 9.607896 | 4.17 | 9.833679 | 7.02 |
| 32 | .592954 | 4.27 | .808836 | 7.02 | 32 | .608146 | 4.18 | .834100 | 7.03 |
| 33 | .593210 | 4.27 | .809257 | 7.02 | 33 | .608397 | 4.17 | .834522 | 7.02 |
| 34 | .593466 | 4.25 | .809678 | 7.02 | 34 | .608647 | 4.17 | .834943 | 7.02 |
| 35 | .593721 | 4.27 | .810099 | 7.02 | 35 | .608897 | 4.17 | .835364 | 7.03 |
| 36 | .593977 | 4.27 | .810520 | 7.00 | 36 | .609147 | 4.17 | .835786 | 7.02 |
| 37 | .594233 | 4.25 | .810940 | 7.02 | 37 | .609397 | 4.17 | .836207 | 7.03 |
| 38 | .594488 | 4.25 | .811361 | 7.02 | 38 | .609647 | 4.17 | .836629 | 7.02 |
| 39 | .594743 | 4.27 | .811782 | 7.02 | 39 | .609897 | 4.17 | .837050 | 7.03 |
| 40 | .594999 | 4.25 | .812203 | 7.02 | 40 | .610147 | 4.17 | .837472 | 7.02 |
| 41 | 9.595254 | 4.25 | 9.812624 | 7.02 | 41 | 9.610397 | 4.15 | 9.837893 | 7.03 |
| 42 | .595509 | 4.25 | .813045 | 7.02 | 42 | .610646 | 4.17 | .838315 | 7.02 |
| 43 | .595764 | 4.25 | .813466 | 7.00 | 43 | .610896 | 4.15 | .838736 | 7.03 |
| 44 | .596019 | 4.25 | .813886 | 7.02 | 44 | .611145 | 4.15 | .839158 | 7.02 |
| 45 | .596274 | 4.23 | .814307 | 7.02 | 45 | .611394 | 4.17 | .839579 | 7.03 |
| 46 | .596528 | 4.25 | .814728 | 7.02 | 46 | .611644 | 4.15 | .840001 | 7.03 |
| 47 | .596783 | 4.25 | .815149 | 7.02 | 47 | .611893 | 4.15 | .840423 | 7.02 |
| 48 | .597038 | 4.23 | .815570 | 7.02 | 48 | .612142 | 4.15 | .840844 | 7.03 |
| 49 | .597292 | 4.23 | .815991 | 7.02 | 49 | .612391 | 4.15 | .841266 | 7.02 |
| 50 | .597546 | 4.25 | .816412 | 7.02 | 50 | .612640 | 4.13 | .841687 | 7.03 |
| 51 | 9.597801 | 4.23 | 9.816833 | 7.02 | 51 | 9.612888 | 4.15 | 9.842109 | 7.03 |
| 52 | .598055 | 4.23 | .817254 | 7.02 | 52 | .613137 | 4.15 | .842531 | 7.03 |
| 53 | .598309 | 4.23 | .817675 | 7.02 | 53 | .613386 | 4.13 | .842953 | 7.02 |
| 54 | .598563 | 4.23 | .818096 | 7.02 | 54 | .613634 | 4.15 | .843374 | 7.03 |
| 55 | .598817 | 4.23 | .818517 | 7.02 | 55 | .613883 | 4.13 | .843796 | 7.03 |
| 56 | .599071 | 4.22 | .818938 | 7.02 | 56 | .614131 | 4.13 | .844218 | 7.02 |
| 57 | .599324 | 4.23 | .819359 | 7.02 | 57 | .614379 | 4.13 | .844639 | 7.03 |
| 58 | .599578 | 4.22 | .819780 | 7.02 | 58 | .614627 | 4.15 | .845061 | 7.03 |
| 59 | .599831 | 4.23 | .820201 | 7.02 | 59 | .614876 | 4.13 | .845483 | 7.03 |
| 60 | 9.600085 | 4.22 | 9.820622 | 7.02 | 60 | 9.615124 | 4.12 | 9.845905 | 7.03 |

| 54° | | | | | 55° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.615124 | 4.12 | 9.845905 | 7.03 | 0 | 9.629841 | 4.05 | 9.871250 | 7.05 |
| 1 | .615371 | 4.13 | .846327 | 7.03 | 1 | .630084 | 4.03 | .871673 | 7.05 |
| 2 | .615619 | 4.13 | .846749 | 7.02 | 2 | .630326 | 4.05 | .872096 | 7.05 |
| 3 | .615867 | 4.13 | .847170 | 7.03 | 3 | .630569 | 4.03 | .872519 | 7.05 |
| 4 | .616115 | 4.12 | .847592 | 7.03 | 4 | .630811 | 4.05 | .872942 | 7.07 |
| 5 | .616362 | 4.13 | .848014 | 7.03 | 5 | .631054 | 4.03 | .873366 | 7.05 |
| 6 | .616610 | 4.12 | .848436 | 7.03 | 6 | .631296 | 4.03 | .873789 | 7.05 |
| 7 | .616857 | 4.12 | .848858 | 7.03 | 7 | .631538 | 4.03 | .874212 | 7.07 |
| 8 | .617104 | 4.12 | .849280 | 7.03 | 8 | .631780 | 4.03 | .874636 | 7.05 |
| 9 | .617351 | 4.13 | .849702 | 7.03 | 9 | .632022 | 4.03 | .875059 | 7.05 |
| 10 | .617599 | 4.10 | .850124 | 7.03 | 10 | .632264 | 4.02 | .875482 | 7.07 |
| 11 | 9.617845 | 4.12 | 9.850546 | 7.03 | 11 | 9.632505 | 4.03 | 9.875906 | 7.05 |
| 12 | .618092 | 4.12 | .850968 | 7.03 | 12 | .632747 | 4.03 | .876329 | 7.05 |
| 13 | .618339 | 4.12 | .851390 | 7.03 | 13 | .632989 | 4.02 | .876752 | 7.07 |
| 14 | .618586 | 4.12 | .851812 | 7.03 | 14 | .633230 | 4.03 | .877176 | 7.05 |
| 15 | .618833 | 4.10 | .852234 | 7.03 | 15 | .633472 | 4.02 | .877599 | 7.07 |
| 16 | .619079 | 4.12 | .852656 | 7.03 | 16 | .633713 | 4.02 | .878023 | 7.05 |
| 17 | .619326 | 4.10 | .853078 | 7.03 | 17 | .633954 | 4.03 | .878446 | 7.07 |
| 18 | .619572 | 4.10 | .853500 | 7.05 | 18 | .634196 | 4.02 | .878870 | 7.07 |
| 19 | .619818 | 4.12 | .853923 | 7.03 | 19 | .634437 | 4.02 | .879294 | 7.05 |
| 20 | .620065 | 4.10 | .854345 | 7.03 | 20 | .634678 | 4.02 | .879717 | 7.07 |
| 21 | 9.620311 | 4.10 | 9.854767 | 7.03 | 21 | 9.634919 | 4.00 | 9.880141 | 7.07 |
| 22 | .620557 | 4.10 | .855189 | 7.05 | 22 | .635159 | 4.02 | .880565 | 7.05 |
| 23 | .620803 | 4.08 | .855612 | 7.03 | 23 | .635400 | 4.02 | .880988 | 7.07 |
| 24 | .621048 | 4.10 | .856034 | 7.03 | 24 | .635641 | 4.00 | .881412 | 7.07 |
| 25 | .621294 | 4.10 | .856456 | 7.03 | 25 | .635881 | 4.02 | .881836 | 7.07 |
| 26 | .621540 | 4.10 | .856878 | 7.05 | 26 | .636122 | 4.00 | .882260 | 7.05 |
| 27 | .621786 | 4.08 | .857301 | 7.03 | 27 | .636362 | 4.02 | .882683 | 7.07 |
| 28 | .622031 | 4.08 | .857723 | 7.03 | 28 | .636603 | 4.00 | .883107 | 7.07 |
| 29 | .622276 | 4.10 | .858145 | 7.05 | 29 | .636843 | 4.00 | .883531 | 7.07 |
| 30 | .622522 | 4.08 | .858568 | 7.03 | 30 | .637083 | 4.00 | .883955 | 7.07 |
| 31 | 9.622767 | 4.08 | 9.858990 | 7.05 | 31 | 9.637323 | 4.00 | 9.884379 | 7.07 |
| 32 | .623012 | 4.08 | .859413 | 7.03 | 32 | .637563 | 4.00 | .884803 | 7.07 |
| 33 | .623257 | 4.08 | .859835 | 7.05 | 33 | .637803 | 4.00 | .885227 | 7.07 |
| 34 | .623502 | 4.08 | .860258 | 7.03 | 34 | .638043 | 4.00 | .885651 | 7.07 |
| 35 | .623747 | 4.08 | .860680 | 7.05 | 35 | .638283 | 3.98 | .886075 | 7.07 |
| 36 | .623992 | 4.08 | .861103 | 7.03 | 36 | .638522 | 4.00 | .886499 | 7.07 |
| 37 | .624237 | 4.07 | .861525 | 7.05 | 37 | .638762 | 3.98 | .886923 | 7.07 |
| 38 | .624481 | 4.08 | .861948 | 7.03 | 38 | .639001 | 4.00 | .887347 | 7.08 |
| 39 | .624726 | 4.07 | .862370 | 7.05 | 39 | .639241 | 3.98 | .887772 | 7.07 |
| 40 | .624970 | 4.08 | .862793 | 7.03 | 40 | .639480 | 3.98 | .888196 | 7.07 |
| 41 | 9.625215 | 4 07 | 9.863215 | 7.05 | 41 | 9.639719 | 3.98 | 9.888620 | 7.07 |
| 42 | .625459 | 4.07 | .863638 | 7.05 | 42 | .639958 | 3.98 | .889044 | 7.08 |
| 43 | .625703 | 4.07 | .864061 | 7.03 | 43 | .640197 | 3.98 | .889469 | 7.07 |
| 44 | .625947 | 4.07 | .864483 | 7.05 | 44 | .640436 | 3.98 | .889893 | 7.07 |
| 45 | .626191 | 4.07 | .864906 | 7.05 | 45 | .640675 | 3.98 | .890317 | 7.08 |
| 46 | .626435 | 4.07 | .865329 | 7.05 | 46 | .640914 | 3.98 | .890742 | 7.07 |
| 47 | .626679 | 4.07 | .865752 | 7.03 | 47 | .641153 | 3.97 | .891166 | 7.08 |
| 48 | .626923 | 4.05 | .866174 | 7.05 | 48 | .641391 | 3.98 | .891591 | 7.07 |
| 49 | .627166 | 4.07 | .866597 | 7.05 | 49 | .641630 | 3.97 | .892015 | 7.08 |
| 50 | .627410 | 4.07 | .867020 | 7.05 | 50 | .641868 | 3.98 | .892440 | 7.07 |
| 51 | 9.627654 | 4.05 | 9.867443 | 7.05 | 51 | 9.642107 | 3.97 | 9.892864 | 7.08 |
| 52 | .627897 | 4.05 | .867866 | 7.05 | 52 | .642345 | 3.97 | .893289 | 7.08 |
| 53 | .628140 | 4.07 | .868289 | 7.05 | 53 | .642583 | 3.98 | .893714 | 7.07 |
| 54 | .628384 | 4.05 | .868712 | 7.05 | 54 | .642822 | 3.97 | .894138 | 7.08 |
| 55 | .628627 | 4.05 | .869135 | 7.05 | 55 | .643060 | 3.97 | .894563 | 7.08 |
| 56 | .628870 | 4.05 | .869558 | 7.05 | 56 | .643298 | 3.95 | .894988 | 7.07 |
| 57 | .629113 | 4.05 | .869981 | 7.05 | 57 | .643535 | 3.97 | .895412 | 7.08 |
| 58 | .629356 | 4.03 | .870404 | 7.05 | 58 | .643773 | 3.97 | .895837 | 7.08 |
| 59 | .629598 | 4.05 | .870827 | 7.05 | 59 | .644011 | 3.97 | .896262 | 7.08 |
| 60 | 9.629841 | 4.05 | 9.871250 | 7.05 | 60 | 9.644249 | 3.95 | 9.896687 | 7.08 |

| 56° | | | | | 57° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.644249 | 3.95 | 9.896687 | 7.08 | 0 | 9.658356 | 3.87 | 9.922247 | 7.12 |
| 1 | .644486 | 3.97 | .897112 | 7.08 | 1 | .658588 | 3.88 | .922674 | 7.13 |
| 2 | .644724 | 3.95 | .897537 | 7.08 | 2 | .658821 | 3.87 | .923102 | 7.12 |
| 3 | .644961 | 3.95 | .897962 | 7.08 | 3 | .659053 | 3.88 | .923529 | 7.12 |
| 4 | .645198 | 3.95 | .898387 | 7.08 | 4 | .659286 | 3.87 | .923956 | 7.13 |
| 5 | .645435 | 3.97 | .898812 | 7.08 | 5 | .659518 | 3.87 | .924384 | 7.12 |
| 6 | .645673 | 3.95 | .899237 | 7.08 | 6 | .659750 | 3.88 | .924811 | 7.13 |
| 7 | .645910 | 3.95 | .899662 | 7.08 | 7 | .659983 | 3.87 | .925239 | 7.12 |
| 8 | .646147 | 3.95 | .900087 | 7.08 | 8 | .660215 | 3.87 | .925666 | 7.13 |
| 9 | .646384 | 3.93 | .900512 | 7.10 | 9 | .660447 | 3.87 | .926094 | 7.12 |
| 10 | .646620 | 3.95 | .900938 | 7.08 | 10 | .660679 | 3.85 | .926521 | 7.13 |
| 11 | 9.646857 | 3.95 | 9.901363 | 7.08 | 11 | 9.660910 | 3.87 | 9.926949 | 7.13 |
| 12 | .647094 | 3.93 | .901788 | 7.08 | 12 | .661142 | 3.87 | .927377 | 7.12 |
| 13 | .647330 | 3.95 | .902213 | 7.10 | 13 | .661374 | 3.85 | .927804 | 7.13 |
| 14 | .647567 | 3.93 | .902639 | 7.08 | 14 | .661605 | 3.87 | .928232 | 7.13 |
| 15 | .647803 | 3.93 | .903064 | 7.10 | 15 | .661837 | 3.85 | .928660 | 7.13 |
| 16 | .648039 | 3.95 | .903490 | 7.08 | 16 | .662068 | 3.87 | .929088 | 7.13 |
| 17 | .648276 | 3.93 | .903915 | 7.10 | 17 | .662300 | 3.85 | .929516 | 7.13 |
| 18 | .648512 | 3.93 | .904341 | 7.08 | 18 | .662531 | 3.85 | .929944 | 7.13 |
| 19 | .648748 | 3.93 | .904766 | 7.10 | 19 | .662762 | 3.85 | .930372 | 7.13 |
| 20 | .648984 | 3.93 | .905192 | 7.08 | 20 | .662993 | 3.85 | .930800 | 7.13 |
| 21 | 9.649220 | 3.93 | 9.905617 | 7.10 | 21 | 9.663224 | 3.85 | 9.931228 | 7.13 |
| 22 | .649456 | 3.92 | .906043 | 7.10 | 22 | .663455 | 3.85 | .931656 | 7.15 |
| 23 | .649691 | 3.93 | .906469 | 7.08 | 23 | .663686 | 3.85 | .932085 | 7.13 |
| 24 | .649927 | 3.93 | .906894 | 7.10 | 24 | .663917 | 3.85 | .932513 | 7.13 |
| 25 | .650163 | 3.92 | .907320 | 7.10 | 25 | .664148 | 3.83 | .932941 | 7.13 |
| 26 | .650398 | 3.92 | .907746 | 7.10 | 26 | .664378 | 3.85 | .933369 | 7.15 |
| 27 | .650633 | 3.93 | .908172 | 7.10 | 27 | .664609 | 3.83 | .933798 | 7.13 |
| 28 | .650869 | 3.92 | .908598 | 7.10 | 28 | .664839 | 3.85 | .934226 | 7.15 |
| 29 | .651104 | 3.92 | .909024 | 7.10 | 29 | .665070 | 3.83 | .934655 | 7.13 |
| 30 | .651339 | 3.92 | .909450 | 7.10 | 30 | .665300 | 3.83 | .935083 | 7.15 |
| 31 | 9.651574 | 3.92 | 9.909876 | 7.10 | 31 | 9.665530 | 3.83 | 9.935512 | 7.15 |
| 32 | .651809 | 3.92 | .910302 | 7.10 | 32 | .665760 | 3.83 | .935941 | 7.13 |
| 33 | .652044 | 3.92 | .910728 | 7.10 | 33 | .665990 | 3.83 | .936369 | 7.15 |
| 34 | .652279 | 3.92 | .911154 | 7.10 | 34 | .666220 | 3.83 | .936798 | 7.15 |
| 35 | .652514 | 3.90 | .911580 | 7.10 | 35 | .666450 | 3.83 | .937227 | 7.15 |
| 36 | .652748 | 3.92 | .912006 | 7.10 | 36 | .666680 | 3.83 | .937656 | 7.15 |
| 37 | .652983 | 3.90 | .912432 | 7.12 | 37 | .666910 | 3.82 | .938085 | 7.13 |
| 38 | .653217 | 3.92 | .912859 | 7.10 | 38 | .667139 | 3.83 | .938513 | 7.15 |
| 39 | .653452 | 3.90 | .913285 | 7.10 | 39 | .667369 | 3.83 | .938942 | 7.15 |
| 40 | .653686 | 3.90 | .913711 | 7.12 | 40 | .667599 | 3.82 | .939371 | 7.17 |
| 41 | 9.653920 | 3.92 | 9.914138 | 7.10 | 41 | 9.667828 | 3.82 | 9.939801 | 7.15 |
| 42 | .654155 | 3.90 | .914564 | 7.12 | 42 | .668057 | 3.83 | .940230 | 7.15 |
| 43 | .654389 | 3.90 | .914991 | 7.10 | 43 | .668287 | 3.82 | .940659 | 7.15 |
| 44 | .654623 | 3.90 | .915417 | 7.12 | 44 | .668516 | 3.82 | .941088 | 7.15 |
| 45 | .654857 | 3.88 | .915844 | 7.10 | 45 | .668745 | 3.82 | .941517 | 7.17 |
| 46 | .655090 | 3.90 | .916270 | 7.12 | 46 | .668974 | 3.82 | .941947 | 7.15 |
| 47 | .655324 | 3.90 | .916697 | 7.12 | 47 | .669203 | 3.82 | .942376 | 7.15 |
| 48 | .655558 | 3.90 | .917124 | 7.10 | 48 | .669432 | 3.82 | .942806 | 7.15 |
| 49 | .655792 | 3.88 | .917550 | 7.12 | 49 | .669661 | 3.80 | .943235 | 7.17 |
| 50 | .656025 | 3.88 | .917977 | 7.12 | 50 | .669889 | 3.82 | .943665 | 7.15 |
| 51 | 9.656258 | 3.90 | 9.918404 | 7.12 | 51 | 9.670118 | 3.82 | 9.944094 | 7.17 |
| 52 | .656492 | 3.88 | .918831 | 7.12 | 52 | .670347 | 3.80 | .944524 | 7.15 |
| 53 | .656725 | 3.88 | .919258 | 7.12 | 53 | .670575 | 3.82 | .944953 | 7.17 |
| 54 | .656958 | 3.88 | .919685 | 7.12 | 54 | .670804 | 3.80 | .945383 | 7.17 |
| 55 | .657191 | 3.88 | .920112 | 7.12 | 55 | .671032 | 3.80 | .945813 | 7.17 |
| 56 | .657424 | 3.88 | .920539 | 7.12 | 56 | .671260 | 3.80 | .946243 | 7.17 |
| 57 | .657657 | 3.88 | .920966 | 7.12 | 57 | .671488 | 3.80 | .946673 | 7.17 |
| 58 | .657890 | 3.88 | .921393 | 7.12 | 58 | .671716 | 3.82 | .947103 | 7.17 |
| 59 | .658123 | 3.88 | .921820 | 7.12 | 59 | .671945 | 3.78 | .947533 | 7.17 |
| 60 | 9.658356 | 3.87 | 9.922247 | 7.12 | 60 | 9.672172 | 3.80 | 9.947963 | 7.17 |

| | 58° | | | | | 59° | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.672172 | 3.80 | 9.947963 | 7.17 | 0 | 9.685708 | 3.72 | 9.973868 | 7.23 |
| 1 | .672400 | 3.80 | .948393 | 7.17 | 1 | .685931 | 3.72 | .974302 | 7.23 |
| 2 | .672628 | 3.80 | .948823 | 7.17 | 2 | .686154 | 3.72 | .974736 | 7.22 |
| 3 | .672856 | 3.78 | .949253 | 7.17 | 3 | .686377 | 3.72 | .975169 | 7.23 |
| 4 | .673083 | 3.80 | .949683 | 7.18 | 4 | .686600 | 3.72 | .975603 | 7.23 |
| 5 | .673311 | 3.78 | .950114 | 7.17 | 5 | .686823 | 3.72 | .976037 | 7.23 |
| 6 | .673538 | 3.80 | .950544 | 7.18 | 6 | .687046 | 3.72 | .976471 | 7.23 |
| 7 | .673766 | 3.78 | .950975 | 7.17 | 7 | .687269 | 3.72 | .976905 | 7.23 |
| 8 | .673993 | 3.78 | .951405 | 7.18 | 8 | .687492 | 3.70 | .977339 | 7.23 |
| 9 | .674220 | 3.80 | .951836 | 7.17 | 9 | .687714 | 3.72 | .977773 | 7.23 |
| 10 | .674448 | 3.78 | .952266 | 7.18 | 10 | .687937 | 3.70 | .978207 | 7.23 |
| 11 | 9.674675 | 3.78 | 9.952697 | 7.18 | 11 | 9.688159 | 3.72 | 9.978641 | 7.23 |
| 12 | .674902 | 3.78 | .953128 | 7.17 | 12 | .688382 | 3.70 | .979075 | 7.25 |
| 13 | .675129 | 3.78 | .953558 | 7.18 | 13 | .688604 | 3.70 | .979510 | 7.23 |
| 14 | .675356 | 3.77 | .953989 | 7.18 | 14 | .688826 | 3.70 | .979944 | 7.25 |
| 15 | .675582 | 3.78 | .954420 | 7.18 | 15 | .689048 | 3.72 | .980379 | 7.23 |
| 16 | .675809 | 3.78 | .954851 | 7.18 | 16 | .689271 | 3.70 | .980813 | 7.25 |
| 17 | .676036 | 3.77 | .955282 | 7.18 | 17 | .689493 | 3.70 | .981248 | 7.23 |
| 18 | .676262 | 3.78 | .955713 | 7.18 | 18 | .689715 | 3.70 | .981682 | 7.25 |
| 19 | .676489 | 3.77 | .956144 | 7.18 | 19 | .689937 | 3.68 | .982117 | 7.25 |
| 20 | .676715 | 3.77 | .956575 | 7.18 | 20 | .690158 | 3.70 | .982552 | 7 25 |
| 21 | 9.676941 | 3.78 | 9.957006 | 7.20 | 21 | 9.690380 | 3.70 | 9.982987 | 7.25 |
| 22 | .677168 | 3.77 | .957438 | 7.18 | 22 | .690602 | 3.68 | .983422 | 7.25 |
| 23 | .677394 | 3.77 | .957869 | 7.18 | 23 | .690823 | 3.70 | .983857 | 7.25 |
| 24 | .677620 | 3.77 | .958300 | 7.20 | 24 | .691045 | 3.68 | .984292 | 7.25 |
| 25 | .677846 | 3.77 | .958732 | 7.18 | 25 | .691266 | 3.70 | .984727 | 7.25 |
| 26 | .678072 | 3.77 | .959163 | 7.20 | 26 | .691488 | 3.68 | .985162 | 7.25 |
| 27 | .678298 | 3.75 | .959595 | 7.18 | 27 | .691709 | 3.68 | .985597 | 7.27 |
| 28 | .678523 | 3.77 | .960026 | 7.20 | 28 | .691930 | 3.68 | .986033 | 7.25 |
| 29 | .678749 | 3.77 | .960458 | 7.20 | 29 | .692151 | 3.68 | .986468 | 7.27 |
| 30 | .678975 | 3.75 | .960890 | 7.18 | 30 | .692372 | 3.68 | .986904 | 7.25 |
| 31 | 9.679200 | 3.77 | 9.961321 | 7.20 | 31 | 9.692593 | 3.68 | 9.987339 | 7.27 |
| 32 | .679426 | 3.75 | .961753 | 7.20 | 32 | .692814 | 3.68 | .987775 | 7.25 |
| 33 | .679651 | 3.75 | .962185 | 7.20 | 33 | .693035 | 3.68 | .988210 | 7.27 |
| 34 | .679876 | 3.77 | .962617 | 7.20 | 34 | .693256 | 3.68 | .988646 | 7.27 |
| 35 | .680102 | 3.75 | .963049 | 7.20 | 35 | .693477 | 3.67 | .989082 | 7.27 |
| 36 | .680327 | 3.75 | .963481 | 7.20 | 36 | .693697 | 3.68 | .989518 | 7.27 |
| 37 | .680552 | 3.75 | .963913 | 7.20 | 37 | .693918 | 3.67 | .989954 | 7.27 |
| 38 | .680777 | 3.75 | .964345 | 7.22 | 38 | .694138 | 3.68 | .990390 | 7.27 |
| 39 | .681002 | 3.75 | .964778 | 7.20 | 39 | .694359 | 3.67 | .990826 | 7.27 |
| 40 | .681227 | 3.73 | .965210 | 7.20 | 40 | .694579 | 3.67 | .991262 | 7.27 |
| 41 | 9.681451 | 3.75 | 9.965642 | 7.22 | 41 | 9.694799 | 3.67 | 9.991698 | 7.27 |
| 42 | .681676 | 3.75 | .966075 | 7.20 | 42 | .695019 | 3.68 | .992134 | 7.28 |
| 43 | .681901 | 3.73 | .966507 | 7.22 | 43 | .695240 | 3.67 | .992571 | 7.27 |
| 44 | .682125 | 3.75 | .966940 | 7.20 | 44 | .695460 | 3.67 | .993007 | 7.28 |
| 45 | .682350 | 3.73 | .967372 | 7.22 | 45 | .695680 | 3.65 | .993444 | 7.27 |
| 46 | .682574 | 3.73 | .967805 | 7.22 | 46 | .695899 | 3.67 | .993880 | 7.28 |
| 47 | .682798 | 3.75 | .968238 | 7.20 | 47 | .696119 | 3.67 | .994317 | 7.28 |
| 48 | .683023 | 3.73 | .968670 | 7.22 | 48 | .696339 | 3.67 | .994754 | 7.28 |
| 49 | .683247 | 3.73 | .969103 | 7.22 | 49 | .696559 | 3.65 | .995191 | 7.27 |
| 50 | .683471 | 3.73 | .969536 | 7.22 | 50 | .696778 | 3.67 | .995627 | 7.28 |
| 51 | 9.683695 | 3.73 | 9.969969 | 7.22 | 51 | 9.696998 | 3.65 | 9.996064 | 7.28 |
| 52 | .683919 | 3.73 | .970402 | 7.22 | 52 | .697217 | 3.67 | .996501 | 7.28 |
| 53 | .684143 | 3.73 | .970835 | 7.22 | 53 | .697437 | 3.65 | .996938 | 7.30 |
| 54 | .684367 | 3.72 | .971268 | 7.22 | 54 | .697656 | 3.65 | .997376 | 7.28 |
| 55 | .684590 | 3.73 | .971701 | 7.23 | 55 | .697875 | 3.65 | .997813 | 7.28 |
| 56 | .684814 | 3.72 | .972135 | 7.22 | 56 | .698094 | 3.65 | .998250 | 7.28 |
| 57 | .685037 | 3.73 | .972568 | 7.22 | 57 | .698313 | 3.65 | .998687 | 7.30 |
| 58 | .685261 | 3.72 | .973001 | 7.23 | 58 | .698532 | 3.65 | .999125 | 7.28 |
| 59 | .685484 | 3.73 | .973435 | 7.22 | 59 | .698751 | 3.65 | 9.999562 | 7.30 |
| 60 | 9.685708 | 3.72 | 9.973868 | 7.23 | 60 | 9.698970 | 3.63 | 10.000000 | 7.30 |

| 60° | | | | | 61° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.698970 | 3.65 | 10.000000 | 7.30 | 0 | 9.711968 | 3.57 | 10.026397 | 7.37 |
| 1 | .699189 | 3.63 | .000438 | 7.28 | 1 | .712182 | 3.58 | .026839 | 7.37 |
| 2 | .699407 | 3.65 | .000875 | 7.30 | 2 | .712397 | 3.57 | .027281 | 7.38 |
| 3 | .699626 | 3.65 | .001313 | 7.30 | 3 | .712611 | 3.57 | .027724 | 7.38 |
| 4 | .699845 | 3.63 | .001751 | 7.30 | 4 | .712825 | 3.57 | .028167 | 7.37 |
| 5 | .700063 | 3.65 | .002189 | 7.30 | 5 | .713039 | 3.57 | .028609 | 7.38 |
| 6 | .700282 | 3.63 | .002627 | 7.30 | 6 | .713253 | 3.57 | .029052 | 7.38 |
| 7 | .700500 | 3.63 | .003065 | 7.30 | 7 | .713467 | 3.57 | .029495 | 7.38 |
| 8 | .700718 | 3.63 | .003503 | 7.32 | 8 | .713681 | 3.57 | .029938 | 7.38 |
| 9 | .700936 | 3.63 | .003942 | 7.30 | 9 | .713895 | 3.57 | .030381 | 7.40 |
| 10 | .701154 | 3.63 | .004380 | 7.30 | 10 | .714109 | 3.57 | .030825 | 7.38 |
| 11 | 9.701372 | 3.63 | 10.004818 | 7.32 | 11 | 9.714323 | 3.55 | 10.031268 | 7.38 |
| 12 | .701590 | 3.63 | .005257 | 7.30 | 12 | .714536 | 3.57 | .031711 | 7.40 |
| 13 | .701808 | 3.63 | .005695 | 7.32 | 13 | .714750 | 3.55 | .032155 | 7.38 |
| 14 | .702026 | 3.63 | .006134 | 7.32 | 14 | .714963 | 3.57 | .032598 | 7.40 |
| 15 | .702244 | 3.63 | .006573 | 7.32 | 15 | .715177 | 3.55 | .033042 | 7.40 |
| 16 | .702462 | 3.62 | .007012 | 7.30 | 16 | .715390 | 3.55 | .033486 | 7.38 |
| 17 | .702679 | 3.63 | .007450 | 7.32 | 17 | .715603 | 3.57 | .033929 | 7.40 |
| 18 | .702897 | 3.62 | .007889 | 7.32 | 18 | .715817 | 3.55 | .034373 | 7.40 |
| 19 | .703114 | 3.63 | .008328 | 7.32 | 19 | .716030 | 3.55 | .034817 | 7.40 |
| 20 | .703332 | 3.62 | .008767 | 7.33 | 20 | .716243 | 3.55 | .035261 | 7.40 |
| 21 | 9.703549 | 3.62 | 10.009207 | 7.32 | 21 | 9.716456 | 3.55 | 10.035705 | 7.42 |
| 22 | .703766 | 3.62 | .009646 | 7.32 | 22 | .716669 | 3.55 | .036150 | 7.40 |
| 23 | .703983 | 3.62 | .010085 | 7.33 | 23 | .716882 | 3.55 | .036594 | 7.40 |
| 24 | .704200 | 3.62 | .010525 | 7.32 | 24 | .717095 | 3.53 | .037038 | 7.42 |
| 25 | .704417 | 3.62 | .010964 | 7.33 | 25 | .717307 | 3.55 | .037483 | 7.42 |
| 26 | .704634 | 3.62 | .011404 | 7.32 | 26 | .717520 | 3.53 | .037928 | 7.40 |
| 27 | .704851 | 3.62 | .011843 | 7.33 | 27 | .717732 | 3.55 | .038372 | 7.42 |
| 28 | .705068 | 3.62 | .012283 | 7.33 | 28 | .717945 | 3.53 | .038817 | 7.42 |
| 29 | .705285 | 3.60 | .012723 | 7.33 | 29 | .718157 | 3.55 | .039262 | 7.42 |
| 30 | .705501 | 3.62 | .013163 | 7.33 | 30 | .718370 | 3.53 | .039707 | 7.42 |
| 31 | 9.705718 | 3.62 | 10.013603 | 7.33 | 31 | 9.718582 | 3.53 | 10.040152 | 7.42 |
| 32 | .705935 | 3.60 | .014043 | 7.33 | 32 | .718794 | 3.55 | .040597 | 7.42 |
| 33 | .706151 | 3.60 | .014483 | 7.33 | 33 | .719007 | 3.53 | .041042 | 7.43 |
| 34 | .706367 | 3.62 | .014923 | 7.33 | 34 | .719219 | 3.53 | .041488 | 7.42 |
| 35 | .706584 | 3.60 | .015363 | 7.35 | 35 | .719431 | 3.53 | .041933 | 7.43 |
| 36 | .706800 | 3.60 | .015804 | 7.33 | 36 | .719643 | 3.53 | .042379 | 7.42 |
| 37 | .707016 | 3.60 | .016244 | 7.33 | 37 | .719855 | 3.52 | .042824 | 7.43 |
| 38 | .707232 | 3.60 | .016684 | 7.33 | 38 | .720066 | 3.53 | .043270 | 7.43 |
| 39 | .707448 | 3.60 | .017125 | 7.35 | 39 | .720278 | 3.53 | .043716 | 7.43 |
| 40 | .707664 | 3.60 | .017566 | 7.35 | 40 | .720490 | 3.52 | .044162 | 7.43 |
| 41 | 9.707880 | 3.60 | 10.018007 | 7.33 | 41 | 9.720701 | 3.53 | 10.044608 | 7.43 |
| 42 | .708096 | 3.58 | .018447 | 7.35 | 42 | .720913 | 3.52 | .045054 | 7.43 |
| 43 | .708311 | 3.60 | .018888 | 7.35 | 43 | .721124 | 3.53 | .045500 | 7.43 |
| 44 | .708527 | 3.60 | .019329 | 7.35 | 44 | .721336 | 3.52 | .045946 | 7.45 |
| 45 | .708743 | 3.58 | .019770 | 7.37 | 45 | .721547 | 3.52 | .046393 | 7.43 |
| 46 | .708958 | 3.60 | .020212 | 7.35 | 46 | .721758 | 3.53 | .046839 | 7.45 |
| 47 | .709174 | 3.58 | .020653 | 7.35 | 47 | .721970 | 3.52 | .047286 | 7.43 |
| 48 | .709389 | 3.58 | .021094 | 7.35 | 48 | .722181 | 3.52 | .047732 | 7.45 |
| 49 | .709604 | 3.58 | .021535 | 7.37 | 49 | .722392 | 3.52 | .048179 | 7.45 |
| 50 | .709819 | 3.58 | .021977 | 7.37 | 50 | .722603 | 3.52 | .048626 | 7.45 |
| 51 | 9.710035 | 3.58 | 10.022419 | 7.35 | 51 | 9.722814 | 3.50 | 10.049073 | 7.45 |
| 52 | .710250 | 3.58 | .022860 | 7.37 | 52 | .723024 | 3.52 | .049520 | 7.45 |
| 53 | .710465 | 3.58 | .023302 | 7.37 | 53 | .723235 | 3.52 | .049967 | 7.45 |
| 54 | .710680 | 3.58 | .023744 | 7.37 | 54 | .723446 | 3.52 | .050414 | 7.45 |
| 55 | .710895 | 3.57 | .024186 | 7.37 | 55 | .723657 | 3.50 | .050861 | 7.47 |
| 56 | .711109 | 3.58 | .024628 | 7.37 | 56 | .723867 | 3.52 | .051309 | 7.45 |
| 57 | .711324 | 3.58 | .025070 | 7.37 | 57 | .724078 | 3.50 | .051756 | 7.47 |
| 58 | .711539 | 3.57 | .025512 | 7.37 | 58 | .724288 | 3.50 | .052204 | 7.47 |
| 59 | .711753 | 3.58 | .025954 | 7.38 | 59 | .724498 | 3.52 | .052652 | 7.45 |
| 60 | 9.711968 | 3.57 | 10.026397 | 7.37 | 60 | 9.724709 | 3.50 | 10.053099 | 7.47 |

| 62° | | | | | 63° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.724709 | 3.50 | 10.053099 | 7.47 | 0 | 9.737200 | 3.43 | 10.080153 | 7.58 |
| 1 | .724919 | 3.50 | .053547 | 7.47 | 1 | .737406 | 3.43 | .080608 | 7.57 |
| 2 | .725129 | 3.50 | .053995 | 7.47 | 2 | .737612 | 3.43 | .081062 | 7.57 |
| 3 | .725339 | 3.50 | .054443 | 7.48 | 3 | .737818 | 3.43 | .081516 | 7.58 |
| 4 | .725549 | 3.50 | .054892 | 7.47 | 4 | .738024 | 3.43 | .081971 | 7.57 |
| 5 | .725759 | 3.50 | .055340 | 7.47 | 5 | .738230 | 3.43 | .082425 | 7.58 |
| 6 | .725969 | 3.50 | .055788 | 7.48 | 6 | .738436 | 3.43 | .082880 | 7.58 |
| 7 | .726179 | 3.48 | .056237 | 7.47 | 7 | .738642 | 3.42 | .083335 | 7.58 |
| 8 | .726388 | 3.50 | .056685 | 7.48 | 8 | .738847 | 3.43 | .083790 | 7.58 |
| 9 | .726598 | 3.50 | .057134 | 7.48 | 9 | .739053 | 3.42 | .084245 | 7.58 |
| 10 | .726808 | 3.48 | .057583 | 7.48 | 10 | .739258 | 3.43 | .084700 | 7.58 |
| 11 | 9.727017 | 3.50 | 10.058032 | 7.48 | 11 | 9.739464 | 3.42 | 10.085155 | 7.60 |
| 12 | .727227 | 3.48 | .058481 | 7.48 | 12 | .739669 | 3.43 | .085611 | 7.58 |
| 13 | .727436 | 3.48 | .058930 | 7.48 | 13 | .739875 | 3.42 | .086066 | 7.60 |
| 14 | .727645 | 3.50 | .059379 | 7.48 | 14 | .740080 | 3.42 | .086522 | 7.58 |
| 15 | .727855 | 3.48 | .059828 | 7.50 | 15 | .740285 | 3.42 | .086977 | 7.60 |
| 16 | .728064 | 3.48 | .060278 | 7.48 | 16 | .740490 | 3.42 | .087433 | 7.60 |
| 17 | .728273 | 3.48 | .060727 | 7.50 | 17 | .740695 | 3.42 | .087889 | 7.60 |
| 18 | .728482 | 3.48 | .061177 | 7.48 | 18 | .740900 | 3.42 | .088345 | 7.60 |
| 19 | .728691 | 3.48 | .061626 | 7.50 | 19 | .741105 | 3.42 | .088801 | 7.62 |
| 20 | .728900 | 3.48 | .062076 | 7.50 | 20 | .741310 | 3.42 | .089258 | 7.60 |
| 21 | 9.729109 | 3.47 | 10.062526 | 7.50 | 21 | 9.741515 | 3.40 | 10.089714 | 7.62 |
| 22 | .729317 | 3.48 | .062976 | 7.50 | 22 | .741719 | 3.42 | .090171 | 7.60 |
| 23 | .729526 | 3.48 | .063426 | 7.50 | 23 | .741924 | 3.42 | .090627 | 7.62 |
| 24 | .729735 | 3.47 | .063876 | 7.52 | 24 | .742129 | 3.40 | .091084 | 7.62 |
| 25 | .729943 | 3.48 | .064327 | 7.50 | 25 | .742333 | 3.42 | .091541 | 7.62 |
| 26 | .730152 | 3.47 | .064777 | 7.50 | 26 | .742538 | 3.40 | .091998 | 7.62 |
| 27 | .730360 | 3.48 | .065227 | 7.52 | 27 | .742742 | 3.40 | .092455 | 7.62 |
| 28 | .730569 | 3.47 | .065678 | 7.52 | 28 | .742946 | 3.40 | .092912 | 7.63 |
| 29 | .730777 | 3.47 | .066129 | 7.52 | 29 | .743150 | 3.42 | .093370 | 7.62 |
| 30 | .730985 | 3.47 | .066580 | 7.50 | 30 | .743355 | 3.40 | .093827 | 7.63 |
| 31 | 9.731193 | 3.47 | 10.067030 | 7.53 | 31 | 9.743559 | 3.40 | 10.094285 | 7.63 |
| 32 | .731401 | 3.47 | .067482 | 7.52 | 32 | .743762 | 3.40 | .094743 | 7.62 |
| 33 | .731609 | 3.47 | .067933 | 7.52 | 33 | .743967 | 3.40 | .095200 | 7.63 |
| 34 | .731817 | 3.47 | .068384 | 7.52 | 34 | .744171 | 3.40 | .095658 | 7.63 |
| 35 | .732025 | 3.47 | .068835 | 7.53 | 35 | .744375 | 3.38 | .096116 | 7.65 |
| 36 | .732233 | 3.47 | .069287 | 7.52 | 36 | .744578 | 3.40 | .096575 | 7.63 |
| 37 | .732441 | 3.45 | .069738 | 7.53 | 37 | .744782 | 3.40 | .097033 | 7.63 |
| 38 | .732648 | 3.47 | .070190 | 7.53 | 38 | .744986 | 3.38 | .097491 | 7.65 |
| 39 | .732856 | 3.47 | .070642 | 7.52 | 39 | .745189 | 3.40 | .097950 | 7.63 |
| 40 | .733064 | 3.45 | .071093 | 7.53 | 40 | .745393 | 3.38 | .098408 | 7.65 |
| 41 | 9.733271 | 3.45 | 10.071545 | 7.55 | 41 | 9.745596 | 3.40 | 10.098867 | 7.65 |
| 42 | .733478 | 3.47 | .071998 | 7.53 | 42 | .745800 | 3.38 | .099326 | 7.65 |
| 43 | .733686 | 3.45 | .072450 | 7.53 | 43 | .746003 | 3.38 | .099785 | 7.65 |
| 44 | .733893 | 3.45 | .072902 | 7.53 | 44 | .746206 | 3.38 | .100244 | 7.67 |
| 45 | .734100 | 3.45 | .073354 | 7.55 | 45 | .746409 | 3.40 | .100704 | 7.65 |
| 46 | .734307 | 3.47 | .073807 | 7.55 | 46 | .746613 | 3.38 | .101163 | 7.67 |
| 47 | .734515 | 3.43 | .074260 | 7.53 | 47 | .746816 | 3.38 | .101623 | 7.65 |
| 48 | .734721 | 3.45 | .074712 | 7.55 | 48 | .747019 | 3.38 | .102082 | 7.67 |
| 49 | .734928 | 3.45 | .075165 | 7.55 | 49 | .747222 | 3.37 | .102542 | 7.67 |
| 50 | .735135 | 3.45 | .075618 | 7.55 | 50 | .747424 | 3.38 | .103002 | 7.67 |
| 51 | 9.735342 | 3.45 | 10.076071 | 7.55 | 51 | 9.747627 | 3.38 | 10.103462 | 7.67 |
| 52 | .735549 | 3.43 | .076524 | 7.55 | 52 | .747830 | 3.38 | .103922 | 7.67 |
| 53 | .735755 | 3.45 | .076977 | 7.57 | 53 | .748033 | 3.37 | .104382 | 7.68 |
| 54 | .735962 | 3.45 | .077431 | 7.55 | 54 | .748235 | 3.38 | .104843 | 7.67 |
| 55 | .736169 | 3.43 | .077884 | 7.57 | 55 | .748438 | 3.37 | .105303 | 7.68 |
| 56 | .736375 | 3.43 | .078338 | 7.57 | 56 | .748640 | 3.38 | .105764 | 7.67 |
| 57 | .736581 | 3.45 | .078792 | 7.55 | 57 | .748843 | 3.37 | .106224 | 7.68 |
| 58 | .736788 | 3.43 | .079245 | 7.57 | 58 | .749045 | 3.37 | .106685 | 7.68 |
| 59 | .736994 | 3.43 | .079699 | 7.57 | 59 | .749247 | 3.37 | .107146 | 7.68 |
| 60 | 9.737200 | 3.43 | 10.080153 | 7.58 | 60 | 9.749449 | 3.38 | 10.107607 | 7.70 |

| 64° | | | | | 65° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D.1″. |
| 0 | 9.749449 | 3.38 | 10.107607 | 7.70 | 0 | 9.761463 | 3.30 | 10.135515 | 7.82 |
| 1 | .749652 | 3.37 | .108069 | 7.68 | 1 | .761661 | 3.32 | .135984 | 7.83 |
| 2 | .749854 | 3.37 | .108530 | 7.70 | 2 | .761860 | 3.30 | .136454 | 7.82 |
| 3 | .750056 | 3.37 | .108992 | 7.68 | 3 | .762058 | 3.30 | .136923 | 7.83 |
| 4 | .750258 | 3.35 | .109453 | 7.70 | 4 | .762256 | 3.30 | .137393 | 7.83 |
| 5 | .750459 | 3.37 | .109915 | 7.70 | 5 | .762454 | 3.30 | .137863 | 7.83 |
| 6 | .750661 | 3.37 | .110377 | 7.70 | 6 | .762652 | 3.30 | .138333 | 7.83 |
| 7 | .750863 | 3.37 | .110839 | 7.70 | 7 | .762850 | 3.28 | .138803 | 7.83 |
| 8 | .751065 | 3.35 | .111301 | 7.70 | 8 | .763047 | 3.30 | .139273 | 7.85 |
| 9 | .751266 | 3.37 | .111763 | 7.72 | 9 | .763245 | 3.30 | .139744 | 7.83 |
| 10 | .751468 | 3.35 | .112226 | 7.70 | 10 | .763443 | 3.30 | .140214 | 7.85 |
| 11 | 9.751669 | 3.37 | 10.112688 | 7.72 | 11 | 9.763641 | 3.28 | 10.140685 | 7.85 |
| 12 | .751871 | 3.35 | .113151 | 7.72 | 12 | .763838 | 3.30 | .141156 | 7.85 |
| 13 | .752072 | 3.35 | .113614 | 7.72 | 13 | .764036 | 3.28 | .141627 | 7.85 |
| 14 | .752273 | 3.37 | .114077 | 7.72 | 14 | .764233 | 3.28 | .142098 | 7.85 |
| 15 | .752475 | 3.35 | .114540 | 7.72 | 15 | .764430 | 3.30 | .142569 | 7.87 |
| 16 | .752676 | 3.35 | .115003 | 7.72 | 16 | .764628 | 3.28 | .143041 | 7.85 |
| 17 | .752877 | 3.35 | .115466 | 7.72 | 17 | .764825 | 3.28 | .143512 | 7.87 |
| 18 | .753078 | 3.35 | .115929 | 7.73 | 18 | .765022 | 3.28 | .143984 | 7.87 |
| 19 | .753279 | 3.35 | .116393 | 7.73 | 19 | .765219 | 3.28 | .144456 | 7.87 |
| 20 | .753480 | 3.35 | .116857 | 7.73 | 20 | .765416 | 3.28 | .144928 | 7.87 |
| 21 | 9.753681 | 3.33 | 10.117321 | 7.73 | 21 | 9.765613 | 3.28 | 10.145400 | 7.87 |
| 22 | .753881 | 3.35 | .117785 | 7.73 | 22 | .765810 | 3.28 | .145872 | 7.88 |
| 23 | .754082 | 3.35 | .118249 | 7.73 | 23 | .766007 | 3.28 | .146345 | 7.88 |
| 24 | .754283 | 3.33 | .118713 | 7.73 | 24 | .766204 | 3.28 | .146818 | 7.87 |
| 25 | .754483 | 3.35 | .119177 | 7.75 | 25 | .766401 | 3.27 | .147290 | 7.88 |
| 26 | .754684 | 3.33 | .119642 | 7.73 | 26 | .766597 | 3.28 | .147763 | 7.88 |
| 27 | .754884 | 3.35 | .120106 | 7.75 | 27 | .766794 | 3.28 | .148236 | 7.90 |
| 28 | .755085 | 3.33 | .120571 | 7.75 | 28 | .766991 | 3.27 | .148710 | 7.88 |
| 29 | .755285 | 3.33 | .121036 | 7.75 | 29 | .767187 | 3.28 | .149183 | 7.90 |
| 30 | .755485 | 3.33 | .121501 | 7.75 | 30 | .767384 | 3.27 | .149657 | 7.88 |
| 31 | 9.755685 | 3.35 | 10.121966 | 7.75 | 31 | 9.767580 | 3.27 | 10.150130 | 7.90 |
| 32 | .755886 | 3.33 | .122431 | 7.77 | 32 | .767776 | 3.27 | .150604 | 7.90 |
| 33 | .756086 | 3.33 | .122897 | 7.75 | 33 | .767972 | 3.28 | .151078 | 7.90 |
| 34 | .756286 | 3.33 | .123362 | 7.77 | 34 | .768169 | 3.27 | .151552 | 7.92 |
| 35 | .756486 | 3.32 | .123828 | 7.77 | 35 | .768365 | 3.27 | .152027 | 7.90 |
| 36 | .756685 | 3.33 | .124294 | 7.77 | 36 | .768561 | 3.27 | .152501 | 7.92 |
| 37 | .756885 | 3.33 | .124760 | 7.77 | 37 | .768757 | 3.27 | .152976 | 7.90 |
| 38 | .757085 | 3.33 | .125226 | 7.77 | 38 | .768953 | 3.27 | .153450 | 7.92 |
| 39 | .757285 | 3.32 | .125692 | 7.77 | 39 | .769149 | 3.25 | .153925 | 7.92 |
| 40 | .757484 | 3.33 | .126158 | 7.78 | 40 | .769344 | 3.27 | .154400 | 7.93 |
| 41 | 9.757684 | 3.32 | 10.126625 | 7.78 | 41 | 9.769540 | 3.27 | 10.154876 | 7.92 |
| 42 | .757883 | 3.33 | .127092 | 7.77 | 42 | .769736 | 3.25 | .155351 | 7.92 |
| 43 | .758083 | 3.32 | .127558 | 7.78 | 43 | .769931 | 3.27 | .155826 | 7.93 |
| 44 | .758282 | 3.32 | .128025 | 7.78 | 44 | .770127 | 3.27 | .156302 | 7.93 |
| 45 | .758481 | 3.33 | .128492 | 7.80 | 45 | .770323 | 3.25 | .156778 | 7.93 |
| 46 | .758681 | 3.32 | .128960 | 7.78 | 46 | .770518 | 3.25 | .157254 | 7.93 |
| 47 | .758880 | 3.32 | .129427 | 7.78 | 47 | .770713 | 3.27 | .157730 | 7.93 |
| 48 | .759079 | 3.32 | .129894 | 7.80 | 48 | .770909 | 3.25 | .158206 | 7.95 |
| 49 | .759278 | 3.32 | .130362 | 7.80 | 49 | .771104 | 3.25 | .158683 | 7.93 |
| 50 | .759477 | 3.32 | .130830 | 7.80 | 50 | .771299 | 3.25 | .159159 | 7.95 |
| 51 | 9.759676 | 3.32 | 10.131298 | 7.80 | 51 | 9.771494 | 3.25 | 10.159636 | 7.95 |
| 52 | .759875 | 3.30 | .131766 | 7.80 | 52 | .771689 | 3.25 | .160113 | 7.95 |
| 53 | .760073 | 3.32 | .132234 | 7.80 | 53 | .771884 | 3.25 | .160590 | 7.95 |
| 54 | .760272 | 3.32 | .132702 | 7.80 | 54 | .772079 | 3.25 | .161067 | 7.97 |
| 55 | .760471 | 3.30 | .133170 | 7.82 | 55 | .772274 | 3.25 | .161545 | 7.95 |
| 56 | .760669 | 3.32 | .133639 | 7.82 | 56 | .772469 | 3.25 | .162022 | 7.97 |
| 57 | .760868 | 3.30 | .134108 | 7.82 | 57 | .772664 | 3.23 | .162500 | 7.97 |
| 58 | .761066 | 3.32 | .134577 | 7.82 | 58 | .772858 | 3.25 | .162978 | 7.97 |
| 59 | .761265 | 3.30 | .135046 | 7.82 | 59 | .773053 | 3.25 | .163456 | 7.97 |
| 60 | 9.761463 | 3.30 | 10.135515 | 7.82 | 60 | 9.773248 | 3.23 | 10.163934 | 7.98 |

| 66° | | | | | 67° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D.1″. |
| 0 | 9.773248 | 3.23 | 10.163934 | 7.98 | 0 | 9.784809 | 3.18 | 10.192931 | 8.15 |
| 1 | .773442 | 3.23 | .164413 | 7.97 | 1 | .785000 | 3.18 | .193420 | 8.13 |
| 2 | .773636 | 3.25 | .164891 | 7.98 | 2 | .785191 | 3.17 | .193908 | 8.15 |
| 3 | .773831 | 3.23 | .165370 | 7.98 | 3 | .785381 | 3.18 | .194397 | 8.15 |
| 4 | .774025 | 3.23 | .165849 | 7.98 | 4 | .785572 | 3.18 | .194886 | 8.17 |
| 5 | .774219 | 3.25 | .166328 | 7.98 | 5 | .785763 | 3.17 | .195376 | 8.15 |
| 6 | .774414 | 3.23 | .166807 | 7.98 | 6 | .785953 | 3.18 | .195865 | 8.17 |
| 7 | .774608 | 3.23 | .167286 | 8.00 | 7 | .786144 | 3.17 | .196355 | 8.17 |
| 8 | .774802 | 3.23 | .167766 | 7.98 | 8 | .786334 | 3.17 | .196845 | 8.17 |
| 9 | .774996 | 3.23 | .168245 | 8.00 | 9 | .786524 | 3.18 | .197335 | 8.17 |
| 10 | .775190 | 3.23 | .168725 | 8.00 | 10 | .786715 | 3.17 | .197825 | 8.17 |
| 11 | 9.775384 | 3.22 | 10.169205 | 8.00 | 11 | 9.786905 | 3.17 | 10.198315 | 8.18 |
| 12 | .775577 | 3.23 | .169685 | 8.00 | 12 | .787095 | 3.17 | .198806 | 8.18 |
| 13 | .775771 | 3.23 | .170165 | 8.02 | 13 | .787285 | 3.17 | .199297 | 8.18 |
| 14 | .775965 | 3.23 | .170646 | 8.02 | 14 | .787475 | 3.17 | .199788 | 8.18 |
| 15 | .776159 | 3.22 | .171127 | 8.00 | 15 | .787665 | 3.17 | .200279 | 8.18 |
| 16 | .776352 | 3.23 | .171607 | 8.02 | 16 | .787855 | 3.17 | .200770 | 8.20 |
| 17 | .776546 | 3.22 | .172088 | 8.02 | 17 | .788045 | 3.17 | .201262 | 8.18 |
| 18 | .776739 | 3.23 | .172569 | 8.03 | 18 | .788235 | 3.17 | .201753 | 8.20 |
| 19 | .776933 | 3.22 | .173051 | 8.02 | 19 | .788425 | 3.15 | .202245 | 8.20 |
| 20 | .777126 | 3.22 | .173532 | 8.03 | 20 | .788614 | 3.17 | .202737 | 8.20 |
| 21 | 9.777319 | 3.22 | 10.174014 | 8.03 | 21 | 9.788804 | 3.15 | 10.203229 | 8.22 |
| 22 | .777512 | 3.22 | .174496 | 8.03 | 22 | .788993 | 3.17 | .203722 | 8.22 |
| 23 | .777705 | 3.23 | .174978 | 8.03 | 23 | .789183 | 3.15 | .204215 | 8.20 |
| 24 | .777899 | 3.22 | .175460 | 8.03 | 24 | .789372 | 3.17 | .204707 | 8.22 |
| 25 | .778092 | 3.22 | .175942 | 8.05 | 25 | .789562 | 3.15 | .205200 | 8.23 |
| 26 | .778285 | 3.20 | .176425 | 8.03 | 26 | .789751 | 3.15 | .205694 | 8.22 |
| 27 | .778477 | 3.22 | .176907 | 8.05 | 27 | .789940 | 3.17 | .206187 | 8.23 |
| 28 | .778670 | 3.22 | .177390 | 8.05 | 28 | .790130 | 3.15 | .206681 | 8.22 |
| 29 | .778863 | 3.22 | .177873 | 8.05 | 29 | .790319 | 3.15 | .207174 | 8.23 |
| 30 | .779056 | 3.20 | .178356 | 8.05 | 30 | .790508 | 3.15 | .207668 | 8.23 |
| 31 | 9.779248 | 3.22. | 10.178839 | 8.07 | 31 | 9.790697 | 3.15 | 10.208162 | 8.25 |
| 32 | .779441 | 3.22 | .179323 | 8.07 | 32 | .790886 | 3.15 | .208657 | 8.23 |
| 33 | .779634 | 3.20 | .179807 | 8.05 | 33 | .791075 | 3.15 | .209151 | 8.25 |
| 34 | .779826 | 3.20 | .180290 | 8.07 | 34 | .791264 | 3.15 | .209646 | 8.25 |
| 35 | .780018 | 3.22 | .180774 | 8.08 | 35 | .791453 | 3.13 | .210141 | 8.25 |
| 36 | .780211 | 3.20 | .181259 | 8.07 | 36 | .791641 | 3.15 | .210636 | 8.25 |
| 37 | .780403 | 3.20 | .181743 | 8.07 | 37 | .791830 | 3.15 | .211131 | 8.27 |
| 38 | .780595 | 3.20 | .182227 | 8.08 | 38 | .792019 | 3.13 | .211627 | 8.27 |
| 39 | .780787 | 3.22 | .182712 | 8.08 | 39 | .792207 | 3.15 | .212123 | 8.25 |
| 40 | .780980 | 3.20 | .183197 | 8.08 | 40 | .792396 | 3.13 | .212618 | 8.28 |
| 41 | 9.781172 | 3.20 | 10.183682 | 8 08 | 41 | 9.792584 | 3.13 | 10.213115 | 8.27 |
| 42 | .781364 | 3.20 | .184167 | 8.10 | 42 | .792772 | 3.15 | .213611 | 8.27 |
| 43 | .781556 | 3.18 | .184653 | 8.08 | 43 | .792961 | 3.13 | .214107 | 8.28 |
| 44 | .781747 | 3.20 | .185138 | 8.10 | 44 | .793149 | 3.13 | .214604 | 8.28 |
| 45 | .781939 | 3.20 | .185624 | 8.10 | 45 | .793337 | 3.13 | .215101 | 8.28 |
| 46 | .782131 | 3.20 | .186110 | 8.10 | 46 | .793525 | 3.15 | .215598 | 8.28 |
| 47 | .782323 | 3.18 | .186596 | 8.10 | 47 | .793714 | 3.13 | .216095 | 8.30 |
| 48 | .782514 | 3.20 | .187082 | 8.10 | 48 | .793902 | 3.13 | .216593 | 8.28 |
| 49 | .782706 | 3.18 | .187568 | 8.12 | 49 | .794090 | 3.12 | .217090 | 8.30 |
| 50 | .782897 | 3.20 | .188055 | 8.12 | 50 | .794277 | 3.13 | .217588 | 8.30 |
| 51 | 9.783089 | 3.18 | 10.188542 | 8.12 | 51 | 9.794465 | 3.13 | 10.218086 | 8.32 |
| 52 | .783280 | 3.18 | .189029 | 8.12 | 52 | .794653 | 3.13 | .218585 | 8.30 |
| 53 | .783471 | 3.20 | .189516 | 8.12 | 53 | .794841 | 3.12 | .219083 | 8.32 |
| 54 | .783663 | 3.18 | .190003 | 8.13 | 54 | .795028 | 3.13 | .219582 | 8.32 |
| 55 | .783854 | 3.18 | .190491 | 8.12 | 55 | .795216 | 3.13 | 220081 | 8.32 |
| 56 | .784045 | 3.18 | .190978 | 8.13 | 56 | .795404 | 3.12 | .220580 | 8.32 |
| 57 | .784236 | 3.18 | .191466 | 8.13 | 57 | .795591 | 3.13 | .221079 | 8.32 |
| 58 | .784427 | 3.18 | .191954 | 8.15 | 58 | .795779 | 3.12 | .221578 | 8.33 |
| 59 | .784618 | 3.18 | .192443 | 8.13 | 59 | .795966 | 3.12 | .222078 | 8.33 |
| 60 | 9.784809 | 3.18 | 10.192931 | 8.15 | 60 | 9.796153 | 3.13 | 10.222578 | 8.33 |

| 68° | | | | | 69° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.796153 | 3.13 | 10.222578 | 8.33 | 0 | 9.807286 | 3.07 | 10.252957 | 8.55 |
| 1 | .796341 | 3.12 | .223078 | 8.33 | 1 | .807470 | 3.07 | .253470 | 8.55 |
| 2 | .796528 | 3.12 | .223578 | 8.35 | 2 | .807654 | 3.05 | .253983 | 8.57 |
| 3 | .796715 | 3.12 | .224079 | 8.33 | 3 | .807837 | 3.07 | .254497 | 8.55 |
| 4 | .796902 | 3.12 | .224579 | 8.35 | 4 | .808021 | 3.05 | .255010 | 8.57 |
| 5 | .797089 | 3.12 | .225080 | 8.35 | 5 | .808204 | 3.07 | .255524 | 8.58 |
| 6 | .797276 | 3.12 | .225581 | 8.37 | 6 | .808388 | 3.05 | .256039 | 8.57 |
| 7 | .797463 | 3.12 | .226083 | 8.35 | 7 | .808571 | 3.07 | .256553 | 8.58 |
| 8 | .797650 | 3.12 | .226584 | 8.37 | 8 | .808755 | 3.05 | .257068 | 8.57 |
| 9 | .797837 | 3.10 | .227086 | 8.37 | 9 | .808938 | 3.05 | .257582 | 8.60 |
| 10 | .798023 | 3.12 | .227588 | 8.37 | 10 | .809121 | 3.07 | .258098 | 8.58 |
| 11 | 9.798210 | 3.12 | 10.228090 | 8.37 | 11 | 9.809305 | 3.05 | 10.258613 | 8.60 |
| 12 | .798397 | 3.10 | .228592 | 8.38 | 12 | .809488 | 3.05 | .259129 | 8.58 |
| 13 | .798583 | 3.12 | .229095 | 8.38 | 13 | .809671 | 3.05 | .259644 | 8.60 |
| 14 | .798770 | 3.10 | .229598 | 8.38 | 14 | .809854 | 3.05 | .260160 | 8.62 |
| 15 | .798956 | 3.10 | .230101 | 8.38 | 15 | .810037 | 3.05 | .260677 | 8.60 |
| 16 | .799142 | 3.12 | .230604 | 8.38 | 16 | .810220 | 3.05 | .261193 | 8.62 |
| 17 | .799329 | 3.10 | .231107 | 8.40 | 17 | .810403 | 3.03 | .261710 | 8.62 |
| 18 | .799515 | 3.10 | .231611 | 8.40 | 18 | .810585 | 3.05 | .262227 | 8.62 |
| 19 | .799701 | 3.10 | .232115 | 8.40 | 19 | .810768 | 3.05 | .262744 | 8.63 |
| 20 | .799887 | 3.12 | .232619 | 8.40 | 20 | .810951 | 3.05 | .263262 | 8.62 |
| 21 | 9.800074 | 3.10 | 10.233123 | 8 40 | 21 | 9.811134 | 3.03 | 10.263779 | 8.63 |
| 22 | .800260 | 3.10 | .233627 | 8.42 | 22 | .811316 | 3.05 | .264297 | 8.63 |
| 23 | .800446 | 3.08 | .234132 | 8.42 | 23 | .811499 | 3.03 | .264815 | 8.65 |
| 24 | .800631 | 3.10 | .234637 | 8.42 | 24 | .811681 | 3.05 | .265334 | 8.65 |
| 25 | .800817 | 3.10 | .235142 | 8.42 | 25 | .811864 | 3.03 | .265853 | 8.63 |
| 26 | .801003 | 3.10 | .235647 | 8.43 | 26 | .812046 | 3.03 | .266371 | 8.67 |
| 27 | .801189 | 3.10 | .236153 | 8.42 | 27 | .812228 | 3.03 | .266891 | 8.65 |
| 28 | .801375 | 3.08 | .236658 | 8.43 | 28 | .812410 | 3.05 | .267410 | 8.67 |
| 29 | .801560 | 3.10 | .237164 | 8.43 | 29 | .812593 | 3.03 | .267930 | 8.65 |
| 30 | .801746 | 3.08 | .237670 | 8.45 | 30 | .812775 | 3.03 | .268449 | 8.68 |
| 31 | 9.801931 | 3.10 | 10.238177 | 8.43 | 31 | 9.812957 | 3.03 | 10.268970 | 8.67 |
| 32 | .802117 | 3.08 | .238683 | 8.45 | 32 | .813139 | 3.03 | .269490 | 8.68 |
| 33 | .802302 | 3.08 | .239190 | 8.45 | 33 | .813321 | 3.03 | .270011 | 8.67 |
| 34 | .802487 | 3.10 | .239697 | 8.45 | 34 | .813503 | 3.03 | .270531 | 8.68 |
| 35 | .802673 | 3.08 | .240204 | 8.47 | 35 | .813685 | 3.02 | .271052 | 8.70 |
| 36 | .802858 | 3.08 | .240712 | 8.45 | 36 | .813866 | 3.03 | .271574 | 8.68 |
| 37 | .803043 | 3.08 | .241219 | 8.47 | 37 | .814048 | 3.03 | .272095 | 8.70 |
| 38 | .803228 | 3.08 | .241727 | 8.47 | 38 | .814230 | 3.02 | .272617 | 8.70 |
| 39 | .803413 | 3.08 | .242235 | 8.48 | 39 | .814411 | 3.03 | .273139 | 8.72 |
| 40 | .803598 | 3.08 | .242744 | 8.47 | 40 | .814593 | 3.03 | .273662 | 8.70 |
| 41 | 9.803783 | 3.08 | 10.243252 | 8.48 | 41 | 9.814775 | 3.02 | 10.274184 | 8.72 |
| 42 | .803968 | 3.08 | .243761 | 8.48 | 42 | .814956 | 3.02 | .274707 | 8.72 |
| 43 | .804153 | 3.08 | .244270 | 8.48 | 43 | .815137 | 3.03 | .275230 | 8.72 |
| 44 | .804338 | 3.07 | .244779 | 8.50 | 44 | .815319 | 3.02 | .275753 | 8.73 |
| 45 | .804522 | 3.08 | .245289 | 8.48 | 45 | .815500 | 3.02 | .276277 | 8.73 |
| 46 | .804707 | 3.08 | .245798 | 8.50 | 46 | .815681 | 3.02 | .276801 | 8.73 |
| 47 | .804892 | 3.07 | .246308 | 8.50 | 47 | .815862 | 3.03 | .277325 | 8.73 |
| 48 | .805076 | 3.08 | .246818 | 8.52 | 48 | .816044 | 3.02 | .277849 | 8.75 |
| 49 | .805261 | 3.07 | .247329 | 8.50 | 49 | .816225 | 3.02 | .278374 | 8.75 |
| 50 | .805445 | 3.07 | .247839 | 8.52 | 50 | .816406 | 3.02 | .278899 | 8.75 |
| 51 | 9.805629 | 3.08 | 10.248350 | 8.52 | 51 | 9.816587 | 3.00 | 10.279424 | 8.75 |
| 52 | .805814 | 3.07 | .248861 | 8.52 | 52 | .816767 | 3.02 | .279949 | 8.77 |
| 53 | .805998 | 3.07 | .249372 | 8.52 | 53 | .816948 | 3.02 | .280475 | 8.75 |
| 54 | .806182 | 3.07 | .249883 | 8.53 | 54 | .817129 | 3.02 | .281000 | 8.78 |
| 55 | .806366 | 3.07 | .250395 | 8.53 | 55 | .817310 | 3.00 | .281527 | 8.77 |
| 56 | .806550 | 3.07 | .250907 | 8.53 | 56 | .817490 | 3.02 | .282053 | 8.78 |
| 57 | .806734 | 3.07 | .251419 | 8.55 | 57 | .817671 | 3.02 | .282580 | 8.77 |
| 58 | .806918 | 3.07 | .251932 | 8.53 | 58 | .817852 | 3.00 | .283106 | 8.80 |
| 59 | .807102 | 3.07 | .252444 | 8.55 | 59 | .818032 | 3.02 | .283634 | 8.78 |
| 60 | 9.807286 | 3.07 | 10.252957 | 8.55 | 60 | 9.818213 | 3.00 | 10.284161 | 8.80 |

