FOUNDATION COURSE

IN

Mensuration

AND

Mechanical Drawing

BY
J. B. POORE, M. E.
Senior Member American Society Mechanical Engineers

FOUNDATION COURSE
J. B. POORE, PUBLISHER
WASHINGTON, N. J.

FOUNDATION COURSE

IN

Mensuration

AND

Mechanical Drawing

BY

J. B. POORE, M. E.

Senior Member American Society Mechanical Engineers

FOUNDATION COURSE

J. B. POORE, PUBLISHER

WASHINGTON, N. J.

INTRODUCTION.

THIS COURSE is fundamental. It is designed to help you to rise from the ranks in that great army of men who are fighting life's battle along mechanical lines. In any pursuit in life the Course is very helpful because it is practical. In any mechanical pursuit it is indispensable if you would be more than a drifter—a mere drudge. In mechanical drawing it is absolutely essential, for without the fundamentals taught in this course you cannot hope to accomplish anything. Thousands of young men attempt expensive correspondence courses in mechanical drawing every year only to drop out discouraged, because the course assumes that they have this foundation already laid. They give up the course because they have not the basic knowledge on which the course is constructed. There is no text book that comprises more than a part of this basic instruction; and much that is very important does not appear in any text book.

In the course of a busy life along mechanical lines, the impression that this lack of a suitable text book covering these fundamentals is indeed very serious has been strengthened almost daily by the many requests for such information. Believing that a real service may thereby be rendered to many thousands of men, the author has prepared this basic course in simple, practical form to help the busy man to rise to higher usefulness and to more valuable service—to *a better job and higher pay.*

TO THE STUDENT.

There is presented to you herein a conscientious effort to help you to acquire a fundamental knowledge of Mensuration and Mechanical Drawing. The extent to which it shall be a benefit to you will be determined by your own efforts. Whether you learn much or little will depend upon the earnestness of your application and the fidelity with which you follow every suggestion. Do not hurry through the Course. Take just as much time as may be necessary to do the work thoroughly and with scrupulous attention to details.

Take up the drawings in order as you are referred to them by the text, and study them in connection with the text until you have a clear conception of the purpose of the drawing and of the object represented. Study the problems and their solution in connection with the drawing to which reference is made. Work out every calculation in detail, and be sure that you understand the reason for every operation before you perform it. Commit to memory each definition. Learn every rule and every principle, and study their application until you cannot forget them. When a practice is stated, make it yours. Never fail to look up a reference, and note well how it applies. Always *do the work that is suggested,* and give it your *very best effort.* All of this will require time and patient endeavor; but that is what will make this Course valuable to you. *Application* of principles, rules and practice is what will fix them in your mind.

Subdivisions of sections are indicated by letters. The number references, as No. 60, No. 83, etc., refer to the drawings. The section references, as Sec. 27, Sec. 24*a*, etc., refer to the textbook.

CONTENTS.

DRAWING AND MENSURATION.

Sec. 1. The first thing in the course is the drawing-board (See No. 1). You should have a board large enough to hold a 15 x 18 sheet, at least. It should be soft wood so as to receive thumb tacks readily. Have it made smooth, with square corners and straight and smooth edges, along which the head of the T-square must slide. Place the sheet upon the drawing-board and place the T-square on the sheet with the head of the T-square along the left end of the drawing-board. Make the upper or lower edge of the sheet coincide with the edge of the T-square, and fasten the sheet with a thumb tack in each corner. Then with the T-square draw a line along the upper and the lower edges of the sheet. These marginal lines may be half an inch from the edge. Then place the upper edge of the T-square along the middle of the sheet and draw a short line ⅜″ (about) long at each end. These are sheet setting lines, to enable you with the use of the T-square to replace the sheet in an exactly true position at any time. Arrange the position of your drawing-board so that the light falls upon it from the upper left hand corner. Place your ink where it may not be overturned. (See No. 1.)

a. No. 2 shows the T-square held in proper manner by the left hand while the right holds the ruling pen in position for drawing a horizontal line.

b. No. 3 shows a right angled triangle placed in position against the upper edge of the T-square for drawing a vertical line.