| 70° | | | | | 71° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.818213 | 3.00 | 10.284161 | 8.80 | 0 | 9.828938 | 2.95 | 10.316296 | 9.07 |
| 1 | .818393 | 3.00 | .284689 | 8.78 | 1 | .829115 | 2.95 | .316840 | 9.08 |
| 2 | .818573 | 3.02 | .285216 | 8.82 | 2 | .829292 | 2.95 | .317385 | 9.07 |
| 3 | .818754 | 3.00 | .285745 | 8.80 | 3 | .829469 | 2.95 | .317929 | 9.10 |
| 4 | .818934 | 3.00 | .286273 | 8.82 | 4 | .829646 | 2.95 | .318475 | 9.08 |
| 5 | .819114 | 3.00 | .286802 | 8.82 | 5 | .829823 | 2.95 | .319020 | 9.08 |
| 6 | .819294 | 3.00 | .287331 | 8.82 | 6 | .830000 | 2.95 | .319565 | 9.10 |
| 7 | .819474 | 3.00 | .287860 | 8.82 | 7 | .830177 | 2.93 | .320111 | 9.12 |
| 8 | .819654 | 3.00 | .288389 | 8.83 | 8 | .830353 | 2.95 | .320658 | 9.10 |
| 9 | .819834 | 3.00 | .288919 | 8.83 | 9 | .830530 | 2.93 | .321204 | 9.12 |
| 10 | .820014 | 3.00 | .289449 | 8.83 | 10 | .830706 | 2.95 | .321751 | 9.12 |
| 11 | 9.820194 | 3.00 | 10.289979 | 8.85 | 11 | 9.830883 | 2.93 | 10.322298 | 9.12 |
| 12 | .820374 | 2.98 | .290510 | 8.85 | 12 | .831059 | 2.95 | .322845 | 9.13 |
| 13 | .820553 | 3.00 | .291041 | 8.85 | 13 | .831236 | 2.93 | .323393 | 9.13 |
| 14 | .820733 | 3.00 | .291572 | 8.85 | 14 | .831412 | 2.95 | .323941 | 9.13 |
| 15 | .820913 | 2.98 | .292103 | 8.87 | 15 | .831589 | 2.93 | .324489 | 9.15 |
| 16 | .821092 | 3.00 | .292635 | 8.85 | 16 | .831765 | 2.93 | .325038 | 9.15 |
| 17 | .821272 | 2.98 | .293166 | 8.87 | 17 | .831941 | 2.93 | .325587 | 9.15 |
| 18 | .821451 | 3.00 | .293698 | 8.88 | 18 | .832117 | 2.93 | .326136 | 9.17 |
| 19 | .821631 | 2.98 | .294231 | 8.88 | 19 | .832293 | 2.93 | .326686 | 9.15 |
| 20 | .821810 | 2.98 | .294764 | 8.87 | 20 | .832469 | 2.93 | .327235 | 9.18 |
| 21 | 9.821989 | 2.98 | 10.295296 | 8.90 | 21 | 9.832645 | 2.93 | 10.327786 | 9.17 |
| 22 | .822168 | 3.00 | .295830 | 8.88 | 22 | .832821 | 2.93 | .328336 | 9.18 |
| 23 | .822348 | 2.98 | .296363 | 8.90 | 23 | .832997 | 2.93 | .328887 | 9.18 |
| 24 | .822527 | 2.98 | .296897 | 8.90 | 24 | .833173 | 2.93 | .329438 | 9.18 |
| 25 | .822706 | 2.98 | .297431 | 8.90 | 25 | .833349 | 2.93 | .329989 | 9.20 |
| 26 | .822885 | 2.98 | .297965 | 8.92 | 26 | .833525 | 2.92 | .330541 | 9.20 |
| 27 | .823064 | 2.98 | .298500 | 8.90 | 27 | .833700 | 2.93 | .331093 | 9.20 |
| 28 | .823243 | 2.97 | .299034 | 8.93 | 28 | .833876 | 2.92 | .331645 | 9.22 |
| 29 | .823421 | 2.98 | .299570 | 8.92 | 29 | 834051 | 2.93 | .332198 | 9.20 |
| 30 | .823600 | 2.98 | .300105 | 8.93 | 30 | .834227 | 2.92 | .332750 | 9.23 |
| 31 | 9.823779 | 2.98 | 10.300641 | 8.92 | 31 | 9.834402 | 2.93 | 10.333304 | 9.22 |
| 32 | .823958 | 2.97 | .301176 | 8.95 | 32 | .834578 | 2.92 | .333857 | 9.23 |
| 33 | .824136 | 2.98 | .301713 | 8.93 | 33 | .834753 | 2.92 | .334411 | 9.23 |
| 34 | .824315 | 2.97 | .302249 | 8.95 | 34 | .834928 | 2.93 | .334965 | 9.25 |
| 35 | .824493 | 2.98 | .302786 | 8.95 | 35 | .835104 | 2.92 | .335520 | 9.23 |
| 36 | .824672 | 2.97 | .303323 | 8.95 | 36 | .835279 | 2.92 | .336074 | 9.25 |
| 37 | .824850 | 2.97 | .303860 | 8.97 | 37 | .835454 | 2.92 | .336629 | 9.27 |
| 38 | .825028 | 2.98 | .304398 | 8 97 | 38 | .835629 | 2.92 | .337185 | 9.27 |
| 39 | .825207 | 2.97 | .304936 | 8.97 | 39 | .835804 | 2.92 | .337741 | 9.27 |
| 40 | .825385 | 2.97 | .305474 | 8.97 | 40 | .835979 | 2.92 | .338297 | 9.27 |
| 41 | 9.825563 | 2.97 | 10.306012 | 8.98 | 41 | 9.836154 | 2.92 | 10.338853 | 9.28 |
| 42 | .825741 | 2.97 | .306551 | 8.98 | 42 | .836329 | 2.92 | .339410 | 9.28 |
| 43 | .825919 | 2.97 | .307090 | 8.98 | 43 | .836504 | 2.90 | .339967 | 9.28 |
| 44 | .826097 | 2.97 | .307629 | 9.00 | 44 | .836678 | 2.92 | .340524 | 9.30 |
| 45 | .826275 | 2.97 | .308169 | 8.98 | 45 | .836853 | 2.92 | .341082 | 9.30 |
| 46 | .826453 | 2.97 | .308708 | 9.02 | 46 | .837028 | 2.90 | .341640 | 9.30 |
| 47 | .826631 | 2.97 | .309249 | 9.00 | 47 | .837202 | 2.88 | .342198 | 9.30 |
| 48 | .826809 | 2.97 | .309789 | 9.02 | 48 | .837377 | 2.90 | .342756 | 9.32 |
| 49 | .826987 | 2.95 | .310330 | 9.02 | 49 | .837551 | 2.92 | .343315 | 9.33 |
| 50 | .827164 | 2.97 | .310871 | 9.02 | 50 | .837726 | 2.90 | .343875 | 9.32 |
| 51 | 9.827342 | 2.95 | 10.311412 | 9.02 | 51 | 9.837900 | 2.92 | 10.344434 | 9.33 |
| 52 | .827519 | 2.97 | .311953 | 9.03 | 52 | .838075 | 2.90 | .344994 | 9.33 |
| 53 | .827697 | 2.95 | .312495 | 9.03 | 53 | .838249 | 2.90 | .345554 | 9.35 |
| 54 | .827874 | 2.97 | .313037 | 9.05 | 54 | .838423 | 2.90 | .346115 | 9.35 |
| 55 | 828052 | 2.95 | .313580 | 9.03 | 55 | .838597 | 2.90 | .346676 | 9.35 |
| 56 | .828229 | 2.95 | .314122 | 9.05 | 56 | .838771 | 2.90 | .347237 | 9.35 |
| 57 | 828406 | 2.97 | .314665 | 9.07 | 57 | .838945 | 2.90 | .347798 | 9.37 |
| 58 | .828584 | 2.95 | .315209 | 9.05 | 58 | .839119 | 2.90 | .348360 | 9.37 |
| 59 | .828761 | 2.95 | .315752 | 9.07 | 59 | .839293 | 2.90 | .348922 | 9.38 |
| 60 | 9.828938 | 2.95 | 10.316296 | 9.07 | 60 | 9.839467 | 2.90 | 10.349485 | 9.38 |

| 72° | | | | | 73° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.839467 | 2.90 | 10.349485 | 9.38 | 0 | 9.849805 | 2.85 | 10.383870 | 9.73 |
| 1 | .839641 | 2.90 | .350048 | 9.38 | 1 | .849976 | 2.85 | .384454 | 9.73 |
| 2 | .839815 | 2.90 | .350611 | 9.40 | 2 | .850147 | 2.83 | .385038 | 9.75 |
| 3 | .839989 | 2.88 | .351175 | 9.38 | 3 | .850317 | 2.85 | .385623 | 9.77 |
| 4 | .840162 | 2.90 | .351738 | 9.42 | 4 | .850488 | 2.83 | .386209 | 9.75 |
| 5 | .840336 | 2.90 | .352303 | 9.40 | 5 | .850658 | 2.85 | .386794 | 9.77 |
| 6 | .840510 | 2.88 | .352867 | 9.42 | 6 | .850829 | 2.83 | .387380 | 9.78 |
| 7 | .840683 | 2.90 | .353432 | 9.42 | 7 | .850999 | 2.83 | .387967 | 9.78 |
| 8 | .840857 | 2.88 | .353997 | 9.43 | 8 | .851169 | 2.85 | .388554 | 9.78 |
| 9 | .841030 | 2.90 | .354563 | 9.43 | 9 | .851340 | 2.83 | .389141 | 9.78 |
| 10 | .841204 | 2.88 | .355129 | 9.43 | 10 | .851510 | 2.83 | .389728 | 9.80 |
| 11 | 9.841377 | 2.88 | 10.355695 | 9.43 | 11 | 9.851680 | 2.83 | 10.390316 | 9.82 |
| 12 | .841550 | 2.88 | .356261 | 9.45 | 12 | .851850 | 2.83 | .390905 | 9.80 |
| 13 | .841723 | 2.88 | .356828 | 9.45 | 13 | .852020 | 2.83 | .391493 | 9.82 |
| 14 | .841896 | 2.90 | .357395 | 9.47 | 14 | .852190 | 2.83 | .392082 | 9.83 |
| 15 | .842070 | 2.88 | .357963 | 9.47 | 15 | .852360 | 2.83 | .392672 | 9.83 |
| 16 | .842243 | 2.88 | .358531 | 9.47 | 16 | .852530 | 2.83 | .393262 | 9.83 |
| 17 | .842416 | 2.88 | .359099 | 9.48 | 17 | .852700 | 2.83 | .393852 | 9.85 |
| 18 | .842589 | 2.88 | .359668 | 9.48 | 18 | .852870 | 2.83 | .394443 | 9.85 |
| 19 | .842762 | 2.87 | .360237 | 9.48 | 19 | .853040 | 2.82 | .395034 | 9.85 |
| 20 | .842934 | 2.88 | .360806 | 9.50 | 20 | .853209 | 2.83 | .395625 | 9.87 |
| 21 | 9.843107 | 2.88 | 10.361376 | 9.50 | 21 | 9.853379 | 2.83 | 10.396217 | 9.87 |
| 22 | .843280 | 2.88 | .361946 | 9.50 | 22 | .853549 | 2.82 | .396809 | 9.88 |
| 23 | .843453 | 2.87 | .362516 | 9.52 | 23 | .853718 | 2.83 | .397402 | 9.88 |
| 24 | .843625 | 2.88 | .363087 | 9.52 | 24 | .853888 | 2.82 | .397995 | 9.90 |
| 25 | .843798 | 2.87 | .363658 | 9.52 | 25 | .854057 | 2.83 | .398589 | 9.88 |
| 26 | .843970 | 2.88 | .364229 | 9.53 | 26 | .854227 | 2.82 | .399182 | 9.92 |
| 27 | .844143 | 2.87 | .364801 | 9.53 | 27 | .854396 | 2.82 | .399777 | 9.90 |
| 28 | .844315 | 2.88 | .365373 | 9.53 | 28 | .854565 | 2.83 | .400371 | 9.92 |
| 29 | .844488 | 2.87 | .365945 | 9.55 | 29 | .854735 | 2.82 | .400966 | 9.93 |
| 30 | .844660 | 2.87 | .366518 | 9.55 | 30 | .854904 | 2.82 | .401562 | 9.93 |
| 31 | 9.844832 | 2.87 | 10.367091 | 9.57 | 31 | 9.855073 | 2.82 | 10.402158 | 9.93 |
| 32 | .845004 | 2.88 | .367665 | 9.57 | 32 | .855242 | 2.82 | .402754 | 9.95 |
| 33 | .845177 | 2.87 | .368239 | 9.57 | 33 | .855411 | 2.82 | .403351 | 9.95 |
| 34 | .845349 | 2.87 | .368813 | 9.57 | 34 | .855580 | 2.82 | .403948 | 9.95 |
| 35 | .845521 | 2.87 | .369387 | 9.58 | 35 | .855749 | 2.82 | .404545 | 9.97 |
| 36 | .845693 | 2.87 | .369962 | 9.60 | 36 | .855918 | 2.82 | .405143 | 9.98 |
| 37 | .845865 | 2.87 | .370538 | 9.58 | 37 | .856087 | 2.80 | .405742 | 9.97 |
| 38 | .846037 | 2.85 | .371113 | 9.60 | 38 | .856255 | 2.82 | .406340 | 9.98 |
| 39 | .846208 | 2.87 | .371689 | 9.62 | 39 | .856424 | 2.82 | .406939 | 10.00 |
| 40 | .846380 | 2.87 | .372266 | 9.60 | 40 | .856593 | 2.82 | .407539 | 10.00 |
| 41 | 9.846552 | 2.87 | 10.372842 | 9.62 | 41 | 9.856762 | 2.80 | 10.408139 | 10.00 |
| 42 | .846724 | 2.85 | .373419 | 9.63 | 42 | .856930 | 2.82 | .408739 | 10.02 |
| 43 | .846895 | 2.87 | .373997 | 9.63 | 43 | .857099 | 2.80 | .409340 | 10.02 |
| 44 | .847067 | 2.85 | .374575 | 9.63 | 44 | .857267 | 2.82 | .409941 | 10.03 |
| 45 | .847238 | 2.87 | .375153 | 9.63 | 45 | .857436 | 2.80 | .410543 | 10.03 |
| 46 | .847410 | 2.85 | .375731 | 9.65 | 46 | .857604 | 2.80 | .411145 | 10.03 |
| 47 | .847581 | 2.87 | .376310 | 9.67 | 47 | .857772 | 2.82 | .411747 | 10.05 |
| 48 | .847753 | 2.85 | .376890 | 9.65 | 48 | .857941 | 2.80 | .412350 | 10.07 |
| 49 | .847924 | 2.85 | .377469 | 9.67 | 49 | .858109 | 2.80 | .412954 | 10.05 |
| 50 | .848095 | 2.87 | .378049 | 9.68 | 50 | .858277 | 2.80 | .413557 | 10.07 |
| 51 | 9.848267 | 2.85 | 10.378630 | 9.67 | 51 | 9.858445 | 2.80 | 10.414161 | 10.08 |
| 52 | .848438 | 2.85 | .379210 | 9.70 | 52 | .858613 | 2.80 | .414766 | 10.08 |
| 53 | .848609 | 2.85 | .379792 | 9.68 | 53 | .858781 | 2.80 | .415371 | 10.08 |
| 54 | .848780 | 2.85 | .380373 | 9.70 | 54 | .858949 | 2.80 | .415976 | 10.10 |
| 55 | .848951 | 2.85 | .380955 | 9.70 | 55 | .859117 | 2.80 | .416582 | 10.12 |
| 56 | .849122 | 2.85 | .381537 | 9.72 | 56 | .859285 | 2.80 | .417189 | 10.10 |
| 57 | .849293 | 2.85 | .382120 | 9.72 | 57 | .859453 | 2.80 | .417795 | 10.12 |
| 58 | .849464 | 2.83 | .382703 | 9.72 | 58 | .859621 | 2.78 | .418402 | 10.13 |
| 59 | .849634 | 2.85 | .383286 | 9.73 | 59 | .859788 | 2.80 | .419010 | 10.13 |
| 60 | 9.849805 | 2.85 | 10.383870 | 9.73 | 68 | 9.859956 | 2.80 | 10.419618 | 10.13 |

| 74° | | | | | 75° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.859956 | 2.80 | 10.419618 | 10.13 | 0 | 9.869924 | 2.75 | 10.456928 | 10.60 |
| 1 | .860124 | 2.78 | .420226 | 10.15 | 1 | .870089 | 2.73 | .457564 | 10.62 |
| 2 | .860291 | 2.80 | .420835 | 10.17 | 2 | .870253 | 2.75 | .458201 | 10.63 |
| 3 | .860459 | 2.78 | .421445 | 10.15 | 3 | .870418 | 2.73 | .458839 | 10.62 |
| 4 | .860626 | 2.80 | .422054 | 10.17 | 4 | .870582 | 2.75 | .459476 | 10.65 |
| 5 | .860794 | 2.78 | .422664 | 10.18 | 5 | .870747 | 2.73 | .460115 | 10.65 |
| 6 | .860961 | 2.78 | .423275 | 10.18 | 6 | .870911 | 2.75 | .460754 | 10.65 |
| 7 | .861128 | 2.80 | .423886 | 10.20 | 7 | .871076 | 2.73 | .461393 | 10.67 |
| 8 | .861296 | 2.78 | .424498 | 10.20 | 8 | .871240 | 2.73 | .462033 | 10.67 |
| 9 | .861463 | 2.78 | .425110 | 10.20 | 9 | .871404 | 2.73 | .462673 | 10.68 |
| 10 | .861630 | 2.78 | .425722 | 10.22 | 10 | .871568 | 2.73 | .463314 | 10 70 |
| 11 | 9.861797 | 2.78 | 10.426335 | 10.22 | 11 | 9.871732 | 2.73 | 10.463956 | 10.70 |
| 12 | .861964 | 2.78 | .426948 | 10.23 | 12 | .871896 | 2.73 | .464598 | 10.70 |
| 13 | .862131 | 2.78 | .427562 | 10.23 | 13 | .872060 | 2.73 | .465240 | 10.72 |
| 14 | .862298 | 2.78 | .428176 | 10.23 | 14 | .872224 | 2.73 | 465883 | 10.73 |
| 15 | .862465 | 2.78 | .428790 | 10.27 | 15 | .872388 | 2.73 | .466527 | 10.73 |
| 16 | .862632 | 2.78 | .429406 | 10.25 | 16 | .872552 | 2.73 | .467171 | 10.73 |
| 17 | .862799 | 2.77 | .430021 | 10.27 | 17 | .872716 | 2.73 | .467815 | 10.75 |
| 18 | .862965 | 2.78 | .430637 | 10.27 | 18 | .872880 | 2.72 | .468460 | 10.77 |
| 19 | .863132 | 2.78 | .431253 | 10.28 | 19 | .873043 | 2.73 | .469106 | 10.77 |
| 20 | .863299 | 2.77 | .431870 | 10.30 | 20 | .873207 | 2.73 | .469752 | 10.77 |
| 21 | 9.863465 | 2.78 | 10.432488 | 10.28 | 21 | 9.873371 | 2.72 | 10.470398 | 10.78 |
| 22 | .863632 | 2.78 | .433105 | 10.32 | 22 | .873534 | 2.73 | .471045 | 10.80 |
| 23 | .863799 | 2.77 | .433724 | 10.30 | 23 | .873698 | 2.72 | .471693 | 10.80 |
| 24 | .863965 | 2.77 | .434342 | 10.32 | 24 | .873861 | 2.73 | .472341 | 10.82 |
| 25 | .864131 | 2.78 | .434961 | 10.33 | 25 | .874025 | 2.72 | .472990 | 10.82 |
| 26 | .864298 | 2.77 | .435581 | 10.33 | 26 | .874188 | 2.72 | .473639 | 10.83 |
| 27 | .864464 | 2.77 | .436201 | 10.33 | 27 | .874351 | 2.73 | .474289 | 10.83 |
| 28 | .864630 | 2.78 | .436821 | 10.35 | 28 | .874515 | 2.72 | .474939 | 10.85 |
| 29 | .864797 | 2.77 | .437442 | 10.37 | 29 | .874678 | 2.72 | .475590 | 10.87 |
| 30 | .864963 | 2.77 | .438064 | 10.37 | 30 | .874841 | 2.72 | .476242 | 10.85 |
| 31 | 9.865129 | 2.77 | 10.438686 | 10.37 | 31 | 9.875004 | 2.72 | 10.476893 | 10.88 |
| 32 | .865295 | 2.77 | .439308 | 10.38 | 32 | .875167 | 2.72 | .477546 | 10.88 |
| 33 | .865461 | 2.77 | .439931 | 10.38 | 33 | .875330 | 2.72 | .478199 | 10.88 |
| 34 | .865627 | 2.77 | .440554 | 10.40 | 34 | .875493 | 2.72 | .478852 | 10.90 |
| 35 | .865793 | 2.77 | .441178 | 10.40 | 35 | .875656 | 2.72 | .479506 | 10.92 |
| 36 | .865959 | 2.75 | .441802 | 10.42 | 36 | .875819 | 2.72 | .480161 | 10.92 |
| 37 | .866124 | 2.77 | .442427 | 10.42 | 37 | .875982 | 2.72 | .480816 | 10.93 |
| 38 | .866290 | 2.77 | .443052 | 10.43 | 38 | .876145 | 2.72 | .481472 | 10.93 |
| 39 | .866456 | 2.77 | .443678 | 10.43 | 39 | .876308 | 2.70 | .482128 | 10.95 |
| 40 | .866622 | 2.75 | .444304 | 10.45 | 40 | .876470 | 2.72 | .482785 | 10.95 |
| 41 | 9.866787 | 2.77 | 10.444931 | 10.45 | 41 | 9.876633 | 2.72 | 10.483442 | 10.97 |
| 42 | .866953 | 2.75 | .445558 | 10.45 | 42 | .876796 | 2.70 | .484100 | 10.98 |
| 43 | .867118 | 2.77 | .446185 | 10.47 | 43 | .876958 | 2.72 | .484759 | 10.98 |
| 44 | .867284 | 2.75 | .446813 | 10.48 | 44 | .877121 | 2.70 | .485418 | 10.98 |
| 45 | .867449 | 2.75 | .447442 | 10.48 | 45 | .877283 | 2.70 | .486077 | 10.98 |
| 46 | .867614 | 2.77 | .448071 | 10.48 | 46 | .877445 | 2.72 | .486738 | 11.00 |
| 47 | .867780 | 2.75 | .448700 | 10.50 | 47 | .877608 | 2.70 | .487398 | 11 02 |
| 48 | .867945 | 2.75 | .449330 | 10.52 | 48 | .877770 | 2.70 | .488059 | 11.03 |
| 49 | .868110 | 2.75 | .449961 | 10.52 | 49 | .877932 | 2.72 | .488721 | 11.05 |
| 50 | .868275 | 2.77 | .450592 | 10.52 | 50 | .878095 | 2.70 | .489384 | 11.05 |
| 51 | 9.868441 | 2.75 | 10.451223 | 10.53 | 51 | 9.878257 | 2.70 | 10.490047 | 11.05 |
| 52 | .868606 | 2.75 | .451855 | 10.53 | 52 | .878419 | 2.70 | .490710 | 11.07 |
| 53 | .868771 | 2.75 | .452487 | 10.55 | 53 | .878581 | 2.70 | .491374 | 11.08 |
| 54 | .868936 | 2.73 | .453120 | 10.57 | 54 | .878743 | 2.70 | .492039 | 11.08 |
| 55 | .869100 | 2.75 | .453754 | 10.57 | 55 | .878905 | 2.70 | .492704 | 11.10 |
| 56 | .869265 | 2.75 | .454388 | 10.57 | 56 | .879067 | 2.70 | .493370 | 11.10 |
| 57 | .869430 | 2.75 | .455022 | 10.58 | 57 | 879229 | 2.68 | .494036 | 11.12 |
| 58 | .869595 | 2.75 | .455657 | 10.58 | 58 | .879390 | 2.70 | .494703 | 11.13 |
| 59 | .869760 | 2.73 | .456292 | 10.60 | 59 | .879552 | 2.70 | .495371 | 11.13 |
| 60 | 9.869924 | 2.75 | 10.456928 | 10.60 | 60 | 9.879714 | 2.70 | 10.496039 | 11.13 |

| 76° | | | | | 77° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.879714 | 2.70 | 10.496039 | 11.13 | 0 | 9.889329 | 2.65 | 10.537241 | 11.77 |
| 1 | .879876 | 2.68 | .496707 | 11.17 | 1 | .889488 | 2.65 | .537947 | 11.78 |
| 2 | .880037 | 2.70 | .497377 | 11.17 | 2 | .889647 | 2.63 | .538654 | 11.80 |
| 3 | .880199 | 2.68 | .498047 | 11.17 | 3 | .889805 | 2.65 | .539362 | 11.82 |
| 4 | .880360 | 2.70 | .498717 | 11.18 | 4 | .889964 | 2.65 | .540071 | 11.82 |
| 5 | .880522 | 2.68 | .499388 | 11.20 | 5 | .890123 | 2.63 | .540780 | 11.83 |
| 6 | .880683 | 2.70 | .500060 | 11.20 | 6 | .890281 | 2.65 | .541490 | 11.83 |
| 7 | .880845 | 2.68 | .500732 | 11.22 | 7 | .890440 | 2.63 | .542200 | 11.85 |
| 8 | .881006 | 2.68 | .501405 | 11.22 | 8 | .890598 | 2.65 | .542911 | 11.87 |
| 9 | .881167 | 2.70 | .502078 | 11.23 | 9 | .890757 | 2.63 | .543623 | 11.88 |
| 10 | .881329 | 2.68 | .502752 | 11.23 | 10 | .890915 | 2.63 | .544336 | 11.88 |
| 11 | 9.881490 | 2.68 | 10.503426 | 11.27 | 11 | 9.891073 | 2.65 | 10.545049 | 11.90 |
| 12 | .881651 | 2.68 | .504102 | 11.25 | 12 | .891232 | 2.63 | .545763 | 11.90 |
| 13 | .881812 | 2.68 | .504777 | 11.28 | 13 | .891390 | 2.63 | .546477 | 11.93 |
| 14 | .881973 | 2.68 | .505454 | 11.28 | 14 | .891548 | 2.63 | .547193 | 11.93 |
| 15 | .882134 | 2.68 | .506131 | 11.28 | 15 | .891706 | 2.63 | .547909 | 11.95 |
| 16 | .882295 | 2.68 | .506808 | 11.30 | 16 | .891864 | 2.63 | .548626 | 11.95 |
| 17 | .882456 | 2.68 | .507486 | 11.32 | 17 | .892022 | 2.63 | .549343 | 11.97 |
| 18 | .882617 | 2.67 | .508165 | 11.32 | 18 | .892180 | 2.63 | .550061 | 11.98 |
| 19 | .882777 | 2.68 | .508844 | 11.33 | 19 | .892338 | 2.63 | .550780 | 12.00 |
| 20 | .882938 | 2.68 | .509524 | 11.35 | 20 | .892496 | 2.63 | .551500 | 12.00 |
| 21 | 9.883099 | 2.68 | 10.510205 | 11.35 | 21 | 9.892654 | 2.63 | 10.552220 | 12.02 |
| 22 | .883260 | 2.67 | .510886 | 11.37 | 22 | .892812 | 2.62 | .552941 | 12.03 |
| 23 | .883420 | 2.68 | .511568 | 11.37 | 23 | .892969 | 2.63 | .553663 | 12.03 |
| 24 | .883581 | 2.67 | .512250 | 11.38 | 24 | .893127 | 2.63 | .554385 | 12.07 |
| 25 | .883741 | 2.68 | .512933 | 11.40 | 25 | .893285 | 2.62 | .555109 | 12.07 |
| 26 | .883902 | 2.67 | .513617 | 11.40 | 26 | .893442 | 2.63 | .555833 | 12.07 |
| 27 | .884062 | 2.68 | .514301 | 11.42 | 27 | .893600 | 2.63 | .556557 | 12.10 |
| 28 | .884223 | 2.67 | .514986 | 11.43 | 28 | .893758 | 2.62 | .557283 | 12.10 |
| 29 | .884383 | 2.67 | .515672 | 11.43 | 29 | .893915 | 2.62 | .558009 | 12.12 |
| 30 | .884543 | 2.67 | .516358 | 11.45 | 30 | .894072 | 2.63 | .558736 | 12.12 |
| 31 | 9.884703 | 2.68 | 10.517045 | 11.45 | 31 | 9.894230 | 2.62 | 10.559463 | 12.15 |
| 32 | .884864 | 2.67 | .517732 | 11.47 | 32 | .894387 | 2.62 | .560192 | 12.15 |
| 33 | .885024 | 2.67 | .518420 | 11.48 | 33 | .894544 | 2.63 | .560921 | 12.17 |
| 34 | .885184 | 2.67 | .519109 | 11.48 | 34 | .894702 | 2.62 | .561651 | 12.17 |
| 35 | .885344 | 2.67 | .519798 | 11.50 | 35 | .894859 | 2.62 | .562381 | 12.20 |
| 36 | .885504 | 2.67 | .520488 | 11.52 | 36 | .895016 | 2.62 | .563113 | 12.20 |
| 37 | .885664 | 2.67 | .521179 | 11.50 | 37 | .895173 | 2.62 | .563845 | 12.20 |
| 38 | .885824 | 2.65 | .521870 | 11.53 | 38 | .895330 | 2.62 | .564577 | 12.23 |
| 39 | .885983 | 2.67 | .522562 | 11.53 | 39 | .895487 | 2.62 | .565311 | 12.23 |
| 40 | .886143 | 2.67 | .523254 | 11.55 | 40 | .895644 | 2.62 | .566045 | 12.27 |
| 41 | 9.886303 | 2.67 | 10.523947 | 11.57 | 41 | 9.895801 | 2.62 | 10.566781 | 12.25 |
| 42 | .886463 | 2.65 | .524641 | 11.57 | 42 | .895958 | 2.62 | .567516 | 12.28 |
| 43 | .886622 | 2.67 | .525335 | 11.58 | 43 | .896115 | 2.62 | .568253 | 12.28 |
| 44 | .886782 | 2.65 | .526030 | 11.60 | 44 | .896272 | 2.60 | .568990 | 12.32 |
| 45 | .886941 | 2.67 | .526726 | 11.62 | 45 | .896428 | 2.62 | .569729 | 12.32 |
| 46 | .887101 | 2.65 | .527423 | 11.62 | 46 | .896585 | 2.62 | .570468 | 12.32 |
| 47 | .887260 | 2.67 | .528120 | 11.62 | 47 | .896742 | 2.60 | .571207 | 12.35 |
| 48 | .887420 | 2.65 | .528817 | 11.65 | 48 | .896898 | 2.62 | .571948 | 12.35 |
| 49 | .887579 | 2.67 | .529516 | 11.65 | 49 | .897055 | 2.60 | .572689 | 12.37 |
| 50 | .887739 | 2.65 | .530215 | 11.65 | 50 | .897211 | 2.62 | .573431 | 12.38 |
| 51 | 9.887898 | 2.65 | 10.530914 | 11.67 | 51 | 9.897368 | 2.60 | 10.574174 | 12.38 |
| 52 | .888057 | 2.65 | .531614 | 11.68 | 52 | .897524 | 2.60 | .574917 | 12.42 |
| 53 | .888216 | 2.65 | .532315 | 11.70 | 53 | .897680 | 2.62 | .575662 | 12.42 |
| 54 | .888375 | 2.65 | .533017 | 11.70 | 54 | .897837 | 2.60 | .576407 | 12.43 |
| 55 | .888534 | 2.65 | .533719 | 11.72 | 55 | .897993 | 2.60 | .577153 | 12.45 |
| 56 | .888693 | 2.65 | .534422 | 11.73 | 56 | .898149 | 2.60 | .577900 | 12.45 |
| 57 | .888852 | 2.65 | .535126 | 11.73 | 57 | .898305 | 2.60 | .578647 | 12.48 |
| 58 | .889011 | 2.65 | .535830 | 11.75 | 58 | .898461 | 2.62 | .579396 | 12.48 |
| 59 | .889170 | 2.65 | .536535 | 11.77 | 59 | .898618 | 2.60 | .580145 | 12.50 |
| 60 | 9.889329 | 2.65 | 10.537241 | 11.77 | 60 | 9.898774 | 2.60 | 10.580895 | 12.50 |

| 78° | | | | | 79° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.898774 | 2.60 | 10.580895 | 12.50 | 0 | 9.908051 | 2.55 | 10.627452 | 13.40 |
| 1 | .898930 | 2.60 | .581645 | 12.53 | 1 | .908204 | 2.55 | .628256 | 13.40 |
| 2 | .899086 | 2.58 | .582397 | 12.53 | 2 | .908357 | 2.57 | .629060 | 13.43 |
| 3 | .899241 | 2.60 | .583149 | 12.57 | 3 | .908511 | 2.55 | .629866 | 13.45 |
| 4 | .899397 | 2.60 | .583903 | 12.57 | 4 | .908664 | 2.55 | .630673 | 13.45 |
| 5 | .899553 | 2.60 | .584657 | 12.57 | 5 | .908817 | 2.55 | .631480 | 13.48 |
| 6 | .899709 | 2.60 | .585411 | 12.60 | 6 | .908970 | 2.55 | .632289 | 13.48 |
| 7 | .899865 | 2.58 | .586167 | 12.60 | 7 | .909123 | 2.55 | .633098 | 13.52 |
| 8 | .900020 | 2.60 | .586923 | 12.63 | 8 | .909276 | 2.53 | .633909 | 13.52 |
| 9 | .900176 | 2.58 | .587681 | 12.63 | 9 | .909428 | 2.55 | .634720 | 13.55 |
| 10 | .900331 | 2.60 | .588439 | 12.65 | 10 | .909581 | 2.55 | .635533 | 13.55 |
| 11 | 9.900487 | 2.58 | 10.589198 | 12.65 | 11 | 9.909734 | 2.55 | 10.636346 | 13.58 |
| 12 | .900642 | 2.60 | .589957 | 12.68 | 12 | .909887 | 2.53 | .637161 | 13.58 |
| 13 | .900798 | 2.58 | .590718 | 12.68 | 13 | .910039 | 2.55 | .637976 | 13.60 |
| 14 | .900953 | 2.58 | .591479 | 12.72 | 14 | .910192 | 2.55 | .638792 | 13.63 |
| 15 | .901108 | 2.60 | .592242 | 12.72 | 15 | .910345 | 2.53 | .639610 | 13.63 |
| 16 | .901264 | 2.58 | .593005 | 12.73 | 16 | .910497 | 2.55 | .640428 | 13.67 |
| 17 | .901419 | 2.58 | .593769 | 12.73 | 17 | .910650 | 2.53 | .641248 | 13.67 |
| 18 | .901574 | 2.58 | .594533 | 12.77 | 18 | .910802 | 2.55 | .642068 | 13.70 |
| 19 | .901729 | 2.58 | .595299 | 12.78 | 19 | .910955 | 2.53 | .642890 | 13.72 |
| 20 | .901884 | 2.60 | .596066 | 12.78 | 20 | .911107 | 2.53 | .643713 | 13.72 |
| 21 | 9.902040 | 2.58 | 10.596833 | 12.80 | 21 | 9.911259 | 2.55 | 10.644536 | 13.75 |
| 22 | .902195 | 2.58 | .597601 | 12.82 | 22 | .911412 | 2.53 | .645361 | 13.75 |
| 23 | .902350 | 2.57 | .598370 | 12.83 | 23 | .911564 | 2.53 | .646186 | 13.78 |
| 24 | .902504 | 2.58 | .599140 | 12.85 | 24 | .911716 | 2.53 | .647013 | 13.80 |
| 25 | .902659 | 2.58 | .599911 | 12.85 | 25 | .911868 | 2.53 | .647841 | 13.82 |
| 26 | .902814 | 2.58 | .600682 | 12.88 | 26 | .912020 | 2.53 | .648670 | 13.82 |
| 27 | .902969 | 2.58 | .601455 | 12.88 | 27 | .912172 | 2.53 | .649499 | 13.85 |
| 28 | .903124 | 2.57 | .602228 | 12.92 | 28 | .912324 | 2.53 | .650330 | 13.87 |
| 29 | .903278 | 2.58 | .603003 | 12.92 | 29 | .912476 | 2.53 | .651162 | 13.88 |
| 30 | .903433 | 2.58 | .603778 | 12.93 | 30 | .912628 | 2.53 | .651995 | 13.90 |
| 31 | 9.903588 | 2.57 | 10.604554 | 12.95 | 31 | 9.912780 | 2.53 | 10.652829 | 13.92 |
| 32 | .903742 | 2.58 | .605331 | 12.95 | 32 | .912932 | 2.53 | .653664 | 13.95 |
| 33 | .903897 | 2.57 | .606108 | 12.98 | 33 | .913084 | 2.52 | .654501 | 13.95 |
| 34 | .904051 | 2.58 | .606887 | 13.00 | 34 | .913235 | 2.53 | .655338 | 13.97 |
| 35 | .904206 | 2.57 | .607667 | 13.00 | 35 | .913387 | 2.53 | .656176 | 14.00 |
| 36 | .904360 | 2.57 | .608447 | 13.02 | 36 | .913539 | 2.52 | .657016 | 14.00 |
| 37 | .904514 | 2.57 | .609228 | 13.03 | 37 | .913690 | 2.53 | .657856 | 14.03 |
| 38 | .904668 | 2.58 | .610010 | 13.07 | 38 | .913842 | 2.52 | .658698 | 14.03 |
| 39 | .904823 | 2.57 | .610794 | 13 07 | 39 | .913993 | 2.53 | .659540 | 14.07 |
| 40 | .904977 | 2.57 | .611578 | 13.08 | 40 | .914145 | 2.52 | .660384 | 14.08 |
| 41 | 9.905131 | 2.57 | 10.612363 | 13.08 | 41 | 9.914296 | 2.53 | 10.661229 | 14.10 |
| 42 | .905285 | 2.57 | .613148 | 13.12 | 42 | .914448 | 2.52 | .662075 | 14.12 |
| 43 | .905439 | 2.57 | .613935 | 13.13 | 43 | .914599 | 2.52 | .662922 | 14.13 |
| 44 | .905593 | 2.57 | .614723 | 13.13 | 44 | .914750 | 2.53 | .663770 | 14.15 |
| 45 | .905747 | 2.57 | .615511 | 13.17 | 45 | .914902 | 2.52 | .664619 | 14.18 |
| 46 | .905901 | 2.57 | .616301 | 13.17 | 46 | .915053 | 2.52 | .665470 | 14.18 |
| 47 | .906055 | 2.57 | .617091 | 13.20 | 47 | .915204 | 2.52 | .666321 | 14.22 |
| 48 | .906209 | 2.57 | .617883 | 13.20 | 48 | .915355 | 2.52 | .667174 | 14.23 |
| 49 | .906363 | 2.55 | .618675 | 13.22 | 49 | .915506 | 2.52 | .668028 | 14.25 |
| 50 | .906516 | 2.57 | .619468 | 13.23 | 50 | .915657 | 2.52 | .668883 | 14.27 |
| 51 | 9.906670 | 2.57 | 10.620262 | 13.25 | 51 | 9.915808 | 2.52 | 10.669739 | 14.28 |
| 52 | .906824 | 2.55 | .621057 | 13.27 | 52 | .915959 | 2.52 | .670596 | 14.30 |
| 53 | .906977 | 2.57 | .621853 | 13.28 | 53 | .916110 | 2.52 | .671454 | 14.33 |
| 54 | .907131 | 2.55 | .622650 | 13.30 | 54 | .916261 | 2.52 | .672314 | 14.33 |
| 55 | .907284 | 2.57 | .623448 | 13.32 | 55 | .916412 | 2.50 | .673174 | 14.37 |
| 56 | .907438 | 2.55 | .624247 | 13.33 | 56 | .916562 | 2.52 | .674036 | 14.38 |
| 57 | .907591 | 2.55 | .625047 | 13.35 | 57 | .916713 | 2.52 | .674899 | 14.40 |
| 58 | .907744 | 2.57 | .625848 | 13.37 | 58 | .916864 | 2.50 | .675763 | 14.42 |
| 59 | .907898 | 2.55 | .626650 | 13.37 | 59 | .917014 | 2.52 | .676628 | 14.45 |
| 60 | 9.908051 | 2.55 | 10.627452 | 13.40 | 60 | 9.917165 | 2.52 | 10.677495 | 14.45 |

| | 80° | | | | | 81° | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.917165 | 2.52 | 10.677495 | 14.45 | 0 | 9.926119 | 2.47 | 10.731786 | 15.78 |
| 1 | .917316 | 2.50 | .678362 | 14.48 | 1 | .926267 | 2.47 | .732733 | 15.78 |
| 2 | .917466 | 2.50 | .679231 | 14.50 | 2 | .926415 | 2.45 | .733680 | 15.83 |
| 3 | .917616 | 2.52 | .680101 | 14.52 | 3 | .926562 | 2.47 | .734630 | 15.83 |
| 4 | .917767 | 2.50 | .680972 | 14.55 | 4 | .926710 | 2.47 | .735580 | 15.87 |
| 5 | .917917 | 2.52 | .681845 | 14.55 | 5 | .926858 | 2.47 | .736532 | 15.90 |
| 6 | .918068 | 2.50 | .682718 | 14.58 | 6 | .927006 | 2.45 | .737486 | 15.92 |
| 7 | .918218 | 2.50 | .683593 | 14.60 | 7 | .927153 | 2.47 | .738441 | 15.95 |
| 8 | .918368 | 2.50 | .684469 | 14.62 | 8 | .927301 | 2.45 | .739398 | 15.97 |
| 9 | .918518 | 2.50 | .685346 | 14.63 | 9 | .927448 | 2.47 | .740356 | 16.00 |
| 10 | .918668 | 2.50 | .686224 | 14.67 | 10 | .927596 | 2.45 | .741316 | 16.02 |
| 11 | 9.918818 | 2.50 | 10.687104 | 14.68 | 11 | 9.927743 | 2.47 | 10.742277 | 16.03 |
| 12 | .918968 | 2.50 | .687985 | 14.70 | 12 | .927891 | 2.45 | .743239 | 16.08 |
| 13 | .919118 | 2.50 | .688867 | 14.72 | 13 | .928038 | 2.45 | .744204 | 16.08 |
| 14 | .919268 | 2.50 | .689750 | 14.73 | 14 | .928185 | 2.47 | .745169 | 16.13 |
| 15 | .919418 | 2.50 | .690634 | 14.77 | 15 | .928333 | 2.45 | .746137 | 16.13 |
| 16 | .919568 | 2.50 | .691520 | 14.78 | 16 | .928480 | 2.45 | .747105 | 16.18 |
| 17 | .919718 | 2.50 | .692407 | 14.80 | 17 | .928627 | 2.45 | .748076 | 16.20 |
| 18 | .919868 | 2.50 | .693295 | 14.83 | 18 | .928774 | 2.45 | .749048 | 16.22 |
| 19 | .920018 | 2.48 | .694185 | 14.83 | 19 | .928921 | 2.45 | .750021 | 16.25 |
| 20 | .920167 | 2.50 | .695075 | 14.87 | 20 | .929068 | 2.45 | .750996 | 16.28 |
| 21 | 9.920317 | 2.48 | 10.695967 | 14.90 | 21 | 9.929215 | 2.45 | 10.751973 | 16.30 |
| 22 | .920466 | 2.50 | .696861 | 14.90 | 22 | .929362 | 2.45 | .752951 | 16.33 |
| 23 | .920616 | 2.50 | .697755 | 14.93 | 23 | .929509 | 2.45 | .753931 | 16.35 |
| 24 | .920766 | 2.48 | .698651 | 14.95 | 24 | .929656 | 2.45 | .754912 | 16.38 |
| 25 | .920915 | 2.48 | .699548 | 14.97 | 25 | .929803 | 2.45 | .755895 | 16.42 |
| 26 | .921064 | 2.50 | .700446 | 15.00 | 26 | .929950 | 2.45 | .756880 | 16.43 |
| 27 | .921214 | 2.48 | .701346 | 15.02 | 27 | .930097 | 2.43 | .757866 | 16.47 |
| 28 | .921363 | 2.48 | .702247 | 15.03 | 28 | .930243 | 2.45 | .758854 | 16.50 |
| 29 | .921512 | 2.50 | .703149 | 15.05 | 29 | .930390 | 2.45 | .759844 | 16.52 |
| 30 | .921662 | 2.48 | .704052 | 15.08 | 30 | .930537 | 2.43 | .760835 | 16.53 |
| 31 | 9.921811 | 2.48 | 10.704957 | 15.10 | 31 | 9.930683 | 2.45 | 10.761827 | 16.58 |
| 32 | .921960 | 2.48 | .705863 | 15.13 | 32 | .930830 | 2.43 | .762822 | 16.60 |
| 33 | .922109 | 2.48 | .706771 | 15.15 | 33 | .930976 | 2.45 | .763818 | 16.62 |
| 34 | .922258 | 2.48 | .707680 | 15.17 | 34 | .931123 | 2.43 | .764815 | 16.67 |
| 35 | .922407 | 2.48 | .708590 | 15.18 | 35 | .931269 | 2.45 | .765815 | 16.68 |
| 36 | .922556 | 2.48 | .709501 | 15.22 | 36 | .931416 | 2.43 | .766816 | 16.72 |
| 37 | .922705 | 2.48 | .710414 | 15.23 | 37 | .931562 | 2.43 | .767819 | 16.73 |
| 38 | .922854 | 2.48 | .711328 | 15.25 | 38 | .931708 | 2.45 | .768823 | 16.77 |
| 39 | .923003 | 2.48 | .712243 | 15.28 | 39 | .931855 | 2.43 | .769829 | 16.80 |
| 40 | .923152 | 2.48 | .713160 | 15.30 | 40 | .932001 | 2.43 | .770837 | 16.82 |
| 41 | 9.923301 | 2.47 | 10.714078 | 15.33 | 41 | 9.932147 | 2.43 | 10.771846 | 16.87 |
| 42 | .923449 | 2.48 | .714998 | 15.35 | 42 | .932293 | 2.43 | .772858 | 16.87 |
| 43 | .923598 | 2.48 | .715919 | 15.37 | 43 | .932439 | 2.43 | .773870 | 16.92 |
| 44 | .923747 | 2.47 | .716841 | 15 38 | 44 | .932585 | 2.43 | .774885 | 16.95 |
| 45 | .923895 | 2.48 | .717764 | 15.42 | 45 | .932731 | 2.43 | .775902 | 16.97 |
| 46 | .924044 | 2.47 | .718689 | 15.45 | 46 | .932877 | 2.43 | .776920 | 17.00 |
| 47 | .924192 | 2.48 | .719616 | 15.45 | 47 | .933023 | 2.43 | .777940 | 17.02 |
| 48 | .924341 | 2.47 | .720543 | 15.48 | 48 | .933169 | 2.43 | .778961 | 17.07 |
| 49 | .924489 | 2.47 | .721472 | 15.52 | 49 | .933315 | 2.42 | .779985 | 17.08 |
| 50 | .924637 | 2.48 | .722403 | 15.53 | 50 | .933460 | 2.43 | .781010 | 17.12 |
| 51 | 9.924786 | 2.47 | 10.723335 | 15.55 | 51 | 9.933606 | 2.43 | 10.782037 | 17.13 |
| 52 | .924934 | 2.47 | .724268 | 15.58 | 52 | .933752 | 2.42 | .783065 | 17.18 |
| 53 | .925082 | 2.48 | .725203 | 15.60 | 53 | .933897 | 2.43 | .784096 | 17.20 |
| 54 | .925231 | 2.47 | .726139 | 15.63 | 54 | .934043 | 2.43 | .785128 | 17.23 |
| 55 | .925379 | 2.47 | .727077 | 15.65 | 55 | .934189 | 2.42 | .786162 | 17.27 |
| 56 | .925527 | 2.47 | .728016 | 15.67 | 56 | .934334 | 2 43 | .787198 | 17.30 |
| 57 | .925675 | 2.47 | .728956 | 15.70 | 57 | .934480 | 2.42 | .788236 | 17.33 |
| 58 | .925823 | 2.47 | .729898 | 15.73 | 58 | .934625 | 2.42 | .789276 | 17.35 |
| 59 | .925971 | 2.47 | .730842 | 15.73 | 59 | .934770 | 2.43 | .790317 | 17.40 |
| 60 | 9.926119 | 2.47 | 10.731786 | 15.78 | 60 | 9.934916 | 2.42 | 10.791361 | 17.42 |

| 82° | | | | | 83° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.934916 | 2.42 | 10.791361 | 17.42 | 0 | 9.943559 | 2.38 | 10.857665 | 19.55 |
| 1 | .935061 | 2.42 | .792406 | 17.45 | 1 | .943702 | 2.38 | .858838 | 19.58 |
| 2 | .935206 | 2.43 | .793453 | 17.48 | 2 | .943845 | 2.37 | .860013 | 19.63 |
| 3 | .935352 | 2.42 | .794502 | 17.50 | 3 | .943987 | 2.38 | .861191 | 19.67 |
| 4 | .935497 | 2.42 | .795552 | 17.55 | 4 | .944130 | 2.38 | .862371 | 19.72 |
| 5 | .935642 | 2.42 | .796605 | 17.58 | 5 | .944273 | 2.37 | .863554 | 19.75 |
| 6 | .935787 | 2.42 | .797660 | 17.60 | 6 | .944415 | 2.38 | .864739 | 19.80 |
| 7 | .935932 | 2.42 | .798716 | 17.63 | 7 | .944558 | 2.37 | .865927 | 19.83 |
| 8 | .936077 | 2.42 | .799774 | 17.68 | 8 | .944700 | 2.38 | .867117 | 19.88 |
| 9 | .936222 | 2.42 | .800835 | 17.70 | 9 | .944843 | 2.37 | .868310 | 19.92 |
| 10 | .936367 | 2.42 | .801897 | 17.73 | 10 | .944985 | 2.37 | .869505 | 19.97 |
| 11 | 9.936512 | 2.42 | 10.802961 | 17.77 | 11 | 9.945127 | 2.38 | 10.870703 | 20.00 |
| 12 | .936657 | 2.40 | .804027 | 17.80 | 12 | .945270 | 2.37 | .871903 | 20.05 |
| 13 | .936801 | 2.42 | .805095 | 17.83 | 13 | .945412 | 2.37 | .873106 | 20.10 |
| 14 | .936946 | 2.42 | .806165 | 17.87 | 14 | .945554 | 2.37 | .874312 | 20.13 |
| 15 | .937091 | 2.42 | .807237 | 17.90 | 15 | .945696 | 2.37 | .875520 | 20.18 |
| 16 | .937236 | 2.40 | .808311 | 17.93 | 16 | .945838 | 2.38 | .876731 | 20.23 |
| 17 | .937380 | 2.42 | .809387 | 17.97 | 17 | .945981 | 2.37 | .877945 | 20.27 |
| 18 | .937525 | 2.40 | .810465 | 18.00 | 18 | .946123 | 2.37 | .879161 | 20.30 |
| 19 | .937669 | 2.42 | .811545 | 18.03 | 19 | .946265 | 2.37 | .880379 | 20.37 |
| 20 | .937814 | 2.40 | .812627 | 18.07 | 20 | .946407 | 2.37 | .881601 | 20.40 |
| 21 | 9.937958 | 2.42 | 10.813711 | 18.10 | 21 | 9.946549 | 2.35 | 10.882825 | 20.45 |
| 22 | .938103 | 2.40 | .814797 | 18.13 | 22 | .946690 | 2.37 | .884052 | 20.48 |
| 23 | .938247 | 2.40 | .815885 | 18.17 | 23 | .946832 | 2.37 | .885281 | 20.55 |
| 24 | .938391 | 2.42 | .816975 | 18.20 | 24 | .946974 | 2.37 | .886514 | 20.58 |
| 25 | .938536 | 2.40 | .818067 | 18.23 | 25 | .947116 | 2.37 | .887749 | 20.62 |
| 26 | .938680 | 2.40 | .819161 | 18.27 | 26 | .947258 | 2.35 | .888986 | 20.68 |
| 27 | .938824 | 2.40 | .820257 | 18.32 | 27 | .947399 | 2.37 | .890227 | 20.72 |
| 28 | .938968 | 2.40 | .821356 | 18.33 | 28 | .947541 | 2.37 | .891470 | 20.77 |
| 29 | .939112 | 2.38 | .822456 | 18.38 | 29 | .947683 | 2.35 | .892716 | 20.82 |
| 30 | .939257 | 2.40 | .823559 | 18.42 | 30 | .947824 | 2.37 | .893965 | 20.87 |
| 31 | 9.939401 | 2.40 | 10.824664 | 18.43 | 31 | 9.947966 | 2.35 | 10.895217 | 20.92 |
| 32 | .939545 | 2.38 | .825770 | 18.48 | 32 | .948107 | 2.37 | .896472 | 20.95 |
| 33 | .939688 | 2.40 | .826879 | 18.52 | 33 | .948249 | 2.35 | .897729 | 21.00 |
| 34 | .939832 | 2.40 | .827990 | 18.57 | 34 | .948390 | 2.35 | .898989 | 21.07 |
| 35 | .939976 | 2.40 | .829104 | 18.58 | 35 | .948531 | 2.37 | .900253 | 21.10 |
| 36 | .940120 | 2.40 | .830219 | 18.63 | 36 | .948673 | 2.35 | .901519 | 21.15 |
| 37 | .940264 | 2.40 | .831337 | 18.65 | 37 | .948814 | 2.35 | .902788 | 21.20 |
| 38 | .940408 | 2.38 | .832456 | 18.70 | 38 | .948955 | 2.35 | .904060 | 21.25 |
| 39 | .940551 | 2.40 | .833578 | 18.75 | 39 | .949096 | 2.35 | .905335 | 21.30 |
| 40 | .940695 | 2.40 | .834703 | 18.77 | 40 | .949237 | 2.37 | .906613 | 21.33 |
| 41 | 9.940839 | 2.38 | 10.835829 | 18.80 | 41 | 9.949379 | 2.35 | 10.907893 | 21.40 |
| 42 | .940982 | 2.40 | .836957 | 18.85 | 42 | .949520 | 2.35 | .909177 | 21.45 |
| 43 | .941126 | 2.38 | .838088 | 18.88 | 43 | .949661 | 2.35 | .910464 | 21.50 |
| 44 | .941269 | 2.40 | .839221 | 18.93 | 44 | .9498[illegible]2 | 2.35 | .911754 | 21.55 |
| 45 | .941413 | 2.38 | .840357 | 18.95 | 45 | .949943 | 2.33 | .913047 | 21.60 |
| 46 | .941556 | 2.38 | .841494 | 19.00 | 46 | .950083 | 2.35 | .914343 | 21.65 |
| 47 | .941699 | 2.40 | .842634 | 19.03 | 47 | .950224 | 2.35 | .915642 | 21.70 |
| 48 | .941843 | 2.38 | .843776 | 19.08 | 48 | .950365 | 2.35 | .916944 | 21.75 |
| 49 | .941986 | 2.38 | .844921 | 19.12 | 49 | .950506 | 2.35 | .918249 | 21.82 |
| 50 | .942129 | 2.38 | .846068 | 19.15 | 50 | .950647 | 2.33 | .919558 | 21.85 |
| 51 | 9.942272 | 2.38 | 10.847217 | 19.18 | 51 | 9.950787 | 2.35 | 10.920869 | 21.92 |
| 52 | .942415 | 2.40 | .848368 | 19.23 | 52 | .950928 | 2.35 | .922184 | 21.97 |
| 53 | .942559 | 2.38 | .849522 | 19.27 | 53 | .951069 | 2.33 | .923502 | 22.02 |
| 54 | .942702 | 2.38 | .850678 | 19.30 | 54 | .951209 | 2.35 | .924823 | 22.07 |
| 55 | .942845 | 2.38 | .851836 | 19.35 | 55 | .951350 | 2.33 | .926147 | 22.13 |
| 56 | .942988 | 2.38 | .852997 | 19.40 | 56 | .951490 | 2.35 | .927475 | 22.17 |
| 57 | .943131 | 2.37 | .854161 | 19.42 | 57 | .951631 | 2.33 | .928805 | 22.23 |
| 58 | .943273 | 2.38 | .855326 | 19.47 | 58 | .951771 | 2.33 | .930139 | 22.30 |
| 59 | .943416 | 2.38 | .856494 | 19.52 | 59 | .951911 | 2.35 | .931477 | 22.33 |
| 60 | 9.943559 | 2.38 | 10.857665 | 19.55 | 60 | 9.952052 | 2.33 | 10.932817 | 22.40 |

| | 84° | | | | | 85° | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.952052 | 2.33 | 10.932817 | 22.40 | 0 | 9.960397 | 2.30 | 11.020101 | 26.40 |
| 1 | .952192 | 2.33 | .934161 | 22.45 | 1 | .960535 | 2.28 | .021685 | 26.48 |
| 2 | .952332 | 2.35 | .935508 | 22.52 | 2 | .960672 | 2.30 | .023274 | 26.57 |
| 3 | .952473 | 2.33 | .936859 | 22.57 | 3 | .960810 | 2.30 | .024868 | 26.65 |
| 4 | .952613 | 2.33 | .938213 | 22.62 | 4 | .960948 | 2.30 | .026467 | 26.73 |
| 5 | .952753 | 2.33 | .939570 | 22.68 | 5 | .961086 | 2.28 | .028071 | 26.80 |
| 6 | .952893 | 2.33 | .940931 | 22.75 | 6 | .961223 | 2.30 | .029679 | 26.90 |
| 7 | .953033 | 2.33 | .942296 | 22.78 | 7 | .961361 | 2.28 | .031293 | 26.98 |
| 8 | .953173 | 2.33 | .943663 | 22.85 | 8 | .961498 | 2.30 | .032912 | 27.07 |
| 9 | .953313 | 2.33 | .945034 | 22.92 | 9 | .961636 | 2.28 | .034536 | 27.13 |
| 10 | .953453 | 2.33 | .946409 | 22.97 | 10 | .961773 | 2.30 | .036164 | 27.23 |
| 11 | 9.953593 | 2.32 | 10.947787 | 23.03 | 11 | 9.961911 | 2.28 | 11.037798 | 27.33 |
| 12 | .953732 | 2.33 | .949169 | 23.08 | 12 | .962048 | 2.30 | .039438 | 27.40 |
| 13 | .953872 | 2.33 | .950554 | 23.15 | 13 | .962186 | 2.28 | .041082 | 27.50 |
| 14 | .954012 | 2.33 | .951943 | 23.22 | 14 | .962323 | 2.28 | .042732 | 27.58 |
| 15 | .954152 | 2.32 | .953336 | 23.27 | 15 | .962460 | 2.28 | .044387 | 27.67 |
| 16 | .954291 | 2.33 | .954732 | 23.33 | 16 | .962597 | 2.30 | .046047 | 27.77 |
| 17 | .954431 | 2.33 | .956132 | 23.38 | 17 | .962735 | 2.28 | .047713 | 27.85 |
| 18 | .954571 | 2.32 | .957535 | 23.45 | 18 | .962872 | 2.28 | .049384 | 27.93 |
| 19 | .954710 | 2.33 | .958942 | 23.52 | 19 | .963009 | 2.28 | .051060 | 28.03 |
| 20 | .954850 | 2.32 | .960353 | 23.57 | 20 | .963146 | 2.28 | .052742 | 28.13 |
| 21 | 9.954989 | 2.33 | 10.961767 | 23.65 | 21 | 9.963283 | 2.28 | 11.054430 | 28.22 |
| 22 | .955129 | 2.32 | .963186 | 23.70 | 22 | .963420 | 2.28 | .056123 | 28.30 |
| 23 | .955268 | 2.32 | .964608 | 23.77 | 23 | .963557 | 2.28 | .057821 | 28.40 |
| 24 | .955407 | 2.33 | .966034 | 23.82 | 24 | .963694 | 2.28 | .059525 | 28.50 |
| 25 | .955547 | 2.32 | .967463 | 23.90 | 25 | .963831 | 2.28 | .061235 | 28.60 |
| 26 | .955686 | 2.32 | .968897 | 23.95 | 26 | .963968 | 2.27 | .062951 | 28.68 |
| 27 | .955825 | 2.32 | .970334 | 24.02 | 27 | .964104 | 2.28 | .064672 | 28.78 |
| 28 | .955964 | 2.32 | .971775 | 24.10 | 28 | .964241 | 2.28 | .066399 | 28.88 |
| 29 | .956103 | 2.33 | .973221 | 24.15 | 29 | .964378 | 2.28 | .068132 | 28.98 |
| 30 | .956243 | 2.32 | .974670 | 24.22 | 30 | .964515 | 2.27 | .069871 | 29.08 |
| 31 | 9.956382 | 2.32 | 10.976123 | 24.28 | 31 | 9.964651 | 2.28 | 11.071616 | 29.18 |
| 32 | .956521 | 2.32 | .977580 | 24.35 | 32 | .964788 | 2.27 | .073367 | 29.28 |
| 33 | .956660 | 2.32 | .979041 | 24.42 | 33 | .964924 | 2.28 | .075124 | 29.38 |
| 34 | .956799 | 2.30 | .980506 | 24.48 | 34 | .965061 | 2.27 | .076887 | 29.48 |
| 35 | .956937 | 2.32 | .981975 | 24.55 | 35 | .965197 | 2.28 | .078656 | 29.58 |
| 36 | .957076 | 2.32 | .983448 | 24.63 | 36 | .965334 | 2.27 | .080431 | 29.68 |
| 37 | .957215 | 2.32 | .984926 | 24.68 | 37 | .965460 | 2.28 | .082212 | 29.80 |
| 38 | .957354 | 2.32 | .986407 | 24.77 | 38 | .965607 | 2.27 | .084000 | 29.90 |
| 39 | .957493 | 2.30 | .987893 | 24.83 | 39 | .965743 | 2.27 | .085794 | 30.00 |
| 40 | .957631 | 2.32 | .989383 | 24.90 | 40 | .965879 | 2.28 | .087594 | 30.12 |
| 41 | 9.957770 | 2.32 | 10.990877 | 24.97 | 41 | 9.966016 | 2.27 | 11.089401 | 30.22 |
| 42 | .957909 | 2.30 | .992375 | 25.03 | 42 | .966152 | 2.27 | .091214 | 30.32 |
| 43 | .958047 | 2.32 | .993877 | 25.12 | 43 | .966288 | 2.27 | .093033 | 30.43 |
| 44 | .958186 | 2.30 | .995384 | 25.18 | 44 | .966424 | 2.27 | .094859 | 30.55 |
| 45 | .958324 | 2.32 | .996895 | 25.27 | 45 | .996560 | 2.27 | .096692 | 30.67 |
| 46 | .958463 | 2.30 | .998411 | 25.33 | 46 | .966696 | 2.27 | .098532 | 30.77 |
| 47 | .958601 | 2.30 | .999931 | 25.40 | 47 | .966832 | 2.27 | .100378 | 30.87 |
| 48 | .958739 | 2.32 | 11.001455 | 25.48 | 48 | .966968 | 2.27 | .102230 | 31.00 |
| 49 | .958878 | 2.30 | .002984 | 25.52 | 49 | .967104 | 2.27 | .104090 | 31.12 |
| 50 | .959016 | 2.30 | .004517 | 25.63 | 50 | .967240 | 2.27 | .105957 | 31.22 |
| 51 | 9.959154 | 2.30 | 11.006055 | 25.70 | 51 | 9.967376 | 2.27 | 11.107830 | 31.35 |
| 52 | .959292 | 2.32 | .007597 | 25.78 | 52 | .967512 | 2.25 | .109711 | 31.45 |
| 53 | .959431 | 2.30 | .009144 | 25.85 | 53 | .967647 | 2.27 | .111598 | 31.58 |
| 54 | .959569 | 2.30 | .010695 | 25.93 | 54 | .967783 | 2.27 | .113493 | 31.68 |
| 55 | .959707 | 2.30 | .012251 | 26.00 | 55 | .967919 | 2.25 | .115394 | 31.82 |
| 56 | .959845 | 2.30 | .013811 | 26.10 | 56 | .968054 | 2.27 | .117303 | 31.93 |
| 57 | .959983 | 2.30 | .015377 | 26.17 | 57 | .968190 | 2.27 | .119219 | 32.07 |
| 58 | .960121 | 2.30 | .016947 | 26.23 | 58 | .968326 | 2.25 | .121143 | 32.18 |
| 59 | .960259 | 2.30 | .018521 | 26.33 | 59 | .968461 | 2.27 | .123074 | 32.30 |
| 60 | 9.960397 | 2.30 | 11.020101 | 26.40 | 60 | 9.968597 | 2.25 | 11.125012 | 32.43 |

| 86° | | | | | 87° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. | ′ | Vers. | D. 1″. | Ex. sec. | D. 1″. |
| 0 | 9.968597 | 2.25 | 11.125012 | 32.43 | 0 | 9.976654 | 2.23 | 11.257854 | 42.52 |
| 1 | .968732 | 2.27 | .126958 | 32.55 | 1 | .976788 | 2.22 | .260405 | 42.73 |
| 2 | .968868 | 2.25 | .128911 | 32.70 | 2 | .976921 | 2.22 | .262969 | 42.95 |
| 3 | .969003 | 2.25 | .130873 | 32.80 | 3 | .977054 | 2.22 | .265546 | 43.20 |
| 4 | .969138 | 2.27 | .132841 | 32.95 | 4 | .977187 | 2.22 | .268138 | 43.42 |
| 5 | .969274 | 2.25 | .134818 | 33.07 | 5 | .977320 | 2.20 | .270743 | 43.67 |
| 6 | .969409 | 2.25 | .136802 | 33.22 | 6 | .977452 | 2.22 | .273363 | 43.88 |
| 7 | .969544 | 2.25 | .138795 | 33.33 | 7 | .977585 | 2.22 | .275996 | 44.15 |
| 8 | .969679 | 2.25 | .140795 | 33.47 | 8 | .977718 | 2.22 | .278645 | 44.38 |
| 9 | .969814 | 2.25 | .142803 | 33.62 | 9 | .977851 | 2.22 | .281308 | 44.63 |
| 10 | .969949 | 2.25 | .144820 | 33.73 | 10 | .977984 | 2.20 | .283986 | 44.88 |
| 11 | 9.970084 | 2.27 | 11.146844 | 33.88 | 11 | 9.978116 | 2.22 | 11.286679 | 45.13 |
| 12 | .970220 | 2.23 | .148877 | 34.02 | 12 | .978249 | 2.22 | .289387 | 45.38 |
| 13 | .970354 | 2.25 | .150918 | 34.17 | 13 | .978382 | 2.20 | .292110 | 45.65 |
| 14 | .970489 | 2.25 | .152968 | 34.30 | 14 | .978514 | 2.22 | .294849 | 45.92 |
| 15 | .970624 | 2.25 | .155026 | 34.43 | 15 | .978647 | 2.20 | .297604 | 46.17 |
| 16 | .970759 | 2.25 | .157092 | 34.60 | 16 | .978779 | 2.22 | .300374 | 46.45 |
| 17 | .970894 | 2.25 | .159168 | 34.73 | 17 | .978912 | 2.20 | .303161 | 46.72 |
| 18 | .971029 | 2.25 | .161252 | 34.87 | 18 | .979044 | 2.22 | .305964 | 47.00 |
| 19 | .971164 | 2.23 | .163344 | 35.03 | 19 | .979177 | 2.20 | .308784 | 47.27 |
| 20 | .971298 | 2.25 | .165446 | 35.17 | 20 | .979309 | 2.22 | .311620 | 47.55 |
| 21 | 9.971433 | 2.25 | 11.167556 | 35.33 | 21 | 9.979442 | 2.20 | 11.314473 | 47.83 |
| 22 | .971568 | 2.23 | .169676 | 35.48 | 22 | .979574 | 2.20 | .317343 | 48.13 |
| 23 | .971702 | 2.25 | .171805 | 35.63 | 23 | .979706 | 2.20 | .320231 | 48.43 |
| 24 | .971837 | 2.23 | .173943 | 35.78 | 24 | .979838 | 2.20 | .323137 | 48.72 |
| 25 | .971971 | 2.25 | .176090 | 35.93 | 25 | .979970 | 2.22 | .326060 | 49.02 |
| 26 | .972106 | 2.23 | .178246 | 36.10 | 26 | .980103 | 2.20 | .329001 | 49.33 |
| 27 | .972240 | 2.23 | .180412 | 36.27 | 27 | .980235 | 2.20 | .331961 | 49.63 |
| 28 | .972374 | 2.25 | .182588 | 36.42 | 28 | .980367 | 2.20 | .334939 | 49.93 |
| 29 | .972509 | 2.23 | .184773 | 36.58 | 29 | .980499 | 2.20 | .337935 | 50.27 |
| 30 | .972643 | 2.23 | .186968 | 36.75 | 30 | .980631 | 2.20 | .340951 | 50.58 |
| 31 | 9.972777 | 2.25 | 11.189173 | 36.90 | 31 | 9.980763 | 2.20 | 11.343986 | 50.92 |
| 32 | .972912 | 2.23 | .191387 | 37.08 | 32 | .980895 | 2.18 | .347041 | 51.23 |
| 33 | .973046 | 2.23 | .193612 | 37.25 | 33 | .881026 | 2.20 | .350115 | 51.58 |
| 34 | .973180 | 2.23 | .195847 | 37.42 | 34 | .981158 | 2.20 | .353210 | 51.92 |
| 35 | .973314 | 2.23 | .198092 | 37.58 | 35 | .981290 | 2.20 | .356325 | 52.25 |
| 36 | .973448 | 2.23 | .200347 | 37.77 | 36 | .981422 | 2.20 | .359460 | 52.62 |
| 37 | .973582 | 2.23 | .202613 | 37.93 | 37 | .981554 | 2.18 | .362617 | 52.95 |
| 38 | .973716 | 2.23 | .204889 | 38.12 | 38 | .981685 | 2.20 | .365794 | 53.32 |
| 39 | .973850 | 2.23 | .207176 | 38.28 | 39 | .981817 | 2.20 | .368993 | 53.68 |
| 40 | .973984 | 2.23 | .209473 | 38.47 | 40 | .981949 | 2.18 | .372214 | 54.07 |
| 41 | 9.974118 | 2.23 | 11.211781 | 38.67 | 41 | 9.982080 | 2.20 | 11.375458 | 54.42 |
| 42 | .974252 | 2.23 | .214101 | 38.83 | 42 | .982212 | 2.18 | .378723 | 54.80 |
| 43 | .974386 | 2.22 | .216431 | 39.03 | 43 | .982343 | 2.20 | .382011 | 55.20 |
| 44 | .974519 | 2.23 | .218773 | 39.20 | 44 | .982475 | 2.18 | .385323 | 55.58 |
| 45 | .974653 | 2.23 | .221125 | 39.42 | 45 | .982606 | 2.18 | .388658 | 55.97 |
| 46 | .974787 | 2.22 | .223490 | 39.58 | 46 | .982737 | 2.20 | .392016 | 56.38 |
| 47 | .974920 | 2.23 | .225865 | 39.80 | 47 | .982869 | 2.18 | .395399 | 56.80 |
| 48 | .975054 | 2.23 | .228253 | 39.98 | 48 | .983000 | 2.18 | .398807 | 57.20 |
| 49 | .975188 | 2.22 | .230652 | 40.18 | 49 | .983131 | 2.18 | .402239 | 57.62 |
| 50 | .975321 | 2.23 | .233063 | 40.38 | 50 | .983262 | 2.20 | .405696 | 58.07 |
| 51 | 9.975455 | 2.22 | 11.235486 | 40.58 | 51 | 9.983394 | 2.18 | 11.409180 | 58.48 |
| 52 | .975588 | 2.23 | .237921 | 40.78 | 52 | .983525 | 2.18 | .412689 | 58.93 |
| 53 | .975722 | 2.22 | .240368 | 41.00 | 53 | .983656 | 2.18 | .416225 | 59.38 |
| 54 | .975855 | 2.22 | .242828 | 41.20 | 54 | .983787 | 2.18 | .419788 | 59.83 |
| 55 | .975988 | 2.23 | .245300 | 41.42 | 55 | .983918 | 2.18 | .423378 | 60.28 |
| 56 | .976122 | 2.22 | .247785 | 41.63 | 56 | .984049 | 2.18 | .426995 | 60.77 |
| 57 | .976255 | 2.22 | .250283 | 41.83 | 57 | .984180 | 2.18 | .430641 | 61.25 |
| 58 | .976388 | 2.22 | .252793 | 42.07 | 58 | .984311 | 2.18 | .434316 | 61.73 |
| 59 | .976521 | 2.22 | .255317 | 42.28 | 59 | .984442 | 2.18 | .438020 | 62.22 |
| 60 | 9.976654 | 2.23 | 11.257854 | 42.52 | 60 | 9.984573 | 2.17 | 11.441753 | 62.73 |

TABLE XXVI.—LOGARITHMIC VERSED SIGNS AND EXTERNAL SECANTS.

| 88° | | | | | 89° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ′ | Vers. | D. 1″. | Ex. sec. | q+l | ′ | Vers. | D. 1″. | Ex. sec. | q+l |
| | | | | 15.29* | | | | | 15.30* |
| 0 | 9.984573 | 2.17 | 11.441753 | 9086 | 0 | 9.992354 | 2.13 | 11.750498 | 6801 |
| 1 | .984703 | 2.18 | .445517 | 9215 | 1 | .992482 | 2.15 | .757925 | 6929 |
| 2 | .984834 | 2.18 | .449311 | 9345 | 2 | .992611 | 2.13 | .765477 | 7056 |
| 3 | .984965 | 2.18 | .453137 | 9474 | 3 | .992739 | 2.15 | .773158 | 7184 |
| 4 | .985096 | 2.17 | .456994 | 9603 | 4 | .992868 | 2.13 | .780973 | 7312 |
| 5 | .985226 | 2.18 | .460883 | 9732 | 5 | .992996 | 2.13 | .788926 | 7440 |
| 6 | .985357 | 2.17 | .464805 | 9862 | 6 | .993124 | 2.15 | .797022 | 7567 |
| 7 | .985487 | 2.18 | .468761 | 9991 | 7 | .993253 | 2.13 | .805268 | 7695 |
| 8 | .985618 | 2.17 | .472751 | ◆120 | 8 | .993381 | 2.13 | .813668 | 7823 |
| 9 | .985748 | 2.18 | .476775 | 0249 | 9 | .993509 | 2.13 | .822229 | 7950 |
| 10 | .985879 | 2.17 | .480834 | 0378 | 10 | .993637 | 2.13 | .830956 | 8078 |
| 11 | 9.986009 | 2.18 | 11.484929 | 0507 | 11 | 9.993765 | 2.15 | 11.839858 | 8205 |
| 12 | .986140 | 2.17 | .489061 | 0636 | 12 | .993894 | 2.13 | .848940 | 8333 |
| 13 | .986270 | 2.17 | .493230 | 0765 | 13 | .994022 | 2.13 | .858211 | 8460 |
| 14 | .986400 | 2.18 | .497437 | 0894 | 14 | .994150 | 2.13 | .867679 | 8588 |
| 15 | .986531 | 2.17 | .501683 | 1023 | 15 | .994278 | 2.13 | .877351 | 8715 |
| 16 | .986661 | 2.17 | .505968 | 1152 | 16 | .994406 | 2.13 | .887239 | 8843 |
| 17 | .986791 | 2.17 | .510293 | 1281 | 17 | .994534 | 2.13 | .897350 | 8970 |
| 18 | .986921 | 2.17 | .514659 | 1410 | 18 | .994662 | 2.12 | .907697 | 9097 |
| 19 | .987051 | 2.17 | .519066 | 1539 | 19 | .994789 | 2.13 | .918290 | 9225 |
| 20 | .987181 | 2.17 | .523516 | 1668 | 20 | .994917 | 2.13 | .929141 | 9352 |
| 21 | 9.987311 | 2.17 | 11.528010 | 1797 | 21 | 9.995045 | 2.13 | 11.940264 | 9479 |
| 22 | .987441 | 2.17 | .532548 | 1925 | 22 | .995173 | 2.13 | .951672 | 9607 |
| 23 | .987571 | 2.17 | .537131 | 2054 | 23 | .995301 | 2.12 | .963381 | 9734 |
| 24 | .987701 | 2.17 | .541760 | 2183 | 24 | .995428 | 2.13 | .975408 | 9862 |
| 25 | .987831 | 2.17 | .546437 | 2312 | 25 | .995556 | 2.12 | 11.987769 | 9988 |
| 26 | .987961 | 2.17 | .551161 | 2440 | 26 | .995683 | 2.13 | 12.000485 | →116 |
| 27 | .988091 | 2.17 | .555935 | 2569 | 27 | .995811 | 2.13 | .013578 | 0243 |
| 28 | .988221 | 2.15 | .560759 | 2698 | 28 | .995939 | 2.12 | .027069 | 0370 |
| 29 | .988350 | 2.17 | .565634 | 2826 | 29 | .996066 | 2.12 | .040984 | 0497 |
| 30 | .988480 | 2.17 | .570561 | 2955 | 30 | .996193 | 2.13 | .055352 | 0624 |
| 31 | 9.988610 | 2.15 | 11.575542 | 3083 | 31 | 9.996321 | 2.12 | 12.070202 | 0751 |
| 32 | .988739 | 2.17 | .580578 | 3212 | 32 | .996448 | 2.13 | .085569 | 0878 |
| 33 | .988869 | 2.15 | .585670 | 3340 | 33 | .996576 | 2.12 | .101490 | 1005 |
| 34 | .988998 | 2.17 | .590819 | 3469 | 34 | .996703 | 2.12 | .118008 | 1132 |
| 35 | .989128 | 2.15 | .596027 | 3597 | 35 | .996830 | 2.12 | .135168 | 1259 |
| 36 | .989257 | 2.17 | .601295 | 3726 | 36 | .996957 | 2.13 | .153024 | 1386 |
| 37 | .989387 | 2.15 | .606625 | 3854 | 37 | .997085 | 2.12 | .171634 | 1513 |
| 38 | .989516 | 2.17 | .612018 | 3983 | 38 | .997212 | 2.12 | .191066 | 1640 |
| 39 | .989646 | 2.15 | .617475 | 4111 | 39 | .997339 | 2.12 | .211396 | 1767 |
| 40 | .989775 | 2.15 | .622998 | 4239 | 40 | .997466 | 2.12 | .232712 | 1894 |
| 41 | 9.989904 | 2.17 | 11.628589 | 4368 | 41 | 9.997593 | 2.12 | 12.255116 | 2020 |
| 42 | .990034 | 2.15 | .634250 | 4496 | 42 | .997720 | 2.12 | .278723 | 2147 |
| 43 | .990163 | 2.15 | .639982 | 4624 | 43 | .997847 | 2.12 | .303674 | 2274 |
| 44 | .990292 | 2.15 | .645788 | 4752 | 44 | .997974 | 2.12 | .330129 | 2401 |
| 45 | .990421 | 2.15 | .651668 | 4881 | 45 | .998101 | 2.12 | .358285 | 2527 |
| 46 | .990550 | 2.15 | .657626 | 5009 | 46 | .998228 | 2.12 | .388375 | 2654 |
| 47 | .990679 | 2.15 | .663663 | 5137 | 47 | .998355 | 2.10 | .420686 | 2781 |
| 48 | .990808 | 2.15 | .669781 | 5265 | 48 | .998481 | 2.12 | .455575 | 2907 |
| 49 | .990937 | 2.15 | .675984 | 5393 | 49 | .998608 | 2.12 | .493490 | 3034 |
| 50 | .991066 | 2.15 | .682272 | 5521 | 50 | .998735 | 2.12 | .535009 | 3161 |
| 51 | 9.991195 | 2.15 | 11.688649 | 5649 | 51 | 9.998862 | 2.10 | 12.580893 | 3287 |
| 52 | .991324 | 2.15 | .695117 | 5777 | 52 | .998988 | 2.12 | .632172 | 3414 |
| 53 | .991453 | 2.15 | .701679 | 5905 | 53 | .999115 | 2.10 | .690291 | 3540 |
| 54 | .991582 | 2.13 | .708338 | 6033 | 54 | .999241 | 2.12 | .757364 | 3667 |
| 55 | .991710 | 2.15 | .715097 | 6161 | 55 | .999368 | 2.10 | .836672 | 3793 |
| 56 | .991839 | 2.15 | .721958 | 6289 | 56 | .999494 | 2.12 | 12.933708 | 3920 |
| 57 | .991968 | 2.13 | .728925 | 6417 | 57 | .999621 | 2.10 | 13.058774 | 4046 |
| 58 | .992096 | 2.15 | .736002 | 6545 | 58 | .999747 | 2.12 | .234991 | 4172 |
| 59 | .992225 | 2.15 | .743192 | 6673 | 59 | .999874 | 2.10 | .536148 | 4299 |
| 60 | 9.992354 | 2.13 | 11.750498 | 6801 | 60 | 10.000000 | 2.10 | Inf. pos. | 4426 |
| | | | | 15.30* | | | | | 15.31* |

| ′ | 0° | | 1° | | 2° | | 3° | | 4° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .00000 | One. | .01745 | .99985 | .03490 | .99939 | .05234 | .99863 | .06976 | .99756 | 60 |
| 1 | .00029 | One. | .01774 | .99984 | .03519 | .99938 | .05263 | .99861 | .07005 | .99754 | 59 |
| 2 | .00058 | One. | .01803 | .99984 | .03548 | .99937 | .05292 | .99860 | .07034 | .99752 | 58 |
| 3 | .00087 | One. | .01832 | .99983 | .03577 | .99936 | .05321 | .99858 | .07063 | .99750 | 57 |
| 4 | .00116 | One. | .01862 | .99983 | .03606 | .99935 | .05350 | .99857 | .07092 | .99748 | 56 |
| 5 | .00145 | One. | .01891 | .99982 | .03635 | .99934 | .05379 | .99855 | .07121 | .99746 | 55 |
| 6 | .00175 | One. | .01920 | .99982 | .03664 | .99933 | .05408 | .99854 | .07150 | .99744 | 54 |
| 7 | .00204 | One. | .01949 | .99981 | .03693 | .99932 | .05437 | .99852 | .07179 | .99742 | 53 |
| 8 | .00233 | One. | .01978 | .99980 | .03723 | .99931 | .05466 | .99851 | .07208 | .99740 | 52 |
| 9 | .00262 | One. | .02007 | .99980 | .03752 | .99930 | .05495 | .99849 | .07237 | .99738 | 51 |
| 10 | .00291 | One. | .02036 | .99979 | .03781 | .99929 | .05524 | .99847 | .07266 | .99736 | 50 |
| 11 | .00320 | .99999 | .02065 | .99979 | .03810 | .99927 | .05553 | .99846 | .07295 | .99734 | 49 |
| 12 | .00349 | .99999 | .02094 | .99978 | .03839 | .99926 | .05582 | .99844 | .07324 | .99731 | 48 |
| 13 | .00378 | .99999 | .02123 | .99977 | .03868 | .99925 | .05611 | .99842 | .07353 | .99729 | 47 |
| 14 | .00407 | .99999 | .02152 | .99977 | .03897 | .99924 | .05640 | .99841 | .07382 | .99727 | 46 |
| 15 | .00436 | .99999 | .02181 | .99976 | .03926 | .99923 | .05669 | .99839 | .07411 | .99725 | 45 |
| 16 | .00465 | .99999 | .02211 | .99976 | .03955 | .99922 | .05698 | .99838 | .07440 | .99723 | 44 |
| 17 | .00495 | .99999 | .02240 | .99975 | .03984 | .99921 | .05727 | .99836 | .07469 | .99721 | 43 |
| 18 | .00524 | .99999 | .02269 | .99974 | .04013 | .99919 | .05756 | .99834 | .07498 | .99719 | 42 |
| 19 | .00553 | .99998 | .02298 | .99974 | .04042 | .99918 | .05785 | .99833 | .07527 | .99716 | 41 |
| 20 | .00582 | .99998 | .02327 | .99973 | .04071 | .99917 | .05814 | .99831 | .07556 | .99714 | 40 |
| 21 | .00611 | .99998 | .02356 | .99972 | .04100 | .99916 | .05844 | .99829 | .07585 | .99712 | 39 |
| 22 | .00640 | .99998 | .02385 | .99972 | .04129 | .99915 | .05873 | .99827 | .07614 | .99710 | 38 |
| 23 | .00669 | .99998 | .02414 | .99971 | .04159 | .99913 | .05902 | .99826 | .07643 | .99708 | 37 |
| 24 | .00698 | .99998 | .02443 | .99970 | .04188 | .99912 | .05931 | .99824 | .07672 | .99705 | 36 |
| 25 | .00727 | .99997 | .02472 | .99969 | .04217 | .99911 | .05960 | .99822 | .07701 | .99703 | 35 |
| 26 | .00756 | .99997 | .02501 | .99969 | .04246 | .99910 | .05989 | .99821 | .07730 | .99701 | 34 |
| 27 | .00785 | .99997 | .02530 | .99968 | .04275 | .99909 | .06018 | .99819 | .07759 | .99699 | 33 |
| 28 | .00814 | .99997 | .02560 | .99967 | .04304 | .99907 | .06047 | .99817 | .07788 | .99696 | 32 |
| 29 | .00844 | .99996 | .02589 | .99966 | .04333 | .99906 | .06076 | .99815 | .07817 | .99694 | 31 |
| 30 | .00873 | .99996 | .02618 | .99966 | .04362 | .99905 | .06105 | .99813 | .07846 | .99692 | 30 |
| 31 | .00902 | .99996 | .02647 | .99965 | .04391 | .99904 | .06134 | .99812 | .07875 | .99689 | 29 |
| 32 | .00931 | .99996 | .02676 | .99964 | .04420 | .99902 | .06163 | .99810 | .07904 | .99687 | 28 |
| 33 | .00960 | .99995 | .02705 | .99963 | .04449 | .99901 | .06192 | .99808 | .07933 | .99685 | 27 |
| 34 | .00989 | .99995 | .02734 | .99963 | .04478 | .99900 | .06221 | .99806 | .07962 | .99683 | 26 |
| 35 | .01018 | .99995 | .02763 | .99962 | .04507 | .99898 | .06250 | .99804 | .07991 | .99680 | 25 |
| 36 | .01047 | .99995 | .02792 | .99961 | .04536 | .99897 | .06279 | .99803 | .08020 | .99678 | 24 |
| 37 | .01076 | .99994 | .02821 | .99960 | .04565 | .99896 | .06308 | .99801 | .08049 | .99676 | 23 |
| 38 | .01105 | .99994 | .02850 | .99959 | .04594 | .99894 | .06337 | .99799 | .08078 | .99673 | 22 |
| 39 | .01134 | .99994 | .02879 | .99959 | .04623 | .99893 | .06366 | .99797 | .08107 | .99671 | 21 |
| 40 | .01164 | .99993 | .02908 | .99958 | .04653 | .99892 | .06395 | .99795 | .08136 | .99668 | 20 |
| 41 | .01193 | .99993 | .02938 | .99957 | .04682 | .99890 | .06424 | .99793 | .08165 | .99666 | 19 |
| 42 | .01222 | .99993 | .02967 | .99956 | .04711 | .99889 | .06453 | .99792 | .08194 | .99664 | 18 |
| 43 | .01251 | .99992 | .02996 | .99955 | .04740 | .99888 | .06482 | .99790 | .08223 | .99661 | 17 |
| 44 | .01280 | .99992 | .03025 | .99954 | .04769 | .99886 | .06511 | .99788 | .08252 | .99659 | 16 |
| 45 | .01309 | .99991 | .03054 | .99953 | .04798 | .99885 | .06540 | .99786 | .08281 | .99657 | 15 |
| 46 | .01338 | .99991 | .03083 | .99952 | .04827 | .99883 | .06569 | .99784 | .08310 | .99654 | 14 |
| 47 | .01367 | .99991 | .03112 | .99952 | .04856 | .99882 | .06598 | .99782 | .08339 | .99652 | 13 |
| 48 | .01396 | .99990 | .03141 | .99951 | .04885 | .99881 | .06627 | .99780 | .08368 | .99649 | 12 |
| 49 | .01425 | .99990 | .03170 | .99950 | .04914 | .99879 | .06656 | .99778 | .08397 | .99647 | 11 |
| 50 | .01454 | .99989 | .03199 | .99949 | .04943 | .99878 | .06685 | .99776 | .08426 | .99644 | 10 |
| 51 | .01483 | .99989 | .03228 | .99948 | .04972 | .99876 | .06714 | .99774 | .08455 | .99642 | 9 |
| 52 | .01513 | .99989 | .03257 | .99947 | .05001 | .99875 | .06743 | .99772 | .08484 | .99639 | 8 |
| 53 | .01542 | .99988 | .03286 | .99946 | .05030 | .99873 | .06773 | .99770 | .08513 | .99637 | 7 |
| 54 | .01571 | .99988 | .03316 | .99945 | .05059 | .99872 | .06802 | .99768 | .08542 | .99635 | 6 |
| 55 | .01600 | .99987 | .03345 | .99944 | .05088 | .99870 | .06831 | .99766 | .08571 | .99632 | 5 |
| 56 | .01629 | .99987 | .03374 | .99943 | .05117 | .99869 | .06860 | .99764 | .08600 | .99630 | 4 |
| 57 | .01658 | .99986 | .03403 | .99942 | .05146 | .99867 | .06889 | .99762 | .08629 | .99627 | 3 |
| 58 | .01687 | .99986 | .03432 | .99941 | .05175 | .99866 | .06918 | .99760 | .08658 | .99625 | 2 |
| 59 | .01716 | .99985 | .03461 | .99940 | .05205 | .99864 | .06947 | .99758 | .08687 | .99622 | 1 |
| 60 | .01745 | .99985 | .03490 | .99939 | .05234 | .99863 | .06976 | .99756 | .08716 | .99619 | 0 |
| | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | |
| ′ | 89° | | 88° | | 87° | | 86° | | 85° | | ′ |

# TABLE XXVII.—NATURAL SINES AND COSINES.

| ′ | 5° | | 6° | | 7° | | 8° | | 9° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .08716 | .99619 | .10453 | .99452 | .12187 | .99255 | .13917 | .99027 | .15643 | .98769 | 60 |
| 1 | .08745 | .99617 | .10482 | .99449 | .12216 | .99251 | .13946 | .99023 | .15672 | .98764 | 59 |
| 2 | .08774 | .99614 | .10511 | .99446 | .12245 | .99248 | .13975 | .99019 | .15701 | .98760 | 58 |
| 3 | .08803 | .99612 | .10540 | .99443 | .12274 | .99244 | .14004 | .99015 | .15730 | .98755 | 57 |
| 4 | .08831 | .99609 | .10569 | .99440 | .12302 | .99240 | .14033 | .99011 | .15758 | .98751 | 56 |
| 5 | .08860 | .99607 | .10597 | .99437 | .12331 | .99237 | .14061 | .99006 | .15787 | .98746 | 55 |
| 6 | .08889 | .99604 | .10626 | .99434 | .12360 | .99233 | .14090 | .99002 | .15816 | .98741 | 54 |
| 7 | .08918 | 99602 | .10655 | .99431 | .12389 | .99230 | .14119 | .98998 | .15845 | .98737 | 53 |
| 8 | .08947 | .99599 | .10684 | .99428 | .12418 | .99226 | .14148 | .98994 | .15873 | .98732 | 52 |
| 9 | .08976 | .99596 | .10713 | .99424 | .12447 | .99222 | .14177 | .98990 | .15902 | .98728 | 51 |
| 10 | .09005 | .99594 | .10742 | .99421 | .12476 | .99219 | .14205 | .98986 | .15931 | .98723 | 50 |
| 11 | .09034 | .99591 | .10771 | .99418 | .12504 | .99215 | .14234 | .98982 | .15959 | .98718 | 49 |
| 12 | .09063 | .99588 | .10800 | .99415 | .12533 | .99211 | .14263 | .98978 | .15988 | .98714 | 48 |
| 13 | .09092 | .99586 | .10829 | .99412 | .12562 | .99208 | .14292 | .98973 | .16017 | .98709 | 47 |
| 14 | .09121 | .99583 | .10858 | .99409 | .12591 | .99204 | .14320 | .98969 | .16046 | .98704 | 46 |
| 15 | .09150 | .99580 | .10887 | .99406 | .12620 | .99200 | .14349 | .98965 | .16074 | .98700 | 45 |
| 16 | .09179 | .99578 | .10916 | .99402 | .12649 | .99197 | .14378 | .98961 | .16103 | .98695 | 44 |
| 17 | .09208 | .99575 | .10945 | .99399 | .12678 | .99193 | .14407 | .98957 | .16132 | .98690 | 43 |
| 18 | .09237 | .99572 | .10973 | .99396 | .12706 | .99189 | .14436 | .98953 | .16160 | .98686 | 42 |
| 19 | .09266 | .99570 | .11002 | .99393 | .12735 | .99186 | .14464 | .98948 | .16189 | .98681 | 41 |
| 20 | .09295 | .99567 | .11031 | .99390 | .12764 | .99182 | .14493 | .98944 | .16218 | .98676 | 40 |
| 21 | .09324 | .99564 | .11060 | .99386 | .12793 | .99178 | .14522 | .98940 | .16246 | .98671 | 39 |
| 22 | .09353 | .99562 | .11089 | .99383 | .12822 | .99175 | .14551 | .98936 | .16275 | .98667 | 38 |
| 23 | .09382 | .99559 | .11118 | .99380 | .12851 | .99171 | .14580 | .98931 | .16304 | .98662 | 37 |
| 24 | .09411 | .99556 | .11147 | .99377 | .12880 | .99167 | .14608 | .98927 | .16333 | .98657 | 36 |
| 25 | .09440 | .99553 | .11176 | .99374 | .12908 | .99163 | .14637 | .98923 | .16361 | .98652 | 35 |
| 26 | .09469 | .99551 | .11205 | .99370 | .12937 | .99160 | .14666 | .98919 | .16390 | .98648 | 34 |
| 27 | .09498 | .99548 | .11234 | .99367 | .12966 | .99156 | .14695 | .98914 | .16419 | .98643 | 33 |
| 28 | .09527 | .99545 | .11263 | .99364 | .12995 | .99152 | .14723 | .98910 | .16447 | .98638 | 32 |
| 29 | .09556 | .99542 | .11291 | .99360 | .13024 | .99148 | .14752 | .98906 | .16476 | .98633 | 31 |
| 30 | .09585 | .99540 | .11320 | .99357 | .13053 | .99144 | .14781 | .98902 | .16505 | .98629 | 30 |
| 31 | .09614 | .99537 | .11349 | .99354 | .13081 | .99141 | .14810 | .98897 | .16533 | .98624 | 29 |
| 32 | .09642 | .99534 | .11378 | .99351 | .13110 | .99137 | .14838 | .98893 | .16562 | .98619 | 28 |
| 33 | .09671 | .99531 | .11407 | .99347 | .13139 | .99133 | .14867 | .98889 | .16591 | .98614 | 27 |
| 34 | .09700 | .99528 | .11436 | .99344 | .13168 | .99129 | .14896 | .98884 | .16620 | .98609 | 26 |
| 35 | .09729 | .99526 | .11465 | .99341 | .13197 | .99125 | .14925 | .98880 | .16648 | .98604 | 25 |
| 36 | .09758 | .99523 | .11494 | .99337 | .13226 | .99122 | .14954 | .98876 | .16677 | .98600 | 24 |
| 37 | .09787 | .99520 | .11523 | .99334 | .13254 | .99118 | .14982 | .98871 | .16706 | .98595 | 23 |
| 38 | .09816 | 99517 | .11552 | .99331 | .13283 | .99114 | .15011 | .98867 | .16734 | .98590 | 22 |
| 39 | .09845 | .99514 | .11580 | .99327 | .13312 | .99110 | .15040 | .98863 | .16763 | .98585 | 21 |
| 40 | .09874 | .99511 | .11609 | .99324 | .13341 | .99106 | .15069 | .98858 | .16792 | .98580 | 20 |
| 41 | .09903 | .99508 | .11638 | .99320 | .13370 | .99102 | .15097 | .98854 | .16820 | .98575 | 19 |
| 42 | .09932 | .99506 | .11667 | .99317 | .13399 | .99098 | .15126 | .98849 | .16849 | .98570 | 18 |
| 43 | .09961 | .99503 | .11696 | .99314 | .13427 | .99094 | .15155 | .98845 | .16878 | .98565 | 17 |
| 44 | .09990 | .99500 | .11725 | .99310 | .13456 | .99091 | .15184 | .98841 | .16906 | .98561 | 16 |
| 45 | .10019 | .99497 | .11754 | .99307 | .13485 | .99087 | .15212 | .98836 | .16935 | .98556 | 15 |
| 46 | .10048 | .99494 | .11783 | .99303 | .13514 | .99083 | .15241 | .98832 | .16964 | .98551 | 14 |
| 47 | .10077 | .99491 | .11812 | .99300 | .13543 | .99079 | .15270 | .98827 | .16992 | .98546 | 13 |
| 48 | .10106 | .99488 | .11840 | .99297 | .13572 | .99075 | .15299 | .98823 | .17021 | .98541 | 12 |
| 49 | .10135 | .99485 | .11869 | .99293 | .13600 | .99071 | .15327 | .98818 | .17050 | .98536 | 11 |
| 50 | .10164 | .99482 | .11898 | .99290 | .13629 | .99067 | .15356 | .98814 | .17078 | .98531 | 10 |
| 51 | .10192 | .99479 | .11927 | .99286 | .13658 | .99063 | .15385 | .98809 | .17107 | .98526 | 9 |
| 52 | .10221 | .99476 | .11956 | .99283 | .13687 | .99059 | .15414 | .98805 | .17136 | .98521 | 8 |
| 53 | .10250 | .99473 | .11985 | .99279 | .13716 | .99055 | .15442 | .98800 | .17164 | .98516 | 7 |
| 54 | .10279 | .99470 | .12014 | .99276 | .13744 | .99051 | .15471 | .98796 | .17193 | .98511 | 6 |
| 55 | .10308 | .99467 | .12043 | .99272 | .13773 | .99047 | .15500 | .98791 | .17222 | .98506 | 5 |
| 56 | .10337 | .99464 | .12071 | .99269 | .13802 | .99043 | .15529 | .98787 | .17250 | .98501 | 4 |
| 57 | 10366 | .99461 | .12100 | .99265 | .13831 | .99039 | .15557 | .98782 | .17279 | .98496 | 3 |
| 58 | .10395 | .99458 | .12129 | .99262 | .13860 | .99035 | .15586 | .98778 | .17308 | .98491 | 2 |
| 59 | .10424 | .99455 | .12158 | .99258 | .13889 | .99031 | .15615 | .98773 | .17336 | .98486 | 1 |
| 60 | .10453 | .99452 | .12187 | .99255 | .13917 | .99027 | .15643 | .98769 | .17365 | .98481 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 84° | | 83° | | 82° | | 81° | | 80° | | |

| ′ | 10° | | 11° | | 12° | | 13° | | 14° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .17365 | .98481 | .19081 | .98163 | .20791 | .97815 | .22495 | .97437 | .24192 | .97030 | 60 |
| 1 | .17393 | .98476 | .19109 | .98157 | .20820 | .97809 | .22523 | .97430 | .24220 | .97023 | 59 |
| 2 | .17422 | .98471 | .19138 | .98152 | .20848 | .97803 | .22552 | .97424 | .24249 | .97015 | 58 |
| 3 | .17451 | .98466 | .19167 | .98146 | .20877 | .97797 | .22580 | .97417 | .24277 | .97008 | 57 |
| 4 | .17479 | .98461 | .19195 | .98140 | .20905 | .97791 | .22608 | .97411 | .24305 | .97001 | 56 |
| 5 | .17508 | .98455 | .19224 | .98135 | .20933 | .97784 | .22637 | .97404 | .24333 | .96994 | 55 |
| 6 | .17537 | .98450 | .19252 | .98129 | .20962 | .97778 | .22665 | .97398 | .24362 | .96987 | 54 |
| 7 | .17565 | .98445 | .19281 | .98124 | .20990 | .97772 | .22693 | .97391 | .24390 | .96980 | 53 |
| 8 | .17594 | .98440 | .19309 | .98118 | .21019 | .97766 | 22722 | .97384 | .24418 | .96973 | 52 |
| 9 | .17623 | .98435 | .19338 | .98112 | .21047 | .97760 | .22750 | .97378 | .24446 | .96966 | 51 |
| 10 | .17651 | .98430 | .19366 | .98107 | .21076 | .97754 | .22778 | .97371 | .24474 | .96959 | 50 |
| 11 | .17680 | .98425 | .19395 | .98101 | .21104 | .97748 | .22807 | .97365 | .24503 | .96952 | 49 |
| 12 | .17708 | .98420 | .19423 | .98096 | .21132 | .97742 | .22835 | .97358 | .24531 | .96945 | 48 |
| 13 | .17737 | .98414 | .19452 | .98090 | .21161 | .97735 | .22863 | .97351 | .24559 | .96937 | 47 |
| 14 | .17766 | .98409 | .19481 | .98084 | .21189 | .97729 | .22892 | .97345 | .24587 | .96930 | 46 |
| 15 | .17794 | .98404 | .19509 | .98079 | .21218 | .97723 | .22920 | .97338 | .24615 | .96923 | 45 |
| 16 | .17823 | .98399 | .19538 | .98073 | .21246 | .97717 | .22948 | .97331 | .24644 | .96916 | 44 |
| 17 | .17852 | .98394 | .19566 | .98067 | .21275 | .97711 | .22977 | .97325 | .24672 | .96909 | 43 |
| 18 | .17880 | .98389 | .19595 | .98061 | .21303 | .97705 | .23005 | .97318 | .24700 | .96902 | 42 |
| 19 | .17909 | .98383 | .19623 | .98056 | .21331 | .97698 | .23033 | .97311 | .24728 | .96894 | 41 |
| 20 | .17937 | .98378 | .19652 | .98050 | .21360 | .97692 | .23062 | .97304 | .24756 | .96887 | 40 |
| 21 | .17966 | .98373 | .19680 | .98044 | .21388 | .97686 | .23090 | .97298 | .24784 | .96880 | 39 |
| 22 | .17995 | .98368 | .19709 | .98039 | .21417 | .97680 | .23118 | .97291 | .24813 | .96873 | 38 |
| 23 | .18023 | .98362 | .19737 | .98033 | .21445 | .97673 | .23146 | .97284 | .24841 | .96866 | 37 |
| 24 | .18052 | .98357 | .19766 | .98027 | .21474 | .97667 | .23175 | .97278 | .24869 | .96858 | 36 |
| 25 | .18081 | .98352 | .19794 | .98021 | .21502 | .97661 | .23203 | .97271 | .24897 | .96851 | 35 |
| 26 | .18109 | .98347 | .19823 | .98016 | .21530 | .97655 | .23231 | .97264 | .24925 | .96844 | 34 |
| 27 | .18138 | .98341 | .19851 | .98010 | .21559 | .97648 | .23260 | .97257 | .24954 | .96837 | 33 |
| 28 | .18166 | .98336 | .19880 | .98004 | .21587 | .97642 | .23288 | .97251 | .24982 | .96829 | 32 |
| 29 | .18195 | .98331 | .19908 | .97998 | .21616 | .97636 | .23316 | .97244 | .25010 | .96822 | 31 |
| 30 | .18224 | .98325 | .19937 | .97992 | .21644 | .97630 | .23345 | .97237 | .25038 | .96815 | 30 |
| 31 | .18252 | .98320 | .19965 | .97987 | .21672 | .97623 | .23373 | .97230 | .25066 | .96807 | 29 |
| 32 | .18281 | .98315 | .19994 | .97981 | .21701 | .97617 | .23401 | .97223 | .25094 | .96800 | 28 |
| 33 | .18309 | .98310 | .20022 | .97975 | .21729 | .97611 | .23429 | .97217 | .25122 | .96793 | 27 |
| 34 | .18338 | .98304 | .20051 | .97969 | .21758 | .97604 | .23458 | .97210 | .25151 | .96786 | 26 |
| 35 | .18367 | .98299 | .20079 | .97963 | .21786 | .97598 | .23486 | .97203 | .25179 | .96778 | 25 |
| 36 | .18395 | .98294 | .20108 | .97958 | .21814 | .97592 | .23514 | .97196 | .25207 | .96771 | 24 |
| 37 | .18424 | .98288 | .20136 | .97952 | .21843 | .97585 | .23542 | .97189 | .25235 | .96764 | 23 |
| 38 | .18452 | .98283 | .20165 | .97946 | .21871 | .97579 | .23571 | .97182 | .25263 | .96756 | 22 |
| 39 | .18481 | .98277 | .20193 | .97940 | .21899 | .97573 | .23599 | .97176 | .25291 | .96749 | 21 |
| 40 | .18509 | .98272 | .20222 | .97934 | .21928 | .97566 | .23627 | .97169 | .25320 | .96742 | 20 |
| 41 | .18538 | .98267 | .20250 | .97928 | .21956 | .97560 | .23656 | .97162 | .25348 | .96734 | 19 |
| 42 | .18567 | .98261 | .20279 | .97922 | .21985 | .97553 | .23684 | .97155 | .25376 | .96727 | 18 |
| 43 | .18595 | .98256 | .20307 | .97916 | .22013 | .97547 | .23712 | .97148 | .25404 | .96719 | 17 |
| 44 | .18624 | .98250 | .20336 | .97910 | .22041 | .97541 | .23740 | .97141 | .25432 | .96712 | 16 |
| 45 | .18652 | .98245 | .20364 | .97905 | .22070 | .97534 | .23769 | .97134 | .25460 | .96705 | 15 |
| 46 | .18681 | .98240 | .20393 | .97899 | .22098 | .97528 | .23797 | .97127 | .25488 | .96697 | 14 |
| 47 | .18710 | .98234 | .20421 | .97893 | .22126 | .97521 | .23825 | .97120 | .25516 | .96690 | 13 |
| 48 | .18738 | .98229 | .20450 | .97887 | .22155 | .97515 | .23853 | .97113 | .25545 | .96682 | 12 |
| 49 | .18767 | .98223 | .20478 | .97881 | .22183 | .97508 | .23882 | .97106 | .25573 | .96675 | 11 |
| 50 | .18795 | .98218 | .20507 | .97875 | .22212 | .97502 | .23910 | .97100 | .25601 | .96667 | 10 |
| 51 | .18824 | .98212 | .20535 | .97869 | .22240 | .97496 | .23938 | .97093 | .25629 | .96660 | 9 |
| 52 | .18852 | .98207 | .20563 | .97863 | .22268 | .97489 | .23966 | .97086 | .25657 | .96653 | 8 |
| 53 | .18881 | .98201 | .20592 | .97857 | .22297 | .97483 | .23995 | .97079 | .25685 | .96645 | 7 |
| 54 | .18910 | .98196 | .20620 | .97851 | .22325 | .97476 | .24023 | .97072 | .25713 | .96638 | 6 |
| 55 | .18938 | .98190 | .20649 | .97845 | .22353 | .97470 | .24051 | .97065 | .25741 | .96630 | 5 |
| 56 | .18967 | .98185 | .20677 | .97839 | .22382 | .97463 | .24079 | .97058 | .25769 | .96623 | 4 |
| 57 | .18995 | .98179 | .20706 | .97833 | .22410 | .97457 | .24108 | .97051 | .25798 | .96615 | 3 |
| 58 | .19024 | .98174 | .20734 | .97827 | .22438 | .97450 | .24136 | .97044 | .25826 | .96608 | 2 |
| 59 | .19052 | .98168 | .20763 | .97821 | .22467 | .97444 | .24164 | .97037 | .25854 | .96600 | 1 |
| 60 | .19081 | .98163 | .20791 | .97815 | .22495 | .97437 | .24192 | .97030 | .25882 | .96593 | 0 |
| | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | |
| ′ | 79° | | 78° | | 77° | | 76° | | 75° | | ′ |

| ′ | 15° | | 16° | | 17° | | 18° | | 19° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .25882 | .96593 | .27564 | .96126 | .29237 | .95630 | .30902 | .95106 | .32557 | .94552 | 60 |
| 1 | .25910 | .96585 | .27592 | .96118 | .29265 | .95622 | .30929 | .95097 | .32584 | .94542 | 59 |
| 2 | .25938 | .96578 | .27620 | .96110 | .29293 | .95613 | .30957 | .95088 | .32612 | .94533 | 58 |
| 3 | .25966 | .96570 | .27648 | .96102 | .29321 | .95605 | .30985 | .95079 | .32639 | .94523 | 57 |
| 4 | .25994 | .96562 | .27676 | .96094 | .29348 | .95596 | .31012 | .95070 | .32667 | .94514 | 56 |
| 5 | .26022 | .96555 | .27704 | .96086 | .29376 | .95588 | .31040 | .95061 | .32694 | .94504 | 55 |
| 6 | .26050 | .96547 | .27731 | .96078 | .29404 | .95579 | .31068 | .95052 | .32722 | .94495 | 54 |
| 7 | .26079 | .96540 | .27759 | .96070 | .29432 | .95571 | .31095 | .95043 | .32749 | .94485 | 53 |
| 8 | .26107 | .96532 | .27787 | .96062 | .29460 | .95562 | .31123 | .95033 | .32777 | .94476 | 52 |
| 9 | .26135 | .96524 | .27815 | .96054 | .29487 | .95554 | .31151 | .95024 | .32804 | .94466 | 51 |
| 10 | .26163 | .96517 | .27843 | .96046 | .29515 | .95545 | .31178 | .95015 | .32832 | .94457 | 50 |
| 11 | .26191 | .96509 | .27871 | .96037 | .29543 | .95536 | .31206 | .95006 | .32859 | .94447 | 49 |
| 12 | .26219 | .96502 | .27899 | .96029 | .29571 | .95528 | .31233 | .94997 | .32887 | .94438 | 48 |
| 13 | .26247 | .96494 | .27927 | .96021 | .29599 | .95519 | .31261 | .94988 | .32914 | .94428 | 47 |
| 14 | .26275 | .96486 | .27955 | .96013 | .29626 | .95511 | .31289 | .94979 | .32942 | .94418 | 46 |
| 15 | .26303 | .96479 | .27983 | .96005 | .29654 | .95502 | .31316 | .94970 | .32969 | .94409 | 45 |
| 16 | .26331 | .96471 | .28011 | .95997 | .29682 | .95493 | .31344 | .94961 | .32997 | .94399 | 44 |
| 17 | .26359 | .96463 | .28039 | .95989 | .29710 | .95485 | .31372 | .94952 | .33024 | .94390 | 43 |
| 18 | .26387 | .96456 | .28067 | .95981 | .29737 | .95476 | .31399 | .94943 | .33051 | .94380 | 42 |
| 19 | .26415 | .96448 | .28095 | .95972 | .29765 | .95467 | .31427 | .94933 | .33079 | .94370 | 41 |
| 20 | .26443 | .96440 | .28123 | .95964 | .29793 | .95459 | .31454 | .94924 | .33106 | .94361 | 40 |
| 21 | .26471 | .96433 | .28150 | .95956 | .29821 | .95450 | .31482 | .94915 | .33134 | .94351 | 39 |
| 22 | .26500 | .96425 | .28178 | .95948 | .29849 | .95441 | .31510 | .94906 | .33161 | .94342 | 38 |
| 23 | .26528 | .96417 | .28206 | .95940 | .29876 | .95433 | .31537 | .94897 | .33189 | .94332 | 37 |
| 24 | .26556 | .96410 | .28234 | .95931 | .29904 | .95424 | .31565 | .94888 | .33216 | .94322 | 36 |
| 25 | .26584 | .96402 | .28262 | .95923 | .29932 | .95415 | .31593 | .94878 | .33244 | .94313 | 35 |
| 26 | .26612 | .96394 | .28290 | .95915 | .29960 | .95407 | .31620 | .94869 | .33271 | .94303 | 34 |
| 27 | .26640 | .96386 | .28318 | .95907 | .29987 | .95398 | .31648 | .94860 | .33298 | .94293 | 33 |
| 28 | .26668 | .96379 | .28346 | .95898 | .30015 | .95389 | .31675 | .94851 | .33326 | .94284 | 32 |
| 29 | .26696 | .96371 | .28374 | .95890 | .30043 | .95380 | .31703 | .94842 | .33353 | .94274 | 31 |
| 30 | .26724 | .96363 | .28402 | .95882 | .30071 | .95372 | .31730 | .94832 | .33381 | .94264 | 30 |
| 31 | .26752 | .96355 | .28429 | .95874 | .30098 | .95363 | .31758 | .94823 | .33408 | .94254 | 29 |
| 32 | .26780 | .96347 | .28457 | .95865 | .30126 | .95354 | .31786 | .94814 | .33436 | .94245 | 28 |
| 33 | .26808 | .96340 | .28485 | .95857 | .30154 | .95345 | .31813 | .94805 | .33463 | .94235 | 27 |
| 34 | .26836 | .96332 | .28513 | .95849 | .30182 | .95337 | .31841 | .94795 | .33490 | .94225 | 26 |
| 35 | .26864 | .96324 | .28541 | .95841 | .30209 | .95328 | .31868 | .94786 | .33518 | .94215 | 25 |
| 36 | .26892 | .96316 | .28569 | .95832 | .30237 | .95319 | .31896 | .94777 | .33545 | .94206 | 24 |
| 37 | .26920 | .96308 | .28597 | .95824 | .30265 | .95310 | .31923 | .94768 | .33573 | .94196 | 23 |
| 38 | .26948 | .96301 | .28625 | .95816 | .30292 | .95301 | .31951 | .94758 | .33600 | .94186 | 22 |
| 39 | .26976 | .96293 | .28652 | .95807 | .30320 | .95293 | .31979 | .94749 | .33627 | .94176 | 21 |
| 40 | .27004 | .96285 | .28680 | .95799 | .30348 | .95284 | .32006 | .94740 | .33655 | .94167 | 20 |
| 41 | .27032 | .96277 | .28708 | .95791 | .30376 | .95275 | .32034 | .94730 | .33682 | .94157 | 19 |
| 42 | .27060 | .96269 | .28736 | .95782 | .30403 | .95266 | .32061 | .94721 | .33710 | .94147 | 18 |
| 43 | .27088 | .96261 | .28764 | .95774 | .30431 | .95257 | .32089 | .94712 | .33737 | .94137 | 17 |
| 44 | .27116 | .96253 | .28792 | .95766 | .30459 | .95248 | .32116 | .94702 | .33764 | .94127 | 16 |
| 45 | .27144 | .96246 | .28820 | .95757 | .30486 | .95240 | .32144 | .94693 | .33792 | .94118 | 15 |
| 46 | .27172 | .96238 | .28847 | .95749 | .30514 | .95231 | .32171 | .94684 | .33819 | .94108 | 14 |
| 47 | .27200 | .96230 | .28875 | .95740 | .30542 | .95222 | .32199 | .94674 | .33846 | .94098 | 13 |
| 48 | .27228 | .96222 | .28903 | .95732 | .30570 | .95213 | .32227 | .94665 | .33874 | .94088 | 12 |
| 49 | .27256 | .96214 | .28931 | .95724 | .30597 | .95204 | .32254 | .94656 | .33901 | .94078 | 11 |
| 50 | .27284 | .96206 | .28959 | .95715 | .30625 | .95195 | .32282 | .94646 | .33929 | .94068 | 10 |
| 51 | .27312 | .96198 | .28987 | .95707 | .30653 | .95186 | .32309 | .94637 | .33956 | .94058 | 9 |
| 52 | .27340 | .96190 | .29015 | .95698 | .30680 | .95177 | .32337 | .94627 | .33983 | .94049 | 8 |
| 53 | .27368 | .96182 | .29042 | .95690 | .30708 | .95168 | .32364 | .94618 | .34011 | .94039 | 7 |
| 54 | .27396 | .96174 | .29070 | .95681 | .30736 | .95159 | .32392 | .94609 | .34038 | .94029 | 6 |
| 55 | .27424 | .96166 | .29098 | .95673 | .30763 | .95150 | .32419 | .94599 | .34065 | .94019 | 5 |
| 56 | .27452 | .96158 | .29126 | .95664 | .30791 | .95142 | .32447 | .94590 | .34093 | .94009 | 4 |
| 57 | .27480 | .96150 | .29154 | .95656 | .30819 | .95133 | .32474 | .94580 | .34120 | .93999 | 3 |
| 58 | .27508 | .96142 | .29182 | .95647 | .30846 | .95124 | .32502 | .94571 | .34147 | .93989 | 2 |
| 59 | .27536 | .96134 | .29209 | .95639 | .30874 | .95115 | .32529 | .94561 | .34175 | .93979 | 1 |
| 60 | .27564 | .96126 | .29237 | .95630 | .30902 | .95106 | .32557 | .94552 | .34202 | .93969 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 74° | | 73° | | 72° | | 71° | | 70° | | |

| ′ | 20° Sine | 20° Cosin | 21° Sine | 21° Cosin | 22° Sine | 22° Cosin | 23° Sine | 23° Cosin | 24° Sine | 24° Cosin | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .34202 | .93969 | .35837 | .93358 | .37461 | .92718 | .39073 | .92050 | .40674 | .91355 | 60 |
| 1 | .34229 | .93959 | .35864 | .93348 | .37488 | .92707 | .39100 | .92039 | .40700 | .91343 | 59 |
| 2 | .34257 | .93949 | .35891 | .93337 | .37515 | .92697 | .39127 | .92028 | .40727 | .91331 | 58 |
| 3 | .34284 | .93939 | .35918 | .93327 | .37542 | .92686 | .39153 | .92016 | .40753 | .91319 | 57 |
| 4 | .34311 | .93929 | .35945 | .93316 | .37569 | .92675 | .39180 | .92005 | .40780 | .91307 | 56 |
| 5 | .34339 | .93919 | .35973 | .93306 | .37595 | .92664 | .39207 | .91994 | .40806 | .91295 | 55 |
| 6 | .34366 | .93909 | .36000 | .93295 | .37622 | .92653 | .39234 | .91982 | .40833 | .91283 | 54 |
| 7 | .34393 | .93899 | .36027 | .93285 | .37649 | .92642 | .39260 | .91971 | .40860 | .91272 | 53 |
| 8 | .34421 | .93889 | .36054 | .93274 | .37676 | .92631 | .39287 | .91959 | .40886 | .91260 | 52 |
| 9 | .34448 | .93879 | .36081 | .93264 | .37703 | .92620 | .39314 | .91948 | .40913 | .91248 | 51 |
| 10 | .34475 | .93869 | .36108 | .93253 | .37730 | .92609 | .39341 | .91936 | .40939 | .91236 | 50 |
| 11 | .34503 | .93859 | .36135 | .93243 | .37757 | .92598 | .39367 | .91925 | .40966 | .91224 | 49 |
| 12 | .34530 | .93849 | .36162 | .93232 | .37784 | .92587 | .39394 | .91914 | .40992 | .91212 | 48 |
| 13 | .34557 | .93839 | .36190 | .93222 | .37811 | .92576 | .39421 | .91902 | .41019 | .91200 | 47 |
| 14 | .34584 | .93829 | .36217 | .93211 | .37838 | .92565 | .39448 | .91891 | .41045 | .91188 | 46 |
| 15 | .34612 | .93819 | .36244 | .93201 | .37865 | .92554 | .39474 | .91879 | .41072 | .91176 | 45 |
| 16 | .34639 | .93809 | .36271 | .93190 | .37892 | .92543 | .39501 | .91868 | .41098 | .91164 | 44 |
| 17 | .34666 | .93799 | .36298 | .93180 | .37919 | .92532 | .39528 | .91856 | .41125 | .91152 | 43 |
| 18 | .34694 | .93789 | .36325 | .93169 | .37946 | .92521 | .39555 | .91845 | .41151 | .91140 | 42 |
| 19 | .34721 | .93779 | .36352 | .93159 | .37973 | .92510 | .39581 | .91833 | .41178 | .91128 | 41 |
| 20 | .34748 | .93769 | .36379 | .93148 | .37999 | .92499 | .39608 | .91822 | .41204 | .91116 | 40 |
| 21 | .34775 | .93759 | .36406 | .93137 | .38026 | .92488 | .39635 | .91810 | .41231 | .91104 | 39 |
| 22 | .34803 | .93748 | .36434 | .93127 | .38053 | .92477 | .39661 | .91799 | .41257 | .91092 | 38 |
| 23 | .34830 | .93738 | .36461 | .93116 | .38080 | .92466 | .39688 | .91787 | .41284 | .91080 | 37 |
| 24 | .34857 | .93728 | .36488 | .93106 | .38107 | .92455 | .39715 | .91775 | .41310 | .91068 | 36 |
| 25 | .34884 | .93718 | .36515 | .93095 | .38134 | .92444 | .39741 | .91764 | .41337 | .91056 | 35 |
| 26 | .34912 | .93708 | .36542 | .93084 | .38161 | .92432 | .39768 | .91752 | .41363 | .91044 | 34 |
| 27 | .34939 | .93698 | .36569 | .93074 | .38188 | .92421 | .39795 | .91741 | .41390 | .91032 | 33 |
| 28 | .34966 | .93688 | .36596 | .93063 | .38215 | .92410 | .39822 | .91729 | .41416 | .91020 | 32 |
| 29 | .34993 | .93677 | .36623 | .93052 | .38241 | .92399 | .39848 | .91718 | .41443 | .91008 | 31 |
| 30 | .35021 | .93667 | .36650 | .93042 | .38268 | .92388 | .39875 | .91706 | .41469 | .90996 | 30 |
| 31 | .35048 | .93657 | .36677 | .93031 | .38295 | .92377 | .39902 | .91694 | .41496 | .90984 | 29 |
| 32 | .35075 | .93647 | .36704 | .93020 | .38322 | .92366 | .39928 | .91683 | .41522 | .90972 | 28 |
| 33 | .35102 | .93637 | .36731 | .93010 | .38349 | .92355 | .39955 | .91671 | .41549 | .90960 | 27 |
| 34 | .35130 | .93626 | .36758 | .92999 | .38376 | .92343 | .39982 | .91660 | .41575 | .90948 | 26 |
| 35 | .35157 | .93616 | .36785 | .92988 | .38403 | .92332 | .40008 | .91648 | .41602 | .90936 | 25 |
| 36 | .35184 | .93606 | .36812 | .92978 | .38430 | .92321 | .40035 | .91636 | .41628 | .90924 | 24 |
| 37 | .35211 | .93596 | .36839 | .92967 | .38456 | .92310 | .40062 | .91625 | .41655 | .90911 | 23 |
| 38 | .35239 | .93585 | .36867 | .92956 | .38483 | .92299 | .40088 | .91613 | .41681 | .90899 | 22 |
| 39 | .35266 | .93575 | .36894 | .92945 | .38510 | .92287 | .40115 | .91601 | .41707 | .90887 | 21 |
| 40 | .35293 | .93565 | .36921 | .92935 | .38537 | .92276 | .40141 | .91590 | .41734 | .90875 | 20 |
| 41 | .35320 | .93555 | .36948 | .92924 | .38564 | .92265 | .40168 | .91578 | .41760 | .90863 | 19 |
| 42 | .35347 | .93544 | .36975 | .92913 | .38591 | .92254 | .40195 | .91566 | .41787 | .90851 | 18 |
| 43 | .35375 | .93534 | .37002 | .92902 | .38617 | .92243 | .40221 | .91555 | .41813 | .90839 | 17 |
| 44 | .35402 | .93524 | .37029 | .92892 | .38644 | .92231 | .40248 | .91543 | .41840 | .90826 | 16 |
| 45 | .35429 | .93514 | .37056 | .92881 | .38671 | .92220 | .40275 | .91531 | .41866 | .90814 | 15 |
| 46 | .35456 | .93503 | .37083 | .92870 | .38698 | .92209 | .40301 | .91519 | .41892 | .90802 | 14 |
| 47 | .35484 | .93493 | .37110 | .92859 | .38725 | .92198 | .40328 | .91508 | .41919 | .90790 | 13 |
| 48 | .35511 | .93483 | .37137 | .92849 | .38752 | .92186 | .40355 | .91496 | .41945 | .90778 | 12 |
| 49 | .35538 | .93472 | .37164 | .92838 | .38778 | .92175 | .40381 | .91484 | .41972 | .90766 | 11 |
| 50 | .35565 | .93462 | .37191 | .92827 | .38805 | .92164 | .40408 | .91472 | .41998 | .90753 | 10 |
| 51 | .35592 | .93452 | .37218 | .92816 | .38832 | .92152 | .40434 | .91461 | .42024 | .90741 | 9 |
| 52 | .35619 | .93441 | .37245 | .92805 | .38859 | .92141 | .40461 | .91449 | .42051 | .90729 | 8 |
| 53 | .35647 | .93431 | .37272 | .92794 | .38886 | .92130 | .40488 | .91437 | .42077 | .90717 | 7 |
| 54 | .35674 | .93420 | .37299 | .92784 | .38912 | .92119 | .40514 | .91425 | .42104 | .90704 | 6 |
| 55 | .35701 | .93410 | .37326 | .92773 | .38939 | .92107 | .40541 | .91414 | .42130 | .90692 | 5 |
| 56 | .35728 | .93400 | .37353 | .92762 | .38966 | .92096 | .40567 | .91402 | .42156 | .90680 | 4 |
| 57 | .35755 | .93389 | .37380 | .92751 | .38993 | .92085 | .40594 | .91390 | .42183 | .90668 | 3 |
| 58 | .35782 | .93379 | .37407 | .92740 | .39020 | .92073 | .40621 | .91378 | .42209 | .90655 | 2 |
| 59 | .35810 | .93368 | .37434 | .92729 | .39046 | .92062 | .40647 | .91366 | .42235 | .90643 | 1 |
| 60 | .35837 | .93358 | .37461 | .92718 | .39073 | .92050 | .40674 | .91355 | .42262 | .90631 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 69° | | 68° | | 67° | | 66° | | 65° | | |

| ′ | 25° | | 26° | | 27° | | 28° | | 29° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .42262 | .90631 | .43837 | .89879 | .45399 | .89101 | .46947 | .88295 | .48481 | .87462 | 60 |
| 1 | .42288 | .90618 | .43863 | .89867 | .45425 | .89087 | .46973 | .88281 | .48506 | .87448 | 59 |
| 2 | .42315 | .90606 | .43889 | .89854 | .45451 | .89074 | .46999 | .88267 | .48532 | .87434 | 58 |
| 3 | .42341 | .90594 | .43916 | .89841 | .45477 | .89061 | .47024 | .88254 | .48557 | .87420 | 57 |
| 4 | .42367 | .90582 | .43942 | .89828 | .45503 | .89048 | .47050 | .88240 | .48583 | .87406 | 56 |
| 5 | .42394 | .90569 | .43968 | .89816 | .45529 | .89035 | .47076 | .88226 | .48608 | .87391 | 55 |
| 6 | .42420 | .90557 | .43994 | .89803 | .45554 | .89021 | .47101 | .88213 | .48634 | .87377 | 54 |
| 7 | .42446 | .90545 | .44020 | .89790 | .45580 | .89008 | .47127 | .88199 | .48659 | .87363 | 53 |
| 8 | .42473 | .90532 | .44046 | .89777 | .45606 | .88995 | .47153 | .88185 | .48684 | .87349 | 52 |
| 9 | .42499 | .90520 | .44072 | .89764 | .45632 | .88981 | .47178 | .88172 | .48710 | .87335 | 51 |
| 10 | .42525 | .90507 | .44098 | .89752 | .45658 | .88968 | .47204 | .88158 | .48735 | .87321 | 50 |
| 11 | .42552 | .90495 | .44124 | .89739 | .45684 | .88955 | .47229 | .88144 | .48761 | .87306 | 49 |
| 12 | .42578 | .90483 | .44151 | .89726 | .45710 | .88942 | .47255 | .88130 | .48786 | .87292 | 48 |
| 13 | .42604 | .90470 | .44177 | .89713 | .45736 | .88928 | .47281 | .88117 | .48811 | .87278 | 47 |
| 14 | .42631 | .90458 | .44203 | .89700 | .45762 | .88915 | .47306 | .88103 | .48837 | .87264 | 46 |
| 15 | .42657 | .90446 | .44229 | .89687 | .45787 | .88902 | .47332 | .88089 | .48862 | .87250 | 45 |
| 16 | .42683 | .90433 | .44255 | .89674 | .45813 | .88888 | .47358 | .88075 | .48888 | .87235 | 44 |
| 17 | .42709 | .90421 | .44281 | .89662 | .45839 | .88875 | .47383 | .88062 | .48913 | .87221 | 43 |
| 18 | .42736 | .90408 | .44307 | .89649 | .45865 | .88862 | .47409 | .88048 | .48938 | .87207 | 42 |
| 19 | .42762 | .90396 | .44333 | .89636 | .45891 | .88848 | .47434 | .88034 | .48964 | .87193 | 41 |
| 20 | .42788 | .90383 | .44359 | .89623 | .45917 | .88835 | .47460 | .88020 | .48989 | .87178 | 40 |
| 21 | .42815 | .90371 | .44385 | .89610 | .45942 | .88822 | .47486 | .88006 | .49014 | .87164 | 39 |
| 22 | .42841 | .90358 | .44411 | .89597 | .45968 | .88808 | .47511 | .87993 | .49040 | .87150 | 38 |
| 23 | .42867 | .90346 | .44437 | .89584 | .45994 | .88795 | .47537 | .87979 | .49065 | .87136 | 37 |
| 24 | .42894 | .90334 | .44464 | .89571 | .46020 | .88782 | .47562 | .87965 | .49090 | .87121 | 36 |
| 25 | .42920 | .90321 | .44490 | .89558 | .46046 | .88768 | .47588 | .87951 | .49116 | .87107 | 35 |
| 26 | .42946 | .90309 | .44516 | .89545 | .46072 | .88755 | .47614 | .87937 | .49141 | .87093 | 34 |
| 27 | .42972 | .90296 | .44542 | .89532 | .46097 | .88741 | .47639 | .87923 | .49166 | .87079 | 33 |
| 28 | .42999 | .90284 | .44568 | .89519 | .46123 | .88728 | .47665 | .87909 | .49192 | .87064 | 32 |
| 29 | .43025 | .90271 | .44594 | .89506 | .46149 | .88715 | .47690 | .87896 | .49217 | .87050 | 31 |
| 30 | .43051 | .90259 | .44620 | .89493 | .46175 | .88701 | .47716 | .87882 | .49242 | .87036 | 30 |
| 31 | .43077 | .90246 | .44646 | .89480 | .46201 | .88688 | .47741 | .87868 | .49268 | .87021 | 29 |
| 32 | .43104 | .90233 | .44672 | .89467 | .46226 | .88674 | .47767 | .87854 | .49293 | .87007 | 28 |
| 33 | .43130 | .90221 | .44698 | .89454 | .46252 | .88661 | .47793 | .87840 | .49318 | .86993 | 27 |
| 34 | .43156 | .90208 | .44724 | .89441 | .46278 | .88647 | .47818 | .87826 | .49344 | .86978 | 26 |
| 35 | .43182 | .90196 | .44750 | .89428 | .46304 | .88634 | .47844 | .87812 | .49369 | .86964 | 25 |
| 36 | .43209 | .90183 | .44776 | .89415 | .46330 | .88620 | .47869 | .87798 | .49394 | .86949 | 24 |
| 37 | .43235 | .90171 | .44802 | .89402 | .46355 | .88607 | .47895 | .87784 | .49419 | .86935 | 23 |
| 38 | .43261 | .90158 | .44828 | .89389 | .46381 | .88593 | .47920 | .87770 | .49445 | .86921 | 22 |
| 39 | .43287 | .90146 | .44854 | .89376 | .46407 | .88580 | .47946 | .87756 | .49470 | .86906 | 21 |
| 40 | .43313 | .90133 | .44880 | .89363 | .46433 | .88566 | .47971 | .87743 | .49495 | .86892 | 20 |
| 41 | .43340 | .90120 | .44906 | .89350 | .46458 | .88553 | .47997 | .87729 | .49521 | .86878 | 19 |
| 42 | .43366 | .90108 | .44932 | .89337 | .46484 | .88539 | .48022 | .87715 | .49546 | .86863 | 18 |
| 43 | .43392 | .90095 | .44958 | .89324 | .46510 | .88526 | .48048 | .87701 | .49571 | .86849 | 17 |
| 44 | .43418 | .90082 | .44984 | .89311 | .46536 | .88512 | .48073 | .87687 | .49596 | .86834 | 16 |
| 45 | .43445 | .90070 | .45010 | .89298 | .46561 | .88499 | .48099 | .87673 | .49622 | .86820 | 15 |
| 46 | .43471 | .90057 | .45036 | .89285 | .46587 | .88485 | .48124 | .87659 | .49647 | .86805 | 14 |
| 47 | .43497 | .90045 | .45062 | .89272 | .46613 | .88472 | .48150 | .87645 | .49672 | .86791 | 13 |
| 48 | .43523 | .90032 | .45088 | .89259 | .46639 | .88458 | .48175 | .87631 | .49697 | .86777 | 12 |
| 49 | .43549 | .90019 | .45114 | .89245 | .46664 | .88445 | .48201 | .87617 | .49723 | .86762 | 11 |
| 50 | .43575 | .90007 | .45140 | .89232 | .46690 | .88431 | .48226 | .87603 | .49748 | .86748 | 10 |
| 51 | .43602 | .89994 | .45166 | .89219 | .46716 | .88417 | .48252 | .87589 | .49773 | .86733 | 9 |
| 52 | .43628 | .89981 | .45192 | .89206 | .46742 | .88404 | .48277 | .87575 | .49798 | .86719 | 8 |
| 53 | .43654 | .89968 | .45218 | .89193 | .46767 | .88390 | .48303 | .87561 | .49824 | .86704 | 7 |
| 54 | .43680 | .89956 | .45243 | .89180 | .46793 | .88377 | .48328 | .87546 | .49849 | .86690 | 6 |
| 55 | .43706 | .89943 | .45269 | .89167 | .46819 | .88363 | .48354 | .87532 | .49874 | .86675 | 5 |
| 56 | .43733 | .89930 | .45295 | .89153 | .46844 | .88349 | .48379 | .87518 | .49899 | .86661 | 4 |
| 57 | .43759 | .89918 | .45321 | .89140 | .46870 | .88336 | .48405 | .87504 | .49924 | .86646 | 3 |
| 58 | .43785 | .89905 | .45347 | .89127 | .46896 | .88322 | .48430 | .87490 | .49950 | .86632 | 2 |
| 59 | .43811 | .89892 | .45373 | .89114 | .46921 | .88308 | .48456 | .87476 | .49975 | .86617 | 1 |
| 60 | .43837 | .89879 | .45399 | .89101 | .46947 | .88295 | .48481 | .87462 | .50000 | .86603 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 64° | | 63° | | 62° | | 61° | | 60° | | |

| ′ | 30° | | 31° | | 32° | | 33° | | 34° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .50000 | .86603 | .51504 | .85717 | .52992 | .84805 | .54464 | .83867 | .55919 | .82904 | 60 |
| 1 | .50025 | .86588 | .51529 | .85702 | .53017 | .84789 | .54488 | .83851 | .55943 | .82887 | 59 |
| 2 | .50050 | .86573 | .51554 | .85687 | .53041 | .84774 | .54513 | .83835 | .55968 | .82871 | 58 |
| 3 | .50076 | .86559 | .51579 | .85672 | .53066 | .84759 | .54537 | .83819 | .55992 | .82855 | 57 |
| 4 | .50101 | .86544 | .51604 | .85657 | .53091 | .84743 | .54561 | .83804 | .56016 | .82839 | 56 |
| 5 | .50126 | .86530 | .51628 | .85642 | .53115 | .84728 | .54586 | .83788 | .56040 | .82822 | 55 |
| 6 | .50151 | .86515 | .51653 | .85627 | .53140 | .84712 | .54610 | .83772 | .56064 | .82806 | 54 |
| 7 | .50176 | .86501 | .51678 | .85612 | .53164 | .84697 | .54635 | .83756 | .56088 | .82790 | 53 |
| 8 | .50201 | .86486 | .51703 | .85597 | .53189 | .84681 | .54659 | .83740 | .56112 | .82773 | 52 |
| 9 | .50227 | .86471 | .51728 | .85582 | .53214 | .84666 | .54683 | .83724 | .56136 | .82757 | 51 |
| 10 | .50252 | .86457 | .51753 | .85567 | .53238 | .84650 | .54708 | .83708 | .56160 | .82741 | 50 |
| 11 | .50277 | .86442 | .51778 | .85551 | .53263 | .84635 | .54732 | .83692 | .56184 | .82724 | 49 |
| 12 | .50302 | .86427 | .51803 | .85536 | .53288 | .84619 | .54756 | .83676 | .56208 | .82708 | 48 |
| 13 | .50327 | .86413 | .51828 | .85521 | .53312 | .84604 | .54781 | .83660 | .56232 | .82692 | 47 |
| 14 | .50352 | .86398 | .51852 | .85506 | .53337 | .84588 | .54805 | .83645 | .56256 | .82675 | 46 |
| 15 | .50377 | .86384 | .51877 | .85491 | .53361 | .84573 | .54829 | .83629 | .56280 | .82659 | 45 |
| 16 | .50403 | .86369 | .51902 | .85476 | .53386 | .84557 | .54854 | .83613 | .56305 | .82643 | 44 |
| 17 | .50428 | .86354 | .51927 | .85461 | .53411 | .84542 | .54878 | .83597 | .56329 | .82626 | 43 |
| 18 | .50453 | .86340 | .51952 | .85446 | .53435 | .84526 | .54902 | .83581 | .56353 | .82610 | 42 |
| 19 | .50478 | .86325 | .51977 | .85431 | .53460 | .84511 | .54927 | .83565 | .56377 | .82593 | 41 |
| 20 | .50503 | .86310 | .52002 | .85416 | .53484 | .84495 | .54951 | .83549 | .56401 | .82577 | 40 |
| 21 | .50528 | .86295 | .52026 | .85401 | .53509 | .84480 | .54975 | .83533 | .56425 | .82561 | 39 |
| 22 | .50553 | .86281 | .52051 | .85385 | .53534 | .84464 | .54999 | .83517 | .56449 | .82544 | 38 |
| 23 | .50578 | .86266 | .52076 | .85370 | .53558 | .84448 | .55024 | .83501 | .56473 | .82528 | 37 |
| 24 | .50603 | .86251 | .52101 | .85355 | .53583 | .84433 | .55048 | .83485 | .56497 | .82511 | 36 |
| 25 | .50628 | .86237 | .52126 | .85340 | .53607 | .84417 | .55072 | .83469 | .56521 | .82495 | 35 |
| 26 | .50654 | .86222 | .52151 | .85325 | .53632 | .84402 | .55097 | .83453 | .56545 | .82478 | 34 |
| 27 | .50679 | .86207 | .52175 | .85310 | .53656 | .84386 | .55121 | .83437 | .56569 | .82462 | 33 |
| 28 | .50704 | .86192 | .52200 | .85294 | .53681 | .84370 | .55145 | .83421 | .56593 | .82446 | 32 |
| 29 | .50729 | .86178 | .52225 | .85279 | .53705 | .84355 | .55169 | .83405 | .56617 | .82429 | 31 |
| 30 | .50754 | .86163 | .52250 | .85264 | .53730 | .84339 | .55194 | .83389 | .56641 | .82413 | 30 |
| 31 | .50779 | .86148 | .52275 | .85249 | .53754 | .84324 | .55218 | .83373 | .56665 | .82396 | 29 |
| 32 | .50804 | .86133 | .52299 | .85234 | .53779 | .84308 | .55242 | .83356 | .56689 | .82380 | 28 |
| 33 | .50829 | .86119 | .52324 | .85218 | .53804 | .84292 | .55266 | .83340 | .56713 | .82363 | 27 |
| 34 | .50854 | .86104 | .52349 | .85203 | .53828 | .84277 | .55291 | .83324 | .56736 | .82347 | 26 |
| 35 | .50879 | .86089 | .52374 | .85188 | .53853 | .84261 | .55315 | .83308 | .56760 | .82330 | 25 |
| 36 | .50904 | .86074 | .52399 | .85173 | .53877 | .84245 | .55339 | .83292 | .56784 | .82314 | 24 |
| 37 | .50929 | .86059 | .52423 | .85157 | .53902 | .84230 | .55363 | .83276 | .56808 | .82297 | 23 |
| 38 | .50954 | .86045 | .52448 | .85142 | .53926 | .84214 | .55388 | .83260 | .56832 | .82281 | 22 |
| 39 | .50979 | .86030 | .52473 | .85127 | .53951 | .84198 | .55412 | .83244 | .56856 | .82264 | 21 |
| 40 | .51004 | .86015 | .52498 | .85112 | .53975 | .84182 | .55436 | .83228 | .56880 | .82248 | 20 |
| 41 | .51029 | .86000 | .52522 | .85096 | .54000 | .84167 | .55460 | .83212 | .56904 | .82231 | 19 |
| 42 | .51054 | .85985 | .52547 | .85081 | .54024 | .84151 | .55484 | .83195 | .56928 | .82214 | 18 |
| 43 | .51079 | .85970 | .52572 | .85066 | .54049 | .84135 | .55509 | .83179 | .56952 | .82198 | 17 |
| 44 | .51104 | .85956 | .52597 | .85051 | .54073 | .84120 | .55533 | .83163 | .56976 | .82181 | 16 |
| 45 | .51129 | .85941 | .52621 | .85035 | .54097 | .84104 | .55557 | .83147 | .57000 | .82165 | 15 |
| 46 | .51154 | .85926 | .52646 | .85020 | .54122 | .84088 | .55581 | .83131 | .57024 | .82148 | 14 |
| 47 | .51179 | .85911 | .52671 | .85005 | .54146 | .84072 | .55605 | .83115 | .57047 | .82132 | 13 |
| 48 | .51204 | .85896 | .52696 | .84989 | .54171 | .84057 | .55630 | .83098 | .57071 | .82115 | 12 |
| 49 | .51229 | .85881 | .52720 | .84974 | .54195 | .84041 | .55654 | .83082 | .57095 | .82098 | 11 |
| 50 | .51254 | .85866 | .52745 | .84959 | .54220 | .84025 | .55678 | .83066 | .57119 | .82082 | 10 |
| 51 | .51279 | .85851 | .52770 | .84943 | .54244 | .84009 | .55702 | .83050 | 57143 | .82065 | 9 |
| 52 | .51304 | .85836 | .52794 | .84928 | .54269 | .83994 | .55726 | .83034 | .57167 | .82048 | 8 |
| 53 | .51329 | .85821 | .52819 | .84913 | .54293 | .83978 | .55750 | .83017 | .57191 | .82032 | 7 |
| 54 | .51354 | .85806 | .52844 | .84897 | .54317 | .83962 | .55775 | .83001 | .57215 | .82015 | 6 |
| 55 | .51379 | .85792 | .52869 | .84882 | .54342 | .83946 | .55799 | .82985 | .57238 | .81999 | 5 |
| 56 | .51404 | .85777 | .52893 | .84866 | .54366 | .83930 | .55823 | .82969 | .57262 | .81982 | 4 |
| 57 | .51429 | .85762 | .52918 | .84851 | .54391 | .83915 | .55847 | .82953 | .57286 | .81965 | 3 |
| 58 | .51454 | .85747 | .52943 | .84836 | .54415 | .83899 | .55871 | .82936 | .57310 | .81949 | 2 |
| 59 | .51479 | .85732 | .52967 | .84820 | .54440 | .83883 | .55895 | .82920 | .57334 | .81932 | 1 |
| 60 | .51504 | .85717 | .52992 | .84805 | .54464 | .83867 | .55919 | .82904 | .57358 | .81915 | 0 |
| | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | |
| ′ | 59° | | 58° | | 57° | | 56° | | 55° | | ′ |