c. No. 4 shows a bow-pencil held in the right hand, the first finger over the top of the instrument, and the adjusting screw held by the thumb and second finger in position for changing the adjustment. Two hands should never be necessary either to hold or to adjust a bow-pencil.

d. No. 5 shows a bow-pencil as used in striking a circle.

e. No. 6 shows the compasses held in the right hand in position for adjusting, the second finger being used to open the compasses and the first finger to close them, while the third and fourth fingers grip the pivot leg.

f. No. 7 shows the compasses in position for striking a circle, the head of the compasses being held between the thumb and first finger.

g. Great care should be taken to observe at all times your manner of holding these instruments, and to see that they are always held correctly. Correct handling of the instruments has much to do with efficiency. You should frequently return to sheet No. 1 and observe these several correct positions.

Sec. 2. A point indicates position simply; it has not length, breadth or thickness. It may be indicated by a small dot.

Sec. 3. A line has length, but not breadth or thickness, although in drawing we cannot represent a line without appearing to give it breadth.

a. A straight line, or right line, is a line extending uniformly in the same direction.

b. Drawing lines are heavy lines used in representing the outlines of an object. (See No. 12.) Shade lines are drawing lines used to give an object in a drawing the appearance of standing out in relief or else of being depressed. They are two to three times as heavy as an ordinary drawing line. Their application involves discussions that are hardly elementary, and are not taken up in this course. (See No. 17.)

c. A dimension is any measurable extent; and dimension lines are *light* lines used to indicate the limits of a dimension. (See No. 16.)

d. A witness line is a *light* line showing to what lines a dimension extends. In practice it is usually used with an arrow point on each end. Generally the extent of the dimension is written along the witness line. A single witness line (an arrow) may be used to indicate some specific thing. (See No. 15).

e. Dotted lines are used to indicate the outlines of any part of an object that you cannot see by reason of its being behind some other part. A dotted line is composed successively of heavy, short dashes and short spaces. (See No. 13.)

f. A center line is drawn through centers. It is a *light* line made up successively of a long dash and two short dashes with short spaces between. (See No. 11.)

g. Broken lines are used to show the outlines of some object not present that you are representing as being present with the object that you are drawing. A broken line is a *light* line made up successively of a long dash and a short dash with a short space between. (See No. 14.)

h. A horizontal line is a straight line wholly within the plane of the horizon; or, a straight line which, if extended, would touch the horizon at two points. (See Sec. 1, *a.*) (See No. 2.)

i. A vertical line is a line extending perpendicularly to the plane of the horizon; or, extending in the direction of the zenith; that is, straight up. (Sec. 1, *b.*) (See No. 3.)

j. Parallel lines are straight lines lying in the same plane and everywhere equally distant from each other. The opposite sides of No. 19 are parallel.

k. See No. 33. The illustration represents an ordinary bottle cork, and is introduced for the purpose of showing in simple form the use of the dotted line. We have a side view and a view of the top or larger end. Looking at the larger end of the cork the outline of the other end would not be visible; but if we could see it, we would see it lying within the outline of the larger end. We want to show it in its true position; therefore we show it within the outline of the larger end by using a *dotted line.* Note also the *center lines.* See also No. 60. We have a plain round shaft shown in a side view which is broken in order to economize space on the sheet. The set collar is to be used in connection with the shaft, and to show just where and how the collar will appear when in place, the collar with the set screw in it is drawn as if it were in place on the shaft, and the *broken line* is used to show that we are only supposing it to be there. Note also the *horizontal* center line *a—b,* and the *vertical* center line *c—d.* You have noticed that the end lines of the side view are extended, using light lines for the extensions. These are *dimension* lines. You observe also the light line extending from one dimension line to the other, and having an arrow point on each end. It is a *witness* line, showing a dimension of 20 ft. The side lines are *parallel,* and so also are the end lines; and both side lines and end lines are *drawing lines,* and both are *straight* or *right lines.*

Sec. 4. A drawing of an object as it would appear from a position directly in front of one of its sides or ends is called an *elevation.* So we have front elevations, rear elevations, side elevations and end elevations. See No. 89. The two lower drawings show a front or side elevation of the bin and an end elevation.

Sec. 5. A *plan* is a drawing of the top of an object as if viewed from a position directly above it. See No. 89. The upper drawing is a plan of the top of the bin.