| ′ | 35° | | 36° | | 37° | | 38° | | 39° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .57358 | .81915 | .58779 | .80902 | .60182 | .79864 | .61566 | .78801 | .62932 | .77715 | 60 |
| 1 | .57381 | .81899 | .58802 | .80885 | .60205 | .79846 | .61589 | .78783 | .62955 | .77696 | 59 |
| 2 | .57405 | .81882 | .58826 | .80867 | .60228 | .79829 | .61612 | .78765 | .62977 | .77678 | 58 |
| 3 | .57429 | .81865 | .58849 | .80850 | .60251 | .79811 | .61635 | .78747 | .63000 | .77660 | 57 |
| 4 | .57453 | .81848 | .58873 | .80833 | .60274 | .79793 | .61658 | .78729 | .63022 | .77641 | 56 |
| 5 | .57477 | .81832 | .58896 | .80816 | .60298 | .79776 | .61681 | .78711 | .63045 | .77623 | 55 |
| 6 | .57501 | .81815 | .58920 | .80799 | .60321 | .79758 | .61704 | .78694 | .63068 | .77605 | 54 |
| 7 | .57524 | .81798 | .58943 | .80782 | .60344 | .79741 | .61726 | .78676 | .63090 | .77586 | 53 |
| 8 | .57548 | .81782 | .58967 | .80765 | .60367 | .79723 | .61749 | .78658 | .63113 | .77568 | 52 |
| 9 | .57572 | .81765 | .58990 | .80748 | .60390 | .79706 | .61772 | .78640 | .63135 | .77550 | 51 |
| 10 | .57596 | .81748 | .59014 | .80730 | .60414 | .79688 | .61795 | .78622 | .63158 | .77531 | 50 |
| 11 | .57619 | .81731 | .59037 | .80713 | .60437 | .79671 | .61818 | .78604 | .63180 | .77513 | 49 |
| 12 | .57643 | .81714 | .59061 | .80696 | .60460 | .79653 | .61841 | .78586 | .63203 | .77494 | 48 |
| 13 | .57667 | .81698 | .59084 | .80679 | .60483 | .79635 | .61864 | .78568 | .63225 | .77476 | 47 |
| 14 | .57691 | .81681 | .59108 | .80662 | .60506 | .79618 | .61887 | .78550 | .63248 | .77458 | 46 |
| 15 | .57715 | .81664 | .59131 | .80644 | .60529 | .79600 | .61909 | .78532 | .63271 | .77439 | 45 |
| 16 | .57738 | .81647 | .59154 | .80627 | .60553 | .79583 | .61932 | .78514 | .63293 | .77421 | 44 |
| 17 | .57762 | .81631 | .59178 | .80610 | .60576 | .79565 | .61955 | .78496 | .63316 | .77402 | 43 |
| 18 | .57786 | .81614 | .59201 | .80593 | .60599 | .79547 | .61978 | .78478 | .63338 | .77384 | 42 |
| 19 | .57810 | .81597 | .59225 | .80576 | .60622 | .79530 | .62001 | .78460 | .63361 | .77366 | 41 |
| 20 | .57833 | .81580 | .59248 | .80558 | .60645 | .79512 | .62024 | .78442 | .63383 | .77347 | 40 |
| 21 | .57857 | .81563 | .59272 | .80541 | .60668 | .79494 | .62046 | .78424 | .63406 | .77329 | 39 |
| 22 | .57881 | .81546 | .59295 | .80524 | .60691 | .79477 | .62069 | .78405 | .63428 | .77310 | 38 |
| 23 | .57904 | .81530 | .59318 | .80507 | .60714 | .79459 | .62092 | .78387 | .63451 | .77292 | 37 |
| 24 | .57928 | .81513 | .59342 | .80489 | .60738 | .79441 | .62115 | .78369 | .63473 | .77273 | 36 |
| 25 | .57952 | .81496 | .59365 | .80472 | .60761 | .79424 | .62138 | .78351 | .63496 | .77255 | 35 |
| 26 | .57976 | .81479 | .59389 | .80455 | .60784 | .79406 | .62160 | .78333 | .63518 | .77236 | 34 |
| 27 | .57999 | .81462 | .59412 | .80438 | .60807 | .79388 | .62183 | .78315 | .63540 | .77218 | 33 |
| 28 | .58023 | .81445 | .59436 | .80420 | .60830 | .79371 | .62206 | .78297 | .63563 | .77199 | 32 |
| 29 | .58047 | .81428 | .59459 | .80403 | .60853 | .79353 | .62229 | .78279 | .63585 | .77181 | 31 |
| 30 | .58070 | .81412 | .59482 | .80386 | .60876 | .79335 | .62251 | .78261 | .63608 | .77162 | 30 |
| 31 | .58094 | .81395 | .59506 | .80368 | .60899 | .79318 | .62274 | .78243 | .63630 | .77144 | 29 |
| 32 | .58118 | .81378 | .59529 | .80351 | .60922 | .79300 | .62297 | .78225 | .63653 | .77125 | 28 |
| 33 | .58141 | .81361 | .59552 | .80334 | .60945 | .79282 | .62320 | .78206 | .63675 | .77107 | 27 |
| 34 | .58165 | .81344 | .59576 | .80316 | .60968 | .79264 | .62342 | .78188 | .63698 | .77088 | 26 |
| 35 | .58189 | .81327 | .59599 | .80299 | .60991 | .79247 | .62365 | .78170 | .63720 | .77070 | 25 |
| 36 | .58212 | .81310 | .59622 | .80282 | .61015 | .79229 | .62388 | .78152 | .63742 | .77051 | 24 |
| 37 | .58236 | .81293 | .59646 | .80264 | .61038 | .79211 | .62411 | .78134 | .63765 | .77033 | 23 |
| 38 | .58260 | .81276 | .59669 | .80247 | .61061 | .79193 | .62433 | .78116 | .63787 | .77014 | 22 |
| 39 | .58283 | .81259 | .59693 | .80230 | .61084 | .79176 | .62456 | .78098 | .63810 | .76996 | 21 |
| 40 | .58307 | .81242 | .59716 | .80212 | .61107 | .79158 | .62479 | .78079 | .63832 | .76977 | 20 |
| 41 | .58330 | .81225 | .59739 | .80195 | .61130 | .79140 | .62502 | .78061 | .63854 | .76959 | 19 |
| 42 | .58354 | .81208 | .59763 | .80178 | .61153 | .79122 | .62524 | .78043 | .63877 | .76940 | 18 |
| 43 | .58378 | .81191 | .59786 | .80160 | .61176 | .79105 | .62547 | .78025 | .63899 | .76921 | 17 |
| 44 | .58401 | .81174 | .59809 | .80143 | .61199 | .79087 | .62570 | .78007 | .63922 | .76903 | 16 |
| 45 | .58425 | .81157 | .59832 | .80125 | .61222 | .79069 | .62592 | .77988 | .63944 | .76884 | 15 |
| 46 | .58449 | .81140 | .59856 | .80108 | .61245 | .79051 | .62615 | .77970 | .63966 | .76866 | 14 |
| 47 | .58472 | .81123 | .59879 | .80091 | .61268 | .79033 | .62638 | .77952 | .63989 | .76847 | 13 |
| 48 | .58496 | .81106 | .59902 | .80073 | .61291 | .79016 | .62660 | .77934 | .64011 | .76828 | 12 |
| 49 | .58519 | .81089 | .59926 | .80056 | .61314 | .78998 | .62683 | .77916 | .64033 | .76810 | 11 |
| 50 | .58543 | .81072 | .59949 | .80038 | .61337 | .78980 | .62706 | .77897 | .64056 | .76791 | 10 |
| 51 | .58567 | .81055 | .59972 | .80021 | .61360 | .78962 | .62728 | .77879 | .64078 | .76772 | 9 |
| 52 | .58590 | .81038 | .59995 | .80003 | .61383 | .78944 | .62751 | .77861 | .64100 | .76754 | 8 |
| 53 | .58614 | .81021 | .60019 | .79986 | .61406 | .78926 | .62774 | .77843 | .64123 | .76735 | 7 |
| 54 | .58637 | .81004 | .60042 | .79968 | .61429 | .78908 | .62796 | .77824 | .64145 | .76717 | 6 |
| 55 | .58661 | .80987 | .60065 | .79951 | .61451 | .78891 | .62819 | .77806 | .64167 | .76698 | 5 |
| 56 | .58684 | .80970 | .60089 | .79934 | .61474 | .78873 | .62842 | .77788 | .64190 | .76679 | 4 |
| 57 | .58708 | .80953 | .60112 | .79916 | .61497 | .78855 | .62864 | .77769 | .64212 | .76661 | 3 |
| 58 | .58731 | .80936 | .60135 | .79899 | .61520 | .78837 | .62887 | .77751 | .64234 | .76642 | 2 |
| 59 | .58755 | .80919 | .60158 | .79881 | .61543 | .78819 | .62909 | .77733 | .64256 | .76623 | 1 |
| 60 | .58779 | .80902 | .60182 | .79864 | .61566 | .78801 | .62932 | .77715 | .64279 | .76604 | 0 |
| | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 54° | | 53° | | 52° | | 51° | | 50° | | |

| ′ | 40° Sine | 40° Cosin | 41° Sine | 41° Cosin | 42° Sine | 42° Cosin | 43° Sine | 43° Cosin | 44° Sine | 44° Cosin | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .64279 | .76604 | .65606 | .75471 | .66913 | .74314 | .68200 | .73135 | .69466 | .71934 | 60 |
| 1 | .64301 | .76586 | .65628 | .75452 | .66935 | .74295 | .68221 | .73116 | .69487 | .71914 | 59 |
| 2 | .64323 | .76567 | .65650 | .75433 | .66956 | .74276 | .68242 | .73096 | .69508 | .71894 | 58 |
| 3 | .64346 | .76548 | .65672 | .75414 | .66978 | .74256 | .68264 | .73076 | .69529 | .71873 | 57 |
| 4 | .64368 | .76530 | .65694 | .75395 | .66999 | .74237 | .68285 | .73056 | .69549 | .71853 | 56 |
| 5 | .64390 | .76511 | .65716 | .75375 | .67021 | .74217 | .68306 | .73036 | .69570 | .71833 | 55 |
| 6 | .64412 | .76492 | .65738 | .75356 | .67043 | .74198 | .68327 | .73016 | .69591 | .71813 | 54 |
| 7 | .64435 | .76473 | .65759 | .75337 | .67064 | .74178 | .68349 | .72996 | .69612 | .71792 | 53 |
| 8 | .64457 | .76455 | .65781 | .75318 | .67086 | .74159 | .68370 | .72976 | .69633 | .71772 | 52 |
| 9 | .64479 | .76436 | .65803 | .75299 | .67107 | .74139 | .68391 | .72957 | .69654 | .71752 | 51 |
| 10 | .64501 | .76417 | .65825 | .75280 | .67129 | .74120 | .68412 | .72937 | .69675 | .71732 | 50 |
| 11 | .64524 | .76398 | .65847 | .75261 | .67151 | .74100 | .68434 | .72917 | .69696 | .71711 | 49 |
| 12 | .64546 | .76380 | .65869 | .75241 | .67172 | .74080 | .68455 | .72897 | .69717 | .71691 | 48 |
| 13 | .64568 | .76361 | .65891 | .75222 | .67194 | .74061 | .68476 | .72877 | .69737 | .71671 | 47 |
| 14 | .64590 | 76342 | .65913 | .75203 | .67215 | .74041 | .68497 | .72857 | .69758 | .71650 | 46 |
| 15 | .64612 | .76323 | .65935 | .75184 | .67237 | .74022 | .68518 | .72837 | .69779 | .71630 | 45 |
| 16 | .64635 | .76304 | .65956 | .75165 | .67258 | .74002 | .68539 | .72817 | .69800 | .71610 | 44 |
| 17 | .64657 | .76286 | .65978 | .75146 | .67280 | .73983 | .68561 | .72797 | .69821 | .71590 | 43 |
| 18 | .64679 | .76267 | .66000 | .75126 | .67301 | .73963 | .68582 | .72777 | .69842 | .71569 | 42 |
| 19 | .64701 | .76248 | .66022 | .75107 | .67323 | .73944 | .68603 | .72757 | .69862 | .71549 | 41 |
| 20 | .64723 | .76229 | .66044 | .75088 | .67344 | .73924 | .68624 | .72737 | .69883 | .71529 | 40 |
| 21 | .64746 | .76210 | .66066 | .75069 | .67366 | .73904 | .68645 | .72717 | .69904 | .71508 | 39 |
| 22 | .64768 | .76192 | .66088 | .75050 | .67387 | .73885 | .68666 | .72697 | .69925 | .71488 | 38 |
| 23 | .64790 | .76173 | .66109 | .75030 | .67409 | .73865 | .68688 | .72677 | .69946 | .71468 | 37 |
| 24 | .64812 | .76154 | .66131 | .75011 | .67430 | .73846 | .68709 | .72657 | .69966 | .71447 | 36 |
| 25 | .64834 | .76135 | .66153 | .74992 | .67452 | .73826 | .68730 | .72637 | .69987 | .71427 | 35 |
| 26 | .64856 | .76116 | .66175 | .74973 | .67473 | .73806 | .68751 | .72617 | .70008 | .71407 | 34 |
| 27 | .64878 | .76097 | .66197 | .74953 | .67495 | .73787 | .68772 | .72597 | .70029 | .71386 | 33 |
| 28 | .64901 | .76078 | .66218 | .74934 | .67516 | .73767 | .68793 | .72577 | .70049 | .71366 | 32 |
| 29 | .64923 | .76059 | .66240 | .74915 | .67538 | .73747 | .68814 | .72557 | .70070 | .71345 | 31 |
| 30 | .64945 | .76041 | .66262 | .74896 | .67559 | .73728 | .68835 | .72537 | .70091 | .71325 | 30 |
| 31 | .64967 | .76022 | .66284 | .74876 | .67580 | .73708 | .68857 | .72517 | .70112 | .71305 | 29 |
| 32 | .64989 | .76003 | .66306 | .74857 | .67602 | .73688 | .68878 | .72497 | 70132 | .71284 | 28 |
| 33 | .65011 | .75984 | .66327 | .74838 | .67623 | .73669 | .68899 | .72477 | .70153 | .71264 | 27 |
| 34 | .65033 | .75965 | .66349 | .74818 | .67645 | .73649 | .68920 | .72457 | .70174 | .71243 | 26 |
| 35 | .65055 | .75946 | .66371 | .74799 | .67666 | .73629 | .68941 | .72437 | .70195 | .71223 | 25 |
| 36 | .65077 | .75927 | .66393 | .74780 | .67688 | .73610 | .68962 | .72417 | .70215 | .71203 | 24 |
| 37 | .65100 | .75908 | .66414 | .74760 | .67709 | .73590 | .68983 | .72397 | .70236 | .71182 | 23 |
| 38 | .65122 | .75889 | .66436 | .74741 | .67730 | 73570 | .69004 | .72377 | .70257 | .71162 | 22 |
| 39 | .65144 | .75870 | .66458 | .74722 | .67752 | .73551 | .69025 | .72357 | .70277 | .71141 | 21 |
| 40 | .65166 | .75851 | .66480 | .74703 | .67773 | .73531 | .69046 | .72337 | .70298 | .71121 | 20 |
| 41 | .65188 | .75832 | .66501 | .74683 | .67795 | .73511 | .69067 | .72317 | .70319 | .71100 | 19 |
| 42 | .65210 | .75813 | .66523 | .74664 | .67816 | .73491 | .69088 | .72297 | .70339 | .71080 | 18 |
| 43 | .65232 | .75794 | .66545 | .74644 | .67837 | .73472 | .69109 | .72277 | .70360 | .71059 | 17 |
| 44 | .65254 | .75775 | .66566 | .74625 | .67859 | .73452 | .69130 | .72257 | .70381 | .71039 | 16 |
| 45 | .65276 | .75756 | .66588 | .74606 | .67880 | .73432 | .69151 | .72236 | .70401 | .71019 | 15 |
| 46 | .65298 | .75738 | .66610 | .74586 | .67901 | .73413 | .69172 | .72216 | .70422 | .70998 | 14 |
| 47 | .65320 | .75719 | .66632 | .74567 | .67923 | .73393 | .69193 | .72196 | .70443 | .70978 | 13 |
| 48 | .65342 | .75700 | .66653 | .74548 | .67944 | .73373 | .69214 | .72176 | .70463 | .70957 | 12 |
| 49 | .65364 | .75680 | .66675 | .74528 | .67965 | .73353 | .69235 | .72156 | .70484 | .70937 | 11 |
| 50 | .65386 | .75661 | .66697 | .74509 | .67987 | .73333 | .69256 | .72136 | .70505 | .70916 | 10 |
| 51 | .65408 | .75642 | .66718 | .74489 | .68008 | .73314 | .69277 | .72116 | .70525 | .70896 | 9 |
| 52 | .65430 | .75623 | .66740 | .74470 | .68029 | .73294 | .69298 | .72095 | .70546 | .70875 | 8 |
| 53 | .65452 | .75604 | .66762 | .74451 | .68051 | .73274 | .69319 | .72075 | .70567 | .70855 | 7 |
| 54 | .65474 | .75585 | .66783 | .74431 | .68072 | .73254 | .69340 | .72055 | .70587 | .70834 | 6 |
| 55 | .65496 | .75566 | .66805 | .74412 | .68093 | .73234 | .69361 | .72035 | .70608 | .70813 | 5 |
| 56 | .65518 | .75547 | .66827 | .74392 | .68115 | .73215 | .69382 | .72015 | .70628 | .70793 | 4 |
| 57 | .65540 | .75528 | .66848 | .74373 | .68136 | .73195 | .69403 | .71995 | .70649 | .70772 | 3 |
| 58 | .65562 | .75509 | .66870 | .74352 | .68157 | .73175 | .69424 | .71974 | .70670 | .70752 | 2 |
| 59 | .65584 | .75490 | .66891 | .74334 | .68179 | .73155 | .69445 | .71954 | .70690 | .70731 | 1 |
| 60 | .65606 | .75471 | .66913 | .74314 | .68200 | .73135 | .69466 | .71934 | .70711 | .70711 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 49° | | 48° | | 47° | | 46° | | 45° | | |

| ′ | 0° Tang | 0° Cotang | 1° Tang | 1° Cotang | 2° Tang | 2° Cotang | 3° Tang | 3° Cotang | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .00000 | Infinite. | .01746 | 57.2900 | .03492 | 28.6363 | .05241 | 19.0811 | 60 |
| 1 | .00029 | 3437.75 | .01775 | 56.3506 | .03521 | 28.3994 | .05270 | 18.9755 | 59 |
| 2 | .00058 | 1718.87 | .01804 | 55.4415 | .03550 | 28.1664 | .05299 | 18.8711 | 58 |
| 3 | .00087 | 1145.92 | .01833 | 54.5613 | .03579 | 27.9372 | .05328 | 18.7678 | 57 |
| 4 | .00116 | 859.436 | .01862 | 53.7086 | .03609 | 27.7117 | .05357 | 18,6656 | 56 |
| 5 | .00145 | 687.549 | .01891 | 52.8821 | .03638 | 27.4899 | .05387 | 18.5645 | 55 |
| 6 | .00175 | 572.957 | .01920 | 52.0807 | .03667 | 27.2715 | .05416 | 18.4645 | 54 |
| 7 | .00204 | 491.106 | .01949 | 51.3032 | .03696 | 27.0566 | .05445 | 18.3655 | 53 |
| 8 | .00233 | 429.718 | .01978 | 50.5485 | .03725 | 26.8450 | .05474 | 18.2677 | 52 |
| 9 | .00262 | 381.971 | .02007 | 49.8157 | .03754 | 26.6367 | .05503 | 18.1708 | 51 |
| 10 | .00291 | 343.774 | .02036 | 49.1039 | .03783 | 26.4316 | .05533 | 18.0750 | 50 |
| 11 | .00320 | 312.521 | .02066 | 48.4121 | .03812 | 26.2296 | .05562 | 17.9802 | 49 |
| 12 | .00349 | 286.478 | .02095 | 47.7395 | .03842 | 26.0307 | .05591 | 17.8863 | 48 |
| 13 | .00378 | 264.441 | .02124 | 47.0853 | .03871 | 25.8348 | .05620 | 17.7934 | 47 |
| 14 | .00407 | 245.552 | .02153 | 46.4489 | .03900 | 25.6418 | .05649 | 17.7015 | 46 |
| 15 | .00436 | 229.182 | .02182 | 45.8294 | .03929 | 25.4517 | .05678 | 17.6106 | 45 |
| 16 | .00465 | 214.858 | .02211 | 45.2261 | .03958 | 25.2644 | .05708 | 17.5205 | 44 |
| 17 | .00495 | 202.219 | .02240 | 44.6386 | .03987 | 25.0798 | .05737 | 17.4314 | 43 |
| 18 | .00524 | 190.984 | .02269 | 44.0661 | .04016 | 24.8978 | .05766 | 17.3432 | 42 |
| 19 | .00553 | 180.932 | .02298 | 43.5081 | .04046 | 24.7185 | .05795 | 17.2558 | 41 |
| 20 | .00582 | 171.885 | .02328 | 42.9641 | .04075 | 24.5418 | .05824 | 17.1693 | 40 |
| 21 | .00611 | 163.700 | .02357 | 42.4335 | .04104 | 24.3675 | .05854 | 17.0837 | 39 |
| 22 | .00640 | 156.259 | .02386 | 41.9158 | .04133 | 24.1957 | .05883 | 16.9990 | 38 |
| 23 | .00669 | 149.465 | .02415 | 41.4106 | .04162 | 24.0263 | .05912 | 16.9150 | 37 |
| 24 | .00698 | 143.237 | .02444 | 40.9174 | .04191 | 23.8593 | .05941 | 16.8319 | 36 |
| 25 | .00727 | 137.507 | .02473 | 40.4358 | .04220 | 23.6945 | .05970 | 16.7496 | 35 |
| 26 | .00756 | 132.219 | ,02502 | 39.9655 | .04250 | 23.5321 | .05999 | 16.6681 | 34 |
| 27 | .00785 | 127.321 | .02531 | 39.5059 | .04279 | 23.3718 | .06029 | 16.5874 | 33 |
| 28 | .00815 | 122.774 | .02560 | 39.0568 | .04308 | 23.2137 | .06058 | 16.5075 | 32 |
| 29 | .00844 | 118.540 | .02589 | 38.6177 | .04337 | 23.0577 | .06087 | 16.4283 | 31 |
| 30 | .00873 | 114.589 | .02619 | 38.1885 | .04366 | 22.9038 | .06116 | 16.3499 | 30 |
| 31 | .00902 | 110.892 | .02648 | 37.7686 | .04395 | 22.7519 | .06145 | 16.2722 | 29 |
| 32 | .00931 | 107.426 | .02677 | 37.3579 | .04424 | 22.6020 | .06175 | 16.1952 | 28 |
| 33 | .00960 | 104.171 | .02706 | 36.9560 | .04454 | 22.4541 | .06204 | 16.1190 | 27 |
| 34 | .00989 | 101.107 | .02735 | 36.5627 | .04483 | 22.3081 | .06233 | 16.0435 | 26 |
| 35 | .01018 | 98.2179 | .02764 | 36.1776 | .04512 | 22.1640 | .06262 | 15.9687 | 25 |
| 36 | .01047 | 95.4895 | .02793 | 35.8006 | .04541 | 22.0217 | .06291 | 15.8945 | 24 |
| 37 | .01076 | 92.9085 | .02822 | 35.4313 | .04570 | 21.8813 | .06321 | 15.8211 | 23 |
| 38 | .01105 | 90.4633 | .02851 | 35.0695 | .04599 | 21.7426 | .06350 | 15.7483 | 22 |
| 39 | .01135 | 88.1436 | .02881 | 34.7151 | .04628 | 21.6056 | .06379 | 15.6762 | 21 |
| 40 | .01164 | 85.9398 | .02910 | 34.3678 | .04658 | 21.4704 | .06408 | 15.6048 | 20 |
| 41 | .01193 | 83.8435 | .02939 | 34.0273 | .04687 | 21.3369 | .06437 | 15.5340 | 19 |
| 42 | .01222 | 81.8470 | .02968 | 33.6935 | .04716 | 21.2049 | .06467 | 15.4638 | 18 |
| 43 | .01251 | 79.9434 | .02997 | 33.3662 | .04745 | 21.0747 | .06496 | 15.3943 | 17 |
| 44 | .01280 | 78.1263 | .03026 | 33.0452 | .04774 | 20 9460 | .06525 | 15.3254 | 16 |
| 45 | .01309 | 76.3900 | .03055 | 32.7303 | .04803 | 20.8188 | .06554 | 15.2571 | 15 |
| 46 | .01338 | 74.7292 | .03084 | 32.4213 | .04833 | 20.6932 | .06584 | 15.1893 | 14 |
| 47 | .01367 | 73.1390 | .03114 | 32.1181 | .04862 | 20.5691 | .06613 | 15.1222 | 13 |
| 48 | .01396 | 71.6151 | .03143 | 31.8205 | .04891 | 20.4465 | .06642 | 15.0557 | 12 |
| 49 | .01425 | 70.1533 | .03172 | 31.5284 | .04920 | 20.3253 | .06671 | 14.9898 | 11 |
| 50 | .01455 | 68.7501 | .03201 | 31.2416 | .04949 | 20.2056 | .06700 | 14.9244 | 10 |
| 51 | .01484 | 67.4019 | .03230 | 30.9599 | .04978 | 20.0872 | .06730 | 14.8596 | 9 |
| 52 | .01513 | 66.1055 | .03259 | 30.6833 | .05007 | 19.9702 | .06759 | 14.7954 | 8 |
| 53 | .01542 | 64.8580 | .03288 | 30.4116 | .05037 | 19.8546 | .06788 | 14.7317 | 7 |
| 54 | .01571 | 63.6567 | .03317 | 30.1446 | .05066 | 19.7403 | .06817 | 14.6685 | 6 |
| 55 | .01600 | 62.4992 | .03346 | 29.8823 | .05095 | 19.6273 | .06847 | 14.6059 | 5 |
| 56 | .01629 | 61.3829 | .03376 | 29.6245 | .05124 | 19.5156 | .06876 | 14.5438 | 4 |
| 57 | .01658 | 60.3058 | .03405 | 29.3711 | .05153 | 19.4051 | .06905 | 14.4823 | 3 |
| 58 | .01687 | 59.2659 | .03434 | 29.1220 | .05182 | 19.2959 | .06934 | 14.4212 | 2 |
| 59 | .01716 | 58.2612 | .03463 | 28.8771 | .05212 | 19.1879 | .06963 | 14.3607 | 1 |
| 60 | .01746 | 57.2900 | .03492 | 28.6363 | .05241 | 19.0811 | .06993 | 14.3007 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 89° | | 88° | | 87° | | 86° | | |

| ′ | 4° | | 5° | | 6° | | 7° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .06993 | 14.3007 | .08749 | 11.4301 | .10510 | 9.51436 | .12278 | 8.14435 | 60 |
| 1 | .07022 | 14.2411 | .08778 | 11.3919 | .10540 | 9.48781 | .12308 | 8.12481 | 59 |
| 2 | .07051 | 14.1821 | .08807 | 11.3540 | .10569 | 9.46141 | .12338 | 8.10536 | 58 |
| 3 | .07080 | 14.1235 | .08837 | 11.3163 | .10599 | 9.43515 | .12367 | 8.08600 | 57 |
| 4 | .07110 | 14.0655 | .08866 | 11.2789 | .10628 | 9.40904 | .12397 | 8.06674 | 56 |
| 5 | .07139 | 14.0079 | .08895 | 11.2417 | .10657 | 9.38307 | .12426 | 8.04756 | 55 |
| 6 | .07168 | 13.9507 | .08925 | 11.2048 | .10687 | 9.35724 | .12456 | 8.02848 | 54 |
| 7 | .07197 | 13.8940 | .08954 | 11.1681 | .10716 | 9.33155 | .12485 | 8.00948 | 53 |
| 8 | .07227 | 13.8378 | .08983 | 11.1316 | .10746 | 9.30599 | .12515 | 7.99058 | 52 |
| 9 | .07256 | 13.7821 | .09013 | 11.0954 | .10775 | 9.28058 | .12544 | 7.97176 | 51 |
| 10 | .07285 | 13.7267 | .09042 | 11.0594 | .10805 | 9.25530 | .12574 | 7.95302 | 50 |
| 11 | .07314 | 13.6719 | .09071 | 11.0237 | .10834 | 9.23016 | .12603 | 7.93438 | 49 |
| 12 | .07344 | 13.6174 | .09101 | 10.9882 | .10863 | 9.20516 | .12633 | 7.91582 | 48 |
| 13 | .07373 | 13.5634 | .09130 | 10.9529 | .10893 | 9.18028 | .12662 | 7.89734 | 47 |
| 14 | .07402 | 13.5098 | .09159 | 10.9178 | .10922 | 9.15554 | .12692 | 7.87895 | 46 |
| 15 | .07431 | 13.4566 | .09189 | 10.8829 | .10952 | 9.13093 | .12722 | 7.86064 | 45 |
| 16 | .07461 | 13.4039 | .09218 | 10.8483 | .10981 | 9.10646 | .12751 | 7.84242 | 44 |
| 17 | .07490 | 13.3515 | .09247 | 10.8139 | .11011 | 9.08211 | .12781 | 7.82428 | 43 |
| 18 | .07519 | 13.2996 | .09277 | 10.7797 | .11040 | 9.05789 | .12810 | 7.80622 | 42 |
| 19 | .07548 | 13.2480 | .09306 | 10.7457 | .11070 | 9.03379 | .12840 | 7.78825 | 41 |
| 20 | .07578 | 13.1969 | .09335 | 10.7119 | .11099 | 9.00983 | .12869 | 7.77035 | 40 |
| 21 | .07607 | 13.1461 | .09365 | 10.6783 | .11128 | 8.98598 | .12899 | 7.75254 | 39 |
| 22 | .07636 | 13.0958 | .09394 | 10.6450 | .11158 | 8.96227 | .12929 | 7.73480 | 38 |
| 23 | .07665 | 13.0458 | .09423 | 10.6118 | .11187 | 8.93867 | .12958 | 7.71715 | 37 |
| 24 | .07695 | 12.9962 | .09453 | 10.5789 | .11217 | 8.91520 | .12988 | 7.69957 | 36 |
| 25 | .07724 | 12.9469 | .09482 | 10.5462 | .11246 | 8.89185 | .13017 | 7.68208 | 35 |
| 26 | .07753 | 12.8981 | .09511 | 10.5136 | .11276 | 8.86862 | .13047 | 7.66466 | 34 |
| 27 | .07782 | 12.8496 | .09541 | 10.4813 | .11305 | 8.84551 | .13076 | 7.64732 | 33 |
| 28 | .07812 | 12.8014 | .09570 | 10.4491 | .11335 | 8.82252 | .13106 | 7.63005 | 32 |
| 29 | .07841 | 12.7536 | .09600 | 10.4172 | .11364 | 8.79964 | .13136 | 7.61287 | 31 |
| 30 | .07870 | 12.7062 | .09629 | 10.3854 | .11394 | 8.77689 | .13165 | 7.59575 | 30 |
| 31 | .07899 | 12.6591 | .09658 | 10.3538 | .11423 | 8.75425 | .13195 | 7.57872 | 29 |
| 32 | .07929 | 12.6124 | .09688 | 10.3224 | .11452 | 8.73172 | .13224 | 7.56176 | 28 |
| 33 | .07958 | 12.5660 | .09717 | 10.2913 | .11482 | 8.70931 | .13254 | 7.54487 | 27 |
| 34 | .07987 | 12.5199 | .09746 | 10.2602 | .11511 | 8.68701 | .13284 | 7.52806 | 26 |
| 35 | .08017 | 12.4742 | .09776 | 10.2294 | .11541 | 8.66482 | .13313 | 7.51132 | 25 |
| 36 | .08046 | 12.4288 | .09805 | 10.1988 | .11570 | 8.64275 | .13343 | 7.49465 | 24 |
| 37 | .08075 | 12.3838 | .09834 | 10.1683 | .11600 | 8.62078 | .13372 | 7.47806 | 23 |
| 38 | .08104 | 12.3390 | .09864 | 10.1381 | .11629 | 8.59893 | .13402 | 7.46154 | 22 |
| 39 | .08134 | 12.2946 | .09893 | 10.1080 | .11[illegible] | 8.57718 | .13432 | 7.44509 | 21 |
| 40 | .08163 | 12.2505 | .09923 | 10.0780 | .11688 | 8.55555 | .13461 | 7.42871 | 20 |
| 41 | .08192 | 12.2067 | .09952 | 10.0483 | .11718 | [illegible] 53402 | .13491 | 7.41240 | 19 |
| 42 | .08221 | 12.1632 | .09981 | 10.0187 | .11747 | 8.51259 | .13521 | 7.39616 | 18 |
| 43 | .08251 | 12.1201 | .10011 | 9.98931 | .11777 | 8.49128 | .13550 | 7.37999 | 17 |
| 44 | .08280 | 12.0772 | .10040 | 9.96007 | .11806 | 8.47007 | .13580 | 7.36389 | 16 |
| 45 | .08309 | 12.0346 | .10069 | 9.93101 | .11836 | 8.44896 | .13609 | 7.34786 | 15 |
| 46 | .08339 | 11.9923 | .10099 | 9.90211 | .11865 | 8.42795 | .13639 | 7.33190 | 14 |
| 47 | .08368 | 11.9504 | .10128 | 9.87338 | .11895 | 8.40705 | .13669 | 7.31600 | 13 |
| 48 | .08397 | 11.9087 | .10158 | 9.84482 | .11924 | 8.38625 | .13698 | 7.30018 | 12 |
| 49 | .08427 | 11.8673 | .10187 | 9.81641 | .11954 | 8.36555 | .13728 | 7.28442 | 11 |
| 50 | .08456 | 11.8262 | .10216 | 9.78817 | .11983 | 8.34496 | .13758 | 7.26873 | 10 |
| 51 | .08485 | 11.7853 | .10246 | 9.76009 | .12013 | 8.32446 | .13787 | 7.25310 | 9 |
| 52 | .08514 | 11.7448 | .10275 | 9.73217 | .12042 | 8.30406 | .13817 | 7.23754 | 8 |
| 53 | .08544 | 11.7045 | .10305 | 9.70441 | .12072 | 8.28376 | .13846 | 7.22204 | 7 |
| 54 | .08573 | 11.6645 | .10334 | 9.67680 | .12101 | 8.26355 | .13876 | 7.20661 | 6 |
| 55 | .08602 | 11.6248 | .10363 | 9.64935 | .12131 | 8.24345 | .13906 | 7.19125 | 5 |
| 56 | .08632 | 11.5853 | .10393 | 9.62205 | .12160 | 8.22344 | .13935 | 7.17594 | 4 |
| 57 | .08661 | 11.5461 | .10422 | 9.59490 | .12190 | 8.20352 | .13965 | 7.16071 | 3 |
| 58 | .08690 | 11.5072 | .10452 | 9.56791 | .12219 | 8.18370 | .13995 | 7.14553 | 2 |
| 59 | .08720 | 11.4685 | .10481 | 9.54106 | .12249 | 8.16398 | .14024 | 7.13042 | 1 |
| 60 | .08749 | 11.4301 | .10510 | 9.51436 | .12278 | 8.14435 | .14054 | 7.11537 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 85° | | 84° | | 83° | | 82° | | |

TABLE XXVIII.—NATURAL TANGENTS AND COTANGENTS.

| ′ | 8° Tang | 8° Cotang | 9° Tang | 9° Cotang | 10° Tang | 10° Cotang | 11° Tang | 11° Cotang | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .14054 | 7.11537 | .15838 | 6.31375 | .17633 | 5.67128 | .19438 | 5.14455 | 60 |
| 1 | .14084 | 7.10038 | .15868 | 6.30189 | .17663 | 5.66165 | .19468 | 5.13658 | 59 |
| 2 | .14113 | 7.08546 | .15898 | 6.29007 | .17693 | 5.65205 | .19498 | 5.12862 | 58 |
| 3 | .14143 | 7.07059 | .15928 | 6.27829 | .17723 | 5.64248 | .19529 | 5.12069 | 57 |
| 4 | .14173 | 7.05579 | .15958 | 6.26655 | .17753 | 5.63295 | .19559 | 5.11279 | 56 |
| 5 | .14202 | 7.04105 | .15988 | 6.25486 | .17783 | 5.62344 | .19589 | 5.10490 | 55 |
| 6 | .14232 | 7.02637 | .16017 | 6.24321 | .17813 | 5.61397 | .19619 | 5.09704 | 54 |
| 7 | .14262 | 7.01174 | .16047 | 6.23160 | .17843 | 5.60452 | .19649 | 5.08921 | 53 |
| 8 | .14291 | 6.99718 | .16077 | 6.22003 | .17873 | 5.59511 | .19680 | 5.08139 | 52 |
| 9 | .14321 | 6.98268 | .16107 | 6.20851 | .17903 | 5.58573 | .19710 | 5.07360 | 51 |
| 10 | .14351 | 6.96823 | .16137 | 6.19703 | .17933 | 5.57638 | .19740 | 5.06584 | 50 |
| 11 | .14381 | 6.95385 | .16167 | 6.18559 | .17963 | 5.56706 | .19770 | 5.05809 | 49 |
| 12 | .14410 | 6.93952 | .16196 | 6.17419 | .17993 | 5.55777 | .19801 | 5.05037 | 48 |
| 13 | .14440 | 6.92525 | .16226 | 6.16283 | .18023 | 5.54851 | .19831 | 5.04267 | 47 |
| 14 | .14470 | 6.91104 | .16256 | 6.15151 | .18053 | 5.53927 | .19861 | 5.03499 | 46 |
| 15 | .14499 | 6.89688 | .16286 | 6.14023 | .18083 | 5.53007 | .19891 | 5.02734 | 45 |
| 16 | .14529 | 6.88278 | .16316 | 6.12899 | .18113 | 5.52090 | .19921 | 5.01971 | 44 |
| 17 | .14559 | 6.86874 | .16346 | 6.11779 | .18143 | 5.51176 | .19952 | 5.01210 | 43 |
| 18 | .14588 | 6.85475 | .16376 | 6.10664 | .18173 | 5.50264 | .19982 | 5.00451 | 42 |
| 19 | .14618 | 6.84082 | .16405 | 6.09552 | .18203 | 5.49356 | .20012 | 4.99695 | 41 |
| 20 | .14648 | 6.82694 | .16435 | 6.08444 | .18233 | 5.48451 | .20042 | 4.98940 | 40 |
| 21 | .14678 | 6.81312 | .16465 | 6.07340 | .18263 | 5.47548 | .20073 | 4.98188 | 39 |
| 22 | .14707 | 6.79936 | .16495 | 6.06240 | .18293 | 5.46648 | .20103 | 4.97438 | 38 |
| 23 | .14737 | 6.78564 | .16525 | 6.05143 | .18323 | 5.45751 | .20133 | 4.96690 | 37 |
| 24 | .14767 | 6.77199 | .16555 | 6.04051 | .18353 | 5.44857 | .20164 | 4.95945 | 36 |
| 25 | .14796 | 6.75838 | .16585 | 6.02962 | .18384 | 5.43966 | .20194 | 4.95201 | 35 |
| 26 | .14826 | 6.74483 | .16615 | 6.01878 | .18414 | 5.43077 | .20224 | 4.94460 | 34 |
| 27 | .14856 | 6.73133 | .16645 | 6.00797 | .18444 | 5.42192 | .20254 | 4.93721 | 33 |
| 28 | .14886 | 6.71789 | .16674 | 5.99720 | .18474 | 5.41309 | .20285 | 4.92984 | 32 |
| 29 | .14915 | 6.70450 | .16704 | 5.98646 | .18504 | 5.40429 | .20315 | 4.92249 | 31 |
| 30 | .14945 | 6.69116 | .16734 | 5.97576 | .18534 | 5.39552 | .20345 | 4.91516 | 30 |
| 31 | .14975 | 6.67787 | .16764 | 5.96510 | .18564 | 5.38677 | .20376 | 4.90785 | 29 |
| 32 | .15005 | 6.66463 | .16794 | 5.95448 | .18594 | 5.37805 | .20406 | 4.90056 | 28 |
| 33 | .15034 | 6.65144 | .16824 | 5.94390 | .18624 | 5.36936 | .20436 | 4.89330 | 27 |
| 34 | .15064 | 6.63831 | .16854 | 5.93335 | .18654 | 5.36070 | .20466 | 4.88605 | 26 |
| 35 | .15094 | 6.62523 | .16884 | 5.92283 | .18684 | 5.35206 | .20497 | 4.87882 | 25 |
| 36 | .15124 | 6.61219 | .16914 | 5.91236 | .18714 | 5.34345 | .20527 | 4.87162 | 24 |
| 37 | .15153 | 6.59921 | .16944 | 5.90191 | .18745 | 5.33487 | .20557 | 4.86444 | 23 |
| 38 | .15183 | 6.58627 | .16974 | 5.89151 | .18775 | 5.32631 | .20588 | 4.85727 | 22 |
| 39 | .15213 | 6.57339 | .17004 | 5.88114 | .18805 | 5.31778 | .20618 | 4.85013 | 21 |
| 40 | .15243 | 6.56055 | .17033 | 5.87080 | .18835 | 5.30928 | .20648 | 4.84300 | 20 |
| 41 | .15272 | 6.54777 | .17063 | 5.86051 | .18865 | 5.30080 | .20679 | 4.83590 | 19 |
| 42 | .15302 | 6.53503 | .17093 | 5.85024 | .18895 | 5.29235 | .20709 | 4.82882 | 18 |
| 43 | .15332 | 6.52234 | .17123 | 5.84001 | .18925 | 5.28393 | .20739 | 4.82175 | 17 |
| 44 | .15362 | 6.50970 | .17153 | 5.82982 | .18955 | 5.27553 | .20770 | 4.81471 | 16 |
| 45 | .15391 | 6.49710 | .17183 | 5.81966 | .18986 | 5.26715 | .20800 | 4.80769 | 15 |
| 46 | .15421 | 6.48456 | .17213 | 5.80953 | .19016 | 5.25880 | .20830 | 4.80068 | 14 |
| 47 | .15451 | 6.47206 | .17243 | 5.79944 | .19046 | 5.25048 | .20861 | 4.79370 | 13 |
| 48 | .15481 | 6.45961 | .17273 | 5.78938 | .19076 | 5.24218 | .20891 | 4.78673 | 12 |
| 49 | .15511 | 6.44720 | .17303 | 5.77936 | .19106 | 5.23391 | .20921 | 4.77978 | 11 |
| 50 | .15540 | 6.43484 | .17333 | 5.76937 | .19136 | 5.22566 | .20952 | 4.77286 | 10 |
| 51 | .15570 | 6.42253 | .17363 | 5.75941 | .19166 | 5.21744 | .20982 | 4.76595 | 9 |
| 52 | .15600 | 6.41026 | .17393 | 5.74949 | .19197 | 5.20925 | .21013 | 4.75906 | 8 |
| 53 | .15630 | 6.39804 | .17423 | 5.73960 | .19227 | 5.20107 | .21043 | 4.75219 | 7 |
| 54 | .15660 | 6.38587 | .17453 | 5.72974 | .19257 | 5.19293 | .21073 | 4.74534 | 6 |
| 55 | .15689 | 6.37374 | .17483 | 5.71992 | .19287 | 5.18480 | .21104 | 4.73851 | 5 |
| 56 | .15719 | 6.36165 | .17513 | 5.71013 | .19317 | 5.17671 | .21134 | 4.73170 | 4 |
| 57 | .15749 | 6.34961 | .17543 | 5.70037 | .19347 | 5.16863 | .21164 | 4.72490 | 3 |
| 58 | .15779 | 6.33761 | .17573 | 5.69064 | .19378 | 5.16058 | .21195 | 4.71813 | 2 |
| 59 | .15809 | 6.32566 | .17603 | 5.68094 | .19408 | 5.15256 | .21225 | 4.71137 | 1 |
| 60 | .15838 | 6.31375 | .17633 | 5.67128 | .19438 | 5.14455 | .21256 | 4.70463 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 81° | | 80° | | 79° | | 78° | | |

| ′ | 12° | | 13° | | 14° | | 15° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .21256 | 4.70463 | .23087 | 4.33148 | .24933 | 4.01078 | .26795 | 3.73205 | 60 |
| 1 | .21286 | 4.69791 | .23117 | 4.32573 | .24964 | 4.00582 | .26826 | 3.72771 | 59 |
| 2 | .21316 | 4.69121 | .23148 | 4.32001 | .24995 | 4.00086 | .26857 | 3.72338 | 58 |
| 3 | .21347 | 4.68452 | .23179 | 4.31430 | .25026 | 3.99592 | .26888 | 3.71907 | 57 |
| 4 | .21377 | 4.67786 | .23209 | 4.30860 | .25056 | 3.99099 | .26920 | 3.71476 | 56 |
| 5 | .21408 | 4.67121 | .23240 | 4.30291 | .25087 | 3.98607 | .26951 | 3.71046 | 55 |
| 6 | .21438 | 4.66458 | .23271 | 4.29724 | .25118 | 3.98117 | .26982 | 3.70616 | 54 |
| 7 | .21469 | 4.65797 | .23301 | 4.29159 | .25149 | 3.97627 | .27013 | 3.70188 | 53 |
| 8 | .21499 | 4.65138 | .23332 | 4.28595 | .25180 | 3.97139 | .27044 | 3.69761 | 52 |
| 9 | .21529 | 4.64480 | .23363 | 4.28032 | .25211 | 3.96651 | .27076 | 3.69335 | 51 |
| 10 | .21560 | 4.63825 | .23393 | 4.27471 | .25242 | 3.96165 | .27107 | 3.68909 | 50 |
| 11 | .21590 | 4.63171 | .23424 | 4.26911 | .25273 | 3.95680 | .27138 | 3.68485 | 49 |
| 12 | .21621 | 4.62518 | .23455 | 4.26352 | .25304 | 3.95196 | .27169 | 3.68061 | 48 |
| 13 | .21651 | 4.61868 | .23485 | 4.25795 | .25335 | 3.94713 | .27201 | 3.67638 | 47 |
| 14 | .21682 | 4.61219 | .23516 | 4.25239 | .25366 | 3.94232 | .27232 | 3.67217 | 46 |
| 15 | .21712 | 4.60572 | .23547 | 4.24685 | .25397 | 3.93751 | .27263 | 3.66796 | 45 |
| 16 | .21743 | 4.59927 | .23578 | 4.24132 | .25428 | 3.93271 | .27294 | 3.66376 | 44 |
| 17 | .21773 | 4.59283 | .23608 | 4.23580 | .25459 | 3.92793 | .27326 | 3.65957 | 43 |
| 18 | .21804 | 4.58641 | .23639 | 4.23030 | .25490 | 3.92316 | .27357 | 3.65538 | 42 |
| 19 | .21834 | 4.58001 | .23670 | 4.22481 | .25521 | 3.91839 | .27388 | 3.65121 | 41 |
| 20 | .21864 | 4.57363 | .23700 | 4.21933 | .25552 | 3.91364 | .27419 | 3.64705 | 40 |
| 21 | .21895 | 4.56726 | .23731 | 4.21387 | .25583 | 3.90890 | .27451 | 3.64289 | 39 |
| 22 | .21925 | 4.56091 | .23762 | 4.20842 | .25614 | 3.90417 | .27482 | 3.63874 | 38 |
| 23 | .21956 | 4.55458 | .23793 | 4.20298 | .25645 | 3.89945 | .27513 | 3.63461 | 37 |
| 24 | .21986 | 4.54826 | .23823 | 4.19756 | .25676 | 3.89474 | .27545 | 3.63048 | 36 |
| 25 | .22017 | 4.54196 | .23854 | 4.19215 | .25707 | 3.89004 | .27576 | 3.62636 | 35 |
| 26 | .22047 | 4.53568 | .23885 | 4.18675 | .25738 | 3.88536 | .27607 | 3.62224 | 34 |
| 27 | .22078 | 4.52941 | .23916 | 4.18137 | .25769 | 3.88068 | .27638 | 3.61814 | 33 |
| 28 | .22108 | 4.52316 | .23946 | 4.17600 | .25800 | 3.87601 | .27670 | 3.61405 | 32 |
| 29 | .22139 | 4.51693 | .23977 | 4.17064 | .25831 | 3.87136 | .27701 | 3.60996 | 31 |
| 30 | .22169 | 4.51071 | .24008 | 4.16530 | .25862 | 3.86671 | .27732 | 3 60588 | 30 |
| 31 | .22200 | 4.50451 | .24039 | 4.15997 | .25893 | 3.86208 | .27764 | 3.60181 | 29 |
| 32 | .22231 | 4.49832 | .24069 | 4.15465 | .25924 | 3.85745 | .27795 | 3.59775 | 28 |
| 33 | .22261 | 4.49215 | .24100 | 4.14934 | .25955 | 3.85284 | .27826 | 3.59370 | 27 |
| 34 | .22292 | 4.48600 | .24131 | 4.14405 | .25986 | 3.84824 | .27858 | 3.58966 | 26 |
| 35 | .22322 | 4.47986 | .24162 | 4.13877 | .26017 | 3.84364 | .27889 | 3.58562 | 25 |
| 36 | .22353 | 4.47374 | .24193 | 4.13350 | .26048 | 3.83906 | .27921 | 3.58160 | 24 |
| 37 | .22383 | 4.46764 | .24223 | 4.12825 | 26079 | 3.83449 | .27952 | 3.57758 | 23 |
| 38 | .22414 | 4.46155 | .24254 | 4.12301 | .26110 | 3.82992 | .27983 | 3.57357 | 22 |
| 39 | .22444 | 4.45548 | .24285 | 4.11778 | .26141 | 3.82537 | .28015 | 3.56957 | 21 |
| 40 | .22475 | 4.44942 | .24316 | 4.11256 | .26172 | 3.82083 | .28046 | 3.56557 | 20 |
| 41 | .22505 | 4.44338 | .24347 | 4.10736 | .26203 | 3.81630 | .28077 | 3.56159 | 19 |
| 42 | .22536 | 4.43735 | .24377 | 4.10216 | .26235 | 3.81177 | .28109 | 3.55761 | 18 |
| 43 | .22567 | 4.43134 | .24408 | 4.09699 | .26266 | 3.80726 | .28140 | 3.55364 | 17 |
| 44 | .22597 | 4.42534 | .24439 | 4.09182 | .26297 | 3.80276 | .28172 | 3.54968 | 16 |
| 45 | .22628 | 4.41936 | .24470 | 4.08666 | .26328 | 3.79827 | .28203 | 3.54573 | 15 |
| 46 | .22658 | 4.41340 | .24501 | 4.08152 | .26359 | 3.79378 | .28234 | 3.54179 | 14 |
| 47 | .22689 | 4.40745 | .24532 | 4.07639 | .26390 | 3.78931 | .28266 | 3.53785 | 13 |
| 48 | .22719 | 4.40152 | .24562 | 4.07127 | .26421 | 3.78485 | .28297 | 3.53393 | 12 |
| 49 | .22750 | 4.39560 | .24593 | 4.06616 | .26452 | 3.78040 | .28329 | 3.53001 | 11 |
| 50 | .22781 | 4.38969 | .24624 | 4.06107 | .26483 | 3.77595 | .28360 | 3.52609 | 10 |
| 51 | .22811 | 4.38381 | .24655 | 4.05599 | .26515 | 3.77152 | .28391 | 3.52219 | 9 |
| 52 | .22842 | 4.37793 | .24686 | 4.05092 | .26546 | 3.76709 | .28423 | 3.51829 | 8 |
| 53 | .22872 | 4.37207 | .24717 | 4.04586 | .26577 | 3.76268 | .28454 | 3.51441 | 7 |
| 54 | .22903 | 4.36623 | .24747 | 4.04081 | .26608 | 3.75828 | .28486 | 3.51053 | 6 |
| 55 | .22934 | 4.36040 | .24778 | 4.03578 | .26639 | 3.75388 | .28517 | 3.50666 | 5 |
| 56 | .22964 | 4.35459 | .24809 | 4.03076 | .26670 | 3.74950 | .28549 | 3.50279 | 4 |
| 57 | .22995 | 4.34879 | .24840 | 4.02574 | .26701 | 3.74512 | .28580 | 3.49894 | 3 |
| 58 | .23026 | 4.34300 | .24871 | 4.02074 | .26733 | 3.74075 | .28612 | 3.49509 | 2 |
| 59 | .23056 | 4.33723 | .24902 | 4.01576 | .26764 | 3.73640 | .28643 | 3.49125 | 1 |
| 60 | .23087 | 4.33148 | .24933 | 4.01078 | .26795 | 3.73205 | .28675 | 3.48741 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 77° | | 76° | | 75° | | 74° | | |

## TABLE XXVIII.—NATURAL TANGENTS AND COTANGENTS.

| ′ | 16° | | 17° | | 18° | | 19° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .28675 | 3.48741 | .30573 | 3.27085 | .32492 | 3.07768 | .34433 | 2.90421 | 60 |
| 1 | .28706 | 3.48359 | .30605 | 3.26745 | .32524 | 3.07464 | .34465 | 2.90147 | 59 |
| 2 | .28738 | 3.47977 | .30637 | 3.26406 | .32556 | 3.07160 | .34498 | 2.89873 | 58 |
| 3 | .28769 | 3.47596 | .30669 | 3.26067 | .32588 | 3.06857 | .34530 | 2.89600 | 57 |
| 4 | .28800 | 3.47216 | .30700 | 3.25729 | .32621 | 3.06554 | .34563 | 2.89327 | 56 |
| 5 | .28832 | 3.46837 | .30732 | 3.25392 | .32653 | 3.06252 | .34596 | 2.89055 | 55 |
| 6 | .28864 | 3.46458 | .30764 | 3.25055 | .32685 | 3.05950 | .34628 | 2.88783 | 54 |
| 7 | .28895 | 3.46080 | .30796 | 3.24719 | .32717 | 3.05649 | .34661 | 2.88511 | 53 |
| 8 | .28927 | 3.45703 | .30828 | 3.24383 | .32749 | 3.05349 | .34693 | 2.88240 | 52 |
| 9 | .28958 | 3.45327 | .30860 | 3.24049 | .32782 | 3.05049 | .34726 | 2.87970 | 51 |
| 10 | .28990 | 3.44951 | .30891 | 3.23714 | .32814 | 3.04749 | .34758 | 2 87700 | 50 |
| 11 | .29021 | 3.44576 | .30923 | 3.23381 | .32846 | 3.04450 | .34791 | 2.87430 | 49 |
| 12 | .29053 | 3.44202 | .30955 | 3.23048 | .32878 | 3.04152 | .34824 | 2.87161 | 48 |
| 13 | .29084 | 3.43829 | .30987 | 3.22715 | .32911 | 3.03854 | .34856 | 2.86892 | 47 |
| 14 | .29116 | 3.43456 | .31019 | 3.22384 | .32943 | 3.03556 | .34889 | 2.86624 | 46 |
| 15 | .29147 | 3.43084 | .31051 | 3.22053 | .32975 | 3.03260 | .34922 | 2.86356 | 45 |
| 16 | .29179 | 3.42713 | .31083 | 3.21722 | .33007 | 3.02963 | .34954 | 2.86089 | 44 |
| 17 | .29210 | 3.42343 | .31115 | 3.21392 | .33040 | 3.02667 | .34987 | 2.85822 | 43 |
| 18 | .29242 | 3.41973 | .31147 | 3.21063 | .33072 | 3.02372 | .35020 | 2.85555 | 42 |
| 19 | .29274 | 3.41604 | .31178 | 3.20734 | .33104 | 3.02077 | .35052 | 2.85289 | 41 |
| 20 | .29305 | 3.41236 | .31210 | 3.20406 | .33136 | 3.01783 | .35085 | 2.85023 | 40 |
| 21 | .29337 | 3.40869 | .31242 | 3.20079 | .33169 | 3.01489 | .35118 | 2.84758 | 39 |
| 22 | .29368 | 3.40502 | .31274 | 3.19752 | .33201 | 3.01196 | .35150 | 2.84494 | 38 |
| 23 | .29400 | 3.40136 | .31306 | 3.19426 | .33233 | 3.00903 | .35183 | 2.84229 | 37 |
| 24 | .29432 | 3.39771 | .31338 | 3.19100 | .33266 | 3.00611 | .35216 | 2.83965 | 36 |
| 25 | .29463 | 3.39406 | .31370 | 3.18775 | .33298 | 3.00319 | .35248 | 2.83702 | 35 |
| 26 | .29495 | 3.39042 | .31402 | 3.18451 | .33330 | 3.00028 | .35281 | 2.83439 | 34 |
| 27 | .29526 | 3.38679 | .31434 | 3.18127 | .33363 | 2.99738 | .35314 | 2.83176 | 33 |
| 28 | .29558 | 3.38317 | .31466 | 3.17804 | .33395 | 2.99447 | .35346 | 2.82914 | 32 |
| 29 | .29590 | 3.37955 | .31498 | 3.17481 | .33427 | 2.99158 | .35379 | 2.82653 | 31 |
| 30 | .29621 | 3.37594 | .31530 | 3.17159 | .33460 | 2.98868 | .35412 | 2.82391 | 30 |
| 31 | .29653 | 3.37234 | .31562 | 3.16838 | .33492 | 2.98580 | .35445 | 2.82130 | 29 |
| 32 | .29685 | 3.36875 | .31594 | 3.16517 | .33524 | 2.98292 | .35477 | 2.81870 | 28 |
| 33 | .29716 | 3.36516 | .31626 | 3.16197 | .33557 | 2.98004 | .35510 | 2.81610 | 27 |
| 34 | .29748 | 3.36158 | .31658 | 3.15877 | .33589 | 2.97717 | .35543 | 2.81350 | 26 |
| 35 | .29780 | 3.35800 | .31690 | 3.15558 | .33621 | 2.97430 | .35576 | 2.81091 | 25 |
| 36 | .29811 | 3.35443 | .31722 | 3.15240 | .33654 | 2.97144 | .35608 | 2.80833 | 24 |
| 37 | .29843 | 3.35087 | .31754 | 3.14922 | .33686 | 2.96858 | .35641 | 2.80574 | 23 |
| 38 | .29875 | 3.34732 | .31786 | 3.14605 | .33718 | 2.96573 | .35674 | 2.80316 | 22 |
| 39 | .29906 | 3.34377 | .31818 | 3.14288 | .33751 | 2.96288 | .35707 | 2.80059 | 21 |
| 40 | .29938 | 3.34023 | .31850 | 3.13972 | .33783 | 2.96004 | .35740 | 2.79802 | 20 |
| 41 | .29970 | 3.33670 | .31882 | 3.13656 | .33816 | 2.95721 | .35772 | 2.79545 | 19 |
| 42 | .30001 | 3.33317 | .31914 | 3.13341 | .33848 | 2.95437 | .35805 | 2.79289 | 18 |
| 43 | .30033 | 3.32965 | .31946 | 3.13027 | .33881 | 2.95155 | .35838 | 2.79033 | 17 |
| 44 | .30065 | 3.32614 | .31978 | 3.12713 | .33913 | 2.94872 | .35871 | 2.78778 | 16 |
| 45 | .30097 | 3.32264 | .32010 | 3.12400 | .33945 | 2.94591 | .35904 | 2.78523 | 15 |
| 46 | .30128 | 3.31914 | .32042 | 3.12087 | .33978 | 2.94309 | .35937 | 2.78269 | 14 |
| 47 | .30160 | 3.31565 | .32074 | 3.11775 | .34010 | 2.94028 | .35969 | 2.78014 | 13 |
| 48 | .30192 | 3.31216 | .32106 | 3.11464 | .34043 | 2.93748 | .36002 | 2.77761 | 12 |
| 49 | .30224 | 3.30868 | .32139 | 3.11153 | .34075 | 2.93468 | .36035 | 2.77507 | 11 |
| 50 | .30255 | 3.30521 | .32171 | 3.10842 | .34108 | 2.93189 | .36068 | 2.77254 | 10 |
| 51 | .30287 | 3.30174 | .32203 | 3.10532 | .34140 | 2.92910 | .36101 | 2.77002 | 9 |
| 52 | .30319 | 3.29829 | .32235 | 3.10223 | .34173 | 2.92632 | .36134 | 2.76750 | 8 |
| 53 | .30351 | 3.29483 | .32267 | 3.09914 | .34205 | 2.92354 | .36167 | 2.76498 | 7 |
| 54 | .30382 | 3.29139 | .32299 | 3.09606 | .34238 | 2.92076 | .36199 | 2.76247 | 6 |
| 55 | .30414 | 3.28795 | .32331 | 3.09298 | .34270 | 2.91799 | .36232 | 2.75996 | 5 |
| 56 | .30446 | 3.28452 | .32363 | 3.08991 | .34303 | 2.91523 | .36265 | 2.75746 | 4 |
| 57 | .30478 | 3.28109 | .32396 | 3.08685 | .34335 | 2.91246 | .36298 | 2.75496 | 3 |
| 58 | .30509 | 3.27767 | .32428 | 3.08379 | .34368 | 2.90971 | .36331 | 2.75246 | 2 |
| 59 | .30541 | 3.27426 | .32460 | 3.08073 | .34400 | 2.90696 | .36364 | 2.74997 | 1 |
| 60 | .30573 | 3.27085 | .32492 | 3.07768 | .34433 | 2.90421 | .36397 | 2.74748 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 73° | | 72° | | 71° | | 70° | | |

| ′ | 20° | | 21° | | 22° | | 23° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .36397 | 2.74748 | .38386 | 2.60509 | .40403 | 2.47509 | .42447 | 2.35585 | 60 |
| 1 | .36430 | 2.74499 | .38420 | 2.60283 | .40436 | 2.47302 | .42482 | 2.35395 | 59 |
| 2 | .36463 | 2.74251 | .38453 | 2.60057 | .40470 | 2.47095 | .42516 | 2.35205 | 58 |
| 3 | .36496 | 2.74004 | .38487 | 2.59831 | .40504 | 2.46888 | .42551 | 2.35015 | 57 |
| 4 | .36529 | 2.73756 | .38520 | 2.59606 | .40538 | 2.46682 | .42585 | 2.34825 | 56 |
| 5 | .36562 | 2.73509 | .38553 | 2.59381 | .40572 | 2.46476 | .42619 | 2.34636 | 55 |
| 6 | .36595 | 2.73263 | .38587 | 2.59156 | .40606 | 2.46270 | .42654 | 2.34447 | 54 |
| 7 | .36628 | 2.73017 | .38620 | 2.58932 | .40640 | 2.46065 | .42688 | 2.34258 | 53 |
| 8 | .36661 | 2.72771 | .38654 | 2.58708 | .40674 | 2.45860 | .42722 | 2.34069 | 52 |
| 9 | .36694 | 2.72526 | .38687 | 2.58484 | .40707 | 2.45655 | .42757 | 2.33881 | 51 |
| 10 | .36727 | 2.72281 | .38721 | 2.58261 | .40741 | 2.45451 | .42791 | 2.33693 | 50 |
| 11 | .36760 | 2.72036 | .38754 | 2.58038 | .40775 | 2.45246 | .42826 | 2.33505 | 49 |
| 12 | .36793 | 2.71792 | .38787 | 2.57815 | .40809 | 2.45043 | .42860 | 2.33317 | 48 |
| 13 | .36826 | 2.71548 | .38821 | 2.57593 | .40843 | 2.44839 | .42894 | 2.33130 | 47 |
| 14 | .36859 | 2.71305 | .38854 | 2.57371 | .40877 | 2.44636 | .42929 | 2.32943 | 46 |
| 15 | .36892 | 2.71062 | .38888 | 2.57150 | .40911 | 2.44433 | .42963 | 2.32756 | 45 |
| 16 | .36925 | 2.70819 | .38921 | 2.56928 | .40945 | 2.44230 | .42998 | 2.32570 | 44 |
| 17 | .36958 | 2.70577 | .38955 | 2.56707 | .40979 | 2.44027 | .43032 | 2.32383 | 43 |
| 18 | .36991 | 2.70335 | .38988 | 2.56487 | .41013 | 2.43825 | .43067 | 2.32197 | 42 |
| 19 | .37024 | 2.70094 | .39022 | 2.56266 | .41047 | 2.43623 | .43101 | 2.32012 | 41 |
| 20 | .37057 | 2.69853 | .39055 | 2.56046 | .41081 | 2.43422 | .43136 | 2.31826 | 40 |
| 21 | .37090 | 2.69612 | .39089 | 2.55827 | .41115 | 2.43220 | .43170 | 2.31641 | 39 |
| 22 | .37123 | 2.69371 | .39122 | 2.55608 | .41149 | 2.43019 | .43205 | 2.31456 | 38 |
| 23 | .37157 | 2.69131 | .39156 | 2.55389 | .41183 | 2.42819 | .43239 | 2.31271 | 37 |
| 24 | .37190 | 2.68892 | .39190 | 2.55170 | .41217 | 2.42618 | .43274 | 2.31086 | 36 |
| 25 | .37223 | 2.68653 | .39223 | 2.54952 | .41251 | 2.42418 | .43308 | 2.30902 | 35 |
| 26 | .37256 | 2.68414 | .39257 | 2.54734 | .41285 | 2.42218 | .43343 | 2.30718 | 34 |
| 27 | .37289 | 2.68175 | .39290 | 2.54516 | .41319 | 2.42019 | .43378 | 2.30534 | 33 |
| 28 | .37322 | 2 67937 | .39324 | 2.54299 | .41353 | 2.41819 | .43412 | 2.30351 | 32 |
| 29 | .37355 | 2.67700 | .39357 | 2.54082 | .41387 | 2.41620 | .43447 | 2.30167 | 31 |
| 30 | .37388 | 2.67462 | .39391 | 2.53865 | .41421 | 2.41421 | .43481 | 2.29984 | 30 |
| 31 | .37422 | 2.67225 | .39425 | 2.53648 | .41455 | 2.41223 | .43516 | 2.29801 | 29 |
| 32 | .37455 | 2.66989 | .39458 | 2.53432 | .41490 | 2.41025 | .43550 | 2.29619 | 28 |
| 33 | .37488 | 2.66752 | .39492 | 2.53217 | .41524 | 2.40827 | .43585 | 2.29437 | 27 |
| 34 | .37521 | 2.66516 | .39526 | 2.53001 | .41558 | 2.40629 | .43620 | 2.29254 | 26 |
| 35 | .37554 | 2.66281 | .39559 | 2.52786 | .41592 | 2.40432 | .43654 | 2.29073 | 25 |
| 36 | .37588 | 2.66046 | .39593 | 2.52571 | .41626 | 2.40235 | .43689 | 2.28891 | 24 |
| 37 | .37621 | 2.65811 | .39626 | 2.52357 | .41660 | 2.40038 | .43724 | 2.28710 | 23 |
| 38 | .37654 | 2.65576 | .39660 | 2.52142 | .41694 | 2.39841 | .43758 | 2.28528 | 22 |
| 39 | .37687 | 2.65342 | .39694 | 2.51929 | .41728 | 2.39645 | .43793 | 2.28348 | 21 |
| 40 | .37720 | 2.65109 | .39727 | 2.51715 | .41763 | 2.39449 | .43828 | 2.28167 | 20 |
| 41 | .37754 | 2.64875 | .39761 | 2.51502 | .41797 | 2.39253 | .43862 | 2.27987 | 19 |
| 42 | .37787 | 2.64642 | .39795 | 2.51289 | .41831 | 2.39058 | .43897 | 2.27806 | 18 |
| 43 | .37820 | 2.64410 | .39829 | 2.51076 | .41865 | 2.38863 | .43932 | 2.27626 | 17 |
| 44 | .37853 | 2.64177 | .39862 | 2.50864 | 41899 | 2.38668 | .43966 | 2.27447 | 16 |
| 45 | .37887 | 2.63945 | .39896 | 2.50652 | .41933 | 2.38473 | .44001 | 2.27267 | 15 |
| 46 | .37920 | 2.63714 | .39930 | 2.50440 | .41968 | 2.38279 | .44036 | 2.27088 | 14 |
| 47 | .37953 | 2.63483 | .39963 | 2.50229 | .42002 | 2.38084 | .44071 | 2.26909 | 13 |
| 48 | .37986 | 2.63252 | .39997 | 2.50018 | .42036 | 2.37891 | .44105 | 2.26730 | 12 |
| 49 | .38020 | 2.63021 | .40031 | 2.49807 | .42070 | 2.37697 | .44140 | 2.26552 | 11 |
| 50 | .38053 | 2.62791 | .40065 | 2.49597 | .42105 | 2.37504 | .44175 | 2.26374 | 10 |
| 51 | .38086 | 2.62561 | .40098 | 2.49386 | .42139 | 2.37311 | .44210 | 2.26196 | 9 |
| 52 | .38120 | 2.62332 | .40132 | 2.49177 | .42173 | 2.37118 | .44244 | 2.26018 | 8 |
| 53 | .38153 | 2.62103 | .40166 | 2.48967 | .42207 | 2.36925 | .44279 | 2.25840 | 7 |
| 54 | .38186 | 2.61874 | .40200 | 2.48758 | .42242 | 2.36733 | .44314 | 2.25663 | 6 |
| 55 | .38220 | 2.61646 | .40234 | 2.48549 | .42276 | 2.36541 | .44349 | 2.25486 | 5 |
| 56 | .38253 | 2.61418 | .40267 | 2 48340 | .42310 | 2.36349 | .44384 | 2.25309 | 4 |
| 57 | .38286 | 2.61190 | .40301 | 2.48132 | .42345 | 2.36158 | .44418 | 2.25132 | 3 |
| 58 | .38320 | 2.60963 | .40335 | 2.47924 | .42379 | 2.35967 | .44453 | 2.24956 | 2 |
| 59 | .38353 | 2.60736 | .40369 | 2.47716 | .42413 | 2.35776 | .44488 | 2.24780 | 1 |
| 60 | .38386 | 2.60509 | .40403 | 2.47509 | .42447 | 2.35585 | .44523 | 2.24604 | 0 |
| | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | |
| ′ | 69° | | 68° | | 67° | | 66° | | ′ |

| ′ | 24° | | 25° | | 26° | | 27° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .44523 | 2.24604 | .46631 | 2.14451 | .48773 | 2.05030 | .50953 | 1.96261 | 60 |
| 1 | .44558 | 2.24428 | .46666 | 2.14288 | .48809 | 2.04879 | .50989 | 1.96120 | 59 |
| 2 | .44593 | 2.24252 | .46702 | 2.14125 | .48845 | 2.04728 | .51026 | 1.95979 | 58 |
| 3 | .44627 | 2.24077 | .46737 | 2.13963 | .48881 | 2.04577 | .51063 | 1.95838 | 57 |
| 4 | .44662 | 2.23902 | .46772 | 2.13801 | .48917 | 2.04426 | .51099 | 1.95698 | 56 |
| 5 | .44697 | 2.23727 | .46808 | 2.13639 | .48953 | 2.04276 | .51136 | 1.95557 | 55 |
| 6 | .44732 | 2.23553 | .46843 | 2.13477 | .48989 | 2.04125 | .51173 | 1.95417 | 54 |
| 7 | .44767 | 2.23378 | .46879 | 2.13316 | .49026 | 2.03975 | .51209 | 1.95277 | 53 |
| 8 | .44802 | 2.23204 | .46914 | 2.13154 | .49062 | 2.03825 | .51246 | 1.95137 | 52 |
| 9 | .44837 | 2.23030 | .46950 | 2.12993 | .49098 | 2.03675 | .51283 | 1.94997 | 51 |
| 10 | .44872 | 2.22857 | .46985 | 2.12832 | .49134 | 2.03526 | .51319 | 1.94858 | 50 |
| 11 | .44907 | 2.22683 | .47021 | 2.12671 | .49170 | 2.03376 | .51356 | 1.94718 | 49 |
| 12 | .44942 | 2.22510 | .47056 | 2.12511 | .49206 | 2.03227 | .51393 | 1.94579 | 48 |
| 13 | .44977 | 2.22337 | .47092 | 2.12350 | .49242 | 2.03078 | .51430 | 1.94440 | 47 |
| 14 | .45012 | 2.22164 | .47128 | 2.12190 | .49278 | 2.02929 | .51467 | 1.94301 | 46 |
| 15 | .45047 | 2.21992 | .47163 | 2.12030 | .49315 | 2.02780 | .51503 | 1.94162 | 45 |
| 16 | .45082 | 2.21819 | .47199 | 2.11871 | .49351 | 2.02631 | .51540 | 1.94023 | 44 |
| 17 | .45117 | 2.21647 | .47234 | 2.11711 | .49387 | 2.02483 | .51577 | 1.93885 | 43 |
| 18 | .45152 | 2.21475 | .47270 | 2.11552 | .49423 | 2.02335 | .51614 | 1.93746 | 42 |
| 19 | .45187 | 2.21304 | .47305 | 2.11392 | .49459 | 2.02187 | .51651 | 1.93608 | 41 |
| 20 | .45222 | 2.21132 | .47341 | 2.11233 | .49495 | 2.02039 | .51688 | 1.93470 | 40 |
| 21 | .45257 | 2.20961 | .47377 | 2.11075 | .49532 | 2.01891 | .51724 | 1.93332 | 39 |
| 22 | .45292 | 2.20790 | .47412 | 2.10916 | .49568 | 2.01743 | .51761 | 1.93195 | 38 |
| 23 | .45327 | 2.20619 | .47448 | 2.10758 | .49604 | 2.01596 | .51798 | 1.93057 | 37 |
| 24 | .45362 | 2.20449 | .47483 | 2.10600 | .49640 | 2.01449 | .51835 | 1.92920 | 36 |
| 25 | .45397 | 2.20278 | .47519 | 2.10442 | .49677 | 2.01302 | .51872 | 1.92782 | 35 |
| 26 | .45432 | 2.20108 | .47555 | 2.10284 | .49713 | 2.01155 | .51909 | 1.92645 | 34 |
| 27 | .45467 | 2.19938 | .47590 | 2.10126 | .49749 | 2.01008 | .51946 | 1.92508 | 33 |
| 28 | .45502 | 2.19769 | .47626 | 2.09969 | .49786 | 2.00862 | .51983 | 1.92371 | 32 |
| 29 | .45538 | 2.19599 | .47662 | 2.09811 | .49822 | 2.00715 | .52020 | 1.92235 | 31 |
| 30 | .45573 | 2.19430 | .47698 | 2.09654 | .49858 | 2.00569 | .52057 | 1.92098 | 30 |
| 31 | .45608 | 2.19261 | .47733 | 2.09498 | .49894 | 2.00423 | .52094 | 1.91962 | 29 |
| 32 | .45643 | 2.19092 | .47769 | 2.09341 | .49931 | 2.00277 | .52131 | 1.91826 | 28 |
| 33 | .45678 | 2.18923 | .47805 | 2.09184 | .49967 | 2.00131 | .52168 | 1.91690 | 27 |
| 34 | .45713 | 2.18755 | .47840 | 2.09028 | .50004 | 1.99986 | .52205 | 1.91554 | 26 |
| 35 | .45748 | 2.18587 | .47876 | 2.08872 | .50040 | 1.99841 | .52242 | 1.91418 | 25 |
| 36 | .45784 | 2.18419 | .47912 | 2.08716 | .50076 | 1.99695 | .52279 | 1.91282 | 24 |
| 37 | .45819 | 2.18251 | .47948 | 2.08560 | .50113 | 1.99550 | .52316 | 1.91147 | 23 |
| 38 | .45854 | 2.18084 | .47984 | 2.08405 | .50149 | 1.99406 | .52353 | 1.91012 | 22 |
| 39 | .45889 | 2.17916 | .48019 | 2.08250 | .50185 | 1.99261 | .52390 | 1.90876 | 21 |
| 40 | .45924 | 2.17749 | .48055 | 2.08094 | .50222 | 1.99116 | .52427 | 1.90741 | 20 |
| 41 | .45960 | 2.17582 | .48091 | 2.07939 | .50258 | 1.98972 | .52464 | 1.90607 | 19 |
| 42 | .45995 | 2.17416 | .48127 | 2.07785 | .50295 | 1.98828 | .52501 | 1.90472 | 18 |
| 43 | .46030 | 2.17249 | .48163 | 2.07630 | .50331 | 1.98684 | .52538 | 1.90337 | 17 |
| 44 | .46065 | 2.17083 | .48198 | 2.07476 | .50368 | 1.98540 | .52575 | 1.90203 | 16 |
| 45 | .46101 | 2.16917 | .48234 | 2.07321 | .50404 | 1.98396 | .52613 | 1.90069 | 15 |
| 46 | .46136 | 2.16751 | .48270 | 2.07167 | .50441 | 1.98253 | .52650 | 1.89935 | 14 |
| 47 | .46171 | 2.16585 | .48306 | 2.07014 | .50477 | 1.98110 | .52687 | 1.89801 | 13 |
| 48 | .46206 | 2.16420 | .48342 | 2.06860 | .50514 | 1.97966 | .52724 | 1.89667 | 12 |
| 49 | .46242 | 2.16255 | .48378 | 2.06706 | .50550 | 1.97823 | .52761 | 1.89533 | 11 |
| 50 | .46277 | 2.16090 | .48414 | 2.06553 | .50587 | 1.97681 | .52798 | 1.89400 | 10 |
| 51 | .46312 | 2.15925 | .48450 | 2.06400 | .50623 | 1.97538 | .52836 | 1.89266 | 9 |
| 52 | .46348 | 2.15760 | .48486 | 2.06247 | .50660 | 1.97395 | .52873 | 1.89133 | 8 |
| 53 | .46383 | 2.15596 | .48521 | 2.06094 | .50696 | 1.97253 | .52910 | 1.89000 | 7 |
| 54 | .46418 | 2.15432 | .48557 | 2.05942 | .50733 | 1.97111 | .52947 | 1.88867 | 6 |
| 55 | .46454 | 2.15268 | .48593 | 2.05790 | .50769 | 1.96969 | .52985 | 1.88734 | 5 |
| 56 | .46489 | 2.15104 | .48629 | 2.05637 | .50806 | 1.96827 | .53022 | 1.88602 | 4 |
| 57 | .46525 | 2.14940 | .48665 | 2.05485 | .50843 | 1.96685 | .53059 | 1.88469 | 3 |
| 58 | .46560 | 2.14777 | .48701 | 2.05333 | .50879 | 1.96544 | .53096 | 1.88337 | 2 |
| 59 | .46595 | 2.14614 | .48737 | 2.05182 | .50916 | 1.96402 | .53134 | 1.88205 | 1 |
| 60 | .46631 | 2.14451 | .48773 | 2.05030 | .50953 | 1.96261 | .53171 | 1.88073 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 65° | | 64° | | 63° | | 62° | | |

| ′ | 28° Tang | 28° Cotang | 29° Tang | 29° Cotang | 30° Tang | 30° Cotang | 31° Tang | 31° Cotang | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .53171 | 1.88073 | .55431 | 1.80405 | .57735 | 1.73205 | .60086 | 1.66428 | 60 |
| 1 | .53208 | 1.87941 | .55469 | 1.80281 | .57774 | 1.73089 | .60126 | 1.66318 | 59 |
| 2 | .53246 | 1.87809 | .55507 | 1.80158 | .57813 | 1.72973 | .60165 | 1.66209 | 58 |
| 3 | .53283 | 1.87677 | .55545 | 1.80034 | .57851 | 1.72857 | .60205 | 1.66099 | 57 |
| 4 | .53320 | 1.87546 | .55583 | 1.79911 | .57890 | 1.72741 | .60245 | 1.65990 | 56 |
| 5 | .53358 | 1.87415 | .55621 | 1.79788 | .57929 | 1.72625 | .60284 | 1.65881 | 55 |
| 6 | .53395 | 1.87283 | .55659 | 1.79665 | .57968 | 1.72509 | .60324 | 1.65772 | 54 |
| 7 | .53432 | 1.87152 | .55697 | 1.79542 | .58007 | 1.72393 | .60364 | 1.65663 | 53 |
| 8 | .53470 | 1.87021 | .55736 | 1.79419 | .58046 | 1.72278 | .60403 | 1.65554 | 52 |
| 9 | .53507 | 1.86891 | .55774 | 1.79296 | .58085 | 1.72163 | .60443 | 1.65445 | 51 |
| 10 | .53545 | 1.86760 | .55812 | 1.79174 | .58124 | 1.72047 | .60483 | 1.65337 | 50 |
| 11 | .53582 | 1.86630 | .55850 | 1.79051 | .58162 | 1.71932 | .60522 | 1.65228 | 49 |
| 12 | .53620 | 1.86499 | .55888 | 1.78929 | .58201 | 1.71817 | .60562 | 1.65120 | 48 |
| 13 | .53657 | 1.86369 | .55926 | 1.78807 | .58240 | 1.71702 | .60602 | 1.65011 | 47 |
| 14 | .53694 | 1.86239 | .55964 | 1.78685 | .58279 | 1.71588 | .60642 | 1.64903 | 46 |
| 15 | .53732 | 1.86109 | .56003 | 1.78563 | .58318 | 1.71473 | .60681 | 1.64795 | 45 |
| 16 | .53769 | 1.85979 | .56041 | 1.78441 | .58357 | 1.71358 | .60721 | 1.64687 | 44 |
| 17 | .53807 | 1.85850 | .56079 | 1.78319 | .58396 | 1.71244 | .60761 | 1.64579 | 43 |
| 18 | .53844 | 1.85720 | .56117 | 1.78198 | .58435 | 1.71129 | .60801 | 1.64471 | 42 |
| 19 | .53882 | 1.85591 | .56156 | 1.78077 | .58474 | 1.71015 | .60841 | 1.64363 | 41 |
| 20 | .53920 | 1.85462 | .56194 | 1.77955 | .58513 | 1.70901 | .60881 | 1.64256 | 40 |
| 21 | .53957 | 1.85333 | .56232 | 1.77834 | .58552 | 1.70787 | .60921 | 1.64148 | 39 |
| 22 | .53995 | 1.85204 | .56270 | 1.77713 | .58591 | 1.70673 | .60960 | 1.64041 | 38 |
| 23 | .54032 | 1.85075 | .56309 | 1.77592 | .58631 | 1.70560 | .61000 | 1.63934 | 37 |
| 24 | .54070 | 1.84946 | .56347 | 1.77471 | .58670 | 1.70446 | .61040 | 1.63826 | 36 |
| 25 | .54107 | 1.84818 | .56385 | 1.77351 | .58709 | 1.70332 | .61080 | 1.63719 | 35 |
| 26 | .54145 | 1.84689 | .56424 | 1.77230 | .58748 | 1.70219 | .61120 | 1.63612 | 34 |
| 27 | .54183 | 1.84561 | .56462 | 1.77110 | .58787 | 1.70106 | .61160 | 1.63505 | 33 |
| 28 | .54220 | 1.84433 | .56501 | 1.76990 | .58826 | 1.69992 | .61200 | 1.63398 | 32 |
| 29 | .54258 | 1.84305 | .56539 | 1.76869 | .58865 | 1.69879 | .61240 | 1.63292 | 31 |
| 30 | .54296 | 1.84177 | .56577 | 1.76749 | .58905 | 1.69766 | .61280 | 1.63185 | 30 |
| 31 | .54333 | 1.84049 | .56616 | 1.76629 | .58944 | 1.69653 | .61320 | 1.63079 | 29 |
| 32 | .54371 | 1.83922 | .56654 | 1.76510 | .58983 | 1.69541 | .61360 | 1.62972 | 28 |
| 33 | .54409 | 1.83794 | .56693 | 1.76390 | .59022 | 1.69428 | .61400 | 1.62866 | 27 |
| 34 | .54446 | 1.83667 | .56731 | 1.76271 | .59061 | 1.69316 | .61440 | 1.62760 | 26 |
| 35 | .54484 | 1.83540 | .56769 | 1.76151 | .59101 | 1.69203 | .61480 | 1.62654 | 25 |
| 36 | .54522 | 1.83413 | .56808 | 1.76032 | .59140 | 1.69091 | .61520 | 1.62548 | 24 |
| 37 | .54560 | 1.83286 | .56846 | 1.75913 | .59179 | 1.68979 | .61561 | 1.62442 | 23 |
| 38 | .54597 | 1.83159 | .56885 | 1.75794 | .59218 | 1.68866 | .61601 | 1.62336 | 22 |
| 39 | .54635 | 1.83033 | .56923 | 1.75675 | .59258 | 1.68754 | .61641 | 1.62230 | 21 |
| 40 | .54673 | 1.82906 | .56962 | 1.75556 | .59297 | 1.68643 | .61681 | 1.62125 | 20 |
| 41 | .54711 | 1.82780 | .57000 | 1.75437 | .59336 | 1.68531 | .61721 | 1.62019 | 19 |
| 42 | .54748 | 1.82654 | .57039 | 1.75319 | .59376 | 1.68419 | .61761 | 1.61914 | 18 |
| 43 | .54786 | 1.82528 | .57078 | 1.75200 | .59415 | 1.68308 | .61801 | 1.61808 | 17 |
| 44 | .54824 | 1.82402 | .57116 | 1.75082 | .59454 | 1.68196 | .61842 | 1.61703 | 16 |
| 45 | .54862 | 1.82276 | .57155 | 1.74964 | .59494 | 1.68085 | .61882 | 1.61598 | 15 |
| 46 | .54900 | 1.82150 | .57193 | 1.74846 | .59533 | 1.67974 | .61922 | 1.61493 | 14 |
| 47 | .54938 | 1.82025 | .57232 | 1.74728 | .59573 | 1.67863 | .61962 | 1.61388 | 13 |
| 48 | .54975 | 1.81899 | .57271 | 1.74610 | .59612 | 1.67752 | .62003 | 1.61283 | 12 |
| 49 | .55013 | 1.81774 | .57309 | 1.74492 | .59651 | 1.67641 | .62043 | 1.61179 | 11 |
| 50 | .55051 | 1.81649 | .57348 | 1.74375 | .59691 | 1.67530 | .62083 | 1.61074 | 10 |
| 51 | .55089 | 1.81524 | .57386 | 1.74257 | .59730 | 1.67419 | .62124 | 1.60970 | 9 |
| 52 | .55127 | 1.81399 | .57425 | 1.74140 | .59770 | 1.67309 | .62164 | 1.60865 | 8 |
| 53 | .55165 | 1.81274 | .57464 | 1.74022 | .59809 | 1.67198 | .62204 | 1.60761 | 7 |
| 54 | .55203 | 1.81150 | .57503 | 1.73905 | .59849 | 1.67088 | .62245 | 1.60657 | 6 |
| 55 | .55241 | 1.81025 | .57541 | 1.73788 | .59888 | 1.66978 | .62285 | 1.60553 | 5 |
| 56 | .55279 | 1.80901 | .57580 | 1.73671 | .59928 | 1.66867 | .62325 | 1.60449 | 4 |
| 57 | .55317 | 1.80777 | .57619 | 1.73555 | .59967 | 1.66757 | .62366 | 1.60345 | 3 |
| 58 | .55355 | 1.80653 | .57657 | 1.73438 | .60007 | 1.66647 | .62406 | 1.60241 | 2 |
| 59 | .55393 | 1.80529 | .57696 | 1.73321 | .60046 | 1.66538 | .62446 | 1.60137 | 1 |
| 60 | .55431 | 1.80405 | .57735 | 1.73205 | .60086 | 1.66428 | .62487 | 1.60033 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 61° | | 60° | | 59° | | 58° | | |

| ′ | 32° Tang | 32° Cotang | 33° Tang | 33° Cotang | 34° Tang | 34° Cotang | 35° Tang | 35° Cotang | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .62487 | 1.60033 | .64941 | 1.53986 | .67451 | 1.48256 | .70021 | 1.42815 | 60 |
| 1 | .62527 | 1.59930 | .64982 | 1.53888 | .67493 | 1.48163 | .70064 | 1.42726 | 59 |
| 2 | .62568 | 1.59826 | .65024 | 1.53791 | .67536 | 1.48070 | .70107 | 1.42638 | 58 |
| 3 | .62608 | 1.59723 | .65065 | 1.53693 | .67578 | 1.47977 | .70151 | 1.42550 | 57 |
| 4 | .62649 | 1.59620 | .65106 | 1.53595 | .67620 | 1.47885 | .70194 | 1.42462 | 56 |
| 5 | .62689 | 1.59517 | .65148 | 1.53497 | .67663 | 1.47792 | .70238 | 1.42374 | 55 |
| 6 | .62730 | 1.59414 | .65189 | 1.53400 | .67705 | 1.47699 | .70281 | 1.42286 | 54 |
| 7 | .62770 | 1.59311 | .65231 | 1.53302 | .67748 | 1.47607 | .70325 | 1.42198 | 53 |
| 8 | .62811 | 1.59208 | .65272 | 1.53205 | .67790 | 1.47514 | .70368 | 1.42110 | 52 |
| 9 | .62852 | 1.59105 | .65314 | 1.53107 | .67832 | 1.47422 | .70412 | 1.42022 | 51 |
| 10 | .62892 | 1.59002 | .65355 | 1.53010 | .67875 | 1.47330 | .70455 | 1.41934 | 50 |
| 11 | .62933 | 1.58900 | .65397 | 1.52913 | .67917 | 1.47238 | .70499 | 1.41847 | 49 |
| 12 | .62973 | 1.58797 | .65438 | 1.52816 | .67960 | 1.47146 | .70542 | 1.41759 | 48 |
| 13 | .63014 | 1.58695 | .65480 | 1.52719 | .68002 | 1.47053 | .70586 | 1.41672 | 47 |
| 14 | .63055 | 1.58593 | .65521 | 1.52622 | .68045 | 1.46962 | .70629 | 1.41584 | 46 |
| 15 | .63095 | 1.58490 | .65563 | 1.52525 | .68088 | 1.46870 | .70673 | 1.41497 | 45 |
| 16 | .63136 | 1.58388 | .65604 | 1.52429 | .68130 | 1.46778 | .70717 | 1.41409 | 44 |
| 17 | .63177 | 1.58286 | .65646 | 1.52332 | .68173 | 1.46686 | .70760 | 1.41322 | 43 |
| 18 | .63217 | 1.58184 | .65688 | 1.52235 | .68215 | 1.46595 | .70804 | 1.41235 | 42 |
| 19 | .63258 | 1.58083 | .65729 | 1.52139 | .68258 | 1.46503 | .70848 | 1.41148 | 41 |
| 20 | .63299 | 1.57981 | .65771 | 1.52043 | .68301 | 1.46411 | .70891 | 1.41061 | 40 |
| 21 | .63340 | 1.57879 | .65813 | 1.51946 | .68343 | 1.46320 | .70935 | 1.40974 | 39 |
| 22 | .63380 | 1.57778 | .65854 | 1.51850 | .68386 | 1.46229 | .70979 | 1.40887 | 38 |
| 23 | .63421 | 1.57676 | .65896 | 1.51754 | .68429 | 1.46137 | .71023 | 1.40800 | 37 |
| 24 | .63462 | 1.57575 | .65938 | 1.51658 | .68471 | 1.46046 | .71066 | 1.40714 | 36 |
| 25 | .63503 | 1.57474 | .65980 | 1.51562 | .68514 | 1.45955 | .71110 | 1.40627 | 35 |
| 26 | .63544 | 1.57372 | .66021 | 1.51466 | .68557 | 1.45864 | .71154 | 1.40540 | 34 |
| 27 | .63584 | 1.57271 | .66063 | 1.51370 | .68600 | 1.45773 | .71198 | 1.40454 | 33 |
| 28 | .63625 | 1.57170 | .66105 | 1.51275 | .68642 | 1.45682 | .71242 | 1.40367 | 32 |
| 29 | .63666 | 1.57069 | .66147 | 1.51179 | .68685 | 1.45592 | .71285 | 1.40281 | 31 |
| 30 | .63707 | 1.56969 | .66189 | 1.51084 | .68728 | 1.45501 | .71329 | 1.40195 | 30 |
| 31 | .63748 | 1.56868 | .66230 | 1.50988 | .68771 | 1.45410 | .71373 | 1.40109 | 29 |
| 32 | .63789 | 1.56767 | .66272 | 1.50893 | .68814 | 1.45320 | .71417 | 1.40022 | 28 |
| 33 | .63830 | 1.56667 | .66314 | 1.50797 | .68857 | 1.45229 | .71461 | 1.39936 | 27 |
| 34 | .63871 | 1.56566 | .66356 | 1.50702 | .68900 | 1.45139 | .71505 | 1.39850 | 26 |
| 35 | .63912 | 1.56466 | .66398 | 1.50607 | .68942 | 1.45049 | .71549 | 1.39764 | 25 |
| 36 | .63953 | 1.56366 | .66440 | 1.50512 | .68985 | 1.44958 | .71593 | 1.39679 | 24 |
| 37 | .63994 | 1.56265 | .66482 | 1.50417 | .69028 | 1.44868 | .71637 | 1.39593 | 23 |
| 38 | .64035 | 1.56165 | .66524 | 1.50322 | .69071 | 1.44778 | .71681 | 1.39507 | 22 |
| 39 | .64076 | 1.56065 | .66566 | 1.50228 | .69114 | 1.44688 | .71725 | 1.39421 | 21 |
| 40 | .64117 | 1.55966 | .66608 | 1.50133 | .69157 | 1.44598 | .71769 | 1.39336 | 20 |
| 41 | .64158 | 1.55866 | .66650 | 1.50038 | .69200 | 1.44508 | .71813 | 1.39250 | 19 |
| 42 | .64199 | 1.55766 | .66692 | 1.49944 | .69243 | 1.44418 | .71857 | 1.39165 | 18 |
| 43 | .64240 | 1.55666 | .66734 | 1.49849 | .69286 | 1.44329 | .71901 | 1.39079 | 17 |
| 44 | .64281 | 1.55567 | .66776 | 1.49755 | .69329 | 1.44239 | .71946 | 1.38994 | 16 |
| 45 | .64322 | 1.55467 | .66818 | 1.49661 | .69372 | 1.44149 | .71990 | 1.38909 | 15 |
| 46 | .64363 | 1.55368 | .66860 | 1.49566 | .69416 | 1.44060 | .72034 | 1.38824 | 14 |
| 47 | .64404 | 1.55269 | .66902 | 1.49472 | .69459 | 1.43970 | .72078 | 1.38738 | 13 |
| 48 | .64446 | 1.55170 | .66944 | 1.49378 | .69502 | 1.43881 | .72122 | 1.38653 | 12 |
| 49 | .64487 | 1.55071 | .66986 | 1.49284 | .69545 | 1.43792 | .72167 | 1.38568 | 11 |
| 50 | .64528 | 1.54972 | .67028 | 1.49190 | .69588 | 1.43703 | .72211 | 1.38484 | 10 |
| 51 | .64569 | 1.54873 | .67071 | 1.49097 | .69631 | 1.43614 | .72255 | 1.38399 | 9 |
| 52 | .64610 | 1.54774 | .67113 | 1.49003 | .69675 | 1.43525 | .72299 | 1.38314 | 8 |
| 53 | .64652 | 1.54675 | .67155 | 1.48909 | .69718 | 1.43436 | .72344 | 1.38229 | 7 |
| 54 | .64693 | 1.54576 | .67197 | 1.48816 | .69761 | 1.43347 | .72388 | 1.38145 | 6 |
| 55 | .64734 | 1.54478 | .67239 | 1.48722 | .69804 | 1.43258 | .72432 | 1.38060 | 5 |
| 56 | .64775 | 1.54379 | .67282 | 1.48629 | .69847 | 1.43169 | .72477 | 1.37976 | 4 |
| 57 | .64817 | 1.54281 | .67324 | 1.48536 | .69891 | 1.43080 | .72521 | 1.37891 | 3 |
| 58 | .64858 | 1.54183 | .67366 | 1.48442 | .69934 | 1.42992 | .72565 | 1.37807 | 2 |
| 59 | .64899 | 1.54085 | .67409 | 1.48349 | .69977 | 1.42903 | .72610 | 1.37722 | 1 |
| 60 | .64941 | 1.53986 | .67451 | 1.48256 | .70021 | 1.42815 | .72654 | 1.37638 | 0 |
| ′ | 57° Cotang | 57° Tang | 56° Cotang | 56° Tang | 55° Cotang | 55° Tang | 54° Cotang | 54° Tang | ′ |

| ′ | 36° | | 37° | | 38° | | 39° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .72654 | 1.37638 | .75355 | 1.32704 | .78129 | 1.27994 | .80978 | 1.23490 | 60 |
| 1 | .72699 | 1.37554 | .75401 | 1.32624 | .78175 | 1.27917 | .81027 | 1.23416 | 59 |
| 2 | .72743 | 1.37470 | .75447 | 1.32544 | .78222 | 1.27841 | .81075 | 1.23343 | 58 |
| 3 | .72788 | 1.37386 | .75492 | 1.32464 | .78269 | 1.27764 | .81123 | 1.23270 | 57 |
| 4 | .72832 | 1.37302 | .75538 | 1.32384 | .78316 | 1.27688 | .81171 | 1.23196 | 56 |
| 5 | .72877 | 1.37218 | .75584 | 1.32304 | .78363 | 1.27611 | .81220 | 1.23123 | 55 |
| 6 | .72921 | 1.37134 | .75629 | 1.32224 | .78410 | 1.27535 | .81268 | 1.23050 | 54 |
| 7 | .72966 | 1.37050 | .75675 | 1.32144 | .78457 | 1.27458 | .81316 | 1.22977 | 53 |
| 8 | .73010 | 1.36967 | .75721 | 1.32064 | .78504 | 1.27382 | .81364 | 1.22904 | 52 |
| 9 | .73055 | 1.36883 | .75767 | 1.31984 | .78551 | 1.27306 | .81413 | 1.22831 | 51 |
| 10 | .73100 | 1.36800 | .75812 | 1.31904 | .78598 | 1.27230 | .81461 | 1.22758 | 50 |
| 11 | .73144 | 1.36716 | .75858 | 1.31825 | .78645 | 1.27153 | .81510 | 1.22685 | 49 |
| 12 | .73189 | 1.36633 | .75904 | 1.31745 | .78692 | 1.27077 | .81558 | 1.22612 | 48 |
| 13 | .73234 | 1.36549 | .75950 | 1.31666 | .78739 | 1.27001 | .81606 | 1.22539 | 47 |
| 14 | .73278 | 1.36466 | .75996 | 1.31586 | .78786 | 1.26925 | .81655 | 1.22467 | 46 |
| 15 | .73323 | 1.36383 | .76042 | 1.31507 | .78834 | 1.26849 | .81703 | 1.22394 | 45 |
| 16 | .73368 | 1.36300 | .76088 | 1.31427 | .78881 | 1.26774 | .81752 | 1.22321 | 44 |
| 17 | .73413 | 1.36217 | .76134 | 1.31348 | .78928 | 1.26698 | .81800 | 1.22249 | 43 |
| 18 | .73457 | 1.36134 | .76180 | 1.31269 | .78975 | 1.26622 | .81849 | 1.22176 | 42 |
| 19 | .73502 | 1.36051 | .76226 | 1.31190 | .79022 | 1.26546 | .81898 | 1.22104 | 41 |
| 20 | .73547 | 1.35968 | .76272 | 1.31110 | .79070 | 1.26471 | .81946 | 1.22031 | 40 |
| 21 | .73592 | 1.35885 | .76318 | 1.31031 | .79117 | 1.26395 | .81995 | 1.21959 | 39 |
| 22 | .73637 | 1.35802 | .76364 | 1.30952 | .79164 | 1.26319 | .82044 | 1.21886 | 38 |
| 23 | .73681 | 1.35719 | .76410 | 1.30873 | .79212 | 1.26244 | .82092 | 1.21814 | 37 |
| 24 | .73726 | 1.35637 | .76456 | 1.30795 | .79259 | 1.26169 | .82141 | 1.21742 | 36 |
| 25 | .73771 | 1.35554 | .76502 | 1.30716 | .79306 | 1.26093 | .82190 | 1.21670 | 35 |
| 26 | .73816 | 1.35472 | .76548 | 1.30637 | .79354 | 1.26018 | .82238 | 1.21598 | 34 |
| 27 | .73861 | 1.35389 | .76594 | 1.30558 | .79401 | 1.25943 | .82287 | 1.21526 | 33 |
| 28 | .73906 | 1.35307 | .76640 | 1.30480 | .79449 | 1.25867 | .82336 | 1.21454 | 32 |
| 29 | .73951 | 1.35224 | .76686 | 1.30401 | .79496 | 1.25792 | .82385 | 1.21382 | 31 |
| 30 | .73996 | 1.35142 | .76733 | 1.30323 | .79544 | 1.25717 | .82434 | 1.21310 | 30 |
| 31 | .74041 | 1.35060 | .76779 | 1.30244 | .79591 | 1.25642 | .82483 | 1.21238 | 29 |
| 32 | .74086 | 1.34978 | .76825 | 1.30166 | .79639 | 1.25567 | .82531 | 1.21166 | 28 |
| 33 | .74131 | 1.34896 | .76871 | 1.30087 | .79686 | 1.25492 | .82580 | 1.21094 | 27 |
| 34 | .74176 | 1.34814 | .76918 | 1.30009 | .79734 | 1.25417 | .82629 | 1.21023 | 26 |
| 35 | .74221 | 1.34732 | .76964 | 1.29931 | .79781 | 1.25343 | .82678 | 1.20951 | 25 |
| 36 | .74267 | 1.34650 | .77010 | 1.29853 | .79829 | 1.25268 | .82727 | 1.20879 | 24 |
| 37 | .74312 | 1.34568 | .77057 | 1.29775 | .79877 | 1.25193 | .82776 | 1.20808 | 23 |
| 38 | .74357 | 1.34487 | .77103 | 1.29696 | .79924 | 1.25118 | .82825 | 1.20736 | 22 |
| 39 | .74402 | 1.34405 | .77149 | 1.29618 | .79972 | 1.25044 | .82874 | 1.20665 | 21 |
| 40 | .74447 | 1.34323 | .77196 | 1.29541 | .80020 | 1.24969 | .82923 | 1.20593 | 20 |
| 41 | .74492 | 1.34242 | .77242 | 1.29463 | .80067 | 1.24895 | .82972 | 1.20522 | 19 |
| 42 | .74538 | 1.34160 | .77289 | 1.29385 | .80115 | 1.24820 | .83022 | 1.20451 | 18 |
| 43 | .74583 | 1.34079 | .77335 | 1.29307 | .80163 | 1.24746 | .83071 | 1.20379 | 17 |
| 44 | .74628 | 1.33998 | .77382 | 1.29229 | .80211 | 1.24672 | .83120 | 1.20308 | 16 |
| 45 | .74674 | 1.33916 | .77428 | 1.29152 | .80258 | 1.24597 | .83169 | 1.20237 | 15 |
| 46 | .74719 | 1.33835 | .77475 | 1.29074 | .80306 | 1.24523 | .83218 | 1.20166 | 14 |
| 47 | .74764 | 1.33754 | .77521 | 1.28997 | .80354 | 1.24449 | .83268 | 1.20095 | 13 |
| 48 | .74810 | 1.33673 | .77568 | 1.28919 | .80402 | 1.24375 | .83317 | 1.20024 | 12 |
| 49 | .74855 | 1.33592 | .77615 | 1.28842 | .80450 | 1.24301 | .83366 | 1.19953 | 11 |
| 50 | .74900 | 1.33511 | .77661 | 1.28764 | .80498 | 1.24227 | .83415 | 1.19882 | 10 |
| 51 | .74946 | 1.33430 | .77708 | 1.28687 | .80546 | 1.24153 | .83465 | 1.19811 | 9 |
| 52 | .74991 | 1.33349 | .77754 | 1.28610 | .80594 | 1.24079 | .83514 | 1.19740 | 8 |
| 53 | .75037 | 1.33268 | .77801 | 1.28533 | .80642 | 1.24005 | .83564 | 1.19669 | 7 |
| 54 | .75082 | 1.33187 | .77848 | 1.28456 | .80690 | 1.23931 | .83613 | 1.19599 | 6 |
| 55 | .75128 | 1.33107 | .77895 | 1.28379 | .80738 | 1.23858 | .83662 | 1.19528 | 5 |
| 56 | .75173 | 1.33026 | .77941 | 1.28302 | .80786 | 1.23784 | .83712 | 1.19457 | 4 |
| 57 | .75219 | 1.32946 | .77988 | 1.28225 | .80834 | 1.23710 | .83761 | 1.19387 | 3 |
| 58 | .75264 | 1.32865 | .78035 | 1.28148 | .80882 | 1.23637 | .83811 | 1.19316 | 2 |
| 59 | .75310 | 1.32785 | .78082 | 1.28071 | .80930 | 1.23563 | .83860 | 1.19246 | 1 |
| 60 | .75355 | 1.32704 | .78129 | 1.27994 | .80978 | 1.23490 | .83910 | 1.19175 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 53° | | 52° | | 51° | | 50° | | |

| ′ | 40° | | 41° | | 42° | | 43° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .83910 | 1.19175 | .86929 | 1.15037 | .90040 | 1.11061 | .93252 | 1.07237 | 60 |
| 1 | .83960 | 1.19105 | .86980 | 1.14969 | .90093 | 1.10996 | .93306 | 1.07174 | 59 |
| 2 | .84009 | 1.19035 | .87031 | 1.14902 | .90146 | 1.10931 | .93360 | 1.07112 | 58 |
| 3 | .84059 | 1.18964 | .87082 | 1.14834 | .90199 | 1.10867 | .93415 | 1.07049 | 57 |
| 4 | .84108 | 1.18894 | .87133 | 1.14767 | .90251 | 1.10802 | .93469 | 1.06987 | 56 |
| 5 | .84158 | 1.18824 | .87184 | 1.14699 | .90304 | 1.10737 | .93524 | 1.06925 | 55 |
| 6 | .84208 | 1.18754 | .87236 | 1.14632 | .90357 | 1.10672 | .93578 | 1.06862 | 54 |
| 7 | .84258 | 1.18684 | .87287 | 1.14565 | .90410 | 1.10607 | .93633 | 1.06800 | 53 |
| 8 | .84307 | 1.18614 | .87338 | 1.14498 | .90463 | 1.10543 | .93688 | 1.06738 | 52 |
| 9 | .84357 | 1.18544 | .87389 | 1.14430 | .90516 | 1.10478 | .93742 | 1.06676 | 51 |
| 10 | .84407 | 1.18474 | .87441 | 1.14363 | .90569 | 1.10414 | .93797 | 1.06613 | 50 |
| 11 | .84457 | 1.18404 | .87492 | 1.14296 | .90621 | 1.10349 | .93852 | 1.06551 | 49 |
| 12 | .84507 | 1.18334 | .87543 | 1.14229 | .90674 | 1.10285 | .93906 | 1.06489 | 48 |
| 13 | .84556 | 1.18264 | .87595 | 1.14162 | .90727 | 1.10220 | .93961 | 1.06427 | 47 |
| 14 | .84606 | 1.18194 | .87646 | 1.14095 | .90781 | 1.10156 | .94016 | 1.06365 | 46 |
| 15 | .84656 | 1.18125 | .87698 | 1.14028 | .90834 | 1.10091 | .94071 | 1.06303 | 45 |
| 16 | .84706 | 1.18055 | .87749 | 1.13961 | .90887 | 1.10027 | .94125 | 1.06241 | 44 |
| 17 | .84756 | 1.17986 | .87801 | 1.13894 | .90940 | 1.09963 | .94180 | 1.06179 | 43 |
| 18 | .84806 | 1.17916 | .87852 | 1.13828 | .90993 | 1.09899 | .94235 | 1.06117 | 42 |
| 19 | .84856 | 1.17846 | .87904 | 1.13761 | .91046 | 1.09834 | .94290 | 1.06056 | 41 |
| 20 | .84906 | 1.17777 | .87955 | 1.13694 | .91099 | 1.09770 | .94345 | 1.05994 | 40 |
| 21 | .84956 | 1.17708 | .88007 | 1.13627 | .91153 | 1.09706 | .94400 | 1.05932 | 39 |
| 22 | .85006 | 1.17638 | .88059 | 1.13561 | .91206 | 1.09642 | .94455 | 1.05870 | 38 |
| 23 | .85057 | 1.17569 | .88110 | 1.13494 | .91259 | 1.09578 | .94510 | 1.05809 | 37 |
| 24 | .85107 | 1.17500 | .88162 | 1.13428 | .91313 | 1.09514 | .94565 | 1.05747 | 36 |
| 25 | .85157 | 1.17430 | .88214 | 1.13361 | .91366 | 1.09450 | .94620 | 1.05685 | 35 |
| 26 | .85207 | 1.17361 | .88265 | 1.13295 | .91419 | 1.09386 | .94676 | 1.05624 | 34 |
| 27 | .85257 | 1.17292 | .88317 | 1.13228 | .91473 | 1.09322 | .94731 | 1.05562 | 33 |
| 28 | .85308 | 1.17223 | .88369 | 1.13162 | .91526 | 1.09258 | .94786 | 1.05501 | 32 |
| 29 | .85358 | 1.17154 | .88421 | 1.13096 | .91580 | 1.09195 | .94841 | 1.05439 | 31 |
| 30 | .85408 | 1.17085 | .88473 | 1.13029 | .91633 | 1.09131 | .94896 | 1.05378 | 30 |
| 31 | .85458 | 1.17016 | .88524 | 1.12963 | .91687 | 1.09067 | .94952 | 1.05317 | 29 |
| 32 | .85509 | 1.16947 | .88576 | 1.12897 | .91740 | 1.09003 | .95007 | 1.05255 | 28 |
| 33 | .85559 | 1.16878 | .88628 | 1.12831 | .91794 | 1.08940 | .95062 | 1.05194 | 27 |
| 34 | .85609 | 1.16809 | .88680 | 1.12765 | .91847 | 1.08876 | .95118 | 1.05133 | 26 |
| 35 | .85660 | 1.16741 | .88732 | 1.12699 | .91901 | 1.08813 | .95173 | 1.05072 | 25 |
| 36 | .85710 | 1.16672 | .88784 | 1.12633 | .91955 | 1.08749 | .95229 | 1.05010 | 24 |
| 37 | .85761 | 1.16603 | .88836 | 1.12567 | .92008 | 1.08686 | .95284 | 1.04949 | 23 |
| 38 | .85811 | 1.16535 | .88888 | 1.12501 | .92062 | 1.08622 | .95340 | 1.04888 | 22 |
| 39 | .85862 | 1.16466 | .88940 | 1.12435 | .92116 | 1.08559 | .95395 | 1.04827 | 21 |
| 40 | .85912 | 1.16398 | .88992 | 1.12369 | .92170 | 1.08496 | .95451 | 1.04766 | 20 |
| 41 | .85963 | 1.16329 | .89045 | 1.12303 | .92224 | 1.08432 | .95506 | 1.04705 | 19 |
| 42 | .86014 | 1.16261 | .89097 | 1.12238 | .92277 | 1.08369 | .95562 | 1.04644 | 18 |
| 43 | .86064 | 1.16192 | .89149 | 1.12172 | .92331 | 1.08306 | .95618 | 1.04583 | 17 |
| 44 | .86115 | 1.16124 | .89201 | 1.12106 | .92385 | 1.08243 | .95673 | 1.04522 | 16 |
| 45 | .86166 | 1.16056 | .89253 | 1.12041 | .92439 | 1.08179 | .95729 | 1.04461 | 15 |
| 46 | .86216 | 1.15987 | .89306 | 1.11975 | .92493 | 1.08116 | .95785 | 1.04401 | 14 |
| 47 | .86267 | 1.15919 | .89358 | 1.11909 | .92547 | 1.08053 | .95841 | 1.04340 | 13 |
| 48 | .86318 | 1.15851 | .89410 | 1.11844 | .92601 | 1.07990 | .95897 | 1.04279 | 12 |
| 49 | .86368 | 1.15783 | .89463 | 1 11778 | .92655 | 1.07927 | .95952 | 1.04218 | 11 |
| 50 | .86419 | 1.15715 | .89515 | 1.11713 | .92709 | 1.07864 | .96008 | 1.04158 | 10 |
| 51 | .86470 | 1.15647 | .89567 | 1.11648 | .92763 | 1.07801 | .96064 | 1.04097 | 9 |
| 52 | .86521 | 1.15579 | .89620 | 1.11582 | .92817 | 1.07738 | .96120 | 1.04036 | 8 |
| 53 | .86572 | 1.15511 | .89672 | 1.11517 | .92872 | 1.07676 | .96176 | 1.03976 | 7 |
| 54 | .86623 | 1.15443 | .89725 | 1.11452 | .92926 | 1.07613 | .96232 | 1.03915 | 6 |
| 55 | .86674 | 1.15375 | .89777 | 1.11387 | .92980 | 1.07550 | .96288 | 1.03855 | 5 |
| 56 | .86725 | 1.15308 | .89830 | 1.11321 | .93034 | 1.07487 | .96344 | 1.03794 | 4 |
| 57 | .86776 | 1.15240 | .89883 | 1.11256 | .93088 | 1.07425 | .96400 | 1.03734 | 3 |
| 58 | .86827 | 1.15172 | .89935 | 1.11191 | .93143 | 1.07362 | .96457 | 1.03674 | 2 |
| 59 | .86878 | 1.15104 | .89988 | 1.11126 | .93197 | 1.07299 | .96513 | 1.03613 | 1 |
| 60 | .86929 | 1.15037 | .90040 | 1.11061 | .93252 | 1.07237 | .96569 | 1.03553 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 49° | | 48° | | 47° | | 46° | | |

| ′ | 44° Tang | 44° Cotang | ′ | ′ | 44° Tang | 44° Cotang | ′ | ′ | 44° Tang | 44° Cotang | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .96569 | 1.03553 | 60 | 20 | .97700 | 1.02355 | 40 | 40 | .98843 | 1.01170 | 20 |
| 1 | .96625 | 1.03493 | 59 | 21 | .97756 | 1.02295 | 39 | 41 | .98901 | 1.01112 | 19 |
| 2 | .96681 | 1.03433 | 58 | 22 | .97813 | 1.02236 | 38 | 42 | .98958 | 1.01053 | 18 |
| 3 | .96738 | 1.03372 | 57 | 23 | .97870 | 1.02176 | 37 | 43 | .99016 | 1.00994 | 17 |
| 4 | .96794 | 1.03312 | 56 | 24 | .97927 | 1.02117 | 36 | 44 | .99073 | 1.00935 | 16 |
| 5 | .96850 | 1.03252 | 55 | 25 | .97984 | 1.02057 | 35 | 45 | .99131 | 1.00876 | 15 |
| 6 | .96907 | 1.03192 | 54 | 26 | .98041 | 1.01998 | 34 | 46 | .99189 | 1.00818 | 14 |
| 7 | .96963 | 1.03132 | 53 | 27 | .98098 | 1.01939 | 33 | 47 | .99247 | 1.00759 | 13 |
| 8 | .97020 | 1.03072 | 52 | 28 | .98155 | 1.01879 | 32 | 48 | .99304 | 1.00701 | 12 |
| 9 | .97076 | 1.03012 | 51 | 29 | .98213 | 1.01820 | 31 | 49 | .99362 | 1.00642 | 11 |
| 10 | .97133 | 1.02952 | 50 | 30 | .98270 | 1.01761 | 30 | 50 | .99420 | 1.00583 | 10 |
| 11 | .97189 | 1.02892 | 49 | 31 | .98327 | 1.01702 | 29 | 51 | .99478 | 1.00525 | 9 |
| 12 | .97246 | 1.02832 | 48 | 32 | .98384 | 1.01642 | 28 | 52 | .99536 | 1.00467 | 8 |
| 13 | .97302 | 1.02772 | 47 | 33 | .98441 | 1.01583 | 27 | 53 | .99594 | 1.00408 | 7 |
| 14 | .97359 | 1.02713 | 46 | 34 | .98499 | 1.01524 | 26 | 54 | .99652 | 1.00350 | 6 |
| 15 | .97416 | 1.02653 | 45 | 35 | .98556 | 1.01465 | 25 | 55 | .99710 | 1.00291 | 5 |
| 16 | .97472 | 1.02593 | 44 | 36 | .98613 | 1.01406 | 24 | 56 | .99768 | 1.00233 | 4 |
| 17 | .97529 | 1.02533 | 43 | 37 | .98671 | 1.01347 | 23 | 57 | .99826 | 1.00175 | 3 |
| 18 | .97586 | 1.02474 | 42 | 38 | .98728 | 1.01288 | 22 | 58 | .99884 | 1.00116 | 2 |
| 19 | .97643 | 1.02414 | 41 | 39 | .98786 | 1.01229 | 21 | 59 | .99942 | 1.00058 | 1 |
| 20 | .97700 | 1.02355 | 40 | 40 | .98843 | 1.01170 | 20 | 60 | 1.00000 | 1.00000 | 0 |
| ′ | 45° Cotang | 45° Tang | ′ | ′ | 45° Cotang | 45° Tang | ′ | ′ | 45° Cotang | 45° Tang | ′ |

## TABLE XXIX.—NATURAL VERSED SINES AND EXTERNAL SECANTS

| ′ | 0° | | 1° | | 2° | | 3° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .00000 | .00000 | .00015 | .00015 | .00061 | .00061 | .00137 | .00137 | 0 |
| 1 | .00000 | .00000 | .00016 | .00016 | .00062 | .00062 | .00139 | 00139 | 1 |
| 2 | .00000 | .00000 | .00016 | .00016 | .00063 | .00063 | .00140 | .00140 | 2 |
| 3 | .00000 | .00000 | .00017 | .00017 | .00064 | .00064 | .00142 | .00142 | 3 |
| 4 | .00000 | .00000 | .00017 | .00017 | .00065 | .00065 | .00143 | .00143 | 4 |
| 5 | .00000 | .00000 | .00018 | .00018 | .00066 | .00066 | .00145 | .00145 | 5 |
| 6 | .00000 | .00000 | .00018 | .00018 | .00067 | .00067 | .00146 | .00147 | 6 |
| 7 | .00000 | .00000 | .00019 | .00019 | .00068 | .00068 | .00148 | .00148 | 7 |
| 8 | .00000 | .00000 | .00020 | .00020 | .00069 | .00069 | .00150 | .00150 | 8 |
| 9 | .00000 | .00000 | .00020 | .00020 | .00070 | .00070 | .00151 | .00151 | 9 |
| 10 | .00000 | .00000 | .00021 | .00021 | .00071 | .00072 | .00153 | .00153 | 10 |
| 11 | .00001 | .00001 | .00021 | .00021 | .00073 | .00073 | .00154 | .00155 | 11 |
| 12 | .00001 | .00001 | .00022 | .00022 | .00074 | .00074 | .00156 | .00156 | 12 |
| 13 | .00001 | .00001 | .00023 | .00023 | .00075 | .00075 | .00158 | .00158 | 13 |
| 14 | .00001 | .00001 | .00023 | .00023 | .00076 | .00076 | .00159 | .00159 | 14 |
| 15 | .00001 | .00001 | .00024 | .00024 | .00077 | .00077 | .00161 | .00161 | 15 |
| 16 | .00001 | .00001 | .00024 | .00024 | .00078 | .00078 | .00162 | .00163 | 16 |
| 17 | .00001 | .00001 | .00025 | .00025 | .00079 | .00079 | .00164 | .00164 | 17 |
| 18 | .00001 | .00001 | .00026 | .00026 | .00081 | .00081 | .00166 | .00166 | 18 |
| 19 | .00002 | .00002 | .00026 | .00026 | .00082 | .00082 | .00168 | .00168 | 19 |
| 20 | .00002 | .00002 | .00027 | .00027 | .00083 | .00083 | .00169 | .00169 | 20 |
| 21 | .00002 | .00002 | .00028 | .00028 | .00084 | .00084 | .00171 | .00171 | 21 |
| 22 | .00002 | .00002 | .00028 | .00028 | .00085 | .00085 | .00173 | .00173 | 22 |
| 23 | .00002 | .00002 | .00029 | .00029 | .00087 | .00087 | .00174 | .00175 | 23 |
| 24 | .00002 | .00002 | .00030 | .00030 | .00088 | .00088 | .00176 | .00176 | 24 |
| 25 | .00003 | .00003 | .00031 | .00031 | .00089 | .00089 | .00178 | .00178 | 25 |
| 26 | .00003 | .00003 | .00031 | .00031 | .00090 | .00090 | .00179 | .00180 | 26 |
| 27 | .00003 | .00003 | .00032 | .00032 | .00091 | .00091 | .00181 | .00182 | 27 |
| 28 | .00003 | .00003 | .00033 | .00033 | .00093 | .00093 | .00183 | .00183 | 28 |
| 29 | .00004 | .00004 | .00034 | .00034 | .00094 | .00094 | .00185 | .00185 | 29 |
| 30 | .00004 | .00004 | .00034 | .00034 | .00095 | .00095 | .00187 | .00187 | 30 |
| 31 | .00004 | .00004 | .00035 | .00035 | .00096 | .00097 | .00188 | .00189 | 31 |
| 32 | .00004 | .00004 | .00036 | .00036 | .00098 | .00098 | .00190 | .00190 | 32 |
| 33 | .00005 | .00005 | .00037 | .00037 | .00099 | .00099 | .00192 | .00192 | 33 |
| 34 | .00005 | .00005 | .00037 | .00037 | .00100 | .00100 | .00194 | .00194 | 34 |
| 35 | .00005 | .00005 | .00038 | .00038 | .00102 | .00102 | .00196 | .00196 | 35 |
| 36 | .00005 | .00005 | .00039 | .00039 | .00103 | .00103 | .00197 | .00198 | 36 |
| 37 | .00006 | .00006 | .00040 | .00040 | .00104 | .00104 | .00199 | .00200 | 37 |
| 38 | .00006 | .00006 | .00041 | .00041 | .00106 | .00106 | .00201 | .00201 | 38 |
| 39 | .00006 | .00006 | .00041 | .00041 | .00107 | .00107 | .00203 | .00203 | 39 |
| 40 | .00007 | .00007 | .00042 | .00042 | .00108 | .00108 | .00205 | .00205 | 40 |
| 41 | .00007 | .00007 | .00043 | .00043 | .00110 | .00110 | .00207 | .00207 | 41 |
| 42 | .00007 | .00007 | .00044 | .00044 | .00111 | .00111 | .00208 | .00209 | 42 |
| 43 | .00008 | .00008 | .00045 | .00045 | .00112 | .00113 | .00210 | .00211 | 43 |
| 44 | .00008 | .00008 | .00046 | .00046 | .00114 | .00114 | .00212 | .00213 | 44 |
| 45 | .00009 | .00009 | .00047 | .00047 | .00115 | .00115 | .00214 | .00215 | 45 |
| 46 | .00009 | .00009 | .00048 | .00048 | .00117 | .00117 | .00216 | .00216 | 46 |
| 47 | .00009 | .00009 | .00048 | .00048 | .00118 | .00118 | .00218 | .00218 | 47 |
| 48 | .00010 | .00010 | .00049 | .00049 | .00119 | .00120 | .00220 | .00220 | 48 |
| 49 | .00010 | .00010 | .00050 | .00050 | .00121 | .00121 | .00222 | .00222 | 49 |
| 50 | .00011 | .00011 | .00051 | .00051 | .00122 | .00122 | .00224 | .00224 | 50 |
| 51 | .00011 | .00011 | .00052 | .00052 | .00124 | .00124 | .00226 | .00226 | 51 |
| 52 | .00011 | .00011 | .00053 | .00053 | .00125 | .00125 | .00228 | .00228 | 52 |
| 53 | .00012 | .00012 | .00054 | .00054 | .00127 | .00127 | .00230 | .00230 | 53 |
| 54 | .00012 | .00012 | .00055 | .00055 | .00128 | .00128 | .00232 | .00232 | 54 |
| 55 | .00013 | .00013 | .00056 | .00056 | .00130 | .00130 | .00234 | .00234 | 55 |
| 56 | .00013 | .00013 | .00057 | .00057 | .00131 | .00131 | .00236 | .00236 | 56 |
| 57 | .00014 | .00014 | .00058 | .00058 | .00133 | .00133 | .00238 | .00238 | 57 |
| 58 | .00014 | .00014 | .00059 | .00059 | .00134 | .00134 | .00240 | .00240 | 58 |
| 59 | .00015 | .00015 | .00060 | .00060 | .00136 | .00136 | .00242 | .00242 | 59 |
| 60 | .00015 | .00015 | .00061 | .00061 | .00137 | .00137 | .00244 | .00244 | 60 |

# TABLE XXIX.—NATURAL VERSED SINES AND EXTERNAL SECANTS

| ′ | 4° Vers. | 4° Ex. sec. | 5° Vers. | 5° Ex. sec. | 6° Vers. | 6° Ex. sec. | 7° Vers. | 7° Ex. sec. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .00244 | .00244 | .00381 | .00382 | .00548 | .00551 | .00745 | .00751 | 0 |
| 1 | .00246 | .00246 | .00383 | .00385 | .00551 | .00554 | .00749 | .00755 | 1 |
| 2 | .00248 | .00248 | .00386 | .00387 | .00554 | .00557 | .00752 | .00758 | 2 |
| 3 | .00250 | .00250 | .00388 | .00390 | .00557 | .00560 | .00756 | .00762 | 3 |
| 4 | .00252 | .00252 | .00391 | .00392 | .00560 | .00563 | .00760 | .00765 | 4 |
| 5 | .00254 | .00254 | .00393 | .00395 | .00563 | .00566 | .00763 | .00769 | 5 |
| 6 | .00256 | .00257 | .00396 | .00397 | .00566 | .00569 | .00767 | .00773 | 6 |
| 7 | .00258 | .00259 | .00398 | .00400 | .00569 | .00573 | .00770 | .00776 | 7 |
| 8 | .00260 | .00261 | .00401 | .00403 | .00572 | .00576 | .00774 | .00780 | 8 |
| 9 | .00262 | .00263 | .00404 | .00405 | .00576 | .00579 | .00778 | .00784 | 9 |
| 10 | .00264 | .00265 | .00406 | .00408 | .00579 | .00582 | .00781 | .00787 | 10 |
| 11 | .00266 | .00267 | .00409 | .00411 | .00582 | .00585 | .00785 | .00791 | 11 |
| 12 | .00269 | .00269 | .00412 | .00413 | .00585 | .00588 | .00789 | .00795 | 12 |
| 13 | .00271 | .00271 | .00414 | .00416 | .00588 | .00592 | .00792 | .00799 | 13 |
| 14 | .00273 | .00274 | .00417 | .00419 | .00591 | .00595 | .00796 | .00802 | 14 |
| 15 | .00275 | .00276 | .00420 | .00421 | .00594 | .00598 | .00800 | .00806 | 15 |
| 16 | .00277 | .00278 | .00422 | .00424 | .00598 | .00601 | .00803 | .00810 | 16 |
| 17 | .00279 | .00280 | .00425 | .00427 | .00601 | .00604 | .00807 | .00813 | 17 |
| 18 | .00281 | .00282 | .00428 | .00429 | .00604 | .00608 | .00811 | .00817 | 18 |
| 19 | .00284 | .00284 | .00430 | .00432 | .00607 | .00611 | .00814 | .00821 | 19 |
| 20 | .00286 | .00287 | .00433 | .00435 | .00610 | .00614 | .00818 | .00825 | 20 |
| 21 | .00288 | .00289 | .00436 | .00438 | .00614 | .00617 | .00822 | .00828 | 21 |
| 22 | .00290 | .00291 | .00438 | .00440 | .00617 | .00621 | .00825 | .00832 | 22 |
| 23 | .00293 | .00293 | .00441 | .00443 | .00620 | .00624 | .00829 | .00836 | 23 |
| 24 | .00295 | .00296 | .00444 | .00446 | .00623 | .00627 | .00833 | .00840 | 24 |
| 25 | .00297 | .00298 | .00447 | .00449 | .00626 | .00630 | .00837 | .00844 | 25 |
| 26 | .00299 | .00300 | .00449 | .00451 | .00630 | .00634 | .00840 | .00848 | 26 |
| 27 | .00301 | .00302 | .00452 | .00454 | .00633 | .00637 | .00844 | .00851 | 27 |
| 28 | .00304 | .00305 | .00455 | .00457 | .00636 | .00640 | .00848 | .00855 | 28 |
| 29 | .00306 | .00307 | .00458 | .00460 | .00640 | .00644 | .00852 | .00859 | 29 |
| 30 | .00308 | .00309 | .00460 | .00463 | .00643 | .00647 | .00856 | .00863 | 30 |
| 31 | .00311 | .00312 | .00463 | .00465 | .00646 | .00650 | .00859 | .00867 | 31 |
| 32 | .00313 | .00314 | .00466 | .00468 | .00649 | .00654 | .00863 | .00871 | 32 |
| 33 | .00315 | .00316 | .00469 | .00471 | .00653 | .00657 | .00867 | .00875 | 33 |
| 34 | .00317 | .00318 | .00472 | .00474 | .00656 | .00660 | .00871 | .00878 | 34 |
| 35 | .00320 | .00321 | .00474 | .00477 | .00659 | .00664 | .00875 | .00882 | 35 |
| 36 | .00322 | .00323 | .00477 | .00480 | .00663 | .00667 | .00878 | .00886 | 36 |
| 37 | .00324 | .00326 | .00480 | .00482 | .00666 | .00671 | .00882 | .00890 | 37 |
| 38 | .00327 | .00328 | .00483 | .00485 | .00669 | .00674 | .00886 | .00894 | 38 |
| 39 | .00329 | .00330 | .00486 | .00488 | .00673 | .00677 | .00890 | .00898 | 39 |
| 40 | .00332 | .00333 | .00489 | .00491 | .00676 | .00681 | .00894 | .00902 | 40 |
| 41 | .00334 | .00335 | .00492 | .00494 | .00680 | .00684 | .00898 | .00906 | 41 |
| 42 | .00336 | .00337 | .00494 | .00497 | .00683 | .00688 | .00902 | .00910 | 42 |
| 43 | .00339 | .00340 | .00497 | .00500 | .00686 | .00691 | .00906 | .00914 | 43 |
| 44 | .00341 | .00342 | .00500 | .00503 | .00690 | .00695 | .00909 | .00918 | 44 |
| 45 | .00343 | .00345 | .00503 | .00506 | .00693 | .00698 | .00913 | .00922 | 45 |
| 46 | .00346 | .00347 | .00506 | .00509 | .00697 | .00701 | .00917 | .00926 | 46 |
| 47 | .00348 | .00350 | .00509 | .00512 | .00700 | .00705 | .00921 | .00930 | 47 |
| 48 | .00351 | .00352 | .00512 | .00515 | .00703 | .00708 | .00925 | .00934 | 48 |
| 49 | .00353 | .00354 | .00515 | .00518 | .00707 | .00712 | .00929 | .00938 | 49 |
| 50 | .00356 | .00357 | .00518 | .00521 | .00710 | .00715 | .00933 | .00942 | 50 |
| 51 | .00358 | .00359 | .00521 | .00524 | .00714 | .00719 | .00937 | .00946 | 51 |
| 52 | .00361 | .00362 | .00524 | .00527 | .00717 | .00722 | .00941 | .00950 | 52 |
| 53 | .00363 | .00364 | .00527 | .00530 | .00721 | .00726 | .00945 | .00954 | 53 |
| 54 | .00365 | .00367 | .00530 | .00533 | .00724 | .00730 | .00949 | .00958 | 54 |
| 55 | .00368 | .00369 | .00533 | .00536 | .00728 | .00733 | .00953 | .00962 | 55 |
| 56 | .00370 | .00372 | .00536 | .00539 | .00731 | .00737 | .00957 | .00966 | 56 |
| 57 | .00373 | .00374 | .00539 | .00542 | .00735 | .00740 | .00961 | .00970 | 57 |
| 58 | .00375 | .00377 | .00542 | .00545 | .00738 | .00744 | .00965 | .00975 | 58 |
| 59 | .00378 | .00379 | .00545 | .00548 | .00742 | .00747 | .00969 | .00979 | 59 |
| 60 | .00381 | .00382 | .00548 | .00551 | .00745 | .00751 | .00973 | .00983 | 60 |

TABLE XXIX.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

| ′ | 8° Vers. | 8° Ex. sec. | 9° Vers. | 9° Ex. sec. | 10° Vers. | 10° Ex. sec. | 11° Vers. | 11° Ex. sec. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .00973 | .00983 | .01231 | .01247 | .01519 | .01543 | .01837 | .01872 | 0 |
| 1 | .00977 | .00987 | .01236 | .01251 | .01524 | .01548 | .01843 | .01877 | 1 |
| 2 | .00981 | .00991 | .01240 | .01256 | .01529 | .01553 | .01848 | .01883 | 2 |
| 3 | .00985 | .00995 | .01245 | .01261 | .01534 | .01558 | .01854 | .01889 | 3 |
| 4 | .00989 | .00999 | .01249 | .01265 | .01540 | .01564 | .01860 | .01895 | 4 |
| 5 | .00994 | .01004 | .01254 | .01270 | .01545 | .01569 | .01865 | .01901 | 5 |
| 6 | .00998 | .01008 | .01259 | .01275 | .01550 | .01574 | .01871 | .01906 | 6 |
| 7 | .01002 | .01012 | .01263 | .01279 | .01555 | .01579 | .01876 | .01912 | 7 |
| 8 | .01006 | .01016 | .01268 | .01284 | .01560 | .01585 | .01882 | .01918 | 8 |
| 9 | .01010 | .01020 | .01272 | .01289 | .01565 | .01590 | .01888 | .01924 | 9 |
| 10 | .01014 | .01024 | .01277 | .01294 | .01570 | .01595 | .01893 | .01930 | 10 |
| 11 | .01018 | .01029 | .01282 | .01298 | .01575 | .01601 | .01899 | .01936 | 11 |
| 12 | .01022 | .01033 | .01286 | .01303 | .01580 | .01606 | .01904 | .01941 | 12 |
| 13 | .01027 | .01037 | .01291 | .01308 | .01586 | .01611 | .01910 | .01947 | 13 |
| 14 | .01031 | .01041 | .01296 | .01313 | .01591 | .01616 | .01916 | .01953 | 14 |
| 15 | .01035 | .01046 | .01300 | .01318 | .01596 | .01622 | .01921 | .01959 | 15 |
| 16 | .01039 | .01050 | .01305 | .01322 | .01601 | .01627 | .01927 | .01965 | 16 |
| 17 | .01043 | .01054 | .01310 | .01327 | .01606 | .01633 | .01933 | .01971 | 17 |
| 18 | .01047 | .01059 | .01314 | .01332 | .01612 | .01638 | .01939 | .01977 | 18 |
| 19 | .01052 | .01063 | .01319 | .01337 | .01617 | .01643 | .01944 | .01983 | 19 |
| 20 | .01056 | .01067 | .01324 | .01342 | .01622 | .01649 | .01950 | .01989 | 20 |
| 21 | .01060 | .01071 | .01329 | .01346 | .01627 | .01654 | .01956 | .01995 | 21 |
| 22 | .01064 | .01076 | .01333 | .01351 | .01632 | .01659 | .01961 | .02001 | 22 |
| 23 | .01069 | .01080 | .01338 | .01356 | .01638 | .01665 | .01967 | .02007 | 23 |
| 24 | .01073 | .01084 | .01343 | .01361 | .01643 | .01670 | .01973 | .02013 | 24 |
| 25 | .01077 | .01089 | .01348 | .01366 | .01648 | .01676 | .01979 | .02019 | 25 |
| 26 | .01081 | .01093 | .01352 | .01371 | .01653 | .01681 | .01984 | .02025 | 26 |
| 27 | .01086 | .01097 | .01357 | .01376 | .01659 | .01687 | .01990 | .02031 | 27 |
| 28 | .01090 | .01102 | .01362 | .01381 | .01664 | .01692 | .01996 | .02037 | 28 |
| 29 | .01094 | .01106 | .01367 | .01386 | .01669 | .01698 | .02002 | .02043 | 29 |
| 30 | .01098 | .01111 | .01371 | .01391 | .01675 | .01703 | .02008 | .02049 | 30 |
| 31 | .01103 | .01115 | .01376 | .01395 | .01680 | .01709 | .02013 | .02055 | 31 |
| 32 | .01107 | .01119 | .01381 | .01400 | .01685 | .01714 | .02019 | .02061 | 32 |
| 33 | .01111 | .01124 | .01386 | .01405 | .01690 | .01720 | .02025 | .02067 | 33 |
| 34 | .01116 | .01128 | .01391 | .01410 | .01696 | .01725 | .02031 | .02073 | 34 |
| 35 | .01120 | .01133 | .01396 | .01415 | .01701 | .01731 | .02037 | .02079 | 35 |
| 36 | .01124 | .01137 | .01400 | .01420 | .01706 | .01736 | .02042 | .02085 | 36 |
| 37 | .01129 | .01142 | .01405 | .01425 | .01712 | .01742 | .02048 | .02091 | 37 |
| 38 | .01133 | .01146 | .01410 | .01430 | .01717 | .01747 | .02054 | .02097 | 38 |
| 39 | .01137 | .01151 | .01415 | .01435 | .01723 | .01753 | .02060 | .02103 | 39 |
| 40 | .01142 | .01155 | .01420 | .01440 | .01728 | .01758 | .02066 | .02110 | 40 |
| 41 | .01146 | .01160 | .01425 | .01445 | .01733 | .01764 | .02072 | .02116 | 41 |
| 42 | .01151 | .01164 | .01430 | .01450 | .01739 | .01769 | .02078 | .02122 | 42 |
| 43 | .01155 | .01169 | .01435 | .01455 | .01744 | .01775 | .02084 | .02128 | 43 |
| 44 | .01159 | .01173 | .01439 | .01461 | .01750 | .01781 | .02090 | .02134 | 44 |
| 45 | .01164 | .01178 | .01444 | .01466 | .01755 | .01786 | .02095 | .02140 | 45 |
| 46 | .01168 | .01182 | .01449 | .01471 | .01760 | .01792 | .02101 | .02146 | 46 |
| 47 | .01173 | .01187 | .01454 | .01476 | .01766 | .01798 | .02107 | .02153 | 47 |
| 48 | .01177 | .01191 | .01459 | .01481 | .01771 | .01803 | .02113 | .02159 | 48 |
| 49 | .01182 | .01196 | .01464 | .01486 | .01777 | .01809 | .02119 | .02165 | 49 |
| 50 | .01186 | .01200 | .01469 | .01491 | .01782 | .01815 | .02125 | .02171 | 50 |
| 51 | .01191 | .01205 | .01474 | .01496 | .01788 | .01820 | .02131 | .02178 | 51 |
| 52 | .01195 | .01209 | .01479 | .01501 | .01793 | .01826 | .02137 | .02184 | 52 |
| 53 | .01200 | .01214 | .01484 | .01506 | .01799 | .01832 | .02143 | .02190 | 53 |
| 54 | .01204 | .01219 | .01489 | .01512 | .01804 | .01837 | .02149 | .02196 | 54 |
| 55 | .01209 | .01223 | .01494 | .01517 | .01810 | .01843 | .02155 | .02203 | 55 |
| 56 | .01213 | .01228 | .01499 | .01522 | .01815 | .01849 | .02161 | .02209 | 56 |
| 57 | .01218 | .01233 | .01504 | .01527 | .01821 | .01854 | .02167 | .02215 | 57 |
| 58 | .01222 | .01237 | .01509 | .01532 | .01826 | .01860 | .02173 | .02221 | 58 |
| 59 | .01227 | .01242 | .01514 | .01537 | .01832 | .01866 | .02179 | .02228 | 59 |
| 60 | .01231 | .01247 | .01519 | .01543 | .01837 | .01872 | .02185 | .02234 | 60 |

| ′ | 12° | | 13° | | 14° | | 15° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .02185 | .02234 | .02563 | .02630 | .02970 | .03061 | .03407 | .03528 | 0 |
| 1 | .02191 | .02240 | .02570 | .02637 | .02977 | .03069 | .03415 | .03536 | 1 |
| 2 | .02197 | .02247 | .02576 | .02644 | .02985 | .03076 | .03422 | .03544 | 2 |
| 3 | .02203 | .02253 | .02583 | .02651 | .02992 | .03084 | .03430 | .03552 | 3 |
| 4 | .02210 | .02259 | .02589 | .02658 | .02999 | .03091 | .03438 | .03560 | 4 |
| 5 | .02216 | .02266 | .02596 | .02665 | .03006 | .03099 | .03445 | .03568 | 5 |
| 6 | .02222 | .02272 | .02602 | .02672 | .03013 | .03106 | .03453 | .03576 | 6 |
| 7 | .02228 | .02279 | .02609 | .02679 | .03020 | .03114 | .03460 | .03584 | 7 |
| 8 | .02234 | .02285 | .02616 | .02686 | .03027 | .03121 | .03468 | .03592 | 8 |
| 9 | .02240 | .02291 | .02622 | .02693 | .03034 | .03129 | .03476 | .03601 | 9 |
| 10 | .02246 | .02298 | .02629 | .02700 | .03041 | .03137 | .03483 | .03609 | 10 |
| 11 | .02252 | .02304 | .02635 | .02707 | .03048 | .03144 | .03491 | .03617 | 11 |
| 12 | .02258 | .02311 | .02642 | .02714 | .03055 | .03152 | .03498 | .03625 | 12 |
| 13 | .02265 | .02317 | .02649 | .02721 | .03063 | .03159 | .03506 | .03633 | 13 |
| 14 | .02271 | .02323 | .02655 | .02728 | .03070 | .03167 | .03514 | .03642 | 14 |
| 15 | .02277 | .02330 | .02662 | .02735 | .03077 | .03175 | .03521 | .03650 | 15 |
| 16 | .02283 | .02336 | .02669 | .02742 | .03084 | .03182 | .03529 | .03658 | 16 |
| 17 | .02289 | .02343 | .02675 | .02749 | .03091 | .03190 | .03537 | .03666 | 17 |
| 18 | .02295 | .02349 | .02682 | .02756 | .03098 | .03198 | .03544 | .03674 | 18 |
| 19 | .02302 | .02356 | .02689 | .02763 | .03106 | .03205 | .03552 | .03683 | 19 |
| 20 | .02308 | .02362 | .02696 | .02770 | .03113 | .03213 | .03560 | .03691 | 20 |
| 21 | .02314 | .02369 | .02702 | .02777 | .03120 | .03221 | .03567 | .03699 | 21 |
| 22 | .02320 | .02375 | .02709 | .02784 | .03127 | .03228 | .03575 | .03708 | 22 |
| 23 | .02327 | .02382 | .02716 | .02791 | .03134 | .03236 | .03583 | .03716 | 23 |
| 24 | .02333 | .02388 | .02722 | .02799 | .03142 | .03244 | .03590 | .03724 | 24 |
| 25 | .02339 | .02395 | .02729 | .02806 | .03149 | .03251 | .03598 | .03732 | 25 |
| 26 | .02345 | .02402 | .02736 | .02813 | .03156 | .03259 | .03606 | .03741 | 26 |
| 27 | .02352 | .02408 | .02743 | .02820 | .03163 | .03267 | .03614 | .03749 | 27 |
| 28 | .02358 | .02415 | .02749 | .02827 | .03171 | .03275 | .03621 | .03758 | 28 |
| 29 | .02364 | .02421 | .02756 | .02834 | .03178 | .03282 | .03629 | .03766 | 29 |
| 30 | .02370 | .02428 | .02763 | .02842 | .03185 | .03290 | .03637 | .03774 | 30 |
| 31 | .02377 | .02435 | .02770 | .02849 | .03193 | .03298 | .03645 | .03783 | 31 |
| 32 | .02383 | .02441 | .02777 | .02856 | .03200 | .03306 | .03653 | .03791 | 32 |
| 33 | .02389 | .02448 | .02783 | .02863 | .03207 | .03313 | .03660 | .03799 | 33 |
| 34 | .02396 | .02454 | .02790 | .02870 | .03214 | .03321 | .03668 | .03808 | 34 |
| 35 | .02402 | .02461 | .02797 | .02878 | .03222 | .03329 | .03676 | .03816 | 35 |
| 36 | .02408 | .02468 | .02804 | .02885 | .03229 | .03337 | .03684 | .03825 | 36 |
| 37 | .02415 | .02474 | .02811 | .02892 | .03236 | .03345 | .03692 | .03833 | 37 |
| 38 | .02421 | .02481 | .02818 | .02899 | .03244 | .03353 | .03699 | .03842 | 38 |
| 39 | .02427 | .02488 | .02824 | .02907 | .03251 | .03360 | .03707 | .03850 | 39 |
| 40 | .02434 | .02494 | .02831 | .02914 | .03258 | .03368 | .03715 | .03858 | 40 |
| 41 | .02440 | .02501 | .02838 | .02921 | .03266 | .03376 | .03723 | .03867 | 41 |
| 42 | .02447 | .02508 | .02845 | .02928 | .03273 | .03384 | .03731 | .03875 | 42 |
| 43 | .02453 | .02515 | .02852 | .02936 | .03281 | .03392 | .03739 | .03884 | 43 |
| 44 | .02459 | .02521 | .02859 | .02943 | .03288 | .03400 | .03747 | .03892 | 44 |
| 45 | .02466 | .02528 | .02866 | .02950 | .03295 | .03408 | .03754 | .03901 | 45 |
| 46 | .02472 | .02535 | .02873 | .02958 | .03303 | .03416 | .03762 | .03909 | 46 |
| 47 | .02479 | .02542 | .02880 | .02965 | .03310 | .03424 | .03770 | .03918 | 47 |
| 48 | .02485 | .02548 | .02887 | .02972 | .03318 | .03432 | .03778 | .03927 | 48 |
| 49 | .02492 | .02555 | .02894 | .02980 | .03325 | .03439 | .03786 | .03935 | 49 |
| 50 | .02498 | .02562 | .02900 | .02987 | .03333 | .03447 | .03794 | .03944 | 50 |
| 51 | .02504 | .02569 | .02907 | .02994 | .03340 | .03455 | .03802 | .03952 | 51 |
| 52 | .02511 | .02576 | .02914 | .03002 | .03347 | .03463 | .03810 | .03961 | 52 |
| 53 | .02517 | .02582 | .02921 | .03009 | .03355 | .03471 | .03818 | .03969 | 53 |
| 54 | .02524 | .02589 | .02928 | .03017 | .03362 | .03479 | .03826 | .03978 | 54 |
| 55 | .02530 | .02596 | .02935 | .03024 | .03370 | .03487 | .03834 | .03987 | 55 |
| 56 | .02537 | .02603 | .02942 | .03032 | .03377 | .03495 | .03842 | .03995 | 56 |
| 57 | .02543 | .02610 | .02949 | .03039 | .03385 | .03503 | .03850 | .04004 | 57 |
| 58 | .02550 | .02617 | .02956 | .03046 | .03392 | .03512 | .03858 | .04013 | 58 |
| 59 | .02556 | .02624 | .02963 | .03054 | .03400 | .03520 | .03866 | .04021 | 59 |
| 60 | .02563 | .02630 | .02970 | .03061 | .03407 | .03528 | .03874 | .04030 | 60 |

# TABLE XXIX.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

| ′ | 16° | | 17° | | 18° | | 19° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .03874 | .04030 | .04370 | .04569 | .04894 | .05146 | .05448 | .05762 | 0 |
| 1 | .03882 | .04039 | .04378 | .04578 | .04903 | .05156 | .05458 | .05773 | 1 |
| 2 | .03890 | .04047 | .04387 | .04588 | .04912 | .05166 | .05467 | .05783 | 2 |
| 3 | .03898 | .04056 | .04395 | .04597 | .04921 | .05176 | .05477 | .05794 | 3 |
| 4 | .03906 | .04065 | .04404 | .04606 | .04930 | .05186 | .05486 | .05805 | 4 |
| 5 | .03914 | .04073 | .04412 | .04616 | .04939 | .05196 | .05496 | .05815 | 5 |
| 6 | .03922 | .04082 | .04421 | .04625 | .04948 | .05206 | .05505 | .05826 | 6 |
| 7 | .03930 | .04091 | .04429 | .04635 | .04957 | .05216 | .05515 | .05836 | 7 |
| 8 | .03938 | .04100 | .04438 | .04644 | .04967 | .05226 | .05524 | .05847 | 8 |
| 9 | .03946 | .04108 | .04446 | .04653 | .04976 | .05236 | .05534 | .05858 | 9 |
| 10 | .03954 | .04117 | .04455 | .04663 | .04985 | .05246 | .05543 | .05869 | 10 |
| 11 | .03963 | .04126 | .04464 | .04672 | .04994 | .05256 | .05553 | .05879 | 11 |
| 12 | .03971 | .04135 | .04472 | .04682 | .05003 | .05266 | .05562 | .05890 | 12 |
| 13 | .03979 | .04144 | .04481 | .04691 | .05012 | .05276 | .05572 | .05901 | 13 |
| 14 | .03987 | .04152 | .04489 | .04700 | .05021 | .05286 | .05582 | .05911 | 14 |
| 15 | .03995 | .04161 | .04498 | .04710 | .05030 | .05297 | .05591 | .05922 | 15 |
| 16 | .04003 | .04170 | .04507 | .04719 | .05039 | .05307 | .05601 | .05933 | 16 |
| 17 | .04011 | .04179 | .04515 | .04729 | .05048 | .05317 | .05610 | .05944 | 17 |
| 18 | .04019 | .04188 | .04524 | .04738 | .05057 | .05327 | .05620 | .05955 | 18 |
| 19 | .04028 | .04197 | .04533 | .04748 | .05067 | .05337 | .05630 | .05965 | 19 |
| 20 | .04036 | .04206 | .04541 | .04757 | .05076 | .05347 | .05639 | .05976 | 20 |
| 21 | .04044 | .04214 | .04550 | .04767 | .05085 | .05357 | .05649 | .05987 | 21 |
| 22 | .04052 | .04223 | .04559 | .04776 | .05094 | .05367 | .05658 | .05998 | 22 |
| 23 | .04060 | .04232 | .04567 | .04786 | .05103 | .05378 | .05668 | .06009 | 23 |
| 24 | .04069 | .04241 | .04576 | .04795 | .05112 | .05388 | .05678 | .06020 | 24 |
| 25 | .04077 | .04250 | .04585 | .04805 | .05122 | .05398 | .05687 | .06030 | 25 |
| 26 | .04085 | .04259 | .04593 | .04815 | .05131 | .05408 | .05697 | .06041 | 26 |
| 27 | .04093 | .04268 | .04602 | .04824 | .05140 | .05418 | .05707 | .06052 | 27 |
| 28 | .04102 | .04277 | .04611 | .04834 | .05149 | .05429 | .05716 | .06063 | 28 |
| 29 | .04110 | .04286 | .04620 | .04843 | .05158 | .05439 | .05726 | .06074 | 29 |
| 30 | .04118 | .04295 | .04628 | .04853 | .05168 | .05449 | .05736 | .06085 | 30 |
| 31 | .04126 | .04304 | .04637 | .04863 | .05177 | .05460 | .05746 | .06096 | 31 |
| 32 | .04135 | .04313 | .04646 | .04872 | .05186 | .05470 | .05755 | .06107 | 32 |
| 33 | .04143 | .04322 | .04655 | .04882 | .05195 | .05480 | .05765 | .06118 | 33 |
| 34 | .04151 | .04331 | .04663 | .04891 | .05205 | .05490 | .05775 | .06129 | 34 |
| 35 | .04159 | .04340 | .04672 | .04901 | .05214 | .05501 | .05785 | .06140 | 35 |
| 36 | .04168 | .04349 | .04681 | .04911 | .05223 | .05511 | .05794 | .06151 | 36 |
| 37 | .04176 | .04358 | .04690 | .04920 | .05232 | .05521 | .05804 | .06162 | 37 |
| 38 | .04184 | .04367 | .04699 | .04930 | .05242 | .05532 | .05814 | .06173 | 38 |
| 39 | .04193 | .04376 | .04707 | .04940 | .05251 | .05542 | .05824 | .06184 | 39 |
| 40 | .04201 | .04385 | .04716 | .04950 | .05260 | .05552 | .05833 | .06195 | 40 |
| 41 | .04209 | .04394 | .04725 | .04959 | .05270 | .05563 | .05843 | .06206 | 41 |
| 42 | .04218 | .04403 | .04734 | .04969 | .05279 | .05573 | .05853 | .06217 | 42 |
| 43 | .04226 | .04413 | .04743 | .04979 | .05288 | .05584 | .05863 | .06228 | 43 |
| 44 | .04234 | .04422 | .04752 | .04989 | .05298 | .05594 | .05873 | .06239 | 44 |
| 45 | .04243 | .04431 | .04760 | .04998 | .05307 | .05604 | .05882 | .06250 | 45 |
| 46 | .04251 | .04440 | .04769 | .05008 | .05316 | .05615 | .05892 | .06261 | 46 |
| 47 | .04260 | .04449 | .04778 | .05018 | .05326 | .05625 | .05902 | .06272 | 47 |
| 48 | .04268 | .04458 | .04787 | .05028 | .05335 | .05636 | .05912 | .06283 | 48 |
| 49 | .04276 | .04468 | .04796 | .05038 | .05344 | .05646 | .05922 | .06295 | 49 |
| 50 | .04285 | .04477 | .04805 | .05047 | .05354 | .05657 | .05932 | .06306 | 50 |
| 51 | .04293 | .04486 | .04814 | .05057 | .05363 | .05667 | .05942 | .06317 | 51 |
| 52 | .04302 | .04495 | .04823 | .05067 | .05373 | .05678 | .05951 | .06328 | 52 |
| 53 | .04310 | .04504 | .04832 | .05077 | .05382 | .05688 | .05961 | .06339 | 53 |
| 54 | .04319 | .04514 | .04841 | .05087 | .05391 | .05699 | .05971 | .06350 | 54 |
| 55 | .04327 | .04523 | .04850 | .05097 | .05401 | .05709 | .05981 | .06362 | 55 |
| 56 | .04336 | .04532 | .04858 | .05107 | .05410 | .05720 | .05991 | .06373 | 56 |
| 57 | .04344 | .04541 | .04867 | .05116 | .05420 | .05730 | .06001 | .06384 | 57 |
| 58 | .04353 | .04551 | .04876 | .05126 | .05429 | .05741 | .06011 | .06395 | 58 |
| 59 | .04361 | .04560 | .04885 | .05136 | .05439 | .05751 | .06021 | .06407 | 59 |
| 60 | .04370 | .04569 | .04894 | .05146 | .05448 | .05762 | .06031 | .06418 | 60 |

| ′ | 20° | | 21° | | 22° | | 23° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .06031 | .06418 | .06642 | .07115 | .07282 | .07853 | .07950 | .08636 | 0 |
| 1 | .06041 | .06429 | .06652 | .07126 | .07293 | .07866 | .07961 | .08649 | 1 |
| 2 | .06051 | .06440 | .06663 | .07138 | .07303 | .07879 | .07972 | .08663 | 2 |
| 3 | .06061 | .06452 | .06673 | .07150 | .07314 | .07892 | .07984 | .08676 | 3 |
| 4 | .06071 | .06463 | .06684 | .07162 | .07325 | .07904 | .07995 | .08690 | 4 |
| 5 | .06081 | .06474 | .06694 | .07174 | .07336 | .07917 | .08006 | .08703 | 5 |
| 6 | .06091 | .06486 | .06705 | .07186 | .07347 | .07930 | .08018 | .08717 | 6 |
| 7 | .06101 | .06497 | .06715 | .07199 | .07358 | .07943 | .08029 | .08730 | 7 |
| 8 | .06111 | .06508 | .06726 | .07211 | .07369 | .07955 | .08041 | .08744 | 8 |
| 9 | .06121 | .06520 | .06736 | .07223 | .07380 | .07968 | .08052 | .08757 | 9 |
| 10 | .06131 | .06531 | .06747 | .07235 | .07391 | .07981 | .08064 | .08771 | 10 |
| 11 | .06141 | .06542 | .06757 | .07247 | .07402 | .07994 | .08075 | .08784 | 11 |
| 12 | .06151 | .06554 | .06768 | .07259 | .07413 | .08006 | .08086 | .08798 | 12 |
| 13 | .06161 | .06565 | .06778 | .07271 | .07424 | .08019 | .08098 | .08811 | 13 |
| 14 | .06171 | .06577 | .06789 | .07283 | .07435 | .08032 | .08109 | .08825 | 14 |
| 15 | .06181 | .06588 | .06799 | .07295 | .07446 | .08045 | .08121 | .08839 | 15 |
| 16 | .06191 | .06600 | .06810 | .07307 | .07457 | .08058 | .08132 | .08852 | 16 |
| 17 | .06201 | .06611 | .06820 | .07320 | .07468 | .08071 | .08144 | .08866 | 17 |
| 18 | .06211 | .06622 | .06831 | .07332 | .07479 | .08084 | .08155 | .08880 | 18 |
| 19 | .06221 | .06634 | .06841 | .07344 | .07490 | .08097 | .08167 | .08893 | 19 |
| 20 | .06231 | .06645 | .06852 | .07356 | .07501 | .08109 | .08178 | .08907 | 20 |
| 21 | .06241 | .06657 | .06863 | .07368 | .07512 | .08122 | .08190 | .08921 | 21 |
| 22 | .06252 | .06668 | .06873 | .07380 | .07523 | .08135 | .08201 | .08934 | 22 |
| 23 | .06262 | .06680 | .06884 | .07393 | .07534 | .08148 | .08213 | .08948 | 23 |
| 24 | .06272 | .06691 | .06894 | .07405 | .07545 | .08161 | .08225 | .08962 | 24 |
| 25 | .06282 | .06703 | .06905 | .07417 | .07556 | .08174 | .08236 | .08975 | 25 |
| 26 | .06292 | .06715 | .06916 | .07429 | .07568 | .08187 | .08248 | .08989 | 26 |
| 27 | .06302 | .06726 | .06926 | .07442 | .07579 | .08200 | .08259 | .09003 | 27 |
| 28 | .06312 | .06738 | .06937 | .07454 | .07590 | .08213 | .08271 | .09017 | 28 |
| 29 | .06323 | .06749 | .06948 | .07466 | .07601 | .08226 | .08282 | .09030 | 29 |
| 30 | .06333 | .06761 | .06958 | .07479 | .07612 | .08239 | .08294 | .09044 | 30 |
| 31 | .06343 | .06773 | .06969 | .07491 | .07623 | .08252 | .08306 | .09058 | 31 |
| 32 | .06353 | .06784 | .06980 | .07503 | .07634 | .08265 | .08317 | .09072 | 32 |
| 33 | .06363 | .06796 | .06990 | .07516 | .07645 | .08278 | .08329 | .09086 | 33 |
| 34 | .06374 | .06807 | .07001 | .07528 | .07657 | .08291 | .08340 | .09099 | 34 |
| 35 | .06384 | .06819 | .07012 | .07540 | .07668 | .08305 | .08352 | .09113 | 35 |
| 36 | .06394 | .06831 | .07022 | .07553 | .07679 | .08318 | .08364 | .09127 | 36 |
| 37 | .06404 | .06843 | .07033 | .07565 | .07690 | .08331 | .08375 | .09141 | 37 |
| 38 | .06415 | .06854 | .07044 | .07578 | .07701 | .08344 | .08387 | .09155 | 38 |
| 39 | .06425 | .06866 | .07055 | .07590 | .07713 | .08357 | .08399 | .09169 | 39 |
| 40 | .06435 | .06878 | .07065 | .07602 | .07724 | .08370 | .08410 | .09183 | 40 |
| 41 | .06445 | .06889 | .07076 | .07615 | .07735 | .08383 | .08422 | .09197 | 41 |
| 42 | .06456 | .06901 | .07087 | .07627 | .07746 | .08397 | .08434 | .09211 | 42 |
| 43 | .06466 | .06913 | .07098 | .07640 | .07757 | .08410 | .08445 | .09224 | 43 |
| 44 | .06476 | .06925 | .07108 | .07652 | .07769 | .08423 | .08457 | .09238 | 44 |
| 45 | .06486 | .06936 | .07119 | .07665 | .07780 | .08436 | .08469 | .09252 | 45 |
| 46 | .06497 | .06948 | .07130 | .07677 | .07791 | .08449 | .08481 | .09266 | 46 |
| 47 | .06507 | .06960 | .07141 | .07690 | .07802 | .08463 | .08492 | .09280 | 47 |
| 48 | .06517 | .06972 | .07151 | .07702 | .07814 | .08476 | .08504 | .09294 | 48 |
| 49 | .06528 | .06984 | .07162 | .07715 | .07825 | .08489 | .08516 | .09308 | 49 |
| 50 | .06538 | .06995 | .07173 | .07727 | .07836 | .08503 | .08528 | .09323 | 50 |
| 51 | .06548 | .07007 | .07184 | .07740 | .07848 | .08516 | .08539 | .09337 | 51 |
| 52 | .06559 | .07019 | .07195 | .07752 | .07859 | .08529 | .08551 | .09351 | 52 |
| 53 | .06569 | .07031 | .07206 | .07765 | .07870 | .08542 | .08563 | .09365 | 53 |
| 54 | .06580 | .07043 | .07216 | .07778 | .07881 | .08556 | .08575 | .09379 | 54 |
| 55 | .06590 | .07055 | .07227 | .07790 | .07893 | .08569 | .08586 | .09393 | 55 |
| 56 | .06600 | .07067 | .07238 | .07803 | .07904 | .08582 | .08598 | .09407 | 56 |
| 57 | .06611 | .07079 | .07249 | .07816 | .07915 | .08596 | .08610 | .09421 | 57 |
| 58 | .06621 | .07091 | .07260 | .07828 | .07927 | .08609 | .08622 | .09435 | 58 |
| 59 | .06632 | .07103 | .07271 | .07841 | .07938 | .08623 | .08634 | .09449 | 59 |
| 60 | .06642 | .07115 | .07282 | .07853 | .07950 | .08636 | .08645 | .09464 | 60 |

| ′ | 24° | | 25° | | 26° | | 27 | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .08645 | .09464 | .09369 | .10338 | .10121 | .11260 | .10899 | .12233 | 0 |
| 1 | .08657 | .09478 | .09382 | .10353 | .10133 | .11276 | .10913 | .12249 | 1 |
| 2 | .08669 | .09492 | .09394 | .10368 | .10146 | .11292 | .10926 | .12266 | 2 |
| 3 | .08681 | .09506 | .09406 | .10383 | .10159 | .11308 | .10939 | .12283 | 3 |
| 4 | .08693 | .09520 | .09418 | .10398 | .10172 | .11323 | .10952 | .12299 | 4 |
| 5 | .08705 | .09535 | .09431 | .10413 | .10184 | .11339 | .10965 | .12316 | 5 |
| 6 | .08717 | .09549 | .09443 | .10428 | .10197 | .11355 | .10979 | .12333 | 6 |
| 7 | .08728 | .09563 | .09455 | .10443 | .10210 | .11371 | .10992 | .12349 | 7 |
| 8 | .08740 | .09577 | .09468 | .10458 | .10223 | .11387 | .11005 | .12366 | 8 |
| 9 | .08752 | .09592 | .09480 | .10473 | .10236 | .11403 | .11019 | .12383 | 9 |
| 10 | .08764 | .09606 | .09493 | .10488 | .10248 | .11419 | .11032 | .12400 | 10 |
| 11 | .08776 | .09620 | .09505 | .10503 | .10261 | .11435 | .11045 | .12416 | 11 |
| 12 | .08788 | .09635 | .09517 | .10518 | .10274 | .11451 | .11058 | .12433 | 12 |
| 13 | .08800 | .09649 | .09530 | .10533 | .10287 | .11467 | .11072 | .12450 | 13 |
| 14 | .08812 | .09663 | .09542 | .10549 | .10300 | .11483 | .11085 | .12467 | 14 |
| 15 | .08824 | .09678 | .09554 | .10564 | .10313 | .11499 | .11098 | .12484 | 15 |
| 16 | .08836 | .09692 | .09567 | .10579 | .10326 | .11515 | .11112 | .12501 | 16 |
| 17 | .08848 | .09707 | .09579 | .10594 | .10338 | .11531 | .11125 | .12518 | 17 |
| 18 | .08860 | .09721 | .09592 | .10609 | .10351 | .11547 | .11138 | .12534 | 18 |
| 19 | .08872 | .09735 | .09604 | .10625 | .10364 | .11563 | .11152 | .12551 | 19 |
| 20 | .08884 | .09750 | .09617 | .10640 | .10377 | .11579 | .11165 | .12568 | 20 |
| 21 | .08896 | .09764 | .09629 | .10655 | .10390 | .11595 | .11178 | .12585 | 21 |
| 22 | .08908 | .09779 | .09642 | .10670 | .10403 | .11611 | .11192 | .12602 | 22 |
| 23 | .08920 | .09793 | .09654 | .10686 | .10416 | .11627 | .11205 | .12619 | 23 |
| 24 | .08932 | .09808 | .09666 | .10701 | .10429 | .11643 | .11218 | .12636 | 24 |
| 25 | .08944 | .09822 | .09679 | .10716 | .10442 | .11659 | .11232 | .12653 | 25 |
| 26 | .08956 | .09837 | .09691 | .10731 | .10455 | .11675 | .11245 | .12670 | 26 |
| 27 | .08968 | .09851 | .09704 | .10747 | .10468 | .11691 | .11259 | .12687 | 27 |
| 28 | .08980 | .09866 | .09716 | .10762 | .10481 | .11708 | .11272 | .12704 | 28 |
| 29 | .08992 | .09880 | .09729 | .10777 | .10494 | .11724 | .11285 | .12721 | 29 |
| 30 | .09004 | .09895 | .09741 | .10793 | .10507 | .11740 | .11299 | .12738 | 30 |
| 31 | .09016 | .09909 | .09754 | .10808 | .10520 | .11756 | .11312 | .12755 | 31 |
| 32 | .09028 | .09924 | .09767 | .10824 | .10533 | .11772 | .11326 | .12772 | 32 |
| 33 | .09040 | .09939 | .09779 | .10839 | .10546 | .11789 | .11339 | .12789 | 33 |
| 34 | .09052 | .09953 | .09792 | .10854 | .10559 | .11805 | .11353 | .12807 | 34 |
| 35 | .09064 | .09968 | .09804 | .10870 | .10572 | .11821 | .11366 | .12824 | 35 |
| 36 | .09076 | .09982 | .09817 | .10885 | .10585 | .11838 | .11380 | .12841 | 36 |
| 37 | .09089 | .09997 | .09829 | .10901 | .10598 | .11854 | .11393 | .12858 | 37 |
| 38 | .09101 | .10012 | .09842 | .10916 | .10611 | .11870 | .11407 | .12875 | 38 |
| 39 | .09113 | .10026 | .09854 | .10932 | .10624 | .11886 | .11420 | .12892 | 39 |
| 40 | .09125 | .10041 | .09867 | .10947 | .10637 | .11903 | .11434 | .12910 | 40 |
| 41 | .09137 | .10055 | .09880 | .10963 | .10650 | .11919 | .11447 | .12927 | 41 |
| 42 | .09149 | .10071 | .09892 | .10978 | .10663 | .11936 | .11461 | .12944 | 42 |
| 43 | .09161 | .10085 | .09905 | .10994 | .10676 | .11952 | .11474 | .12961 | 43 |
| 44 | .09174 | .10100 | .09918 | .11009 | .10689 | .11968 | .11488 | .12979 | 44 |
| 45 | .09186 | .10115 | .09930 | .11025 | .10702 | .11985 | .11501 | .12996 | 45 |
| 46 | .09198 | .10130 | .09943 | .11041 | .10715 | .12001 | .11515 | .13013 | 46 |
| 47 | .09210 | .10144 | .09955 | .11056 | .10728 | .12018 | .11528 | .13031 | 47 |
| 48 | .09222 | .10159 | .09968 | .11072 | .10741 | .12034 | .11542 | .13048 | 48 |
| 49 | .09234 | .10174 | .09981 | .11087 | .10755 | .12051 | .11555 | .13065 | 49 |
| 50 | .09247 | .10189 | .09993 | .11103 | .10768 | .12067 | .11569 | .13083 | 50 |
| 51 | .09259 | .10204 | .10006 | .11119 | .10781 | .12084 | .11583 | .13100 | 51 |
| 52 | .09271 | .10218 | .10019 | .11134 | .10794 | .12100 | .11596 | .13117 | 52 |
| 53 | .09283 | .10233 | .10032 | .11150 | .10807 | .12117 | .11610 | .13135 | 53 |
| 54 | .09296 | .10248 | .10044 | .11166 | .10820 | .12133 | .11623 | .13152 | 54 |
| 55 | .09308 | .10263 | .10057 | .11181 | .10833 | .12150 | .11637 | .13170 | 55 |
| 56 | .09320 | .10278 | .10070 | .11197 | .10847 | .12166 | .11651 | .13187 | 56 |
| 57 | .09332 | .10293 | .10082 | .11213 | .10860 | .12183 | .11664 | .13205 | 57 |
| 58 | .09345 | .10308 | .10095 | .11229 | .10873 | .12199 | .11678 | .13222 | 58 |
| 59 | .09357 | .10323 | .10108 | .11244 | .10886 | .12216 | .11692 | .13240 | 59 |
| 60 | .09369 | .10338 | .10121 | .11260 | .10899 | .12233 | .11705 | .13257 | 60 |

| ′ | 28° | | 29° | | 30° | | 31° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .11705 | .13257 | .12538 | .14335 | .13397 | .15470 | .14283 | .16663 | 0 |
| 1 | .11719 | .13275 | .12552 | .14354 | .13412 | .15489 | .14298 | .16684 | 1 |
| 2 | .11733 | .13292 | .12566 | .14372 | .13427 | .15509 | .14313 | .16704 | 2 |
| 3 | .11746 | .13310 | .12580 | .14391 | .13441 | .15528 | .14328 | .16725 | 3 |
| 4 | .11760 | .13327 | .12595 | .14409 | .13456 | .15548 | .14343 | .16745 | 4 |
| 5 | .11774 | .13345 | .12609 | .14428 | .13470 | .15567 | .14358 | .16766 | 5 |
| 6 | .11787 | .13362 | .12623 | .14446 | .13485 | .15587 | .14373 | .16786 | 6 |
| 7 | .11801 | .13380 | .12637 | .14465 | .13499 | .15606 | .14388 | .16806 | 7 |
| 8 | .11815 | .13398 | .12651 | .14483 | .13514 | .15626 | .14403 | .16827 | 8 |
| 9 | .11828 | .13415 | .12665 | .14502 | .13529 | .15645 | .14418 | .16848 | 9 |
| 10 | .11842 | .13433 | .12679 | .14521 | .13543 | .15665 | .14433 | .16868 | 10 |
| 11 | .11856 | .13451 | .12694 | .14539 | .13558 | .15684 | .14449 | .16889 | 11 |
| 12 | .11870 | .13468 | .12708 | .14558 | .13573 | .15704 | .14464 | .16909 | 12 |
| 13 | .11883 | .13486 | .12722 | .14576 | .13587 | .15724 | .14479 | .16930 | 13 |
| 14 | .11897 | .13504 | .12736 | .14595 | .13602 | .15743 | .14494 | .16950 | 14 |
| 15 | .11911 | .13521 | .12750 | .14614 | .13616 | .15763 | .14509 | .16971 | 15 |
| 16 | .11925 | .13539 | .12765 | .14632 | .13631 | .15782 | .14524 | .16992 | 16 |
| 17 | .11938 | .13557 | .12779 | .14651 | .13646 | .15802 | .14539 | .17012 | 17 |
| 18 | .11952 | .13575 | .12793 | .14670 | .13660 | .15822 | .14554 | .17033 | 18 |
| 19 | .11966 | .13593 | .12807 | .14689 | .13675 | .15841 | .14569 | .17054 | 19 |
| 20 | .11980 | .13610 | .12822 | .14707 | .13690 | .15861 | .14584 | .17075 | 20 |
| 21 | .11994 | .13628 | .12836 | .14726 | .13705 | .15881 | .14599 | .17095 | 21 |
| 22 | .12007 | .13646 | .12850 | .14745 | .13719 | .15901 | .14615 | .17116 | 22 |
| 23 | .12021 | .13664 | .12864 | .14764 | .13734 | .15920 | .14630 | .17137 | 23 |
| 24 | .12035 | .13682 | .12879 | .14782 | .13749 | .15940 | .14645 | .17158 | 24 |
| 25 | .12049 | .13700 | .12893 | .14801 | .13763 | .15960 | .14660 | .17178 | 25 |
| 26 | .12063 | .13718 | .12907 | .14820 | .13778 | .15980 | .14675 | .17199 | 26 |
| 27 | .12077 | .13735 | .12921 | .14839 | .13793 | .16000 | .14690 | .17220 | 27 |
| 28 | .12091 | .13753 | .12936 | .14858 | .13808 | .16019 | .14706 | .17241 | 28 |
| 29 | .12104 | .13771 | .12950 | .14877 | .13822 | .16039 | .14721 | .17262 | 29 |
| 30 | .12118 | .13789 | .12964 | .14896 | .13837 | .16059 | .14736 | .17283 | 30 |
| 31 | .12132 | .13807 | .12979 | .14914 | .13852 | .16079 | .14751 | .17304 | 31 |
| 32 | .12146 | .13825 | .12993 | .14933 | .13867 | .16099 | .14766 | .17325 | 32 |
| 33 | .12160 | .13843 | .13007 | .14952 | .13881 | .16119 | .14782 | .17346 | 33 |
| 34 | .12174 | .13861 | .13022 | .14971 | .13896 | .16139 | .14797 | .17367 | 34 |
| 35 | .12188 | .13879 | .13036 | .14990 | .13911 | .16159 | .14812 | .17388 | 35 |
| 36 | .12202 | .13897 | .13051 | .15009 | .13926 | .16179 | .14827 | .17409 | 36 |
| 37 | .12216 | .13916 | .13065 | .15028 | .13941 | .16199 | .14843 | .17430 | 37 |
| 38 | .12230 | .13934 | .13079 | .15047 | .13955 | .16219 | .14858 | .17451 | 38 |
| 39 | .12244 | .13952 | .13094 | .15066 | .13970 | .16239 | .14873 | .17472 | 39 |
| 40 | .12257 | .13970 | .13108 | .15085 | .13985 | .16259 | .14888 | .17493 | 40 |
| 41 | .12271 | .13988 | .13122 | .15105 | .14000 | .16279 | .14904 | .17514 | 41 |
| 42 | .12285 | .14006 | .13137 | .15124 | .14015 | .16299 | .14919 | .17535 | 42 |
| 43 | .12299 | .14024 | .13151 | .15143 | .14030 | .16319 | .14934 | .17556 | 43 |
| 44 | .12313 | .14042 | .13166 | .15162 | .14044 | .16339 | .14949 | .17577 | 44 |
| 45 | .12327 | .14061 | .13180 | .15181 | .14059 | .16359 | .14965 | .17598 | 45 |
| 46 | .12341 | .14079 | .13195 | .15200 | .14074 | .16380 | .14980 | .17620 | 46 |
| 47 | .12355 | .14097 | .13209 | .15219 | .14089 | .16400 | .14995 | .17641 | 47 |
| 48 | .12369 | .14115 | .13223 | .15239 | .14104 | .16420 | .15011 | .17662 | 48 |
| 49 | .12383 | .14134 | .13238 | .15258 | .14119 | .16440 | .15026 | .17683 | 49 |
| 50 | .12397 | .14152 | .13252 | .15277 | .14134 | .16460 | .15041 | .17704 | 50 |
| 51 | .12411 | .14170 | .13267 | .15296 | .14149 | .16481 | .15057 | .17726 | 51 |
| 52 | .12425 | .14188 | .13281 | .15315 | .14164 | .16501 | .15072 | .17747 | 52 |
| 53 | .12439 | .14207 | .13296 | .15335 | .14179 | .16521 | .15087 | .17768 | 53 |
| 54 | .12454 | .14225 | .13310 | .15354 | .14194 | .16541 | .15103 | .17790 | 54 |
| 55 | .12468 | .14243 | .13325 | .15373 | .14208 | .16562 | .15118 | .17811 | 55 |
| 56 | .12482 | .14262 | .13339 | .15393 | .14223 | .16582 | .15134 | .17832 | 56 |
| 57 | .12496 | .14280 | .13354 | .15412 | .14238 | .16602 | .15149 | .17854 | 57 |
| 58 | .12510 | .14299 | .13368 | .15431 | .14253 | .16623 | .15164 | .17875 | 58 |
| 59 | .12524 | .14317 | .13383 | .15451 | .14268 | .16643 | .15180 | .17896 | 59 |
| 60 | .12538 | .14335 | .13397 | .15470 | .14283 | .16663 | .15195 | .17918 | 60 |

| ′ | 32° Vers. | 32° Ex. sec. | 33° Vers. | 33° Ex. sec. | 34° Vers. | 34° Ex. sec. | 35° Vers. | 35° Ex. sec. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .15195 | .17918 | .16133 | .19236 | .17096 | .20622 | .18085 | .22077 | 0 |
| 1 | .15211 | .17939 | .16149 | .19259 | .17113 | .20645 | .18101 | .22102 | 1 |
| 2 | .15226 | .17961 | .16165 | .19281 | .17129 | .20669 | .18118 | .22127 | 2 |
| 3 | .15241 | .17982 | .16181 | .19304 | .17145 | .20693 | .18135 | .22152 | 3 |
| 4 | .15257 | .18004 | .16196 | .19327 | .17161 | .20717 | .18152 | .22177 | 4 |
| 5 | .15272 | .18025 | .16212 | .19349 | .17178 | .20740 | .18168 | .22202 | 5 |
| 6 | .15288 | .18047 | .16228 | .19372 | .17194 | .20764 | .18185 | .22227 | 6 |
| 7 | .15303 | .18068 | .16244 | .19394 | .17210 | .20788 | .18202 | .22252 | 7 |
| 8 | .15319 | .18090 | .16260 | .19417 | .17227 | .20812 | .18218 | .22277 | 8 |
| 9 | .15334 | .18111 | .16276 | .19440 | .17243 | .20836 | .18235 | .22302 | 9 |
| 10 | .15350 | .18133 | .16292 | .19463 | .17259 | .20859 | .18252 | .22327 | 10 |
| 11 | .15365 | .18155 | .16308 | .19485 | .17276 | .20883 | .18269 | .22352 | 11 |
| 12 | .15381 | .18176 | .16324 | .19508 | .17292 | .20907 | .18286 | .22377 | 12 |
| 13 | .15396 | .18198 | .16340 | .19531 | .17308 | .20931 | .18302 | .22402 | 13 |
| 14 | .15412 | .18220 | .16355 | .19554 | .17325 | .20955 | .18319 | .22428 | 14 |
| 15 | .15427 | .18241 | .16371 | .19576 | .17341 | .20979 | .18336 | .22453 | 15 |
| 16 | .15443 | .18263 | .16387 | .19599 | .17357 | .21003 | .18353 | .22478 | 16 |
| 17 | .15458 | .18285 | .16403 | .19622 | .17374 | .21027 | .18369 | .22503 | 17 |
| 18 | .15474 | .18307 | .16419 | .19645 | .17390 | .21051 | .18386 | .22528 | 18 |
| 19 | .15489 | .18328 | .16435 | .19668 | .17407 | .21075 | .18403 | .22554 | 19 |
| 20 | .15505 | .18350 | .16451 | .19691 | .17423 | .21099 | .18420 | .22579 | 20 |
| 21 | .15520 | .18372 | .16467 | .19713 | .17439 | .21123 | .18437 | .22604 | 21 |
| 22 | .15536 | .18394 | .16483 | .19736 | .17456 | .21147 | .18454 | .22629 | 22 |
| 23 | .15552 | .18416 | .16499 | .19759 | .17472 | .21171 | .18470 | .22655 | 23 |
| 24 | .15567 | .18437 | .16515 | .19782 | .17489 | .21195 | .18487 | .22680 | 24 |
| 25 | .15583 | .18459 | .16531 | .19805 | .17505 | .21220 | .18504 | .22706 | 25 |
| 26 | .15598 | .18481 | .16547 | .19828 | .17522 | .21244 | .18521 | .22731 | 26 |
| 27 | .15614 | .18503 | .16563 | .19851 | .17538 | .21268 | .18538 | .22756 | 27 |
| 28 | .15630 | .18525 | .16579 | .19874 | .17554 | .21292 | .18555 | .22782 | 28 |
| 29 | .15645 | .18547 | .16595 | .19897 | .17571 | .21316 | .18572 | .22807 | 29 |
| 30 | .15661 | .18569 | .16611 | .19920 | .17587 | .21341 | .18588 | .22833 | 30 |
| 31 | .15676 | .18591 | .16627 | .19944 | .17604 | .21365 | .18605 | .22858 | 31 |
| 32 | .15692 | .18613 | .16644 | .19967 | .17620 | .21389 | .18622 | .22884 | 32 |
| 33 | .15708 | .18635 | .16660 | .19990 | .17637 | .21414 | .18639 | .22909 | 33 |
| 34 | .15723 | .18657 | .16676 | .20013 | .17653 | .21438 | .18656 | .22935 | 34 |
| 35 | .15739 | .18679 | .16692 | .20036 | .17670 | .21462 | .18673 | .22960 | 35 |
| 36 | .15755 | .18701 | .16708 | .20059 | .17686 | .21487 | .18690 | .22986 | 36 |
| 37 | .15770 | .18723 | .16724 | .20083 | .17703 | .21511 | .18707 | .23012 | 37 |
| 38 | .15786 | .18745 | .16740 | .20106 | .17719 | .21535 | .18724 | .23037 | 38 |
| 39 | .15802 | .18767 | .16756 | .20129 | .17736 | .21560 | .18741 | .23063 | 39 |
| 40 | .15818 | .18790 | .16772 | .20152 | .17752 | .21584 | .18758 | .23089 | 40 |
| 41 | .15833 | .18812 | .16788 | .20176 | .17769 | .21609 | .18775 | .23114 | 41 |
| 42 | .15849 | .18834 | .16805 | .20199 | .17786 | .21633 | .18792 | .23140 | 42 |
| 43 | .15865 | .18856 | .16821 | .20222 | .17802 | .21658 | .18809 | .23166 | 43 |
| 44 | .15880 | .18878 | .16837 | .20246 | .17819 | .21682 | .18826 | .23192 | 44 |
| 45 | .15896 | .18901 | .16853 | .20269 | .17835 | .21707 | .18843 | .23217 | 45 |
| 46 | .15912 | .18923 | .16869 | .20292 | .17852 | .21731 | .18860 | .23243 | 46 |
| 47 | .15928 | .18945 | .16885 | .20316 | .17868 | .21756 | .18877 | .23269 | 47 |
| 48 | .15943 | .18967 | .16902 | .20339 | .17885 | .21781 | .18894 | .23295 | 48 |
| 49 | .15959 | .18990 | .16918 | .20363 | .17902 | .21805 | .18911 | .23321 | 49 |
| 50 | .15975 | .19012 | .16934 | .20386 | .17918 | .21830 | .18928 | .23347 | 50 |
| 51 | .15991 | .19034 | .16950 | .20410 | .17935 | .21855 | .18945 | .23373 | 51 |
| 52 | .16006 | .19057 | .16966 | .20433 | .17952 | .21879 | .18962 | .23399 | 52 |
| 53 | .16022 | .19079 | .16983 | .20457 | .17968 | .21904 | .18979 | .23424 | 53 |
| 54 | .16038 | .19102 | .16999 | .20480 | .17985 | .21929 | .18996 | .23450 | 54 |
| 55 | .16054 | .19124 | .17015 | .20504 | .18001 | .21953 | .19013 | .23476 | 55 |
| 56 | .16070 | .19146 | .17031 | .20527 | .18018 | .21978 | .19030 | .23502 | 56 |
| 57 | .16085 | .19169 | .17047 | .20551 | .18035 | .22003 | .19047 | .23529 | 57 |
| 58 | .16101 | .19191 | .17064 | .20575 | .18051 | .22028 | .19064 | .23555 | 58 |
| 59 | .16117 | .19214 | .17080 | .20598 | .18068 | .22053 | .19081 | .23581 | 59 |
| 60 | .16133 | .19236 | .17096 | .20622 | .18085 | .22077 | .19098 | .23607 | 60 |

| ′ | 36° | | 37° | | 38° | | 39° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .19098 | .23607 | .20136 | .25214 | .21199 | .26902 | .22285 | .28676 | 0 |
| 1 | .19115 | .23633 | .20154 | .25241 | .21217 | .26931 | .22304 | .28706 | 1 |
| 2 | .19133 | .23659 | .20171 | .25269 | .21235 | .26960 | .22322 | .28737 | 2 |
| 3 | .19150 | .23685 | .20189 | .25296 | .21253 | .26988 | .22340 | .28767 | 3 |
| 4 | .19167 | .23711 | .20207 | .25324 | .21271 | .27017 | .22359 | .28797 | 4 |
| 5 | .19184 | .23738 | .20224 | .25351 | .21289 | .27046 | .22377 | .28828 | 5 |
| 6 | .19201 | .23764 | .20242 | .25379 | .21307 | .27075 | .22395 | .28858 | 6 |
| 7 | .19218 | .23790 | .20259 | .25406 | .21324 | .27104 | .22414 | .28889 | 7 |
| 8 | .19235 | .23816 | .20277 | .25434 | .21342 | .27133 | .22432 | .28919 | 8 |
| 9 | .19252 | .23843 | .20294 | .25462 | .21360 | .27162 | .22450 | .28950 | 9 |
| 10 | .19270 | .23869 | .20312 | .25489 | .21378 | .27191 | .22469 | .28980 | 10 |
| 11 | .19287 | .23895 | .20329 | .25517 | .21396 | .27221 | .22487 | .29011 | 11 |
| 12 | .19304 | .23922 | .20347 | .25545 | .21414 | .27250 | .22506 | .29042 | 12 |
| 13 | .19321 | .23948 | .20365 | .25572 | .21432 | .27279 | .22524 | .29072 | 13 |
| 14 | .19338 | .23975 | .20382 | .25600 | .21450 | .27308 | .22542 | .29103 | 14 |
| 15 | .19356 | .24001 | .20400 | .25628 | .21468 | .27337 | .22561 | .29133 | 15 |
| 16 | .19373 | .24028 | .20417 | .25656 | .21486 | .27366 | .22579 | .29164 | 16 |
| 17 | .19390 | .24054 | .20435 | .25683 | .21504 | .27396 | .22598 | .29195 | 17 |
| 18 | .19407 | .24081 | .20453 | .25711 | .21522 | .27425 | .22616 | .29226 | 18 |
| 19 | .19424 | .24107 | .20470 | .25739 | .21540 | .27454 | .22634 | .29256 | 19 |
| 20 | .19442 | .24134 | .20488 | .25767 | .21558 | .27483 | .22653 | .29287 | 20 |
| 21 | .19459 | .24160 | .20506 | .25795 | .21576 | .27513 | .22671 | .29318 | 21 |
| 22 | .19476 | .24187 | .20523 | .25823 | .21595 | .27542 | .22690 | .29349 | 22 |
| 23 | .19493 | .24213 | .20541 | .25851 | .21613 | .27572 | .22708 | .29380 | 23 |
| 24 | .19511 | .24240 | .20559 | .25879 | .21631 | .27601 | .22727 | .29411 | 24 |
| 25 | .19528 | .24267 | .20576 | .25907 | .21649 | .27630 | .22745 | .29442 | 25 |
| 26 | .19545 | .24293 | .20594 | .25935 | .21667 | .27660 | .22764 | .29473 | 26 |
| 27 | .19562 | .24320 | .20612 | .25963 | .21685 | .27689 | .22782 | .29504 | 27 |
| 28 | .19580 | .24347 | .20629 | .25991 | .21703 | .27719 | .22801 | .29535 | 28 |
| 29 | .19597 | .24373 | .20647 | .26019 | .21721 | .27748 | .22819 | .29566 | 29 |
| 30 | .19614 | .24400 | .20665 | .26047 | .21739 | .27778 | .22838 | .29597 | 30 |
| 31 | .19632 | .24427 | .20682 | .26075 | .21757 | .27807 | .22856 | .29628 | 31 |
| 32 | .19649 | .24454 | .20700 | .26104 | .21775 | .27837 | .22875 | .29659 | 32 |
| 33 | .19666 | .24481 | .20718 | .26132 | .21794 | .27867 | .22893 | .29690 | 33 |
| 34 | .19684 | .24508 | .20736 | .26160 | .21812 | .27896 | .22912 | .29721 | 34 |
| 35 | .19701 | .24534 | .20753 | .26188 | .21830 | .27926 | .22930 | .29752 | 35 |
| 36 | .19718 | .24561 | .20771 | .26216 | .21848 | .27956 | .22949 | .29784 | 36 |
| 37 | .19736 | .24588 | .20789 | .26245 | .21866 | .27985 | .22967 | .29815 | 37 |
| 38 | .19753 | .24615 | .20807 | .26273 | .21884 | .28015 | .22986 | .29846 | 38 |
| 39 | .19770 | .24642 | .20824 | .26301 | .21902 | .28045 | .23004 | .29877 | 39 |
| 40 | .19788 | .24669 | .20842 | .26330 | .21921 | .28075 | .23023 | .29909 | 40 |
| 41 | .19805 | .24696 | .20860 | .26358 | .21939 | .28105 | .23041 | .29940 | 41 |
| 42 | .19822 | .24723 | .20878 | .26387 | .21957 | .28134 | .23060 | .29971 | 42 |
| 43 | .19840 | .24750 | .20895 | .26415 | .21975 | .28164 | .23079 | .30003 | 43 |
| 44 | .19857 | .24777 | .20913 | .26443 | .21993 | .28194 | .23097 | .30034 | 44 |
| 45 | .19875 | .24804 | .20931 | .26472 | .22012 | .28224 | .23116 | .30066 | 45 |
| 46 | .19892 | .24832 | .20949 | .26500 | .22030 | .28254 | .23134 | .30097 | 46 |
| 47 | .19909 | .24859 | .20967 | .26529 | .22048 | .28284 | .23153 | .30129 | 47 |
| 48 | .19927 | .24886 | .20985 | .26557 | .22066 | .28314 | .23172 | .30160 | 48 |
| 49 | .19944 | .24913 | .21002 | .26586 | .22084 | .28344 | .23190 | .30192 | 49 |
| 50 | .19962 | .24940 | .21020 | .26615 | .22103 | .28374 | .23209 | .30223 | 50 |
| 51 | .19979 | .24967 | .21038 | .26643 | .22121 | .28404 | .23228 | .30255 | 51 |
| 52 | .19997 | .24995 | .21056 | .26672 | .22139 | .28434 | .23246 | .30287 | 52 |
| 53 | .20014 | .25022 | .21074 | .26701 | .22157 | .28464 | .23265 | .30318 | 53 |
| 54 | .20032 | .25049 | .21092 | .26729 | .22176 | .28495 | .23283 | .30350 | 54 |
| 55 | .20049 | .25077 | .21109 | .26758 | .22194 | .28525 | .23302 | .30382 | 55 |
| 56 | .20066 | .25104 | .21127 | .26787 | .22212 | .28555 | .23321 | .30413 | 56 |
| 57 | .20084 | .25131 | .21145 | .26815 | .22231 | .28585 | .23339 | .30445 | 57 |
| 58 | .20101 | .25159 | .21163 | .26844 | .22249 | .28615 | .23358 | .30477 | 58 |
| 59 | .20119 | .25186 | .21181 | .26873 | .22267 | .28646 | .23377 | .30509 | 59 |
| 60 | .20136 | .25214 | .21199 | .26902 | .22285 | .28676 | .23396 | .30541 | 60 |

| ′ | 40° | | 41° | | 42° | | 43° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .23396 | .30541 | .24529 | .32501 | .25686 | .34563 | .26865 | .36733 | 0 |
| 1 | .23414 | .30573 | .24548 | .32535 | .25705 | .34599 | .26884 | .36770 | 1 |
| 2 | .23433 | .30605 | .24567 | .32568 | .25724 | .34634 | .26904 | .36807 | 2 |
| 3 | .23452 | .30636 | .24586 | .32602 | .25744 | .34669 | .26924 | .36844 | 3 |
| 4 | .23470 | .30668 | .24605 | .32636 | .25763 | .34704 | .26944 | .36881 | 4 |
| 5 | .23489 | .30700 | .24625 | .32669 | .25783 | .34740 | .26964 | .36919 | 5 |
| 6 | .23508 | .30732 | .24644 | .32703 | .25802 | .34775 | .26984 | .36956 | 6 |
| 7 | .23527 | .30764 | .24663 | .32737 | .25822 | .34811 | .27004 | .36993 | 7 |
| 8 | .23545 | .30796 | .24682 | .32770 | .25841 | .34846 | .27024 | .37030 | 8 |
| 9 | .23564 | .30829 | .24701 | .32804 | .25861 | .34882 | .27043 | .37068 | 9 |
| 10 | .23583 | .30861 | .24720 | .32838 | .25880 | .34917 | .27063 | .37105 | 10 |
| 11 | .23602 | .30893 | .24739 | .32872 | .25900 | .34953 | .27083 | .37143 | 11 |
| 12 | .23620 | .30925 | .24759 | .32905 | .25920 | .34988 | .27103 | .37180 | 12 |
| 13 | .23639 | .30957 | .24778 | .32939 | .25939 | .35024 | .27123 | .37218 | 13 |
| 14 | .23658 | .30989 | .24797 | .32973 | .25959 | .35060 | .27143 | .37255 | 14 |
| 15 | .23677 | .31022 | .24816 | .33007 | .25978 | .35095 | .27163 | .37293 | 15 |
| 16 | .23696 | .31054 | .24835 | .33041 | .25998 | .35131 | .27183 | .37330 | 16 |
| 17 | .23714 | .31086 | .24854 | .33075 | .26017 | .35167 | .27203 | .37368 | 17 |
| 18 | .23733 | .31119 | .24874 | .33109 | .26037 | .35203 | .27223 | .37406 | 18 |
| 19 | .23752 | .31151 | .24893 | .33143 | .26056 | .35238 | .27243 | .37443 | 19 |
| 20 | .23771 | .31183 | .24912 | .33177 | .26076 | .35274 | .27263 | .37481 | 20 |
| 21 | .23790 | .31216 | .24931 | .33211 | .26096 | .35310 | .27283 | .37519 | 21 |
| 22 | .23808 | .31248 | .24950 | .33245 | .26115 | .35346 | .27303 | .37556 | 22 |
| 23 | .23827 | .31281 | .24970 | .33279 | .26135 | .35382 | .27323 | .37594 | 23 |
| 24 | .23846 | .31313 | .24989 | .33314 | .26154 | .35418 | .27343 | .37632 | 24 |
| 25 | .23865 | .31346 | .25008 | .33348 | .26174 | .35454 | .27363 | .37670 | 25 |
| 26 | .23884 | .31378 | .25027 | .33382 | .26194 | .35490 | .27383 | .37708 | 26 |
| 27 | .23903 | .31411 | .25047 | .33416 | .26213 | .35526 | .27403 | .37746 | 27 |
| 28 | .23922 | .31443 | .25066 | .33451 | .26233 | .35562 | .27423 | .37784 | 28 |
| 29 | .23941 | .31476 | .25085 | .33485 | .26253 | .35598 | .27443 | .37822 | 29 |
| 30 | .23959 | .31509 | .25104 | .33519 | .26272 | .35634 | .27463 | .37860 | 30 |
| 31 | .23978 | .31541 | .25124 | .33554 | .26292 | .35670 | .27483 | .37898 | 31 |
| 32 | .23997 | .31574 | .25143 | .33588 | .26312 | .35707 | .27503 | .37936 | 32 |
| 33 | .24016 | .31607 | .25162 | .33622 | .26331 | .35743 | .27523 | .37974 | 33 |
| 34 | .24035 | .31640 | .25182 | .33657 | .26351 | .35779 | .27543 | .38012 | 34 |
| 35 | .24054 | .31672 | .25201 | .33691 | .26371 | .35815 | .27563 | .38051 | 35 |
| 36 | .24073 | .31705 | .25220 | .33726 | .26390 | .35852 | .27583 | .38089 | 36 |
| 37 | .24092 | .31738 | .25240 | .33760 | .26410 | .35888 | .27603 | .38127 | 37 |
| 38 | .24111 | .31771 | .25259 | .33795 | .26430 | .35924 | .27623 | .38165 | 38 |
| 39 | .24130 | .31804 | .25278 | .33830 | .26449 | .35961 | .27643 | .38204 | 39 |
| 40 | .24149 | .31837 | .25297 | .33864 | .26469 | .35997 | .27663 | .38242 | 40 |
| 41 | .24168 | .31870 | .25317 | .33899 | .26489 | .36034 | .27683 | .38280 | 41 |
| 42 | .24187 | .31903 | .25336 | .33934 | .26509 | .36070 | .27703 | .38319 | 42 |
| 43 | .24206 | .31936 | .25356 | .33968 | .26528 | .36107 | .27723 | .38357 | 43 |
| 44 | .24225 | .31969 | .25375 | .34003 | .26548 | .36143 | .27743 | .38396 | 44 |
| 45 | .24244 | .32002 | .25394 | .34038 | .26568 | .36180 | .27764 | .38434 | 45 |
| 46 | .24262 | .32035 | .25414 | .34073 | .26588 | .36217 | .27784 | .38473 | 46 |
| 47 | .24281 | .32068 | .25433 | .34108 | .26607 | .36253 | .27804 | .38512 | 47 |
| 48 | .24300 | .32101 | .25452 | .34142 | .26627 | .36290 | .27824 | .38550 | 48 |
| 49 | .24320 | .32134 | .25472 | .34177 | .26647 | .36327 | .27844 | .38589 | 49 |
| 50 | .24339 | .32168 | .25491 | .34212 | .26667 | .36363 | .27864 | .38628 | 50 |
| 51 | .24358 | .32201 | .25511 | .34247 | .26686 | .36400 | .27884 | .38666 | 51 |
| 52 | .24377 | .32234 | .25530 | .34282 | .26706 | .36437 | .27905 | .38705 | 52 |
| 53 | .24396 | .32267 | .25549 | .34317 | .26726 | .36474 | .27925 | .38744 | 53 |
| 54 | .24415 | .32301 | .25569 | .34352 | .26746 | .36511 | .27945 | .38783 | 54 |
| 55 | .24434 | .32334 | .25588 | .34387 | .26766 | .36548 | .27965 | .38822 | 55 |
| 56 | .24453 | .32368 | .25608 | .34423 | .26785 | .36585 | .27985 | .38860 | 56 |
| 57 | .24472 | .32401 | .25627 | .34458 | .26805 | .36622 | .28005 | .38899 | 57 |
| 58 | .24491 | .32434 | .25647 | .34493 | .26825 | .36659 | .28026 | .38938 | 58 |
| 59 | .24510 | .32468 | .25666 | .34528 | .26845 | .36696 | .28046 | .38977 | 59 |
| 60 | .24529 | .32501 | .25686 | .34563 | .26865 | .36733 | .28066 | .39016 | 60 |

| ′ | 44° Vers. | 44° Ex. sec. | 45° Vers. | 45° Ex. sec. | 46° Vers. | 46° Ex. sec. | 47° Vers. | 47° Ex. sec. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .28066 | .39016 | .29289 | .41421 | .30534 | .43956 | .31800 | .46628 | 0 |
| 1 | .28086 | .39055 | .29310 | .41463 | .30555 | .43999 | .31821 | .46674 | 1 |
| 2 | .28106 | .39095 | .29330 | .41504 | .30576 | .44042 | .31843 | .46719 | 2 |
| 3 | .28127 | .39134 | .29351 | .41545 | .30597 | .44086 | .31864 | .46765 | 3 |
| 4 | .28147 | .39173 | .29372 | .41586 | .30618 | .44129 | .31885 | .46811 | 4 |
| 5 | .28167 | .39212 | .29392 | .41627 | .30639 | .44173 | .31907 | .46857 | 5 |
| 6 | .28187 | .39251 | .29413 | .41669 | .30660 | .44217 | .31928 | .46903 | 6 |
| 7 | .28208 | .39291 | .29433 | .41710 | .30681 | .44260 | .31949 | .46949 | 7 |
| 8 | .28228 | .39330 | .29454 | .41752 | .30702 | .44304 | .31971 | .46995 | 8 |
| 9 | .28248 | .39369 | .29475 | .41793 | .30723 | .44347 | .31992 | .47041 | 9 |
| 10 | .28268 | .39409 | .29495 | .41835 | .30744 | .44391 | .32013 | .47087 | 10 |
| 11 | .28289 | .39448 | .29516 | .41876 | .30765 | .44435 | .32035 | .47134 | 11 |
| 12 | .28309 | .39487 | .29537 | .41918 | .30786 | .44479 | .32056 | .47180 | 12 |
| 13 | .28329 | .39527 | .29557 | .41959 | .30807 | .44523 | .32077 | .47226 | 13 |
| 14 | .28350 | .39566 | .29578 | .42001 | .30828 | .44567 | .32099 | .47272 | 14 |
| 15 | .28370 | .39606 | .29599 | .42042 | .30849 | .44610 | .32120 | .47319 | 15 |
| 16 | .28390 | .39646 | .29619 | .42084 | .30870 | .44654 | .32141 | .47365 | 16 |
| 17 | .28410 | .39685 | .29640 | .42126 | .30891 | .44698 | .32163 | .47411 | 17 |
| 18 | .28431 | .39725 | .29661 | .42168 | .30912 | .44742 | .32184 | .47458 | 18 |
| 19 | .28451 | .39764 | .29681 | .42210 | .30933 | .44787 | .32205 | .47504 | 19 |
| 20 | .28471 | .39804 | .29702 | .42251 | .30954 | .44831 | .32227 | .47551 | 20 |
| 21 | .28492 | .39844 | .29723 | .42293 | .30975 | .44875 | .32248 | .47598 | 21 |
| 22 | .28512 | .39884 | .29743 | .42335 | .30996 | .44919 | .32270 | .47644 | 22 |
| 23 | .28532 | .39924 | .29764 | .42377 | .31017 | .44963 | .32291 | .47691 | 23 |
| 24 | .28553 | .39963 | .29785 | .42419 | .31038 | .45007 | .32312 | .47738 | 24 |
| 25 | .28573 | .40003 | .29805 | .42461 | .31059 | .45052 | .32334 | .47784 | 25 |
| 26 | .28593 | .40043 | .29826 | .42503 | .31080 | .45096 | .32355 | .47831 | 26 |
| 27 | .28614 | .40083 | .29847 | .42545 | .31101 | .45141 | .32377 | .47878 | 27 |
| 28 | .28634 | .40123 | .29868 | .42587 | .31122 | .45185 | .32398 | .47925 | 28 |
| 29 | .28655 | .40163 | .29888 | .42630 | .31143 | .45229 | .32420 | .47972 | 29 |
| 30 | .28675 | .40203 | .29909 | .42672 | .31165 | .45274 | .32441 | .48019 | 30 |
| 31 | .28695 | .40243 | .29930 | .42714 | .31186 | .45319 | .32462 | .48066 | 31 |
| 32 | .28716 | .40283 | .29951 | .42756 | .31207 | .45363 | .32484 | .48113 | 32 |
| 33 | .28736 | .40324 | .29971 | .42799 | .31228 | .45408 | .32505 | .48160 | 33 |
| 34 | .28757 | .40364 | .29992 | .42841 | .31249 | .45452 | .32527 | .48207 | 34 |
| 35 | .28777 | .40404 | .30013 | .42883 | .31270 | .45497 | .32548 | .48254 | 35 |
| 36 | .28797 | .40444 | .30034 | .42926 | .31291 | .45542 | .32570 | .48301 | 36 |
| 37 | .28818 | .40485 | .30054 | .42968 | .31312 | .45587 | .32591 | .48349 | 37 |
| 38 | .28838 | .40525 | .30075 | .43011 | .31334 | .45631 | .32613 | .48396 | 38 |
| 39 | .28859 | .40565 | .30096 | .43053 | .31355 | .45676 | .32634 | .48443 | 39 |
| 40 | .28879 | .40606 | .30117 | .43096 | .31376 | .45721 | .32656 | .48491 | 40 |
| 41 | .28900 | .40646 | .30138 | .43139 | .31397 | .45766 | .32677 | .48538 | 41 |
| 42 | .28920 | .40687 | .30158 | .43181 | .31418 | .45811 | .32699 | .48586 | 42 |
| 43 | .28941 | .40727 | .30179 | .43224 | .31439 | .45856 | .32720 | .48633 | 43 |
| 44 | .28961 | .40768 | .30200 | .43267 | .31461 | .45901 | .32742 | .48681 | 44 |
| 45 | .28981 | .40808 | .30221 | .43310 | .31482 | .45946 | .32763 | .48728 | 45 |
| 46 | .29002 | .40849 | .30242 | .43352 | .31503 | .45992 | .32785 | .48776 | 46 |
| 47 | .29022 | .40890 | .30263 | .43395 | .31524 | .46037 | .32806 | .48824 | 47 |
| 48 | .29043 | .40930 | .30283 | .43438 | .31545 | .46082 | .32828 | .48871 | 48 |
| 49 | .29063 | .40971 | .30304 | .43481 | .31567 | .46127 | .32849 | .48919 | 49 |
| 50 | .29084 | .41012 | .30325 | .43524 | .31588 | .46173 | .32871 | .48967 | 50 |
| 51 | .29104 | .41053 | .30346 | .43567 | .31609 | .46218 | .32893 | .49015 | 51 |
| 52 | .29125 | .41093 | .30367 | .43610 | .31630 | .46263 | .32914 | .49063 | 52 |
| 53 | .29145 | .41134 | .30388 | .43653 | .31651 | .46309 | .32936 | .49111 | 53 |
| 54 | .29166 | .41175 | .30409 | .43696 | .31673 | .46354 | .32957 | .49159 | 54 |
| 55 | .29187 | .41216 | .30430 | .43739 | .31694 | .46400 | .32979 | .49207 | 55 |
| 56 | .29207 | .41257 | .30451 | .43783 | .31715 | .46445 | .33001 | .49255 | 56 |
| 57 | .29228 | .41298 | .30471 | .43826 | .31736 | .46491 | .33022 | .49303 | 57 |
| 58 | .29248 | .41339 | .30492 | .43869 | .31758 | .46537 | .33044 | .49351 | 58 |
| 59 | .29269 | .41380 | .30513 | .43912 | .31779 | .46582 | .33065 | .49399 | 59 |
| 60 | .29289 | .41421 | .30534 | .43956 | .31800 | .46628 | .33087 | .49448 | 60 |

| ′ | 48° Vers. | 48° Ex. sec. | 49° Vers. | 49° Ex. sec. | 50° Vers. | 50° Ex. sec. | 51° Vers. | 51° Ex. sec. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .33087 | .49448 | .34394 | .52425 | .35721 | .55572 | .37068 | .58902 | 0 |
| 1 | .33109 | .49496 | .34416 | .52476 | .35744 | .55626 | .37091 | .58959 | 1 |
| 2 | .33130 | .49544 | .34438 | .52527 | .35766 | .55680 | .37113 | .59016 | 2 |
| 3 | .33152 | .49593 | .34460 | .52579 | .35788 | .55734 | .37136 | .59073 | 3 |
| 4 | .33173 | .49641 | .34482 | .52630 | .35810 | .55789 | .37158 | .59130 | 4 |
| 5 | .33195 | .49690 | .34504 | .52681 | .35833 | .55843 | .37181 | .59188 | 5 |
| 6 | .33217 | .49738 | .34526 | .52732 | .35855 | .55897 | .37204 | .59245 | 6 |
| 7 | .33238 | .49787 | .34548 | .52784 | .35877 | .55951 | .37226 | .59302 | 7 |
| 8 | .33260 | .49835 | .34570 | .52835 | .35900 | .56005 | .37249 | .59360 | 8 |
| 9 | .33282 | .49884 | .34592 | .52886 | .35922 | .56060 | .37272 | .59418 | 9 |
| 10 | .33303 | .49933 | .34614 | .52938 | .35944 | .56114 | .37294 | .59475 | 10 |
| 11 | .33325 | .49981 | .34636 | .52989 | .35967 | .56169 | .37317 | .59533 | 11 |
| 12 | .33347 | .50030 | .34658 | .53041 | .35989 | .56223 | .37340 | .59590 | 12 |
| 13 | .33368 | .50079 | .34680 | .53092 | .36011 | .56278 | .37362 | .59648 | 13 |
| 14 | .33390 | .50128 | .34702 | .53144 | .36034 | .56332 | .37385 | .59706 | 14 |
| 15 | .33412 | .50177 | .34724 | .53196 | .36056 | .56387 | .37408 | .59764 | 15 |
| 16 | .33434 | .50226 | .34746 | .53247 | .36078 | .56442 | .37430 | .59822 | 16 |
| 17 | .33455 | .50275 | .34768 | .53299 | .36101 | .56497 | .37453 | .59880 | 17 |
| 18 | .33477 | .50324 | .34790 | .53351 | .36123 | .56551 | .37476 | .59938 | 18 |
| 19 | .33499 | .50373 | .34812 | .53403 | .36146 | .56606 | .37498 | .59996 | 19 |
| 20 | .33520 | .50422 | .34834 | .53455 | .36168 | .56661 | .37521 | .60054 | 20 |
| 21 | .33542 | .50471 | .34856 | .53507 | .36190 | .56716 | .37544 | .60112 | 21 |
| 22 | .33564 | .50521 | .34878 | .53559 | .36213 | .56771 | .37567 | .60171 | 22 |
| 23 | .33586 | .50570 | .34900 | .53611 | .36235 | .56826 | .37589 | .60229 | 23 |
| 24 | .33607 | .50619 | .34923 | .53663 | .36258 | .56881 | .37612 | .60287 | 24 |
| 25 | .33629 | .50669 | .34945 | .53715 | .36280 | .56937 | .37635 | .60346 | 25 |
| 26 | .33651 | .50718 | .34967 | .53768 | .36302 | .56992 | .37658 | .60404 | 26 |
| 27 | .33673 | .50767 | .34989 | .53820 | .36325 | .57047 | .37680 | .60463 | 27 |
| 28 | .33694 | .50817 | .35011 | .53872 | .36347 | .57103 | .37703 | .60521 | 28 |
| 29 | .33716 | .50866 | .35033 | .53924 | .36370 | .57158 | .37726 | .60580 | 29 |
| 30 | .33738 | .50916 | .35055 | .53977 | .36392 | .57213 | .37749 | .60639 | 30 |
| 31 | .33760 | .50966 | .35077 | .54029 | .36415 | .57269 | .37771 | .60698 | 31 |
| 32 | .33782 | .51015 | .35099 | .54082 | .36437 | .57324 | .37794 | .60756 | 32 |
| 33 | .33803 | .51065 | .35122 | .54134 | .36460 | .57380 | .37817 | .60815 | 33 |
| 34 | .33825 | .51115 | .35144 | .54187 | .36482 | .57436 | .37840 | .60874 | 34 |
| 35 | .33847 | .51165 | .35166 | .54240 | .36504 | .57491 | .37862 | .60933 | 35 |
| 36 | .33869 | .51215 | .35188 | .54292 | .36527 | .57547 | .37885 | .60992 | 36 |
| 37 | .33891 | .51265 | .35210 | .54345 | .36549 | .57603 | .37908 | .61051 | 37 |
| 38 | .33912 | .51314 | .35232 | .54398 | .36572 | .57659 | .37931 | .61111 | 38 |
| 39 | .33934 | .51364 | .35254 | .54451 | .36594 | .57715 | .37954 | .61170 | 39 |
| 40 | .33956 | .51415 | .35277 | .54504 | .36617 | .57771 | .37976 | .61229 | 40 |
| 41 | .33978 | .51465 | .35299 | .54557 | .36639 | .57827 | .37999 | .61288 | 41 |
| 42 | .34000 | .51515 | .35321 | .54610 | .36662 | .57883 | .38022 | .61348 | 42 |
| 43 | .34022 | .51565 | .35343 | .54663 | .36684 | .57939 | .38045 | .61407 | 43 |
| 44 | .34044 | .51615 | .35365 | .54716 | .36707 | .57995 | .38068 | .61467 | 44 |
| 45 | .34065 | .51665 | .35388 | .54769 | .36729 | .58051 | .38091 | .61526 | 45 |
| 46 | .34087 | .51716 | .35410 | .54822 | .36752 | .58108 | .38113 | .61586 | 46 |
| 47 | .34109 | .51766 | .35432 | .54876 | .36775 | .58164 | .38136 | .61646 | 47 |
| 48 | .34131 | .51817 | .35454 | .54929 | .36797 | .58221 | .38159 | .61705 | 48 |
| 49 | .34153 | .51867 | .35476 | .54982 | .36820 | .58277 | .38182 | .61765 | 49 |
| 50 | .34175 | .51918 | .35499 | .55036 | .36842 | .58333 | .38205 | .61825 | 50 |
| 51 | .34197 | .51968 | .35521 | .55089 | .36865 | .58390 | .38228 | .61885 | 51 |
| 52 | .34219 | .52019 | .35543 | .55143 | .36887 | .58447 | .38251 | .61945 | 52 |
| 53 | .34241 | .52069 | .35565 | .55196 | .36910 | .58503 | .38274 | .62005 | 53 |
| 54 | .34262 | .52120 | .35588 | .55250 | .36932 | .58560 | .38296 | .62065 | 54 |
| 55 | .34284 | .52171 | .35610 | .55303 | .36955 | .58617 | .38319 | .62125 | 55 |
| 56 | .34306 | .52222 | .35632 | .55357 | .36978 | .58674 | .38342 | .62185 | 56 |
| 57 | .34328 | .52273 | .35654 | .55411 | .37000 | .58731 | .38365 | .62246 | 57 |
| 58 | .34350 | .52323 | .35677 | .55465 | .37023 | .58788 | .38388 | .62306 | 58 |
| 59 | .34372 | .52374 | .35699 | .55518 | .37045 | .58845 | .38411 | .62366 | 59 |
| 60 | .34394 | .52425 | .35721 | .55572 | .37068 | .58902 | .38434 | .62427 | 60 |

TABLE XXIX.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

| ′ | 52° | | 53° | | 54° | | 55° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .38434 | .62427 | .39819 | .66164 | .41221 | .70130 | .42642 | .74345 | 0 |
| 1 | .38457 | .62487 | .39842 | .66228 | .41245 | .70198 | .42666 | .74417 | 1 |
| 2 | .38480 | .62548 | .39865 | .66292 | .41269 | .70267 | .42690 | .74490 | 2 |
| 3 | .38503 | .62609 | .39888 | .66357 | .41292 | .70335 | .42714 | .74562 | 3 |
| 4 | .38526 | .62669 | .39911 | .66421 | .41316 | .70403 | .42738 | .74635 | 4 |
| 5 | .38549 | .62730 | .39935 | .66486 | .41339 | .70472 | .42762 | .74708 | 5 |
| 6 | .38571 | .62791 | .39958 | .66550 | .41363 | .70540 | .42785 | .74781 | 6 |
| 7 | .38594 | .62852 | .39981 | .66615 | .41386 | .70609 | .42809 | .74854 | 7 |
| 8 | .38617 | .62913 | .40005 | .66679 | .41410 | .70677 | .42833 | .74927 | 8 |
| 9 | .38640 | .62974 | .40028 | .66744 | .41433 | .70746 | .42857 | .75000 | 9 |
| 10 | .38663 | .63035 | .40051 | .66809 | .41457 | .70815 | .42881 | .75073 | 10 |
| 11 | .38686 | .63096 | .40074 | .66873 | .41481 | .70884 | .42905 | .75146 | 11 |
| 12 | .38709 | .63157 | .40098 | .66938 | .41504 | .70953 | .42929 | .75219 | 12 |
| 13 | .38732 | .63218 | .40121 | .67003 | .41528 | .71022 | .42953 | .75293 | 13 |
| 14 | .38755 | .63279 | .40144 | .67068 | .41551 | .71091 | .42976 | .75366 | 14 |
| 15 | .38778 | .63341 | .40168 | .67133 | .41575 | .71160 | .43000 | .75440 | 15 |
| 16 | .38801 | .63402 | .40191 | .67199 | .41599 | .71229 | .43024 | .75513 | 16 |
| 17 | .38824 | .63464 | .40214 | .67264 | .41622 | .71298 | .43048 | .75587 | 17 |
| 18 | .38847 | .63525 | .40237 | .67329 | .41646 | .71368 | .43072 | .75661 | 18 |
| 19 | .38870 | .63587 | .40261 | .67394 | .41670 | .71437 | .43096 | .75734 | 19 |
| 20 | .38893 | .63648 | .40284 | .67460 | .41693 | .71506 | .43120 | .75808 | 20 |
| 21 | .38916 | .63710 | .40307 | .67525 | .41717 | .71576 | .43144 | .75882 | 21 |
| 22 | .38939 | .63772 | .40331 | .67591 | .41740 | .71646 | .43168 | .75956 | 22 |
| 23 | .38962 | .63834 | .40354 | .67656 | .41764 | .71715 | .43192 | .76031 | 23 |
| 24 | .38985 | .63895 | .40378 | .67722 | .41788 | .71785 | .43216 | .76105 | 24 |
| 25 | .39009 | .63957 | .40401 | .67788 | .41811 | .71855 | .43240 | .76179 | 25 |
| 26 | .39032 | .64019 | .40424 | .67853 | .41835 | .71925 | .43264 | .76253 | 26 |
| 27 | .39055 | .64081 | .40448 | .67919 | .41859 | .71995 | .43287 | .76328 | 27 |
| 28 | .39078 | .64144 | .40471 | .67985 | .41882 | .72065 | .43311 | .76402 | 28 |
| 29 | .39101 | .64206 | .40494 | .68051 | .41906 | .72135 | .43335 | .76477 | 29 |
| 30 | .39124 | .64268 | .40518 | .68117 | .41930 | .72205 | .43359 | .76552 | 30 |
| 31 | .39147 | .64330 | .40541 | .68183 | .41953 | .72275 | .43383 | .76626 | 31 |
| 32 | .39170 | .64393 | .40565 | .68250 | .41977 | .72346 | .43407 | .76701 | 32 |
| 33 | .39193 | .64455 | .40588 | .68316 | .42001 | .72416 | .43431 | .76776 | 33 |
| 34 | .39216 | .64518 | .40611 | .68382 | .42024 | .72487 | .43455 | .76851 | 34 |
| 35 | .39239 | .64580 | .40635 | .68449 | .42048 | .72557 | .43479 | .76926 | 35 |
| 36 | .39262 | .64643 | .40658 | .68515 | .42072 | .72628 | .43503 | .77001 | 36 |
| 37 | .39286 | .64705 | .40682 | .68582 | .42096 | .72698 | .43527 | .77077 | 37 |
| 38 | .39309 | .64768 | .40705 | .68648 | .42119 | .72769 | .43551 | .77152 | 38 |
| 39 | .39332 | .64831 | .40728 | .68715 | .42143 | .72840 | .43575 | .77227 | 39 |
| 40 | .39355 | .64894 | .40752 | .68782 | .42167 | .72911 | .43599 | .77303 | 40 |
| 41 | .39378 | .64957 | .40775 | .68848 | .42191 | .72982 | .43623 | .77378 | 41 |
| 42 | .39401 | .65020 | .40799 | .68915 | .42214 | .73053 | .43647 | .77454 | 42 |
| 43 | .39424 | .65083 | .40822 | .68982 | .42238 | .73124 | .43671 | .77530 | 43 |
| 44 | .39447 | .65146 | .40846 | .69049 | .42262 | .73195 | .43695 | .77606 | 44 |
| 45 | .39471 | .65209 | .40869 | .69116 | .42285 | .73267 | .43720 | .77681 | 45 |
| 46 | .39494 | .65272 | .40893 | .69183 | .42309 | .73338 | .43744 | .77757 | 46 |
| 47 | .39517 | .65336 | .40916 | .69250 | .42333 | .73409 | .43768 | .77833 | 47 |
| 48 | .39540 | .65399 | .40939 | .69318 | .42357 | .73481 | .43792 | .77910 | 48 |
| 49 | .39563 | .65462 | .40963 | .69385 | .42381 | .73552 | .43816 | .77986 | 49 |
| 50 | .39586 | .65526 | .40986 | .69452 | .42404 | .73624 | .43840 | .78062 | 50 |
| 51 | .39610 | .65589 | .41010 | .69520 | .42428 | .73696 | .43864 | .78138 | 51 |
| 52 | .39633 | .65653 | .41033 | .69587 | .42452 | .73768 | .43888 | .78215 | 52 |
| 53 | .39656 | .65717 | .41057 | .69655 | .42476 | .73840 | .43912 | .78291 | 53 |
| 54 | .39679 | .65780 | .41080 | .69723 | .42499 | .73911 | .43936 | .78368 | 54 |
| 55 | .39702 | .65844 | .41104 | .69790 | .42523 | .73983 | .43960 | .78445 | 55 |
| 56 | .39726 | .65908 | .41127 | .69858 | .42547 | .74056 | .43984 | .78521 | 56 |
| 57 | .39749 | .65972 | .41151 | .69926 | .42571 | .74128 | .44008 | .78598 | 57 |
| 58 | .39772 | .66036 | .41174 | .69994 | .42595 | .74200 | .44032 | .78675 | 58 |
| 59 | .39795 | .66100 | .41198 | .70062 | .42619 | .74272 | .44057 | .78752 | 59 |
| 60 | .39819 | .66164 | .41221 | .70130 | .42642 | .74345 | .44081 | .78829 | 60 |

| ′ | 56° Vers. | 56° Ex. sec. | 57° Vers. | 57° Ex. sec. | 58° Vers. | 58° Ex. sec. | 59° Vers. | 59° Ex. sec. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .44081 | .78829 | .45536 | .83608 | .47008 | .88708 | .48496 | .94160 | 0 |
| 1 | .44105 | .78906 | .45560 | .83690 | .47033 | .88796 | .48521 | .94254 | 1 |
| 2 | .44129 | .78984 | .45585 | .83773 | .47057 | .88884 | .48546 | .94349 | 2 |
| 3 | .44153 | .79061 | .45609 | .83855 | .47082 | .88972 | .48571 | .94443 | 3 |
| 4 | .44177 | .79138 | .45634 | .83938 | .47107 | .89060 | .48596 | .94537 | 4 |
| 5 | .44201 | .79216 | .45658 | .84020 | .47131 | .89148 | .48621 | .94632 | 5 |
| 6 | .44225 | .79293 | .45683 | .84103 | .47156 | .89237 | .48646 | .94726 | 6 |
| 7 | .44250 | .79371 | .45707 | .84186 | .47181 | .89325 | .48671 | .94821 | 7 |
| 8 | .44274 | .79449 | .45731 | .84269 | .47206 | .89414 | .48696 | .94916 | 8 |
| 9 | .44298 | .79527 | .45756 | .84352 | .47230 | .89503 | .48721 | .95011 | 9 |
| 10 | .44322 | .79604 | .45780 | .84435 | .47255 | .89591 | .48746 | .95106 | 10 |
| 11 | .44346 | .79682 | .45805 | .84518 | .47280 | .89680 | .48771 | .95201 | 11 |
| 12 | .44370 | .79761 | .45829 | .84601 | .47304 | .89769 | .48796 | .95296 | 12 |
| 13 | .44395 | .79839 | .45854 | .84685 | .47329 | .89858 | .48821 | .95392 | 13 |
| 14 | .44419 | .79917 | .45878 | .84768 | .47354 | .89948 | .48846 | .95487 | 14 |
| 15 | .44443 | .79995 | .45903 | .84852 | .47379 | .90037 | .48871 | .95583 | 15 |
| 16 | .44467 | .80074 | .45927 | .84935 | .47403 | .90126 | .48896 | .95678 | 16 |
| 17 | .44491 | .80152 | .45951 | .85019 | .47428 | .90216 | .48921 | .95774 | 17 |
| 18 | .44516 | .80231 | .45976 | .85103 | .47453 | .90305 | .48946 | .95870 | 18 |
| 19 | .44540 | .80309 | .46000 | .85187 | .47478 | .90395 | .48971 | .95966 | 19 |
| 20 | .44564 | .80388 | .46025 | .85271 | .47502 | .90485 | .48996 | .96062 | 20 |
| 21 | .44588 | .80467 | .46049 | .85355 | .47527 | .90575 | .49021 | .96158 | 21 |
| 22 | .44612 | .80546 | .46074 | .85439 | .47552 | .90665 | .49046 | .96255 | 22 |
| 23 | .44637 | .80625 | .46098 | .85523 | .47577 | .90755 | .49071 | .96351 | 23 |
| 24 | .44661 | .80704 | .46123 | .85608 | .47601 | .90845 | .49096 | .96448 | 24 |
| 25 | .44685 | .80783 | .46147 | .85692 | .47626 | .90935 | .49121 | .96544 | 25 |
| 26 | .44709 | .80862 | .46172 | .85777 | .47651 | .91026 | .49146 | .96641 | 26 |
| 27 | .44734 | .80942 | .46196 | .85861 | .47676 | .91116 | .49171 | .96738 | 27 |
| 28 | .44758 | .81021 | .46221 | .85946 | .47701 | .91207 | .49196 | .96835 | 28 |
| 29 | .44782 | .81101 | .46246 | .86031 | .47725 | .91297 | .49221 | .96932 | 29 |
| 30 | .44806 | .81180 | .46270 | .86116 | .47750 | .91388 | .49246 | .97029 | 30 |
| 31 | .44831 | .81260 | .46295 | .86201 | .47775 | .91479 | .49271 | .97127 | 31 |
| 32 | .44855 | .81340 | .46319 | .86286 | .47800 | .91570 | .49296 | .97224 | 32 |
| 33 | .44879 | .81419 | .46344 | .86371 | .47825 | .91661 | .49321 | .97322 | 33 |
| 34 | .44903 | .81499 | .46368 | .86457 | .47849 | .91752 | .49346 | .97420 | 34 |
| 35 | .44928 | .81579 | .46393 | .86542 | .47874 | .91844 | .49372 | .97517 | 35 |
| 36 | .44952 | .81659 | .46417 | .86627 | .47899 | .91935 | .49397 | .97615 | 36 |
| 37 | .44976 | .81740 | .46442 | .86713 | .47924 | .92027 | .49422 | .97713 | 37 |
| 38 | .45001 | .81820 | .46466 | .86799 | .47949 | .92118 | .49447 | .97811 | 38 |
| 39 | .45025 | .81900 | .46491 | .86885 | .47974 | .92210 | .49472 | .97910 | 39 |
| 40 | .45049 | .81981 | .46516 | .86970 | .47998 | .92302 | .49497 | .98008 | 40 |
| 41 | .45073 | .82061 | .46540 | .87056 | .48023 | .92394 | .49522 | .98107 | 41 |
| 42 | .45098 | .82142 | .46565 | .87142 | .48048 | .92486 | .49547 | .98205 | 42 |
| 43 | .45122 | .82222 | .46589 | .87229 | .48073 | .92578 | .49572 | .98304 | 43 |
| 44 | .45146 | .82303 | .46614 | .87315 | .48098 | .92670 | .49597 | .98403 | 44 |
| 45 | .45171 | .82384 | .46639 | .87401 | .48123 | .92762 | .49623 | .98502 | 45 |
| 46 | .45195 | .82465 | .46663 | .87488 | .48148 | .92855 | .49648 | .98601 | 46 |
| 47 | .45219 | .82546 | .46688 | .87574 | .48172 | .92947 | .49673 | .98700 | 47 |
| 48 | .45244 | .82627 | .46712 | .87661 | .48197 | .93040 | .49698 | .98799 | 48 |
| 49 | .45268 | .82709 | .46737 | .87748 | .48222 | .93133 | .49723 | .98899 | 49 |
| 50 | .45292 | .82790 | .46762 | .87834 | .48247 | .93226 | .49748 | .98998 | 50 |
| 51 | .45317 | .82871 | .46786 | .87921 | .48272 | .93319 | .49773 | .99098 | 51 |
| 52 | .45341 | .82953 | .46811 | .88008 | .48297 | .93412 | .49799 | .99198 | 52 |
| 53 | .45365 | .83034 | .46836 | .88095 | .48322 | .93505 | .49824 | .99298 | 53 |
| 54 | .45390 | .83116 | .46860 | .88183 | .48347 | .93598 | .49849 | .99398 | 54 |
| 55 | .45414 | .83198 | .46885 | .88270 | .48372 | .93692 | .49874 | .99498 | 55 |
| 56 | .45439 | .83280 | .46909 | .88357 | .48396 | .93785 | .49899 | .99598 | 56 |
| 57 | .45463 | .83362 | .46934 | .88445 | .48421 | .93879 | .49924 | .99698 | 57 |
| 58 | .45487 | .83444 | .46959 | .88532 | .48446 | .93973 | .49950 | .99799 | 58 |
| 59 | .45512 | .83526 | .46983 | .88620 | .48471 | .94066 | .49975 | .99899 | 59 |
| 60 | .45536 | .83608 | .47008 | .88708 | .48496 | .94160 | .50000 | 1.00000 | 60 |

| ′ | 60° Vers. | 60° Ex. sec. | 61° Vers. | 61° Ex. sec. | 62° Vers. | 62° Ex. sec. | 63° Vers. | 63° Ex. sec. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .50000 | 1.00000 | .51519 | 1.06267 | .53053 | 1.13005 | .54601 | 1.20269 | 0 |
| 1 | .50025 | 1.00101 | .51544 | 1.06375 | .53079 | 1.13122 | .54627 | 1.20395 | 1 |
| 2 | .50050 | 1.00202 | .51570 | 1.06483 | .53104 | 1.13239 | .54653 | 1.20521 | 2 |
| 3 | .50076 | 1.00303 | .51595 | 1.06592 | .53130 | 1.13356 | .54679 | 1.20647 | 3 |
| 4 | .50101 | 1.00404 | .51621 | 1.06701 | .53156 | 1.13473 | .54705 | 1.20773 | 4 |
| 5 | .50126 | 1.00505 | .51646 | 1.06809 | .53181 | 1.13590 | .54731 | 1.20900 | 5 |
| 6 | .50151 | 1.00607 | .51672 | 1.06918 | .53207 | 1.13707 | .54757 | 1.21026 | 6 |
| 7 | .50176 | 1.00708 | .51697 | 1.07027 | .53233 | 1.13825 | .54782 | 1.21153 | 7 |
| 8 | .50202 | 1.00810 | .51723 | 1.07137 | .53258 | 1.13942 | .54808 | 1.21280 | 8 |
| 9 | .50227 | 1.00912 | .51748 | 1.07246 | .53284 | 1.14060 | .54834 | 1.21407 | 9 |
| 10 | .50252 | 1.01014 | .51774 | 1.07356 | .53310 | 1.14178 | .54860 | 1.21535 | 10 |
| 11 | .50277 | 1.01116 | .51799 | 1.07465 | .53336 | 1.14296 | .54886 | 1.21662 | 11 |
| 12 | .50303 | 1.01218 | .51825 | 1.07575 | .53361 | 1.14414 | .54912 | 1.21790 | 12 |
| 13 | .50328 | 1.01320 | .51850 | 1.07685 | .53387 | 1.14533 | .54938 | 1.21918 | 13 |
| 14 | .50353 | 1.01422 | .51876 | 1.07795 | .53413 | 1.14651 | .54964 | 1.22045 | 14 |
| 15 | .50378 | 1.01525 | .51901 | 1.07905 | .53439 | 1.14770 | .54990 | 1.22174 | 15 |
| 16 | .50404 | 1.01628 | .51927 | 1.08015 | .53464 | 1.14889 | .55016 | 1.22302 | 16 |
| 17 | .50429 | 1.01730 | .51952 | 1.08126 | .53490 | 1.15008 | .55042 | 1.22430 | 17 |
| 18 | .50454 | 1.01833 | .51978 | 1.08236 | .53516 | 1.15127 | .55068 | 1.22559 | 18 |
| 19 | .50479 | 1.01936 | .52003 | 1.08347 | .53542 | 1.15246 | .55094 | 1.22688 | 19 |
| 20 | .50505 | 1.02039 | .52029 | 1.08458 | .53567 | 1.15366 | .55120 | 1.22817 | 20 |
| 21 | .50530 | 1.02143 | .52054 | 1.08569 | .53593 | 1.15485 | .55146 | 1.22946 | 21 |
| 22 | .50555 | 1.02246 | .52080 | 1.08680 | .53619 | 1.15605 | .55172 | 1.23075 | 22 |
| 23 | .50581 | 1.02349 | .52105 | 1.08791 | .53645 | 1.15725 | .55198 | 1.23205 | 23 |
| 24 | .50606 | 1.02453 | .52131 | 1.08903 | .53670 | 1.15845 | .55224 | 1.23334 | 24 |
| 25 | .50631 | 1.02557 | .52156 | 1.09014 | .53696 | 1.15965 | .55250 | 1.23464 | 25 |
| 26 | .50656 | 1.02661 | .52182 | 1.09126 | .53722 | 1.16085 | .55276 | 1.23594 | 26 |
| 27 | .50682 | 1.02765 | .52207 | 1.09238 | .53748 | 1.16206 | .55302 | 1.23724 | 27 |
| 28 | .50707 | 1.02869 | .52233 | 1.09350 | .53774 | 1.16326 | .55328 | 1.23855 | 28 |
| 29 | .50732 | 1.02973 | .52259 | 1.09462 | .53799 | 1.16447 | .55354 | 1.23985 | 29 |
| 30 | .50758 | 1.03077 | .52284 | 1.09574 | .53825 | 1.16568 | .55380 | 1.24116 | 30 |
| 31 | .50783 | 1.03182 | .52310 | 1.09686 | .53851 | 1.16689 | .55406 | 1.24247 | 31 |
| 32 | .50808 | 1.03286 | .52335 | 1.09799 | .53877 | 1.16810 | .55432 | 1.24378 | 32 |
| 33 | .50834 | 1.03391 | .52361 | 1.09911 | .53903 | 1.16932 | .55458 | 1.24509 | 33 |
| 34 | .50859 | 1.03496 | .52386 | 1.10024 | .53928 | 1.17053 | .55484 | 1.24640 | 34 |
| 35 | .50884 | 1.03601 | .52412 | 1.10137 | .53954 | 1.17175 | .55510 | 1.24772 | 35 |
| 36 | .50910 | 1.03706 | .52438 | 1.10250 | .53980 | 1.17297 | .55536 | 1.24903 | 36 |
| 37 | .50935 | 1.03811 | .52463 | 1.10363 | .54006 | 1.17419 | .55563 | 1.25035 | 37 |
| 38 | .50960 | 1.03916 | .52489 | 1.10477 | .54032 | 1.17541 | .55589 | 1 25167 | 38 |
| 39 | .50986 | 1.04022 | .52514 | 1.10590 | .54058 | 1.17663 | .55615 | 1.25300 | 39 |
| 40 | .51011 | 1.04128 | .52540 | 1.10704 | .54083 | 1.17786 | .55641 | 1.25432 | 40 |
| 41 | .51036 | 1.04233 | .52566 | 1.10817 | .54109 | 1.17909 | .55667 | 1.25565 | 41 |
| 42 | .51062 | 1.04339 | .52591 | 1.10931 | .54135 | 1.18031 | .55693 | 1.25697 | 42 |
| 43 | .51087 | 1.04445 | .52617 | 1.11045 | .54161 | 1 18154 | .55719 | 1.25830 | 43 |
| 44 | .51113 | 1.04551 | .52642 | 1.11159 | .54187 | 1.18277 | .55745 | 1.25963 | 44 |
| 45 | .51138 | 1.04658 | .52668 | 1.11274 | .54213 | 1.18401 | .55771 | 1.26097 | 45 |
| 46 | .51163 | 1.04764 | .52694 | 1.11388 | .54238 | 1.18524 | .55797 | 1.26230 | 46 |
| 47 | .51189 | 1.04870 | .52719 | 1.11503 | .54264 | 1.18648 | .55823 | 1.26364 | 47 |
| 48 | .51214 | 1.04977 | .52745 | 1.11617 | .54290 | 1.18772 | .55849 | 1.26498 | 48 |
| 49 | .51239 | 1.05084 | .52771 | 1.11732 | .54316 | 1.18895 | .55876 | 1.26632 | 49 |
| 50 | .51265 | 1.05191 | .52796 | 1.11847 | .54342 | 1.19019 | .55902 | 1.26766 | 50 |
| 51 | .51290 | 1.05298 | .52822 | 1.11963 | .54368 | 1.19144 | .55928 | 1.26900 | 51 |
| 52 | .51316 | 1.05405 | .52848 | 1.12078 | .54394 | 1.19268 | .55954 | 1.27035 | 52 |
| 53 | .51341 | 1.05512 | .52873 | 1.12193 | .54420 | 1.19393 | .55980 | 1.27169 | 53 |
| 54 | .51366 | 1.05619 | .52899 | 1.12309 | .54446 | 1.19517 | .56006 | 1.27304 | 54 |
| 55 | .51392 | 1.05727 | .52924 | 1.12425 | .54471 | 1.19642 | .56032 | 1.27439 | 55 |
| 56 | .51417 | 1.05835 | .52950 | 1.12540 | .54497 | 1.19767 | .56058 | 1.27574 | 56 |
| 57 | .51443 | 1.05942 | .52976 | 1.12657 | .54523 | 1.19892 | .56084 | 1.27710 | 57 |
| 58 | .51468 | 1.06050 | .53001 | 1.12773 | .54549 | 1.20018 | .56111 | 1.27845 | 58 |
| 59 | .51494 | 1.06158 | .53027 | 1.12889 | .54575 | 1.20143 | .56137 | 1.27981 | 59 |
| 60 | .51519 | 1.06267 | .53053 | 1.13005 | .54601 | 1.20269 | .56163 | 1.28117 | 60 |

| ′ | 64° | | 65° | | 66° | | 67° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .56163 | 1.28117 | .57738 | 1.36620 | .59326 | 1.45859 | .60927 | 1.55930 | 0 |
| 1 | .56189 | 1.28253 | .57765 | 1.36768 | .59353 | 1.46020 | .60954 | 1.56106 | 1 |
| 2 | .56215 | 1.28390 | .57791 | 1.36916 | .59379 | 1.46181 | .60980 | 1.56282 | 2 |
| 3 | .56241 | 1.28526 | .57817 | 1.37064 | .59406 | 1.46342 | .61007 | 1.56458 | 3 |
| 4 | .56267 | 1.28663 | .57844 | 1.37212 | .59433 | 1.46504 | .61034 | 1.56634 | 4 |
| 5 | .56294 | 1.28800 | .57870 | 1.37361 | .59459 | 1.46665 | .61061 | 1.56811 | 5 |
| 6 | .56320 | 1.28937 | .57896 | 1.37509 | .59486 | 1.46827 | .61088 | 1.56988 | 6 |
| 7 | .56346 | 1.29074 | .57923 | 1.37658 | .59512 | 1.46989 | .61114 | 1.57165 | 7 |
| 8 | .56372 | 1.29211 | .57949 | 1.37808 | .59539 | 1.47152 | .61141 | 1.57342 | 8 |
| 9 | .56398 | 1.29349 | .57976 | 1.37957 | .59566 | 1.47314 | .61168 | 1.57520 | 9 |
| 10 | .56425 | 1.29487 | .58002 | 1.38107 | .59592 | 1.47477 | .61195 | 1.57698 | 10 |
| 11 | .56451 | 1.29625 | .58028 | 1.38256 | .59619 | 1.47640 | .61222 | 1.57876 | 11 |
| 12 | .56477 | 1.29763 | .58055 | 1.38406 | .59645 | 1.47804 | .61248 | 1.58054 | 12 |
| 13 | .56503 | 1.29901 | .58081 | 1.38556 | .59672 | 1.47967 | .61275 | 1.58233 | 13 |
| 14 | .56529 | 1.30040 | .58108 | 1.38707 | .59699 | 1.48131 | .61302 | 1.58412 | 14 |
| 15 | .56555 | 1.30179 | .58134 | 1.38857 | .59725 | 1.48295 | .61329 | 1.58591 | 15 |
| 16 | .56582 | 1.30318 | .58160 | 1.39008 | .59752 | 1.48459 | .61356 | 1.58771 | 16 |
| 17 | .56608 | 1.30457 | .58187 | 1.39159 | .59779 | 1.48624 | .61383 | 1.58950 | 17 |
| 18 | .56634 | 1.30596 | .58213 | 1.39311 | .59805 | 1.48789 | .61409 | 1.59130 | 18 |
| 19 | .56660 | 1.30735 | .58240 | 1.39462 | .59832 | 1.48954 | .61436 | 1.59311 | 19 |
| 20 | .56687 | 1.30875 | .58266 | 1.39614 | .59859 | 1.49119 | .61463 | 1.59491 | 20 |
| 21 | .56713 | 1.31015 | .58293 | 1.39766 | .59885 | 1.49284 | .61490 | 1.59672 | 21 |
| 22 | .56739 | 1.31155 | .58319 | 1.39918 | .59912 | 1.49450 | .61517 | 1.59853 | 22 |
| 23 | .56765 | 1.31295 | .58345 | 1.40070 | .59938 | 1.49616 | .61544 | 1.60035 | 23 |
| 24 | .56791 | 1.31436 | .58372 | 1.40222 | .59965 | 1.49782 | .61570 | 1.60217 | 24 |
| 25 | .56818 | 1.31576 | .58398 | 1.40375 | .59992 | 1.49948 | .61597 | 1.60399 | 25 |
| 26 | .56844 | 1.31717 | .58425 | 1.40528 | .60018 | 1.50115 | .61624 | 1.60581 | 26 |
| 27 | .56870 | 1.31858 | .58451 | 1.40681 | .60045 | 1.50282 | .61651 | 1.60763 | 27 |
| 28 | .56896 | 1.31999 | .58478 | 1.40835 | .60072 | 1.50449 | .61678 | 1.60946 | 28 |
| 29 | .56923 | 1.32140 | .58504 | 1.40988 | .60098 | 1.50617 | .61705 | 1.61129 | 29 |
| 30 | .56949 | 1.32282 | .58531 | 1.41142 | .60125 | 1.50784 | .61732 | 1.61313 | 30 |
| 31 | .56975 | 1.32424 | .58557 | 1.41296 | .60152 | 1.50952 | .61759 | 1.61496 | 31 |
| 32 | .57001 | 1.32566 | .58584 | 1.41450 | .60178 | 1.51120 | .61785 | 1.61680 | 32 |
| 33 | .57028 | 1.32708 | .58610 | 1.41605 | .60205 | 1.51289 | .61812 | 1.61864 | 33 |
| 34 | .57054 | 1.32850 | .58637 | 1.41760 | .60232 | 1.51457 | .61839 | 1.62049 | 34 |
| 35 | .57080 | 1.32993 | .58663 | 1.41914 | .60259 | 1.51626 | .61866 | 1.62234 | 35 |
| 36 | .57106 | 1.33135 | .58690 | 1.42070 | .60285 | 1.51795 | .61893 | 1.62419 | 36 |
| 37 | .57133 | 1.33278 | .58716 | 1.42225 | .60312 | 1.51965 | .61920 | 1.62604 | 37 |
| 38 | .57159 | 1.33422 | .58743 | 1.42380 | .60339 | 1.52134 | .61947 | 1.62790 | 38 |
| 39 | .57185 | 1.33565 | .58769 | 1.42536 | .60365 | 1.52304 | .61974 | 1.62976 | 39 |
| 40 | .57212 | 1.33708 | .58796 | 1.42692 | .60392 | 1.52474 | .62001 | 1.63162 | 40 |
| 41 | .57238 | 1.33852 | .58822 | 1.42848 | .60419 | 1.52645 | .62027 | 1.63348 | 41 |
| 42 | .57264 | 1.33996 | .58849 | 1.43005 | .60445 | 1.52815 | .62054 | 1.63535 | 42 |
| 43 | .57291 | 1.34140 | .58875 | 1.43162 | .60472 | 1.52986 | .62081 | 1.63722 | 43 |
| 44 | .57317 | 1.34284 | .58902 | 1.43318 | .60499 | 1.53157 | .62108 | 1.63909 | 44 |
| 45 | .57343 | 1.34429 | .58928 | 1.43476 | .60526 | 1.53329 | .62135 | 1.64097 | 45 |
| 46 | .57369 | 1.34573 | .58955 | 1.43633 | .60552 | 1.53500 | .62162 | 1.64285 | 46 |
| 47 | .57396 | 1.34718 | .58981 | 1.43790 | .60579 | 1.53672 | .62189 | 1.64473 | 47 |
| 48 | .57422 | 1.34863 | .59008 | 1.43948 | .60606 | 1.53845 | .62216 | 1.64662 | 48 |
| 49 | .57448 | 1.35009 | .59034 | 1.44106 | .60633 | 1.54017 | .62243 | 1.64851 | 49 |
| 50 | .57475 | 1.35154 | .59061 | 1.44264 | .60659 | 1.54190 | .62270 | 1.65040 | 50 |
| 51 | .57501 | 1.35300 | .59087 | 1.44423 | .60686 | 1.54363 | .62297 | 1.65229 | 51 |
| 52 | .57527 | 1.35446 | .59114 | 1.44582 | .60713 | 1.54536 | .62324 | 1.65419 | 52 |
| 53 | .57554 | 1.35592 | .59140 | 1.44741 | .60740 | 1.54709 | .62351 | 1.65609 | 53 |
| 54 | .57580 | 1.35738 | .59167 | 1.44900 | .60766 | 1.54883 | .62378 | 1.65799 | 54 |
| 55 | .57606 | 1.35885 | .59194 | 1.45059 | .60793 | 1.55057 | .62405 | 1.65989 | 55 |
| 56 | .57633 | 1.36031 | .59220 | 1.45219 | .60820 | 1.55231 | .62431 | 1.66180 | 56 |
| 57 | .57659 | 1.36178 | .59247 | 1.45378 | .60847 | 1.55405 | .62458 | 1.66371 | 57 |
| 58 | .57685 | 1.36325 | .59273 | 1.45539 | .60873 | 1.55580 | .62485 | 1.66563 | 58 |
| 59 | .57712 | 1.36473 | .59300 | 1.45699 | .60900 | 1.55755 | .62512 | 1.66755 | 59 |
| 60 | .57738 | 1.36620 | .59326 | 1.45859 | .60927 | 1.55930 | .62539 | 1.66947 | 60 |

TABLE XXIX.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

| ′ | 68° |  | 69° |  | 70° |  | 71° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. |  |
| 0 | .62539 | 1.66947 | .64163 | 1.79043 | .65798 | 1.92380 | .67443 | 2.07155 | 0 |
| 1 | .62566 | 1.67139 | .64190 | 1.79254 | .65825 | 1.92614 | .67471 | 2.07415 | 1 |
| 2 | .62593 | 1.67332 | .64218 | 1.79466 | .65853 | 1.92849 | .67498 | 2.07675 | 2 |
| 3 | .62620 | 1.67525 | .64245 | 1.79679 | .65880 | 1.93083 | .67526 | 2.07936 | 3 |
| 4 | .62647 | 1.67718 | .64272 | 1.79891 | .65907 | 1.93318 | .67553 | 2.08197 | 4 |
| 5 | .62674 | 1.67911 | .64299 | 1.80104 | .65935 | 1.93554 | .67581 | 2.08459 | 5 |
| 6 | .62701 | 1.68105 | .64326 | 1.80318 | .65962 | 1.93790 | .67608 | 2.08721 | 6 |
| 7 | .62728 | 1.68299 | .64353 | 1.80531 | .65989 | 1.94026 | .67636 | 2.08983 | 7 |
| 8 | .62755 | 1.68494 | .64381 | 1.80746 | .66017 | 1.94263 | .67663 | 2.09246 | 8 |
| 9 | .62782 | 1.68689 | .64408 | 1.80960 | .66044 | 1.94500 | .67691 | 2.09510 | 9 |
| 10 | .62809 | 1.68884 | .64435 | 1.81175 | .66071 | 1.94737 | .67718 | 2.09774 | 10 |
| 11 | .62836 | 1 69079 | .64462 | 1.81390 | .66099 | 1.94975 | .67746 | 2.10038 | 11 |
| 12 | .62863 | 1.69275 | .64489 | 1.81605 | .66126 | 1.95213 | .67773 | 2.10303 | 12 |
| 13 | .62890 | 1.69471 | .64517 | 1.81821 | .66154 | 1.95452 | .67801 | 2.10568 | 13 |
| 14 | .62917 | 1.69667 | .64544 | 1.82037 | .66181 | 1.95691 | .67829 | 2.10834 | 14 |
| 15 | .62944 | 1.69864 | .64571 | 1.82254 | .66208 | 1.95931 | .67856 | 2.11101 | 15 |
| 16 | .62971 | 1.70061 | .64598 | 1.82471 | .66236 | 1.96171 | .67884 | 2.11367 | 16 |
| 17 | .62998 | 1.70258 | .64625 | 1.82688 | .66263 | 1.96411 | .67911 | 2.11635 | 17 |
| 18 | .63025 | 1.70455 | .64653 | 1.82906 | .66290 | 1.96652 | .67939 | 2.11903 | 18 |
| 19 | .63052 | 1.70653 | .64680 | 1.83124 | .66318 | 1.96893 | .67966 | 2.12171 | 19 |
| 20 | .63079 | 1.70851 | .64707 | 1.83342 | .66345 | 1.97135 | .67994 | 2.12440 | 20 |
| 21 | .63106 | 1.71050 | .64734 | 1.83561 | .66373 | 1.97377 | .68021 | 2.12709 | 21 |
| 22 | .63133 | 1.71249 | .64761 | 1.83780 | .66400 | 1.97619 | .68049 | 2.12979 | 22 |
| 23 | .63161 | 1.71448 | .64789 | 1.83999 | .66427 | 1.97862 | .68077 | 2.13249 | 23 |
| 24 | .63188 | 1.71647 | .64816 | 1.84219 | .66455 | 1.98106 | .68104 | 2.13520 | 24 |
| 25 | .63215 | 1.71847 | .64843 | 1.84439 | .66482 | 1.98349 | .68132 | 2.13791 | 25 |
| 26 | .63242 | 1.72047 | .64870 | 1.84659 | .66510 | 1.98594 | .68159 | 2.14063 | 26 |
| 27 | .63269 | 1.72247 | .64898 | 1.84880 | .66537 | 1.98838 | .68187 | 2.14335 | 27 |
| 28 | .63296 | 1.72448 | .64925 | 1.85102 | .66564 | 1.99083 | .68214 | 2.14608 | 28 |
| 29 | .63323 | 1.72649 | .64952 | 1.85323 | .66592 | 1.99329 | .68242 | 2.14881 | 29 |
| 30 | .63350 | 1.72850 | .64979 | 1.85545 | .66619 | 1.99574 | .68270 | 2.15155 | 30 |
| 31 | .63377 | 1.73052 | .65007 | 1.85767 | .66647 | 1.99821 | .68297 | 2.15429 | 31 |
| 32 | .63404 | 1.73254 | .65034 | 1.85990 | .66674 | 2.00067 | .68325 | 2.15704 | 32 |
| 33 | .63431 | 1.73456 | .65061 | 1.86213 | .66702 | 2.00315 | .68352 | 2.15979 | 33 |
| 34 | .63458 | 1.73659 | .65088 | 1.86437 | .66729 | 2.00562 | .68380 | 2.16255 | 34 |
| 35 | .63485 | 1.73862 | .65116 | 1.86661 | .66756 | 2.00810 | .68408 | 2.16531 | 35 |
| 36 | .63512 | 1.74065 | .65143 | 1.86885 | .66784 | 2.01059 | .68435 | 2.16808 | 36 |
| 37 | .63539 | 1.74269 | .65170 | 1.87109 | .66811 | 2.01308 | .68463 | 2.17085 | 37 |
| 38 | .63566 | 1.74473 | .65197 | 1.87334 | .66839 | 2.01557 | .68490 | 2.17363 | 38 |
| 39 | .63594 | 1.74677 | .65225 | 1.87560 | .66866 | 2.01807 | .68518 | 2.17641 | 39 |
| 40 | .63621 | 1.74881 | .65252 | 1.87785 | .66894 | 2.02057 | .68546 | 2.17920 | 40 |
| 41 | .63648 | 1.75086 | .65279 | 1.88011 | .66921 | 2.02308 | .68573 | 2.18199 | 41 |
| 42 | .63675 | 1.75292 | .65306 | 1.88238 | .66949 | 2.02559 | .68601 | 2.18479 | 42 |
| 43 | .63702 | 1.75497 | .65334 | 1.88465 | .66976 | 2.02810 | .68628 | 2.18759 | 43 |
| 44 | .63729 | 1.75703 | .65361 | 1.88692 | .67003 | 2.03062 | .68656 | 2.19040 | 44 |
| 45 | .63756 | 1.75909 | .65388 | 1.88920 | .67031 | 2.03315 | .68684 | 2.19322 | 45 |
| 46 | .63783 | 1.76116 | .65416 | 1.89148 | .67058 | 2.03568 | .68711 | 2.19604 | 46 |
| 47 | .63810 | 1.76323 | .65443 | 1.89376 | .67086 | 2.03821 | .68739 | 2.19886 | 47 |
| 48 | .63838 | 1.76530 | .65470 | 1.89605 | .67113 | 2.04075 | .68767 | 2.20169 | 48 |
| 49 | .63865 | 1.76737 | .65497 | 1.89834 | .67141 | 2.04329 | .68794 | 2.20453 | 49 |
| 50 | .63892 | 1.76945 | .65525 | 1.90063 | .67168 | 2.04584 | .68822 | 2.20737 | 50 |
| 51 | .63919 | 1.77154 | .65552 | 1.90293 | .67196 | 2.04839 | .68849 | 2.21021 | 51 |
| 52 | .63946 | 1.77362 | .65579 | 1.90524 | .67223 | 2.05094 | .68877 | 2.21306 | 52 |
| 53 | .63973 | 1.77571 | .65607 | 1.90754 | .67251 | 2.05350 | .68905 | 2.21592 | 53 |
| 54 | .64000 | 1 77780 | .65634 | 1.90986 | .67278 | 2.05607 | .68932 | 2.21878 | 54 |
| 55 | .64027 | 1.77990 | .65661 | 1.91217 | .67306 | 2.05864 | .68960 | 2.22165 | 55 |
| 56 | .64055 | 1.78200 | .65689 | 1.91449 | .67333 | 2.06121 | .68988 | 2.22452 | 56 |
| 57 | .64082 | 1.78410 | .65716 | 1.91681 | .67361 | 2.06379 | .69015 | 2.22740 | 57 |
| 58 | .64109 | 1.78621 | .65743 | 1.91914 | .67388 | 2.06637 | .69043 | 2.23028 | 58 |
| 59 | .64136 | 1.78832 | .65771 | 1.92147 | .67416 | 2.06896 | .69071 | 2.23317 | 59 |
| 60 | .64163 | 1.79043 | .65798 | 1.92380 | .67443 | 2.07155 | .69098 | 2.23607 | 60 |

| ′ | 72° | | 73° | | 74° | | 75° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .69098 | 2.23607 | .70763 | 2.42030 | .72436 | 2.62796 | .74118 | 2.86370 | 0 |
| 1 | .69126 | 2.23897 | .70791 | 2.42356 | .72464 | 2.63164 | .74146 | 2.86790 | 1 |
| 2 | .69154 | 2.24187 | .70818 | 2.42683 | .72492 | 2 63533 | .74174 | 2.87211 | 2 |
| 3 | .69181 | 2.24478 | .70846 | 2.43010 | .72520 | 2.63903 | .74202 | 2.87633 | 3 |
| 4 | .69209 | 2.24770 | .70874 | 2.43337 | .72548 | 2.64274 | .74231 | 2.88056 | 4 |
| 5 | .69237 | 2.25062 | .70902 | 2.43666 | .72576 | 2.64645 | .74259 | 2.88479 | 5 |
| 6 | 69264 | 2.25355 | .70930 | 2.43995 | .72604 | 2.65018 | .74287 | 2.88904 | 6 |
| 7 | .69292 | 2.25648 | .70958 | 2.44324 | .72632 | 2.65391 | .74315 | 2.89330 | 7 |
| 8 | .69320 | 2.25942 | .70985 | 2.44655 | .72660 | 2.65765 | .74343 | 2.89756 | 8 |
| 9 | .69347 | 2 26237 | .71013 | 2.44986 | .72688 | 2.66140 | .74371 | 2.90184 | 9 |
| 10 | .69375 | 2.26531 | .71041 | 2.45317 | .72716 | 2.66515 | .74399 | 2.90613 | 10 |
| 11 | .69403 | 2.26827 | .71069 | 2.45650 | .72744 | 2.66892 | .74427 | 2.91042 | 11 |
| 12 | .69430 | 2.27123 | .71097 | 2.45983 | .72772 | 2.67269 | .74455 | 2.91473 | 12 |
| 13 | .69458 | 2.27420 | .71125 | 2.46316 | .72800 | 2.67647 | .74484 | 2.91904 | 13 |
| 14 | .69486 | 2.27717 | .71153 | 2.46651 | .72828 | 2.68025 | .74512 | 2.92337 | 14 |
| 15 | .69514 | 2.28015 | .71180 | 2.46986 | .72856 | 2.68405 | .74540 | 2.92770 | 15 |
| 16 | .69541 | 2.28313 | .71208 | 2.47321 | .72884 | 2.68785 | .74568 | 2.93204 | 16 |
| 17 | .69569 | 2.28612 | .71236 | 2.47658 | .72912 | 2.69167 | .74596 | 2.93640 | 17 |
| 18 | .69597 | 2.28912 | .71264 | 2.47995 | .72940 | 2.69549 | .74624 | 2.94076 | 18 |
| 19 | .69624 | 2.29212 | .71292 | 2.48333 | .72968 | 2.69931 | .74652 | 2.94514 | 19 |
| 20 | .69652 | 2.29512 | .71320 | 2.48671 | .72996 | 2.70315 | .74680 | 2.94952 | 20 |
| 21 | .69680 | 2.29814 | .71348 | 2.49010 | .73024 | 2.70700 | .74709 | 2.95392 | 21 |
| 22 | .69708 | 2.30115 | .71375 | 2.49350 | .73052 | 2.71085 | .74737 | 2.95832 | 22 |
| 23 | .69735 | 2.30418 | .71403 | 2.49691 | .73080 | 2.71471 | .74765 | 2.96274 | 23 |
| 24 | .69763 | 2.30721 | .71431 | 2.50032 | .73108 | 2.71858 | .74793 | 2.96716 | 24 |
| 25 | .69791 | 2.31024 | .71459 | 2.50374 | .73136 | 2.72246 | .74821 | 2.97160 | 25 |
| 26 | .69818 | 2.31328 | .71487 | 2.50716 | .73164 | 2.72635 | .74849 | 2.97604 | 26 |
| 27 | .69846 | 2.31633 | .71515 | 2.51060 | .73192 | 2.73024 | .74878 | 2.98050 | 27 |
| 28 | .69874 | 2.31939 | .71543 | 2.51404 | .73220 | 2.73414 | .74906 | 2.98497 | 28 |
| 29 | .69902 | 2 32244 | .71571 | 2.51748 | .73248 | 2.73806 | .74934 | 2.98944 | 29 |
| 30 | .69929 | 2.32551 | .71598 | 2.52094 | .73276 | 2.74198 | .74962 | 2.99393 | 30 |
| 31 | .69957 | 2.32858 | .71626 | 2.52440 | .73304 | 2.74591 | .74990 | 2.99843 | 31 |
| 32 | .69985 | 2.33166 | .71654 | 2.52787 | .73332 | 2.74984 | .75018 | 3.00293 | 32 |
| 33 | .70013 | 2.33474 | .71682 | 2.53134 | .73360 | 2.75379 | .75047 | 3.00745 | 33 |
| 34 | .70040 | 2.33783 | .71710 | 2.53482 | .73388 | 2.75775 | .75075 | 3.01198 | 34 |
| 35 | .70068 | 2.34092 | .71738 | 2.53831 | .73416 | 2.76171 | .75103 | 3.01652 | 35 |
| 36 | .70096 | 2.34403 | .71766 | 2.54181 | .73444 | 2.76568 | .75131 | 3.02107 | 36 |
| 37 | .70124 | 2.34713 | .71794 | 2.54531 | .73472 | 2.76966 | .75159 | 3.02563 | 37 |
| 38 | .70151 | 2.35025 | .71822 | 2.54883 | .73500 | 2.77365 | .75187 | 3.03020 | 38 |
| 39 | .70179 | 2.35336 | .71850 | 2.55235 | .73529 | 2.77765 | .75216 | 3.03479 | 39 |
| 40 | .70207 | 2.35649 | .71877 | 2.55587 | .73557 | 2.78166 | .75244 | 3.03938 | 40 |
| 41 | .70235 | 2.35962 | .71905 | 2.55940 | .73585 | 2.78568 | .75272 | 3.04398 | 41 |
| 42 | .70263 | 2.36276 | .71933 | 2.56294 | .73613 | 2.78970 | .75300 | 3.04860 | 42 |
| 43 | .70290 | 2.36590 | .71961 | 2.56649 | .73641 | 2.79374 | .75328 | 3.05322 | 43 |
| 44 | .70318 | 2.36905 | .71989 | 2.57005 | .73669 | 2.79778 | .75356 | 3.05786 | 44 |
| 45 | .70346 | 2.37221 | .72017 | 2.57361 | .73697 | 2.80183 | .75385 | 3.06251 | 45 |
| 46 | .70374 | 2.37537 | .72045 | 2.57718 | .73725 | 2.80589 | .75413 | 3.06717 | 46 |
| 47 | .70401 | 2.37854 | .72073 | 2.58076 | .73753 | 2.80996 | .75441 | 3.07184 | 47 |
| 48 | .70429 | 2.38171 | .72101 | 2.58434 | .73781 | 2.81404 | .75469 | 3.07652 | 48 |
| 49 | .70457 | 2.38489 | .72129 | 2.58794 | .73809 | 2.81813 | .75497 | 3.08121 | 49 |
| 50 | .70485 | 2.38808 | .72157 | 2.59154 | .73837 | 2.82223 | .75526 | 3.08591 | 50 |
| 51 | .70513 | 2.39128 | .72185 | 2.59514 | .73865 | 2.82633 | .75554 | 3.09063 | 51 |
| 52 | .70540 | 2.39448 | .72213 | 2.59876 | .73893 | 2.83045 | .75582 | 3.09535 | 52 |
| 53 | .70568 | 2.39768 | .72241 | 2.60238 | .73921 | 2.83457 | .75610 | 3.10009 | 53 |
| 54 | .70596 | 2.40089 | .72269 | 2.60601 | .73950 | 2.83871 | .75639 | 3.10484 | 54 |
| 55 | .70624 | 2.40411 | .72296 | 2.60965 | .73978 | 2.84285 | .75667 | 3.10960 | 55 |
| 56 | .70652 | 2.40734 | .72324 | 2.61330 | .74006 | 2.84700 | .75695 | 3.11437 | 56 |
| 57 | .70679 | 2.41057 | .72352 | 2.61695 | .74034 | 2.85116 | .75723 | 3.11915 | 57 |
| 58 | .70707 | 2.41381 | .72380 | 2.62061 | .74062 | 2.85533 | .75751 | 3.12394 | 58 |
| 59 | .70735 | 2.41705 | .72408 | 2.62428 | .74090 | 2.85951 | .75780 | 3.12875 | 59 |
| 60 | .70763 | 2.42030 | .72436 | 2.62796 | .74118 | 2.86370 | .75808 | 3.13357 | 60 |

| ′ | 76° | | 77° | | 78° | | 79° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .75808 | 3.13357 | .77505 | 3.44541 | .79209 | 3.80973 | .80919 | 4.24084 | 0 |
| 1 | .75836 | 3.13839 | .77533 | 3.45102 | .79237 | 3.81633 | .80948 | 4.24870 | 1 |
| 2 | .75864 | 3.14323 | .77562 | 3.45664 | .79266 | 3.82294 | .80976 | 4.25658 | 2 |
| 3 | .75892 | 3.14809 | .77590 | 3.46228 | .79294 | 3.82956 | .81005 | 4.26448 | 3 |
| 4 | .75921 | 3.15295 | .77618 | 3.46793 | .79322 | 3.83621 | .81033 | 4.27241 | 4 |
| 5 | .75949 | 3.15782 | .77647 | 3.47360 | .79351 | 3.84288 | .81062 | 4.28036 | 5 |
| 6 | .75977 | 3.16271 | .77675 | 3.47928 | .79380 | 3.84956 | .81090 | 4.28833 | 6 |
| 7 | .76005 | 3.16761 | .77703 | 3.48498 | .79408 | 3.85627 | .81119 | 4.29634 | 7 |
| 8 | .76034 | 3.17252 | .77732 | 3.49069 | .79437 | 3.86299 | .81148 | 4.30436 | 8 |
| 9 | .76062 | 3.17744 | .77760 | 3.49642 | .79465 | 3.86973 | .81176 | 4.31241 | 9 |
| 10 | .76090 | 3.18238 | .77788 | 3.50216 | .79493 | 3.87649 | .81205 | 4.32049 | 10 |
| 11 | .76118 | 3.18733 | .77817 | 3.50791 | .79522 | 3.88327 | .81233 | 4.32859 | 11 |
| 12 | .76147 | 3.19228 | .77845 | 3.51368 | .79550 | 3.89007 | .81262 | 4.33671 | 12 |
| 13 | .76175 | 3.19725 | .77874 | 3.51947 | .79579 | 3.89689 | .81290 | 4.34486 | 13 |
| 14 | .76203 | 3.20224 | .77902 | 3.52527 | .79607 | 3.90373 | .81319 | 4.35304 | 14 |
| 15 | .76231 | 3.20723 | .77930 | 3.53109 | .79636 | 3.91058 | .81348 | 4.36124 | 15 |
| 16 | .76260 | 3.21224 | .77959 | 3.53692 | .79664 | 3.91746 | .81376 | 4.36947 | 16 |
| 17 | .76288 | 3.21726 | .77987 | 3.54277 | .79693 | 3.92436 | .81405 | 4.37772 | 17 |
| 18 | .76316 | 3.22229 | .78015 | 3.54863 | .79721 | 3.93128 | .81433 | 4.38600 | 18 |
| 19 | .76344 | 3.22734 | .78044 | 3.55451 | .79750 | 3.93821 | .81462 | 4.39430 | 19 |
| 20 | .76373 | 3.23239 | .78072 | 3.56041 | .79778 | 3.94517 | .81491 | 4.40263 | 20 |
| 21 | .76401 | 3.23746 | .78101 | 3.56632 | .79807 | 3.95215 | .81519 | 4.41099 | 21 |
| 22 | .76429 | 3.24255 | .78129 | 3.57224 | .79835 | 3.95914 | .81548 | 4.41937 | 22 |
| 23 | .76458 | 3.24764 | .78157 | 3.57819 | .79864 | 3.96616 | .81576 | 4.42778 | 23 |
| 24 | .76486 | 3.25275 | .78186 | 3.58414 | .79892 | 3.97320 | .81605 | 4.43622 | 24 |
| 25 | .76514 | 3.25787 | .78214 | 3.59012 | .79921 | 3.98025 | .81633 | 4.44468 | 25 |
| 26 | .76542 | 3.26300 | .78242 | 3.59611 | .79949 | 3.98733 | .81662 | 4.45317 | 26 |
| 27 | .76571 | 3.26814 | .78271 | 3.60211 | .79978 | 3.99443 | .81691 | 4.46169 | 27 |
| 28 | .76599 | 3.27330 | .78299 | 3.60813 | .80006 | 4.00155 | .81719 | 4.47023 | 28 |
| 29 | .76627 | 3.27847 | .78328 | 3.61417 | .80035 | 4.00869 | .81748 | 4.47881 | 29 |
| 30 | .76655 | 3.28366 | .78356 | 3.62023 | .80063 | 4.01585 | .81776 | 4.48740 | 30 |
| 31 | .76684 | 3.28885 | .78384 | 3.62630 | .80092 | 4.02303 | .81805 | 4.49603 | 31 |
| 32 | .76712 | 3.29406 | .78413 | 3.63238 | .80120 | 4.03024 | .81834 | 4.50468 | 32 |
| 33 | .76740 | 3.29929 | .78441 | 3.63849 | .80149 | 4.03746 | .81862 | 4.51337 | 33 |
| 34 | .76769 | 3.30452 | .78470 | 3.64461 | .80177 | 4.04471 | .81891 | 4.52208 | 34 |
| 35 | .76797 | 3.30977 | .78498 | 3.65074 | .80206 | 4.05197 | .81919 | 4.53081 | 35 |
| 36 | .76825 | 3.31503 | .78526 | 3.65690 | .80234 | 4.05926 | .81948 | 4.53958 | 36 |
| 37 | .76854 | 3.32031 | .78555 | 3.66307 | .80263 | 4.06657 | .81977 | 4.54837 | 37 |
| 38 | .76882 | 3.32560 | .78583 | 3.66925 | .80291 | 4.07390 | .82005 | 4.55720 | 38 |
| 39 | .76910 | 3.33090 | .78612 | 3.67545 | .80320 | 4.08125 | .82034 | 4.56605 | 39 |
| 40 | .76938 | 3.33622 | .78640 | 3.68167 | .80348 | 4.08863 | .82063 | 4.57493 | 40 |
| 41 | .76967 | 3.34154 | .78669 | 3.68791 | .80377 | 4.09602 | .82091 | 4.58383 | 41 |
| 42 | .76995 | 3.34689 | .78697 | 3.69417 | .80405 | 4.10344 | .82120 | 4.59277 | 42 |
| 43 | .77023 | 3.35224 | .78725 | 3.70044 | .80434 | 4.11088 | .82148 | 4.60174 | 43 |
| 44 | .77052 | 3.35761 | .78754 | 3.70673 | .80462 | 4.11835 | .82177 | 4.61073 | 44 |
| 45 | .77080 | 3.36299 | .78782 | 3.71303 | .80491 | 4.12583 | .82206 | 4.61976 | 45 |
| 46 | .77108 | 3.36839 | .78811 | 3.71935 | .80520 | 4.13334 | .82234 | 4.62881 | 46 |
| 47 | .77137 | 3.37380 | .78839 | 3.72569 | .80548 | 4.14087 | .82263 | 4.63790 | 47 |
| 48 | .77165 | 3.37923 | .78868 | 3.73205 | .80577 | 4.14842 | .82292 | 4.64701 | 48 |
| 49 | .77193 | 3.38466 | .78896 | 3.73843 | .80605 | 4.15599 | .82320 | 4.65616 | 49 |
| 50 | .77222 | 3.39012 | .78924 | 3.74482 | .80634 | 4.16359 | .82349 | 4.66533 | 50 |
| 51 | .77250 | 3.39558 | .78953 | 3.75123 | .80662 | 4.17121 | .82377 | 4.67454 | 51 |
| 52 | .77278 | 3.40106 | .78981 | 3.75766 | .80691 | 4.17886 | .82406 | 4.68377 | 52 |
| 53 | .77307 | 3.40656 | .79010 | 3.76411 | .80719 | 4.18652 | .82435 | 4.69304 | 53 |
| 54 | .77335 | 3.41206 | .79038 | 3.77057 | .80748 | 4.19421 | .82463 | 4.70234 | 54 |
| 55 | .77363 | 3.41759 | .79067 | 3.77705 | .80776 | 4.20193 | .82492 | 4.71166 | 55 |
| 56 | .77392 | 3.42312 | .79095 | 3.78355 | .80805 | 4.20966 | 82521 | 4.72102 | 56 |
| 57 | .77420 | 3.42867 | .79123 | 3.79007 | .80833 | 4.21742 | 82549 | 4.73041 | 57 |
| 58 | .77448 | 3.43424 | .79152 | 3.79661 | .80862 | 4.22521 | .82578 | 4.73983 | 58 |
| 59 | .77477 | 3.43982 | .79180 | 3.80316 | .80891 | 4.23301 | .82607 | 4.74929 | 59 |
| 60 | .77505 | 3.44541 | .79209 | 3.80973 | .80919 | 4.24084 | .82635 | 4.75877 | 60 |

| ′ | 80° | | 81° | | 82° | | 83° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .82635 | 4.75877 | .84357 | 5.39245 | .86083 | 6.18530 | .87813 | 7.20551 | 0 |
| 1 | .82664 | 4.76829 | .84385 | 5.40422 | .86112 | 6.20020 | .87842 | 7.22500 | 1 |
| 2 | .82692 | 4.77784 | .84414 | 5.41602 | .86140 | 6.21517 | .87871 | 7.24457 | 2 |
| 3 | .82721 | 4.78742 | .84443 | 5.42787 | .86169 | 6.23019 | .87900 | 7.26425 | 3 |
| 4 | .82750 | 4.79703 | .84471 | 5.43977 | .86198 | 6.24529 | .87929 | 7.28402 | 4 |
| 5 | .82778 | 4.80667 | .84500 | 5.45171 | .86227 | 6.26044 | .87957 | 7.30388 | 5 |
| 6 | .82807 | 4.81635 | .84529 | 5.46369 | .86256 | 6.27566 | .87986 | 7.32384 | 6 |
| 7 | .82836 | 4.82606 | .84558 | 5.47572 | .86284 | 6.29095 | .88015 | 7.34390 | 7 |
| 8 | .82864 | 4.83581 | .84586 | 5.48779 | .86313 | 6.30630 | .88044 | 7.36405 | 8 |
| 9 | .82893 | 4.84558 | .84615 | 5.49991 | .86342 | 6.32171 | .88073 | 7.38431 | 9 |
| 10 | .82922 | 4.85539 | .84644 | 5.51208 | .86371 | 6.33719 | .88102 | 7.40466 | 10 |
| 11 | .82950 | 4.86524 | .84673 | 5.52429 | .86400 | 6.35274 | .88131 | 7.42511 | 11 |
| 12 | .82979 | 4.87511 | .84701 | 5.53655 | .86428 | 6.36835 | .88160 | 7.44566 | 12 |
| 13 | .83008 | 4.88502 | .84730 | 5.54886 | .86457 | 6.38403 | .88188 | 7.46632 | 13 |
| 14 | .83036 | 4.89497 | .84759 | 5.56121 | .86486 | 6.39978 | .88217 | 7.48707 | 14 |
| 15 | .83065 | 4.90495 | .84788 | 5.57361 | .86515 | 6.41560 | .88246 | 7.50793 | 15 |
| 16 | .83094 | 4.91496 | .84816 | 5.58606 | .86544 | 6.43148 | .88275 | 7.52889 | 16 |
| 17 | .83122 | 4.92501 | .84845 | 5.59855 | .86573 | 6.44743 | .88304 | 7.54996 | 17 |
| 18 | .83151 | 4.93509 | .84874 | 5.61110 | .86601 | 6.46346 | .88333 | 7.57113 | 18 |
| 19 | .83180 | 4.94521 | .84903 | 5.62369 | .86630 | 6.47955 | .88362 | 7.59241 | 19 |
| 20 | .83208 | 4.95536 | .84931 | 5.63633 | .86659 | 6.49571 | .88391 | 7.61379 | 20 |
| 21 | .83237 | 4.96555 | .84960 | 5.64902 | .86688 | 6.51194 | .88420 | 7.63528 | 21 |
| 22 | .83266 | 4.97577 | .84989 | 5.66176 | .86717 | 6.52825 | .88448 | 7.65688 | 22 |
| 23 | .83294 | 4.98603 | .85018 | 5.67454 | .86746 | 6.54462 | .88477 | 7.67859 | 23 |
| 24 | .83323 | 4.99633 | .85046 | 5.68738 | .86774 | 6.56107 | .88506 | 7.70041 | 24 |
| 25 | .83352 | 5.00666 | .85075 | 5.70027 | .86803 | 6.57759 | .88535 | 7.72234 | 25 |
| 26 | .83380 | 5.01703 | .85104 | 5.71321 | .86832 | 6.59418 | .88564 | 7.74438 | 26 |
| 27 | .83409 | 5.02743 | .85133 | 5.72620 | .86861 | 6.61085 | .88593 | 7.76653 | 27 |
| 28 | .83438 | 5.03787 | .85162 | 5.73924 | .86890 | 6.62759 | .88622 | 7.78880 | 28 |
| 29 | .83467 | 5.04834 | .85190 | 5.75233 | .86919 | 6.64441 | .88651 | 7.81118 | 29 |
| 30 | .83495 | 5.05886 | .85219 | 5.76547 | .86947 | 6.66130 | .88680 | 7.83367 | 30 |
| 31 | .83524 | 5.06941 | .85248 | 5.77866 | .86976 | 6.67826 | .88709 | 7.85628 | 31 |
| 32 | .83553 | 5.08000 | .85277 | 5.79191 | .87005 | 6.69530 | .88737 | 7.87901 | 32 |
| 33 | .83581 | 5.09062 | .85305 | 5.80521 | .87034 | 6.71242 | .88766 | 7.90186 | 33 |
| 34 | .83610 | 5.10129 | .85334 | 5.81856 | .87063 | 6.72962 | .88795 | 7.92482 | 34 |
| 35 | .83639 | 5.11199 | .85363 | 5.83196 | .87092 | 6.74689 | .88824 | 7.94791 | 35 |
| 36 | .83667 | 5.12273 | .85392 | 5.84542 | .87120 | 6.76424 | .88853 | 7.97111 | 36 |
| 37 | .83696 | 5.13350 | .85420 | 5.85893 | .87149 | 6.78167 | .88882 | 7.99444 | 37 |
| 38 | .83725 | 5.14432 | .85449 | 5.87250 | .87178 | 6.79918 | .88911 | 8.01788 | 38 |
| 39 | .83754 | 5.15517 | .85478 | 5.88612 | .87207 | 6.81677 | .88940 | 8.04146 | 39 |
| 40 | .83782 | 5.16607 | .85507 | 5.89979 | .87235 | 6.83443 | .88969 | 8.06515 | 40 |
| 41 | .83811 | 5.17700 | .85536 | 5.91352 | .87265 | 6.85218 | .88998 | 8.08897 | 41 |
| 42 | .83840 | 5.18797 | .85564 | 5.92731 | .87294 | 6.87001 | .89027 | 8.11292 | 42 |
| 43 | .83868 | 5.19898 | .85593 | 5.94115 | .87322 | 6.88792 | .89055 | 8.13699 | 43 |
| 44 | .83897 | 5.21004 | .85622 | 5.95505 | .87351 | 6.90592 | .89084 | 8.16120 | 44 |
| 45 | .83926 | 5.22113 | .85651 | 5.96900 | .87380 | 6.92400 | .89113 | 8.18553 | 45 |
| 46 | .83954 | 5.23226 | .85680 | 5.98301 | .87409 | 6.94216 | .89142 | 8.20999 | 46 |
| 47 | .83983 | 5.24343 | .85708 | 5.99708 | .87438 | 6.96040 | .89171 | 8.23459 | 47 |
| 48 | .84012 | 5.25464 | .85737 | 6.01120 | .87467 | 6.97873 | .89200 | 8.25931 | 48 |
| 49 | .84041 | 5.26590 | .85766 | 6.02538 | .87496 | 6.99714 | .89229 | 8.28417 | 49 |
| 50 | .84069 | 5.27719 | .85795 | 6.03962 | .87524 | 7.01565 | .89258 | 8.30917 | 50 |
| 51 | .84098 | 5.28853 | .85823 | 6.05392 | .87553 | 7.03423 | .89287 | 8.33430 | 51 |
| 52 | .84127 | 5.29991 | .85852 | 6.06828 | .87582 | 7.05291 | .89316 | 8.35957 | 52 |
| 53 | .84155 | 5.31133 | .85881 | 6.08269 | .87611 | 7.07167 | .89345 | 8.38497 | 53 |
| 54 | .84184 | 5.32279 | .85910 | 6.09717 | .87640 | 7.09052 | .89374 | 8.41052 | 54 |
| 55 | .84213 | 5.33429 | .85939 | 6.11171 | .87669 | 7.10946 | .89403 | 8.43620 | 55 |
| 56 | .84242 | 5.34584 | .85967 | 6.12630 | .87698 | 7.12849 | .89431 | 8.46203 | 56 |
| 57 | .84270 | 5.35743 | .85996 | 6.14096 | .87726 | 7.14760 | .89460 | 8.48800 | 57 |
| 58 | .84299 | 5.36906 | .86025 | 6.15568 | .87755 | 7.16681 | .89489 | 8.51411 | 58 |
| 59 | .84328 | 5.38073 | .86054 | 6.17046 | .87784 | 7.18612 | .89518 | 8.54037 | 59 |
| 60 | .84357 | 5.39245 | .86083 | 6.18530 | .87813 | 7.20551 | .89547 | 8.56677 | 60 |

| ′ | 84° | | 85° | | 86° | | ′ |
|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .89547 | 8.56677 | .91284 | 10.47371 | .93024 | 13.33559 | 0 |
| 1 | .89576 | 8.59332 | .91313 | 10.51199 | .93053 | 13.39547 | 1 |
| 2 | .89605 | 8.62002 | .91342 | 10.55052 | .93082 | 13.45586 | 2 |
| 3 | .89634 | 8.64687 | .91371 | 10.58932 | .93111 | 13.51676 | 3 |
| 4 | .89663 | 8.67387 | .91400 | 10.62837 | .93140 | 13.57817 | 4 |
| 5 | .89692 | 8.70103 | .91429 | 10.66769 | .93169 | 13.64011 | 5 |
| 6 | .89721 | 8.72833 | .91458 | 10.70728 | .93198 | 13.70258 | 6 |
| 7 | .89750 | 8.75579 | .91487 | 10.74714 | .93227 | 13.76558 | 7 |
| 8 | .89779 | 8.78341 | .91516 | 10.78727 | .93257 | 13.82913 | 8 |
| 9 | .89808 | 8.81119 | .91545 | 10.82768 | .93286 | 13.89323 | 9 |
| 10 | .89836 | 8.83912 | .91574 | 10.86837 | .93315 | 13.95788 | 10 |
| 11 | .89865 | 8.86722 | .91603 | 10.90934 | .93344 | 14.02310 | 11 |
| 12 | .89894 | 8.89547 | .91632 | 10.95060 | .93373 | 14.08890 | 12 |
| 13 | .89923 | 8.92389 | .91661 | 10.99214 | .93402 | 14.15527 | 13 |
| 14 | .89952 | 8.95248 | .91690 | 11.03397 | .93431 | 14.22223 | 14 |
| 15 | .89981 | 8.98123 | .91719 | 11.07610 | .93460 | 14.28979 | 15 |
| 16 | .90010 | 9.01015 | .91748 | 11.11852 | .93489 | 14.35795 | 16 |
| 17 | .90039 | 9.03923 | .91777 | 11.16125 | .93518 | 14.42672 | 17 |
| 18 | .90068 | 9.06849 | .91806 | 11.20427 | .93547 | 14.49611 | 18 |
| 19 | .90097 | 9.09792 | .91835 | 11.24761 | .93576 | 14.56614 | 19 |
| 20 | .90126 | 9.12752 | .91864 | 11.29125 | .93605 | 14.63679 | 20 |
| 21 | .90155 | 9.15730 | .91893 | 11.33521 | .93634 | 14.70810 | 21 |
| 22 | .90184 | 9.18725 | .91922 | 11.37948 | .93663 | 14.78005 | 22 |
| 23 | .90213 | 9.21739 | .91951 | 11.42408 | .93692 | 14.85268 | 23 |
| 24 | .90242 | 9.24770 | .91980 | 11.46900 | .93721 | 14.92597 | 24 |
| 25 | .90271 | 9.27819 | .92009 | 11.51424 | .93750 | 14.99995 | 25 |
| 26 | .90300 | 9.30887 | .92038 | 11.55982 | .93779 | 15.07462 | 26 |
| 27 | .90329 | 9.33973 | .92067 | 11.60572 | .93808 | 15.14999 | 27 |
| 28 | .90358 | 9.37077 | .92096 | 11.65197 | .93837 | 15.22607 | 28 |
| 29 | .90386 | 9.40201 | .92125 | 11.69856 | .93866 | 15.30287 | 29 |
| 30 | .90415 | 9.43343 | .92154 | 11.74550 | .93895 | 15.38041 | 30 |
| 31 | .90444 | 9.46505 | .92183 | 11.79278 | .93924 | 15.45869 | 31 |
| 32 | .90473 | 9.49685 | .92212 | 11.84042 | .93953 | 15.53772 | 32 |
| 33 | .90502 | 9.52886 | .92241 | 11.88841 | .93982 | 15.61751 | 33 |
| 34 | .90531 | 9.56106 | .92270 | 11.93677 | .94011 | 15.69808 | 34 |
| 35 | .90560 | 9.59346 | .92299 | 11.98549 | .94040 | 15.77944 | 35 |
| 36 | .90589 | 9.62605 | .92328 | 12.03458 | .94069 | 15.86159 | 36 |
| 37 | .90618 | 9.65885 | .92357 | 12.08040 | .94098 | 15.94456 | 37 |
| 38 | .90647 | 9.69186 | .92386 | 12.13388 | .94127 | 16.02835 | 38 |
| 39 | .90676 | 9.72507 | .92415 | 12.18411 | .94156 | 16.11297 | 39 |
| 40 | .90705 | 9.75849 | .92444 | 12.23472 | .94186 | 16.19843 | 40 |
| 41 | .90734 | 9.79212 | .92473 | 12.28572 | .94215 | 16.28476 | 41 |
| 42 | .90763 | 9.82596 | .92502 | 12.33712 | .94244 | 16.37196 | 42 |
| 43 | .90792 | 9.86001 | .92531 | 12.38891 | .94273 | 16.46005 | 43 |
| 44 | .90821 | 9.89428 | .92560 | 12.44112 | .94302 | 16.54903 | 44 |
| 45 | .90850 | 9.92877 | .92589 | 12.49373 | .94331 | 16.63893 | 45 |
| 46 | .90879 | 9.96348 | .92618 | 12.54676 | .94360 | 16.72975 | 46 |
| 47 | .90908 | 9.99841 | .92647 | 12.60021 | .94389 | 16.82152 | 47 |
| 48 | .90937 | 10.03356 | .92676 | 12.65408 | .94418 | 16.91424 | 48 |
| 49 | .90966 | 10.06894 | .92705 | 12.70838 | .94447 | 17.00794 | 49 |
| 50 | .90995 | 10.10455 | .92734 | 12.76312 | .94476 | 17.10262 | 50 |
| 51 | .91024 | 10.14039 | .92763 | 12.81829 | .94505 | 17.19830 | 51 |
| 52 | .91053 | 10.17646 | .92792 | 12.87391 | .94534 | 17.29501 | 52 |
| 53 | .91082 | 10.21277 | .92821 | 12.92999 | .94563 | 17.39274 | 53 |
| 54 | .91111 | 10.24932 | .92850 | 12.98651 | .94592 | 17.49153 | 54 |
| 55 | .91140 | 10.28610 | .92879 | 13.04350 | .94621 | 17.59139 | 55 |
| 56 | .91169 | 10.32313 | .92908 | 13.10096 | .94650 | 17.69233 | 56 |
| 57 | .91197 | 10.36040 | .92937 | 13.15889 | .94679 | 17.79438 | 57 |
| 58 | .91226 | 10.39792 | .92966 | 13.21730 | .94708 | 17.89755 | 58 |
| 59 | .91255 | 10.43569 | .92995 | 13.27620 | .94737 | 18.00185 | 59 |
| 60 | .91284 | 10.47371 | .93024 | 13.33559 | .94766 | 18.10732 | 60 |

# TABLE XXIX.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

| ′ | 87° | | 88° | | 89° | | ′ |
|---|---|---|---|---|---|---|---|
| | Vers. | Ex. sec. | Vers. | Ex. sec. | Vers. | Ex. sec. | |
| 0 | .94766 | 18.10732 | .96510 | 27.65371 | .98255 | 56.29869 | 0 |
| 1 | .94795 | 18.21397 | .96539 | 27.89440 | .98284 | 57.26976 | 1 |
| 2 | .94825 | 18.32182 | .96568 | 28.13917 | .98313 | 58.27431 | 2 |
| 3 | .94854 | 18.43088 | .96597 | 28.38812 | .98342 | 59.31411 | 3 |
| 4 | .94883 | 18.54119 | .96626 | 28.64137 | .98371 | 60.39105 | 4 |
| 5 | .94912 | 18.65275 | .96655 | 28.89903 | .98400 | 61.50715 | 5 |
| 6 | .94941 | 18.76560 | .96684 | 29.16120 | .98429 | 62.66460 | 6 |
| 7 | .94970 | 18.87976 | .96714 | 29.42802 | .98458 | 63.86572 | 7 |
| 8 | .94999 | 18.99524 | .96743 | 29.69960 | .98487 | 65.11304 | 8 |
| 9 | .95028 | 19.11208 | .96772 | 29.97607 | .98517 | 66.40927 | 9 |
| 10 | .95057 | 19.23028 | .96801 | 30.25758 | .98546 | 67.75736 | 10 |
| 11 | .95086 | 19.34989 | .96830 | 30.54425 | .98575 | 69.16047 | 11 |
| 12 | .95115 | 19.47093 | .96859 | 30.83623 | .98604 | 70.62285 | 12 |
| 13 | .95144 | 19.59341 | .96888 | 31.13366 | .98633 | 72.14583 | 13 |
| 14 | .95173 | 19.71737 | .96917 | 31.43671 | .98662 | 73.73586 | 14 |
| 15 | .95202 | 19.84283 | .96946 | 31.74554 | .98691 | 75.39655 | 15 |
| 16 | .95231 | 19.96982 | .96975 | 32.06030 | .98720 | 77.13274 | 16 |
| 17 | .95260 | 20.09838 | .97004 | 32.38118 | .98749 | 78.94968 | 17 |
| 18 | .95289 | 20.22852 | .97033 | 32.70835 | .98778 | 80.85315 | 18 |
| 19 | .95318 | 20.36027 | .97062 | 33.04199 | .98807 | 82.84947 | 19 |
| 20 | .95347 | 20.49368 | .97092 | 33.38232 | .98836 | 84.94561 | 20 |
| 21 | .95377 | 20.62876 | .97121 | 33.72952 | .98866 | 87.14924 | 21 |
| 22 | .95406 | 20.76555 | .97150 | 34.08380 | .98895 | 89.46886 | 22 |
| 23 | .95435 | 20.90409 | .97179 | 34.44539 | .98924 | 91.91387 | 23 |
| 24 | .95464 | 21.04440 | .97208 | 34.81452 | .98953 | 94.49471 | 24 |
| 25 | .95493 | 21.18653 | .97237 | 35.19141 | .98982 | 97.22303 | 25 |
| 26 | .95522 | 21.33050 | .97266 | 35.57633 | .99011 | 100.1119 | 26 |
| 27 | .95551 | 21.47635 | .97295 | 35.96953 | .99040 | 103.1757 | 27 |
| 28 | .95580 | 21.62413 | .97324 | 36.37127 | .99069 | 106.4311 | 28 |
| 29 | .95609 | 21.77386 | .97353 | 36.78185 | .99098 | 109.8966 | 29 |
| 30 | .95638 | 21.92559 | .97382 | 37.20155 | .99127 | 113.5930 | 30 |
| 31 | .95667 | 22.07935 | .97411 | 37.63068 | .99156 | 117.5444 | 31 |
| 32 | .95696 | 22.23520 | .97440 | 38.06957 | .99186 | 121.7780 | 32 |
| 33 | .95725 | 22.39316 | .97470 | 38.51855 | .99215 | 126.3253 | 33 |
| 34 | .95754 | 22.55329 | .97499 | 38.97797 | .99244 | 131.2223 | 34 |
| 35 | .95783 | 22.71563 | .97528 | 39.44820 | .99273 | 136.5111 | 35 |
| 36 | .95812 | 22.88022 | .97557 | 39.92963 | .99302 | 142.2406 | 36 |
| 37 | .95842 | 23.04712 | .97586 | 40.42266 | .99331 | 148.4684 | 37 |
| 38 | .95871 | 23.21637 | .97615 | 40.92772 | .99360 | 155.2623 | 38 |
| 39 | .95900 | 23.38802 | .97644 | 41.44525 | .99389 | 162.7033 | 39 |
| 40 | .95929 | 23.56212 | .97673 | 41.97571 | .99418 | 170.8883 | 40 |
| 41 | .95958 | 23.73873 | .97702 | 42.51961 | .99447 | 179.9350 | 41 |
| 42 | .95987 | 23.91790 | .97731 | 43.07746 | .99476 | 189.9868 | 42 |
| 43 | .96016 | 24.09969 | .97760 | 43.64980 | .99505 | 201.2212 | 43 |
| 44 | .96045 | 24.28414 | .97789 | 44.23720 | .99535 | 213.8600 | 44 |
| 45 | .96074 | 24.47134 | .97819 | 44.84026 | .99564 | 228.1839 | 45 |
| 46 | .96103 | 24.66132 | .97848 | 45.45963 | .99593 | 244.5540 | 46 |
| 47 | .96132 | 24.85417 | .97877 | 46.09596 | .99622 | 263.4427 | 47 |
| 48 | .96161 | 25.04994 | .97906 | 46.74997 | .99651 | 285.4795 | 48 |
| 49 | .96190 | 25.24869 | .97935 | 47.42241 | .99680 | 311.5230 | 49 |
| 50 | .96219 | 25.45051 | .97964 | 48.11406 | .99709 | 342.7752 | 50 |
| 51 | .96248 | 25.65546 | .97993 | 48.82576 | .99738 | 380.9723 | 51 |
| 52 | .96277 | 25.86360 | .98022 | 49.55840 | .99767 | 428.7187 | 52 |
| 53 | .96307 | 26.07503 | .98051 | 50.31290 | .99796 | 490.1070 | 53 |
| 54 | .96336 | 26.28981 | .98080 | 51.09027 | .99825 | 571.9581 | 54 |
| 55 | .96365 | 26.50804 | .98109 | 51.89156 | .99855 | 686.5496 | 55 |
| 56 | .96394 | 26.72978 | .98138 | 52.71790 | .99884 | 858.4369 | 56 |
| 57 | .96423 | 26.95513 | .98168 | 53.57046 | .99913 | 1144.916 | 57 |
| 58 | .96452 | 27.18417 | .98197 | 54.45053 | .99942 | 1717.874 | 58 |
| 59 | .96481 | 27.41700 | .98226 | 55.35946 | .99971 | 3436.747 | 59 |
| 60 | .96510 | 27.65371 | .98255 | 56.29869 | 1.00000 | Infinite | 60 |

# TABLE XXX.—CUBIC YARDS PER 100 FEET. SLOPES ¼ : 1.

| Depth d | Base 12 | Base 14 | Base 16 | Base 18 | Base 22 | Base 24 | Base 26 | Base 28 |
|---|---|---|---|---|---|---|---|---|
| 1 | 45 | 53 | 60 | 68 | 82 | 90 | 97 | 105 |
| 2 | 93 | 107 | 122 | 137 | 167 | 181 | 196 | 211 |
| 3 | 142 | 163 | 186 | 208 | 253 | 275 | 297 | 319 |
| 4 | 193 | 222 | 252 | 281 | 341 | 370 | 400 | 430 |
| 5 | 245 | 282 | 319 | 356 | 431 | 468 | 505 | 542 |
| 6 | 300 | 344 | 389 | 433 | 522 | 567 | 611 | 656 |
| 7 | 356 | 408 | 460 | 512 | 616 | 668 | 719 | 771 |
| 8 | 415 | 474 | 533 | 593 | 711 | 770 | 830 | 889 |
| 9 | 475 | 542 | 608 | 675 | 808 | 875 | 942 | 1008 |
| 10 | 537 | 611 | 685 | 759 | 907 | 981 | 1056 | 1130 |
| 11 | 601 | 682 | 764 | 845 | 1008 | 1090 | 1171 | 1253 |
| 12 | 667 | 756 | 844 | 933 | 1111 | 1200 | 1289 | 1378 |
| 13 | 734 | 831 | 926 | 1023 | 1216 | 1312 | 1408 | 1505 |
| 14 | 804 | 907 | 1010 | 1115 | 1322 | 1426 | 1530 | 1633 |
| 15 | 875 | 986 | 1096 | 1208 | 1431 | 1542 | 1653 | 1764 |
| 16 | 948 | 1067 | 1184 | 1304 | 1541 | 1659 | 1778 | 1896 |
| 17 | 1023 | 1149 | 1274 | 1401 | 1653 | 1779 | 1905 | 2031 |
| 18 | 1100 | 1233 | 1366 | 1500 | 1767 | 1900 | 2033 | 2167 |
| 19 | 1179 | 1319 | 1460 | 1601 | 1882 | 2023 | 2164 | 2305 |
| 20 | 1259 | 1407 | 1555 | 1704 | 2000 | 2148 | 2296 | 2444 |
| 21 | 1342 | 1497 | 1653 | 1808 | 2119 | 2275 | 2431 | 2586 |
| 22 | 1426 | 1589 | 1752 | 1915 | 2241 | 2404 | 2567 | 2730 |
| 23 | 1512 | 1682 | 1853 | 2023 | 2364 | 2534 | 2705 | 2875 |
| 24 | 1600 | 1778 | 1955 | 2133 | 2489 | 2667 | 2844 | 3022 |
| 25 | 1690 | 1875 | 2060 | 2245 | 2616 | 2801 | 2986 | 3171 |
| 26 | 1781 | 1974 | 2166 | 2359 | 2744 | 2937 | 3130 | 3322 |
| 27 | 1875 | 2075 | 2274 | 2475 | 2875 | 3075 | 3275 | 3475 |
| 28 | 1970 | 2178 | 2384 | 2593 | 3007 | 3215 | 3422 | 3630 |
| 29 | 2068 | 2282 | 2496 | 2712 | 3142 | 3356 | 3571 | 3786 |
| 30 | 2167 | 2389 | 2610 | 2833 | 3278 | 3500 | 3722 | 3944 |
| 31 | 2268 | 2497 | 2726 | 2956 | 3416 | 3645 | 3875 | 4105 |
| 32 | 2370 | 2607 | 2844 | 3081 | 3556 | 3793 | 4030 | 4267 |
| 33 | 2475 | 2719 | 2964 | 3208 | 3697 | 3942 | 4186 | 4431 |
| 34 | 2581 | 2833 | 3085 | 3337 | 3841 | 4093 | 4344 | 4596 |
| 35 | 2690 | 2949 | 3208 | 3468 | 3986 | 4245 | 4505 | 4764 |
| 36 | 2800 | 3067 | 3333 | 3600 | 4133 | 4400 | 4667 | 4933 |
| 37 | 2912 | 3186 | 3460 | 3734 | 4282 | 4556 | 4831 | 5105 |
| 38 | 3026 | 3307 | 3589 | 3870 | 4433 | 4715 | 4996 | 5278 |
| 39 | 3142 | 3431 | 3719 | 4008 | 4586 | 4875 | 5164 | 5453 |
| 40 | 3259 | 3556 | 3852 | 4148 | 4741 | 5037 | 5333 | 5630 |
| 41 | 3379 | 3682 | 3986 | 4290 | 4897 | 5201 | 5505 | 5808 |
| 42 | 3500 | 3811 | 4122 | 4433 | 5056 | 5367 | 5678 | 5989 |
| 43 | 3623 | 3942 | 4260 | 4579 | 5216 | 5534 | 5853 | 6171 |
| 44 | 3748 | 4074 | 4400 | 4726 | 5378 | 5704 | 6030 | 6356 |
| 45 | 3875 | 4208 | 4541 | 4875 | 5542 | 5875 | 6208 | 6542 |
| 46 | 4004 | 4344 | 4684 | 5026 | 5707 | 6048 | 6389 | 6730 |
| 47 | 4134 | 4482 | 4830 | 5179 | 5875 | 6223 | 6571 | 6919 |
| 48 | 4267 | 4622 | 4978 | 5333 | 6044 | 6400 | 6756 | 7111 |
| 49 | 4401 | 4764 | 5127 | 5490 | 6216 | 6579 | 6942 | 7305 |
| 50 | 4537 | 4907 | 5278 | 5648 | 6389 | 6759 | 7130 | 7500 |
| 51 | 4675 | 5053 | 5430 | 5808 | 6564 | 6942 | 7319 | 7697 |
| 52 | 4815 | 5200 | 5584 | 5970 | 6741 | 7126 | 7511 | 7896 |
| 53 | 4956 | 5349 | 5741 | 6134 | 6919 | 7312 | 7705 | 8097 |
| 54 | 5100 | 5500 | 5900 | 6300 | 7100 | 7500 | 7900 | 8300 |
| 55 | 5245 | 5653 | 6060 | 6468 | 7282 | 7690 | 8097 | 8505 |
| 56 | 5393 | 5807 | 6222 | 6637 | 7467 | 7881 | 8296 | 8711 |
| 57 | 5542 | 5964 | 6386 | 6808 | 7653 | 8075 | 8497 | 8919 |
| 58 | 5693 | 6122 | 6552 | 6981 | 7841 | 8270 | 8700 | 9130 |
| 59 | 5845 | 6282 | 6719 | 7156 | 8031 | 8468 | 8905 | 9342 |
| 60 | 6000 | 6444 | 6889 | 7333 | 8222 | 8667 | 9111 | 9556 |

| Depth d | Base 12 | Base 14 | Base 16 | Base 18 | Base 22 | Base 24 | Base 26 | Base 28 |
|---|---|---|---|---|---|---|---|---|
| 1 | 46 | 54 | 61 | 69 | 83 | 91 | 98 | 106 |
| 2 | 96 | 111 | 126 | 141 | 170 | 185 | 200 | 215 |
| 3 | 150 | 172 | 194 | 217 | 261 | 283 | 306 | 328 |
| 4 | 207 | 237 | 267 | 296 | 356 | 385 | 415 | 444 |
| 5 | 269 | 306 | 343 | 380 | 454 | 491 | 528 | 565 |
| 6 | 333 | 378 | 422 | 467 | 556 | 600 | 644 | 689 |
| 7 | 402 | 454 | 506 | 557 | 661 | 713 | 765 | 817 |
| 8 | 474 | 533 | 593 | 652 | 770 | 830 | 889 | 948 |
| 9 | 550 | 617 | 683 | 750 | 883 | 950 | 1017 | 1083 |
| 10 | 630 | 704 | 778 | 852 | 1000 | 1074 | 1148 | 1222 |
| 11 | 713 | 794 | 876 | 957 | 1120 | 1202 | 1283 | 1365 |
| 12 | 800 | 889 | 978 | 1067 | 1244 | 1333 | 1422 | 1511 |
| 13 | 891 | 987 | 1083 | 1180 | 1372 | 1469 | 1565 | 1661 |
| 14 | 985 | 1089 | 1193 | 1296 | 1504 | 1607 | 1711 | 1815 |
| 15 | 1083 | 1194 | 1306 | 1417 | 1639 | 1750 | 1861 | 1972 |
| 16 | 1185 | 1304 | 1422 | 1541 | 1779 | 1896 | 2015 | 2133 |
| 17 | 1291 | 1417 | 1543 | 1669 | 1920 | 2046 | 2172 | 2298 |
| 18 | 1400 | 1533 | 1667 | 1800 | 2067 | 2200 | 2333 | 2467 |
| 19 | 1513 | 1654 | 1794 | 1935 | 2217 | 2357 | 2498 | 2639 |
| 20 | 1630 | 1778 | 1926 | 2074 | 2370 | 2519 | 2667 | 2815 |
| 21 | 1750 | 1906 | 2061 | 2217 | 2528 | 2683 | 2839 | 2994 |
| 22 | 1874 | 2037 | 2200 | 2363 | 2689 | 2852 | 3015 | 3178 |
| 23 | 2002 | 2172 | 2343 | 2513 | 2854 | 3024 | 3194 | 3365 |
| 24 | 2133 | 2311 | 2489 | 2667 | 3022 | 3200 | 3378 | 3556 |
| 25 | 2269 | 2454 | 2639 | 2824 | 3194 | 3380 | 3565 | 3750 |
| 26 | 2407 | 2600 | 2793 | 2985 | 3370 | 3563 | 3756 | 3948 |
| 27 | 2550 | 2750 | 2950 | 3150 | 3550 | 3750 | 3950 | 4151 |
| 28 | 2696 | 2904 | 3111 | 3319 | 3733 | 3941 | 4148 | 4356 |
| 29 | 2846 | 3061 | 3276 | 3491 | 3920 | 4135 | 4350 | 4565 |
| 30 | 3000 | 3222 | 3444 | 3667 | 4111 | 4333 | 4556 | 4778 |
| 31 | 3157 | 3387 | 3617 | 3846 | 4306 | 4535 | 4765 | 4994 |
| 32 | 3319 | 3556 | 3793 | 4030 | 4504 | 4741 | 4978 | 5215 |
| 33 | 3483 | 3728 | 3972 | 4217 | 4706 | 4950 | 5194 | 5439 |
| 34 | 3652 | 3904 | 4156 | 4407 | 4911 | 5163 | 5415 | 5667 |
| 35 | 3824 | 4083 | 4343 | 4602 | 5120 | 5380 | 5639 | 5898 |
| 36 | 4000 | 4267 | 4533 | 4800 | 5333 | 5600 | 5867 | 6133 |
| 37 | 4180 | 4454 | 4728 | 5002 | 5550 | 5824 | 6098 | 6372 |
| 38 | 4363 | 4644 | 4926 | 5207 | 5770 | 6052 | 6333 | 6615 |
| 39 | 4550 | 4839 | 5128 | 5417 | 5994 | 6283 | 6572 | 6861 |
| 40 | 4741 | 5037 | 5333 | 5630 | 6222 | 6519 | 6815 | 7111 |
| 41 | 4935 | 5239 | 5543 | 5846 | 6454 | 6757 | 7061 | 7365 |
| 42 | 5133 | 5444 | 5756 | 6067 | 6689 | 7000 | 7311 | 7622 |
| 43 | 5335 | 5654 | 5972 | 6291 | 6928 | 7246 | 7565 | 7883 |
| 44 | 5541 | 5867 | 6193 | 6519 | 7170 | 7496 | 7822 | 8148 |
| 45 | 5750 | 6083 | 6417 | 6750 | 7417 | 7750 | 8083 | 8417 |
| 46 | 5963 | 6304 | 6644 | 6985 | 7667 | 8007 | 8348 | 8689 |
| 47 | 6180 | 6528 | 6876 | 7224 | 7920 | 8269 | 8617 | 8965 |
| 48 | 6400 | 6756 | 7111 | 7467 | 8178 | 8533 | 8889 | 9244 |
| 49 | 6624 | 6987 | 7350 | 7713 | 8439 | 8802 | 9165 | 9528 |
| 50 | 6852 | 7222 | 7593 | 7963 | 8704 | 9074 | 9444 | 9815 |
| 51 | 7083 | 7461 | 7839 | 8217 | 8972 | 9350 | 9728 | 10106 |
| 52 | 7319 | 7704 | 8089 | 8474 | 9244 | 9630 | 10015 | 10400 |
| 53 | 7557 | 7950 | 8343 | 8735 | 9520 | 9913 | 10306 | 10698 |
| 54 | 7800 | 8200 | 8600 | 9000 | 9800 | 10200 | 10600 | 11000 |
| 55 | 8046 | 8454 | 8861 | 9269 | 10083 | 10491 | 10898 | 11306 |
| 56 | 8296 | 8711 | 9126 | 9541 | 10370 | 10785 | 11200 | 11615 |
| 57 | 8550 | 8972 | 9394 | 9817 | 10661 | 11083 | 11506 | 11928 |
| 58 | 8807 | 9237 | 9667 | 10096 | 10956 | 11385 | 11815 | 12244 |
| 59 | 9069 | 9506 | 9943 | 10380 | 11254 | 11691 | 12128 | 12565 |
| 60 | 9333 | 9778 | 10222 | 10667 | 11556 | 12000 | 12444 | 12889 |

TABLE XXX.—CUBIC YARDS PER 100 FEET. SLOPES 1 : 1.

| Depth d | Base 12 | Base 14 | Base 16 | Base 18 | Base 20 | Base 28 | Base 30 | Base 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 48 | 56 | 63 | 70 | 78 | 107 | 115 | 122 |
| 2 | 104 | 119 | 133 | 148 | 163 | 222 | 237 | 252 |
| 3 | 167 | 189 | 211 | 233 | 256 | 344 | 367 | 389 |
| 4 | 237 | 267 | 296 | 326 | 356 | 474 | 504 | 533 |
| 5 | 315 | 352 | 389 | 426 | 463 | 611 | 648 | 685 |
| 6 | 400 | 444 | 489 | 533 | 578 | 756 | 800 | 844 |
| 7 | 493 | 544 | 596 | 648 | 700 | 907 | 959 | 1011 |
| 8 | 593 | 652 | 711 | 770 | 830 | 1067 | 1126 | 1185 |
| 9 | 700 | 767 | 833 | 900 | 967 | 1233 | 1300 | 1367 |
| 10 | 815 | 889 | 963 | 1037 | 1111 | 1407 | 1481 | 1556 |
| 11 | 937 | 1019 | 1100 | 1181 | 1263 | 1589 | 1670 | 1752 |
| 12 | 1067 | 1156 | 1244 | 1333 | 1422 | 1778 | 1867 | 1956 |
| 13 | 1204 | 1300 | 1396 | 1493 | 1589 | 1974 | 2070 | 2167 |
| 14 | 1348 | 1452 | 1556 | 1659 | 1763 | 2178 | 2281 | 2385 |
| 15 | 1500 | 1611 | 1722 | 1833 | 1944 | 2389 | 2500 | 2611 |
| 16 | 1659 | 1778 | 1896 | 2015 | 2133 | 2607 | 2726 | 2844 |
| 17 | 1826 | 1952 | 2078 | 2204 | 2330 | 2833 | 2959 | 3085 |
| 18 | 2000 | 2133 | 2267 | 2400 | 2533 | 3067 | 3200 | 3333 |
| 19 | 2181 | 2322 | 2463 | 2604 | 2744 | 3307 | 3448 | 3589 |
| 20 | 2370 | 2519 | 2667 | 2815 | 2963 | 3556 | 3704 | 3852 |
| 21 | 2567 | 2722 | 2878 | 3033 | 3189 | 3811 | 3967 | 4122 |
| 22 | 2770 | 2933 | 3096 | 3259 | 3422 | 4074 | 4237 | 4400 |
| 23 | 2981 | 3152 | 3322 | 3493 | 3663 | 4344 | 4515 | 4685 |
| 24 | 3200 | 3378 | 3556 | 3733 | 3911 | 4622 | 4800 | 4978 |
| 25 | 3426 | 3611 | 3796 | 3981 | 4167 | 4907 | 5093 | 5278 |
| 26 | 3659 | 3852 | 4044 | 4237 | 4430 | 5200 | 5393 | 5585 |
| 27 | 3900 | 4100 | 4300 | 4500 | 4700 | 5500 | 5700 | 5900 |
| 28 | 4148 | 4356 | 4563 | 4770 | 4978 | 5807 | 6015 | 6222 |
| 29 | 4404 | 4619 | 4833 | 5048 | 5263 | 6122 | 6337 | 6552 |
| 30 | 4667 | 4889 | 5111 | 5333 | 5556 | 6444 | 6667 | 6889 |
| 31 | 4937 | 5167 | 5396 | 5626 | 5856 | 6774 | 7004 | 7233 |
| 32 | 5215 | 5452 | 5689 | 5926 | 6163 | 7111 | 7348 | 7585 |
| 33 | 5500 | 5744 | 5989 | 6233 | 6478 | 7456 | 7700 | 7944 |
| 34 | 5793 | 6044 | 6296 | 6548 | 6800 | 7807 | 8059 | 8311 |
| 35 | 6093 | 6352 | 6611 | 6870 | 7130 | 8167 | 8426 | 8685 |
| 36 | 6400 | 6667 | 6933 | 7200 | 7467 | 8533 | 8800 | 9067 |
| 37 | 6715 | 6989 | 7263 | 7537 | 7811 | 8907 | 9181 | 9456 |
| 38 | 7037 | 7319 | 7600 | 7881 | 8163 | 9289 | 9570 | 9852 |
| 39 | 7367 | 7656 | 7944 | 8233 | 8522 | 9678 | 9967 | 10256 |
| 40 | 7704 | 8000 | 8296 | 8593 | 8889 | 10074 | 10370 | 10667 |
| 41 | 8048 | 8352 | 8656 | 8959 | 9263 | 10478 | 10781 | 11085 |
| 42 | 8400 | 8711 | 9022 | 9333 | 9644 | 10889 | 11200 | 11511 |
| 43 | 8759 | 9078 | 9396 | 9715 | 10033 | 11307 | 11626 | 11944 |
| 44 | 9126 | 9452 | 9778 | 10104 | 10430 | 11733 | 12059 | 12385 |
| 45 | 9500 | 9833 | 10167 | 10500 | 10833 | 12167 | 12500 | 12833 |
| 46 | 9881 | 10222 | 10563 | 10904 | 11244 | 12607 | 12948 | 13289 |
| 47 | 10270 | 10619 | 10967 | 11315 | 11663 | 13056 | 13404 | 13752 |
| 48 | 10667 | 11022 | 11378 | 11733 | 12089 | 13511 | 13867 | 14222 |
| 49 | 11070 | 11433 | 11796 | 12159 | 12522 | 13974 | 14337 | 14700 |
| 50 | 11481 | 11852 | 12222 | 12593 | 12963 | 14444 | 14815 | 15185 |
| 51 | 11900 | 12278 | 12656 | 13033 | 13411 | 14922 | 15300 | 15678 |
| 52 | 12326 | 12711 | 13096 | 13481 | 13867 | 15407 | 15793 | 16178 |
| 53 | 12759 | 13152 | 13544 | 13937 | 14330 | 15900 | 16293 | 16685 |
| 54 | 13200 | 13600 | 14000 | 14400 | 14800 | 16400 | 16800 | 17200 |
| 55 | 13648 | 14056 | 14463 | 14870 | 15278 | 16907 | 17315 | 17722 |
| 56 | 14104 | 14519 | 14933 | 15348 | 15763 | 17422 | 17837 | 18252 |
| 57 | 14567 | 14989 | 15411 | 15833 | 16256 | 17944 | 18367 | 18789 |
| 58 | 15037 | 15467 | 15896 | 16326 | 16756 | 18474 | 18904 | 19333 |
| 59 | 15515 | 15952 | 16389 | 16826 | 17263 | 19011 | 19448 | 19885 |
| 60 | 16000 | 16444 | 16889 | 17333 | 17778 | 19556 | 20000 | 20444 |

TABLE XXX.—CUBIC YARDS PER 100 FEET. SLOPES 1¼ : 1.

| Depth d | Base 12 | Base 14 | Base 16 | Base 18 | Base 20 | Base 28 | Base 30 | Base 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 49 | 56 | 64 | 71 | 79 | 108 | 116 | 123 |
| 2 | 107 | 122 | 137 | 152 | 167 | 226 | 241 | 256 |
| 3 | 175 | 197 | 219 | 242 | 264 | 353 | 375 | 397 |
| 4 | 252 | 281 | 311 | 341 | 370 | 489 | 519 | 548 |
| 5 | 338 | 375 | 412 | 449 | 486 | 634 | 671 | 708 |
| 6 | 433 | 478 | 522 | 567 | 611 | 789 | 833 | 878 |
| 7 | 538 | 590 | 642 | 694 | 745 | 953 | 1005 | 1056 |
| 8 | 652 | 711 | 770 | 830 | 889 | 1126 | 1185 | 1244 |
| 9 | 775 | 842 | 908 | 975 | 1042 | 1308 | 1375 | 1442 |
| 10 | 907 | 981 | 1056 | 1130 | 1204 | 1500 | 1574 | 1648 |
| 11 | 1049 | 1131 | 1212 | 1294 | 1375 | 1701 | 1782 | 1864 |
| 12 | 1200 | 1289 | 1378 | 1467 | 1556 | 1911 | 2000 | 2089 |
| 13 | 1360 | 1456 | 1553 | 1649 | 1745 | 2131 | 2227 | 2323 |
| 14 | 1530 | 1633 | 1737 | 1841 | 1944 | 2359 | 2463 | 2567 |
| 15 | 1708 | 1819 | 1931 | 2042 | 2153 | 2597 | 2708 | 2819 |
| 16 | 1896 | 2015 | 2133 | 2252 | 2370 | 2844 | 2963 | 3081 |
| 17 | 2094 | 2219 | 2345 | 2471 | 2597 | 3101 | 3227 | 3353 |
| 18 | 2300 | 2433 | 2567 | 2700 | 2833 | 3367 | 3500 | 3633 |
| 19 | 2516 | 2656 | 2797 | 2938 | 3079 | 3642 | 3782 | 3923 |
| 20 | 2741 | 2889 | 3037 | 3185 | 3333 | 3926 | 4074 | 4222 |
| 21 | 2975 | 3131 | 3286 | 3442 | 3597 | 4220 | 4375 | 4531 |
| 22 | 3219 | 3381 | 3544 | 3707 | 3870 | 4522 | 4685 | 4848 |
| 23 | 3471 | 3642 | 3812 | 3982 | 4153 | 4834 | 5005 | 5175 |
| 24 | 3733 | 3911 | 4089 | 4267 | 4444 | 5156 | 5333 | 5511 |
| 25 | 4005 | 4190 | 4375 | 4560 | 4745 | 5486 | 5671 | 5856 |
| 26 | 4285 | 4478 | 4670 | 4863 | 5056 | 5826 | 6019 | 6211 |
| 27 | 4575 | 4775 | 4975 | 5175 | 5375 | 6175 | 6375 | 6575 |
| 28 | 4874 | 5081 | 5289 | 5496 | 5704 | 6538 | 6741 | 6948 |
| 29 | 5182 | 5397 | 5612 | 5827 | 6042 | 6901 | 7116 | 7331 |
| 30 | 5500 | 5722 | 5944 | 6167 | 6389 | 7278 | 7500 | 7722 |
| 31 | 5827 | 6056 | 6286 | 6516 | 6745 | 7664 | 7894 | 8123 |
| 32 | 6163 | 6400 | 6637 | 6874 | 7111 | 8059 | 8296 | 8533 |
| 33 | 6508 | 6753 | 6997 | 7242 | 7486 | 8464 | 8708 | 8953 |
| 34 | 6863 | 7115 | 7367 | 7619 | 7870 | 8878 | 9130 | 9381 |
| 35 | 7227 | 7486 | 7745 | 8005 | 8264 | 9301 | 9560 | 9819 |
| 36 | 7600 | 7867 | 8133 | 8400 | 8667 | 9733 | 10000 | 10267 |
| 37 | 7982 | 8256 | 8531 | 8805 | 9079 | 10175 | 10449 | 10723 |
| 38 | 8374 | 8656 | 8937 | 9219 | 9500 | 10626 | 10907 | 11189 |
| 39 | 8775 | 9064 | 9353 | 9642 | 9931 | 11086 | 11375 | 11664 |
| 40 | 9185 | 9481 | 9778 | 10074 | 10370 | 11556 | 11852 | 12148 |
| 41 | 9605 | 9908 | 10212 | 10516 | 10819 | 12034 | 12338 | 12642 |
| 42 | 10033 | 10344 | 10656 | 10967 | 11278 | 12522 | 12833 | 13144 |
| 43 | 10471 | 10790 | 11108 | 11427 | 11745 | 13020 | 13338 | 13656 |
| 44 | 10919 | 11244 | 11570 | 11896 | 12222 | 13526 | 13852 | 14178 |
| 45 | 11375 | 11708 | 12042 | 12375 | 12708 | 14042 | 14375 | 14708 |
| 46 | 11841 | 12181 | 12522 | 12863 | 13204 | 14567 | 14907 | 15248 |
| 47 | 12316 | 12664 | 13012 | 13360 | 13708 | 15101 | 15449 | 15797 |
| 48 | 12800 | 13156 | 13511 | 13867 | 14222 | 15644 | 16000 | 16356 |
| 49 | 13294 | 13656 | 14019 | 14382 | 14745 | 16197 | 16560 | 16923 |
| 50 | 13796 | 14167 | 14537 | 14907 | 15278 | 16759 | 17130 | 17500 |
| 51 | 14308 | 14686 | 15064 | 15442 | 15819 | 17331 | 17708 | 18086 |
| 52 | 14830 | 15215 | 15600 | 15985 | 16370 | 17911 | 18296 | 18681 |
| 53 | 15360 | 15753 | 16145 | 16538 | 16931 | 18501 | 18894 | 19286 |
| 54 | 15900 | 16300 | 16700 | 17100 | 17500 | 19100 | 19500 | 19900 |
| 55 | 16449 | 16856 | 17264 | 17671 | 18079 | 19708 | 20116 | 20523 |
| 56 | 17007 | 17422 | 17837 | 18252 | 18667 | 20326 | 20741 | 21156 |
| 57 | 17575 | 17997 | 18419 | 18442 | 19264 | 20953 | 21375 | 21797 |
| 58 | 18152 | 18581 | 19011 | 19441 | 19870 | 21589 | 22019 | 22448 |
| 59 | 18738 | 19175 | 19612 | 20049 | 20486 | 22234 | 22671 | 23108 |
| 60 | 19333 | 19778 | 20222 | 20667 | 21111 | 22889 | 23333 | 23778 |

TABLE XXX.—CUBIC YARDS PER 100 FEET. SLOPES 1½ : 1.

| Depth d | Base 12 | Base 14 | Base 16 | Base 18 | Base 20 | Base 28 | Base 30 | Base 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 50 | 57 | 65 | 72 | 80 | 109 | 117 | 124 |
| 2 | 111 | 126 | 141 | 156 | 170 | 230 | 244 | 259 |
| 3 | 183 | 206 | 228 | 250 | 272 | 361 | 383 | 406 |
| 4 | 267 | 296 | 326 | 356 | 385 | 504 | 533 | 563 |
| 5 | 361 | 398 | 435 | 472 | 509 | 657 | 694 | 731 |
| 6 | 467 | 511 | 556 | 600 | 644 | 822 | 867 | 911 |
| 7 | 583 | 635 | 687 | 739 | 791 | 998 | 1050 | 1102 |
| 8 | 711 | 770 | 830 | 889 | 948 | 1185 | 1244 | 1304 |
| 9 | 850 | 917 | 983 | 1050 | 1116 | 1383 | 1450 | 1517 |
| 10 | 1000 | 1074 | 1148 | 1222 | 1296 | 1593 | 1667 | 1741 |
| 11 | 1161 | 1243 | 1324 | 1406 | 1487 | 1813 | 1894 | 1976 |
| 12 | 1333 | 1422 | 1511 | 1600 | 1689 | 2044 | 2133 | 2222 |
| 13 | 1517 | 1613 | 1709 | 1806 | 1902 | 2287 | 2383 | 2480 |
| 14 | 1711 | 1815 | 1919 | 2022 | 2126 | 2541 | 2644 | 2748 |
| 15 | 1917 | 2028 | 2139 | 2250 | 2361 | 2806 | 2917 | 3028 |
| 16 | 2133 | 2252 | 2370 | 2489 | 2607 | 3081 | 3200 | 3319 |
| 17 | 2361 | 2487 | 2613 | 2739 | 2865 | 3369 | 3494 | 3620 |
| 18 | 2600 | 2733 | 2867 | 3000 | 3133 | 3667 | 3800 | 3933 |
| 19 | 2850 | 2991 | 3131 | 3272 | 3413 | 3976 | 4117 | 4257 |
| 20 | 3111 | 3259 | 3407 | 3556 | 3704 | 4296 | 4444 | 4592 |
| 21 | 3383 | 3539 | 3694 | 3850 | 4005 | 4628 | 4783 | 4939 |
| 22 | 3667 | 3830 | 3993 | 4156 | 4318 | 4970 | 5133 | 5296 |
| 23 | 3961 | 4131 | 4302 | 4472 | 4642 | 5324 | 5494 | 5665 |
| 24 | 4267 | 4444 | 4622 | 4800 | 4978 | 5689 | 5867 | 6044 |
| 25 | 4583 | 4769 | 4954 | 5139 | 5324 | 6065 | 6250 | 6435 |
| 26 | 4911 | 5104 | 5296 | 5489 | 5681 | 6452 | 6644 | 6837 |
| 27 | 5250 | 5450 | 5650 | 5850 | 6050 | 6850 | 7050 | 7250 |
| 28 | 5600 | 5807 | 6015 | 6222 | 6430 | 7259 | 7467 | 7674 |
| 29 | 5961 | 6176 | 6391 | 6606 | 6820 | 7680 | 7894 | 8109 |
| 30 | 6333 | 6556 | 6778 | 7000 | 7222 | 8111 | 8333 | 8555 |
| 31 | 6717 | 6946 | 7176 | 7406 | 7635 | 8554 | 8783 | 9013 |
| 32 | 7111 | 7348 | 7585 | 7822 | 8059 | 9007 | 9244 | 9482 |
| 33 | 7517 | 7761 | 8006 | 8250 | 8494 | 9472 | 9717 | 9962 |
| 34 | 7933 | 8185 | 8437 | 8689 | 8941 | 9948 | 10200 | 10452 |
| 35 | 8361 | 8620 | 8880 | 9139 | 9398 | 10435 | 10694 | 10954 |
| 36 | 8800 | 9067 | 9333 | 9600 | 9867 | 10933 | 11200 | 11467 |
| 37 | 9250 | 9524 | 9798 | 10072 | 10346 | 11443 | 11717 | 11991 |
| 38 | 9711 | 9993 | 10274 | 10556 | 10837 | 11963 | 12244 | 12526 |
| 39 | 10183 | 10472 | 10761 | 11050 | 11339 | 12494 | 12783 | 13072 |
| 40 | 10667 | 10963 | 11259 | 11556 | 11852 | 13037 | 13333 | 13630 |
| 41 | 11161 | 11465 | 11769 | 12072 | 12376 | 13591 | 13894 | 14198 |
| 42 | 11667 | 11978 | 12289 | 12600 | 12911 | 14156 | 14467 | 14778 |
| 43 | 12183 | 12502 | 12820 | 13139 | 13457 | 14731 | 15050 | 15369 |
| 44 | 12711 | 13037 | 13363 | 13689 | 14015 | 15319 | 15644 | 15970 |
| 45 | 13250 | 13583 | 13917 | 14250 | 14583 | 15917 | 16250 | 16583 |
| 46 | 13800 | 14141 | 14481 | 14822 | 15163 | 16526 | 16867 | 17207 |
| 47 | 14361 | 14709 | 15057 | 15406 | 15754 | 17146 | 17494 | 17843 |
| 48 | 14933 | 15289 | 15644 | 16000 | 16356 | 17778 | 18133 | 18489 |
| 49 | 15517 | 15880 | 16243 | 16606 | 16968 | 18420 | 18783 | 19146 |
| 50 | 16111 | 16481 | 16852 | 17222 | 17592 | 19074 | 19444 | 19815 |
| 51 | 16717 | 17094 | 17472 | 17850 | 18228 | 19739 | 20117 | 20494 |
| 52 | 17333 | 17719 | 18104 | 18489 | 18874 | 20415 | 20800 | 21185 |
| 53 | 17961 | 18354 | 18746 | 19139 | 19531 | 21102 | 21494 | 21887 |
| 54 | 18600 | 19000 | 19400 | 19800 | 20200 | 21800 | 22200 | 22600 |
| 55 | 19250 | 19657 | 20065 | 20472 | 20880 | 22509 | 22917 | 23324 |
| 56 | 19911 | 20326 | 20741 | 21156 | 21570 | 23230 | 23644 | 24059 |
| 57 | 20583 | 21006 | 21428 | 21850 | 22272 | 23961 | 24383 | 24805 |
| 58 | 21267 | 21696 | 22126 | 22556 | 22985 | 24704 | 25133 | 25563 |
| 59 | 21961 | 22398 | 22835 | 23272 | 23709 | 25457 | 25894 | 26332 |
| 60 | 22667 | 23111 | 23556 | 24000 | 24444 | 26222 | 26667 | 27111 |

## TABLE XXX.—CUBIC YARDS PER 100 FEET. SLOPES 2 : 1.

| Depth d | Base 12 | Base 14 | Base 16 | Base 18 | Base 20 | Base 28 | Base 30 | Base 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 52 | 59 | 67 | 74 | 81 | 111 | 119 | 126 |
| 2 | 119 | 133 | 148 | 163 | 178 | 237 | 252 | 267 |
| 3 | 200 | 222 | 244 | 267 | 289 | 378 | 400 | 422 |
| 4 | 296 | 326 | 356 | 385 | 415 | 533 | 563 | 593 |
| 5 | 407 | 444 | 481 | 519 | 556 | 704 | 741 | 778 |
| 6 | 533 | 578 | 622 | 667 | 711 | 889 | 933 | 978 |
| 7 | 674 | 726 | 778 | 830 | 881 | 1089 | 1141 | 1193 |
| 8 | 830 | 889 | 948 | 1007 | 1067 | 1304 | 1363 | 1422 |
| 9 | 1000 | 1067 | 1133 | 1200 | 1267 | 1533 | 1600 | 1667 |
| 10 | 1185 | 1259 | 1333 | 1407 | 1481 | 1778 | 1852 | 1926 |
| 11 | 1385 | 1467 | 1548 | 1630 | 1711 | 2037 | 2119 | 2200 |
| 12 | 1600 | 1689 | 1778 | 1867 | 1956 | 2311 | 2400 | 2489 |
| 13 | 1830 | 1926 | 2022 | 2119 | 2215 | 2600 | 2696 | 2793 |
| 14 | 2074 | 2178 | 2281 | 2385 | 2489 | 2904 | 3007 | 3111 |
| 15 | 2333 | 2444 | 2556 | 2667 | 2778 | 3222 | 3333 | 3444 |
| 16 | 2607 | 2726 | 2844 | 2963 | 3081 | 3556 | 3674 | 3793 |
| 17 | 2896 | 3022 | 3148 | 3274 | 3400 | 3904 | 4030 | 4156 |
| 18 | 3200 | 3333 | 3467 | 3600 | 3733 | 4267 | 4400 | 4533 |
| 19 | 3519 | 3659 | 3800 | 3941 | 4081 | 4644 | 4785 | 4926 |
| 20 | 3852 | 4000 | 4148 | 4296 | 4444 | 5037 | 5185 | 5333 |
| 21 | 4200 | 4356 | 4511 | 4667 | 4822 | 5444 | 5600 | 5756 |
| 22 | 4563 | 4730 | 4889 | 5052 | 5215 | 5867 | 6030 | 6193 |
| 23 | 4941 | 5111 | 5281 | 5452 | 5622 | 6304 | 6474 | 6644 |
| 24 | 5333 | 5511 | 5689 | 5867 | 6044 | 6756 | 6933 | 7111 |
| 25 | 5741 | 5926 | 6111 | 6296 | 6481 | 7222 | 7407 | 7593 |
| 26 | 6163 | 6356 | 6548 | 6741 | 6933 | 7704 | 7896 | 8089 |
| 27 | 6600 | 6800 | 7000 | 7200 | 7400 | 8200 | 8400 | 8600 |
| 28 | 7052 | 7259 | 7467 | 7674 | 7881 | 8711 | 8919 | 9126 |
| 29 | 7519 | 7733 | 7948 | 8163 | 8378 | 9237 | 9452 | 9667 |
| 30 | 8000 | 8222 | 8444 | 8667 | 8889 | 9778 | 10000 | 10222 |
| 31 | 8496 | 8726 | 8956 | 9185 | 9415 | 10333 | 10563 | 10793 |
| 32 | 9007 | 9244 | 9481 | 9719 | 9956 | 10904 | 11141 | 11378 |
| 33 | 9533 | 9778 | 10022 | 10267 | 10511 | 11489 | 11733 | 11978 |
| 34 | 10074 | 10326 | 10578 | 10830 | 11081 | 12089 | 12341 | 12593 |
| 35 | 10630 | 10889 | 11148 | 11407 | 11667 | 12704 | 12963 | 13222 |
| 36 | 11200 | 11467 | 11733 | 12000 | 12267 | 13333 | 13600 | 13867 |
| 37 | 11785 | 12059 | 12333 | 12607 | 12881 | 13978 | 14252 | 14526 |
| 38 | 12385 | 12667 | 12948 | 13230 | 13511 | 14637 | 14919 | 15200 |
| 39 | 13000 | 13289 | 13578 | 13867 | 14156 | 15311 | 15600 | 15889 |
| 40 | 13630 | 13926 | 14222 | 14519 | 14815 | 16000 | 16296 | 16593 |
| 41 | 14274 | 14578 | 14881 | 15185 | 15489 | 16704 | 17007 | 17311 |
| 42 | 14933 | 15244 | 15556 | 15867 | 16178 | 17422 | 17733 | 18044 |
| 43 | 15607 | 15926 | 16224 | 16563 | 16881 | 18156 | 18474 | 18793 |
| 44 | 16296 | 16622 | 16948 | 17274 | 17600 | 18904 | 19230 | 19556 |
| 45 | 17000 | 17333 | 17667 | 18000 | 18333 | 19667 | 20000 | 20333 |
| 46 | 17719 | 18059 | 18400 | 18741 | 19081 | 20444 | 20785 | 21126 |
| 47 | 18452 | 18800 | 19148 | 19496 | 19844 | 21237 | 21585 | 21933 |
| 48 | 19200 | 19556 | 19911 | 20267 | 20622 | 22044 | 22400 | 22756 |
| 49 | 19963 | 20326 | 20689 | 21052 | 21415 | 22867 | 23230 | 23593 |
| 50 | 20741 | 20711 | 21481 | 21852 | 22222 | 23704 | 24074 | 24444 |
| 51 | 21533 | 21911 | 22289 | 22667 | 23044 | 24556 | 24933 | 25311 |
| 52 | 22341 | 22726 | 23111 | 23496 | 23881 | 25422 | 25807 | 26193 |
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| 55 | 24852 | 25259 | 25667 | 26074 | 26481 | 28111 | 28519 | 28926 |
| 56 | 25719 | 26133 | 26548 | 26963 | 27378 | 29037 | 29452 | 29867 |
| 57 | 26600 | 27022 | 27444 | 27867 | 28289 | 29978 | 30400 | 30822 |
| 58 | 27496 | 27926 | 28356 | 28785 | 29215 | 30933 | 31363 | 31793 |
| 59 | 28407 | 28844 | 29281 | 29719 | 30156 | 31904 | 32341 | 32778 |
| 60 | 29333 | 29778 | 30222 | 30667 | 31111 | 32889 | 33333 | 33778 |

TABLE XXX.—CUBIC YARDS PER 100 FEET. SLOPES 3 : 1.

| Depth d | Base 12 | Base 14 | Base 16 | Base 18 | Base 20 | Base 28 | Base 30 | Base 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 56 | 63 | 70 | 78 | 85 | 115 | 122 | 130 |
| 2 | 133 | 148 | 163 | 178 | 193 | 252 | 267 | 281 |
| 3 | 233 | 256 | 278 | 300 | 322 | 411 | 433 | 456 |
| 4 | 356 | 385 | 415 | 444 | 474 | 593 | 622 | 652 |
| 5 | 500 | 537 | 574 | 611 | 648 | 796 | 833 | 870 |
| 6 | 667 | 711 | 756 | 800 | 844 | 1022 | 1067 | 1111 |
| 7 | 856 | 907 | 959 | 1011 | 1063 | 1270 | 1322 | 1374 |
| 8 | 1067 | 1126 | 1185 | 1244 | 1304 | 1541 | 1600 | 1659 |
| 9 | 1300 | 1367 | 1433 | 1500 | 1567 | 1833 | 1900 | 1967 |
| 10 | 1556 | 1630 | 1704 | 1778 | 1852 | 2148 | 2222 | 2296 |
| 11 | 1833 | 1915 | 1996 | 2078 | 2159 | 2485 | 2567 | 2648 |
| 12 | 2133 | 2222 | 2311 | 2400 | 2489 | 2844 | 2933 | 3022 |
| 13 | 2456 | 2552 | 2648 | 2744 | 2841 | 3226 | 3322 | 3419 |
| 14 | 2800 | 2904 | 3007 | 3111 | 3215 | 3630 | 3733 | 3837 |
| 15 | 3167 | 3278 | 3389 | 3500 | 3611 | 4056 | 4167 | 4278 |
| 16 | 3556 | 3674 | 3793 | 3911 | 4030 | 4504 | 4622 | 4741 |
| 17 | 3967 | 4093 | 4219 | 4344 | 4470 | 4974 | 5100 | 5226 |
| 18 | 4400 | 4533 | 4667 | 4800 | 4933 | 5467 | 5600 | 5733 |
| 19 | 4856 | 4996 | 5137 | 5278 | 5419 | 5981 | 6122 | 6263 |
| 20 | 5333 | 5481 | 5630 | 5778 | 5926 | 6519 | 6667 | 6815 |
| 21 | 5833 | 5989 | 6144 | 6300 | 6456 | 7078 | 7233 | 7389 |
| 22 | 6356 | 6519 | 6681 | 6844 | 7007 | 7659 | 7822 | 7985 |
| 23 | 6900 | 7070 | 7241 | 7411 | 7581 | 8263 | 8433 | 8504 |
| 24 | 7467 | 7644 | 7822 | 8000 | 8178 | 8889 | 9067 | 9144 |
| 25 | 8056 | 8241 | 8426 | 8611 | 8796 | 9537 | 9722 | 9807 |
| 26 | 8667 | 8859 | 9052 | 9244 | 9437 | 10207 | 10400 | 10593 |
| 27 | 9300 | 9500 | 9700 | 9900 | 10100 | 10900 | 11100 | 11300 |
| 28 | 9956 | 10163 | 10370 | 10578 | 10785 | 11615 | 11822 | 12030 |
| 29 | 10633 | 10848 | 11063 | 11278 | 11493 | 12352 | 12567 | 12781 |
| 30 | 11333 | 11556 | 11778 | 12000 | 12222 | 13111 | 13333 | 13556 |
| 31 | 12056 | 12285 | 12515 | 12744 | 12974 | 13893 | 14122 | 14352 |
| 32 | 12800 | 13037 | 13274 | 13511 | 13748 | 14696 | 14933 | 15170 |
| 33 | 13567 | 13811 | 14056 | 14300 | 14544 | 15522 | 15767 | 16011 |
| 34 | 14356 | 14607 | 14859 | 15111 | 15363 | 16370 | 16622 | 16874 |
| 35 | 15167 | 15426 | 15685 | 15944 | 16204 | 17241 | 17500 | 17759 |
| 36 | 16000 | 16267 | 16533 | 16800 | 17067 | 18133 | 18400 | 18667 |
| 37 | 16856 | 17130 | 17404 | 17678 | 17952 | 19048 | 19322 | 19596 |
| 38 | 17733 | 18015 | 18296 | 18578 | 18859 | 19985 | 20267 | 20548 |
| 39 | 18633 | 18922 | 19211 | 19500 | 19789 | 20944 | 21233 | 21522 |
| 40 | 19556 | 19852 | 20148 | 20444 | 20741 | 21926 | 22222 | 22516 |
| 41 | 20500 | 20804 | 21107 | 21411 | 21715 | 22930 | 23233 | 23537 |
| 42 | 21467 | 21778 | 22089 | 22400 | 22711 | 23956 | 24267 | 24578 |
| 43 | 22456 | 22774 | 23093 | 23411 | 23730 | 25004 | 25322 | 25641 |
| 44 | 23467 | 23793 | 24119 | 24444 | 24770 | 26074 | 26400 | 26726 |
| 45 | 24500 | 24833 | 25167 | 25500 | 25833 | 27167 | 27500 | 27833 |
| 46 | 25556 | 25896 | 26237 | 26578 | 26919 | 28281 | 28622 | 28963 |
| 47 | 26633 | 26981 | 27330 | 27678 | 28026 | 29419 | 29767 | 30115 |
| 48 | 27733 | 28089 | 28444 | 28800 | 29156 | 30578 | 30933 | 31289 |
| 49 | 28856 | 29219 | 29581 | 29944 | 30307 | 31759 | 32122 | 32485 |
| 50 | 30000 | 30370 | 30741 | 31111 | 31481 | 32963 | 33333 | 33704 |
| 51 | 31167 | 31544 | 31922 | 32300 | 32678 | 34189 | 34567 | 34944 |
| 52 | 32356 | 32741 | 33126 | 33511 | 33896 | 35437 | 35822 | 36207 |
| 53 | 33567 | 33959 | 34352 | 34744 | 35137 | 36707 | 37100 | 37493 |
| 54 | 34800 | 35200 | 35600 | 36000 | 36400 | 38000 | 38400 | 38800 |
| 55 | 36056 | 36463 | 36870 | 37278 | 37685 | 39315 | 39722 | 40130 |
| 56 | 37333 | 37748 | 38163 | 38578 | 38993 | 40652 | 41067 | 41481 |
| 57 | 38633 | 39056 | 39478 | 39900 | 40322 | 42011 | 42433 | 42856 |
| 58 | 39956 | 40385 | 40815 | 41244 | 41674 | 43393 | 43822 | 44252 |
| 59 | 41300 | 41737 | 42174 | 42611 | 43048 | 44796 | 45233 | 45670 |
| 60 | 42667 | 43111 | 43556 | 44000 | 44444 | 46222 | 46667 | 47111 |

## TABLE XXXI.—USEFUL NUMBERS AND FORMULÆ.

| Title. | Symbol. | Number. | Logarithm. |
|---|---|---|---|
| Ratio of circumference to diameter........ | $\pi$ | 3.1415927 | 0.4971499 |
| Reciprocal of same ........................ | $\frac{1}{\pi}$ | 0.3183099 | 9.5028501 |
| Degrees in arc of length equal to radius.... | $\frac{180^\circ}{\pi}$ | 57.295780 | 1.7581226 |
| Minutes " " " " " .... | $\frac{10800'}{\pi}$ | 3437.7468 | 3.5362739 |
| Seconds " " " " " .... | $\frac{648000''}{\pi}$ | 206264.81 | 5.3144251 |
| Length of 1° arc, radius unity............... | $\frac{\pi}{180^\circ}$ | .01745329 | 8.2418774 |
| Length of 1′ arc, " " ............... | $\frac{\pi}{10800}$ | .00029089 | 6.4637261 |
| Length of 1″ arc, " " ............... | $\frac{\pi}{648000}$ | .000004848 | 4.6855749 |
| Radius by which 1 foot of arc = 1 degree. | | 57.295780 | 1.7581226 |
| Radius " " $\frac{1}{10}$ " " = 1 minute. | | 343.77468 | 2.5362739 |
| Radius " " $\frac{1}{100}$ " " = 10 seconds | | 206.26481 | 2.3144251 |
| Factors for dividing a line into extreme and mean ratio......................... | | 0.6180340 | 9.7910124 |
| | | 0.3819660 | 9.5820248 |
| Base of hyperbolic logarithms.............. | $\varepsilon$ | 2.7182818 | 0.4342945 |
| Modulus of common system of logs. = log $\varepsilon$ | $M$ | 0.4342945 | 9.6377843 |
| Reciprocal of same = hyp. log. 10.......... | $\frac{1}{M}$ | 2.3025851 | 0.3622157 |
| Length of seconds pendulum at New York in inches .............................. | | 39.11256 | 1.5923162 |
| Length of seconds pendulum at New York in feet.................................. | | 3.25938 | 0.5131350 |
| Acceleration due to gravity at New York... | $g$ | 32.1688 | 1.5074347 |
| Square root of same ........................ | $\sqrt{g}$ | 5.67175 | 0.7537173 |
| Yards in 1 metre........................... | | 1.093623 | 0.0388676 |
| Feet in 1 " ............................ | | 3.280869 | 0.5159889 |
| Inches in 1 " ............................ | | 39.37043 | 1.5951701 |
| Metres in 1 foot............................ | | 0.304797 | 9.4840111 |
| Metres in 1 yard............................ | | 0.914392 | 9.9611324 |
| Metres in 1 mile............................ | | 1609.330 | 3.2066450 |

## TABLE XXXI.—USEFUL NUMBERS AND FORMULÆ.

| Title. | Symbol. | Number. | Logarithm. |
|---|---|---|---|
| Cubic inches in 1 U. S. gallon.............. | | 231. | 2.3636120 |
| " " " 1 Imperial gallon.......... | | 277.274 | 2.4429092 |
| " " " 1 U. S. bushel.............. | | 2150.42 | 3.3325233 |
| Cubic feet in 1 U. S. gallon................. | | 0.133681 | 9.1260683 |
| " " " 1 Imperial gallon............ | | 0.160459 | 9.2053655 |
| " " " 1 U. S. bushel................. | | 1.244456 | 0.0949796 |
| Weight of 1 cub. foot of water, barom. 30 in. | | | |
| ther. 39°.83 Fah.; pounds.. | | 62.379 | 1.7950384 |
| " 62° " " .. | | 62.321 | 1.7946349 |
| Weight in grains, 1 cubic inch, at 62° Fah.. | | 252.458 | 2.4021892 |
| No. of grains in 1 pound avoir............... | | 7000. | 3.8450980 |
| " " " 1 ounce " ............... | | 437.5 | 2.6409781 |

$r$ = radius of circular arc;
$l$ = length of arc;
$a°$ = degrees in same arc.

$$a° = \frac{l}{r} \cdot \frac{180°}{\pi}$$

$$r = \frac{l}{a°} \cdot \frac{180°}{\pi}$$

$$l = a°r \cdot \frac{\pi}{180°}$$

Radius by which the length of chord $c$ in feet $= \frac{a'}{10}$ in minutes;

$$r = \frac{\frac{1}{2}a'}{10 \sin \frac{1}{2}a'}$$

Hyp. log $x$ = com. log $x \times \frac{1}{M}$, or

$$\text{com. log (hyp. log } x) = \text{com. log (com. log } x) + 0.3622157$$

Com. log $x = M \times$ hyp. log $x$; or

$$\text{com. log (com. log } x) = 9.6377843 + \text{com. log (hyp. log } x)$$

Circumference of circle (radius = $r$).................................. $2\pi r$

Area of circle .................................................... $\pi r^2$

Area of sector (length of arc = $l$)................................. $\frac{1}{2}lr$

Area of sector (angle of arc = $a°$)................................ $\frac{a}{360}\pi r^2$

Approximate area of segment (chord = $c$, mid. ord. = $m$)......... $\frac{2}{3}cm$

# APPENDIX.

Verification of eq. (77).

Eq. (76) $$\rho = \frac{\sin\ \theta}{\sin\ \frac{\theta}{N}} = \sin\theta \cdot \operatorname{cosec}\frac{\theta}{N}$$

$$\frac{d\rho}{d\theta} = \cos\ \theta \cdot \operatorname{cosec}\frac{\theta}{N} - \frac{1}{N} \cdot \sin\theta \cdot \cot\frac{\theta}{N} \cdot \operatorname{cosec}\frac{\theta}{N} \qquad (76\tfrac{1}{2})$$

$$\therefore \quad \frac{d\rho}{d\theta} = \rho\left(\cot\theta - \frac{1}{N}\cot\frac{\theta}{N}\right) \qquad (77)$$

Verification of eq. (81).

Differentiating eq. $(76\frac{1}{2})$

$$\frac{d^2\rho}{d\theta^2} = -\sin\theta\ \operatorname{cosec}\frac{\theta}{N} - \frac{2}{N}\cos\theta\ \cot\frac{\theta}{N}\ \operatorname{cosec}\frac{\theta}{N} +$$

$$\frac{1}{N^2}\sin\theta\ \cot^2\frac{\theta}{N}\ \operatorname{cosec}\frac{\theta}{N} + \frac{1}{N^2}\sin\theta\ \operatorname{cosec}^3\frac{\theta}{N}$$

$$= -\rho - \frac{2\rho}{N}\cot\theta \cdot \cot\frac{\theta}{N} + \frac{\rho}{N^2}\left(\cot^2\frac{\theta}{N} + \operatorname{cosec}^2\frac{\theta}{N}\right)$$

$$\therefore \quad \frac{d^2\rho}{d\theta^2} = \rho\left(-1 - \frac{2}{N}\cot\theta\cot\frac{\theta}{N} + \frac{1}{N^2}\left(2\cot^2\frac{\theta}{N} + 1\right)\right)$$

Now
$$r = \frac{\left(\rho^2 + \frac{d\rho^2}{d\theta^2}\right)^{\frac{3}{2}}}{\rho^2 + 2\frac{d\rho^2}{d\theta^2} - \rho\frac{d^2\rho}{d\theta^2}}$$

in which substitute for $\frac{d\rho}{d\theta}$, and for $\frac{d^2\rho}{d\theta}$, and let

$$\cot\theta - \frac{1}{N}\cot\frac{\theta}{N} = -a$$

$$\frac{\left(\rho^2 + \rho^2(-a)^2\right)^{\frac{3}{2}}}{\rho^2 + 2\rho^2(-a)^2 - \rho^2\left(-1 - \frac{2}{N}\cot\theta\cot\frac{\theta}{N} + \frac{1}{N^2}(2\cot^2\frac{\theta}{N} + 1)\right)}$$

$$= \frac{\rho}{2} \cdot \frac{(1+a^2)^{\frac{3}{2}}}{1 + a^2 + \frac{1}{N}\cot\theta \cdot \cot\frac{\theta}{N} - \frac{1}{N^2}\cot^2\frac{\theta}{N} - \frac{1}{2N^2}}$$

$$= \frac{\rho}{2} \cdot \frac{(1+a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} + a^2 + \frac{1}{N}\cot\frac{\theta}{N}\left(\cot\theta - \frac{1}{N}\cot\frac{\theta}{N}\right)}$$

$$= \frac{\rho}{2} \cdot \frac{(1+a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} + a\left(a - \frac{1}{N}\cot\frac{\theta}{N}\right)}$$

$$\therefore r = \frac{\rho}{2} \cdot \frac{(1+a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} - a\cot\theta}$$

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