Sec. 6. A *section* is a drawing of an object as it would appear to you if it were cut through by an intersecting plane and if the part between you and the cut were removed. See No. 68. It shows a side elevation of an I beam and also a *section.*

Sec. 7. Often in drawing a long object, in order to save space on the sheet, it is represented as if a portion were broken out somewhere between the ends and the remaining portions were brought near each other. Sometimes a cross section is shown between, as in No. 63. No. 60 shows a *broken elevation* and a cross section at one end.

Sec. 8. An inverted plan is a drawing of the underside of the bottom of an object, as if the object were turned bottom upward and were viewed from a point directly above it. The lower drawing in No. 72 is an inverted plan.

Sec. 9. In drawing a plan and any side or end elevation, the side or end to be drawn must be represented as if it were grasped at the bottom and swung up into the same plane as the top, keeping the edge that adjoins the edge of the top near the latter and in correct relation to it.

a. Also in drawing a plan and an inverted plan, the inverted plan must be drawn as if the bottom of the object were swung around and upward into the plane of the top, keeping edges that are on the same side of the object near each other and in proper relation.

b. Also in drawing a side or end elevation and an inverted plan, the inverted plan must be drawn as if the bottom of the object were swung downward into the plane of the side or end, keeping adjoining edges near each other and in relation.

c. Also in drawing elevations of sides that adjoin, the elevations must be drawn as if the sides that are being considered were swung around into the same plane, keeping adjoining edges near each other and in proper relation.

d. Any elevation, plan or inverted plan may be drawn without reference to any other part of the drawing; but in doing so it should not be placed in any position that it would occupy if it were drawn with reference to its relation to some other part of the drawing.

e. The importance of the foregoing rules should not be underestimated; and in order that their application may be entirely clear please see No. 34. *A* is the plan of a kennel. *C* is the front elevation; *E* is the left hand side elevation; *F* is the right hand side elevation; and *D* is the rear elevation. Each is drawn in its place and in its proper relation to the plan. The upper edge of each side adjoins an edge of the top of the kennel; therefore the elevations represent those edges as being adjacent (next to). Also the center lines of the plan, if extended, coincide with the center lines of the elevations. Therefore the elevations are in correct relation to the plan. *C* is the front elevation, and *G* is an elevation of the adjoining right hand side placed in relation to *C*. Adjoining edges on the kennel are represented as being adjacent in the drawing. *B* is the inverted plan. The edge *l*, of the bottom adjoins the edge *l* of the front *C* when the bottom is in place. In the drawing these two edges are represented as being adjacent, and their center lines extended coincide. The inverted plan *B* is in correct relation to the elevation *C*. *B* is also in correct relation to the plan *A*; because when the bottom is in place, the edge *l* is on the same side as the edge *l* of the top, and in the drawing these edges are represented as being nearest each other, and the center line of *B* coincides with the center line of *A*. *B* may be placed also on either of the other sides of *A* and in correct relation to *A*. Imagine the bottom back in place; swing its right edge down and over to the left and up and you will have its edge *o* adjacent to the edge *o* of the plan; likewise if placed on the right its edge *m* will be adjacent to the edge *m* of the plan; and if placed in the rear its edge *n* will be adjacent to the edge *n* of the plan, and in either position it will be in correct relation. *H* is a rear elevation placed independently (the usual practice). It is not placed in relation to *C*, and it is not in a position where it would be supposed to be so placed.

Sec. 10. In drawing sections certain standard shadings are used to indicate the material. (See No. 35.) *a* represents cast iron. (See No. 71.) *b* represents wrought iron. (See No. 61.)

c represents steel. (See No. 60.) *d* represents brass and copper. (See No. 62.) *e* represents lead and babbitt. (See No. 135.) *f* represents concrete. (See No. 48.) *g* represents wood. (See No. 41.) *h*. The lower part represents stone in section; the upper part represents surface of stone and glass.

Sec. 11. The art of drawing the outlines of objects of any shape or form on a plane surface as they appear to the eye from a given position is called *perspective;* and objects so represented in a drawing are said to be drawn in perspective. Parallel lines projected away from you seem to draw constantly closer together as the eye follows them until they can no longer be distinguished one from another. (See No. 32.) The illustration represents to us a curb, a sidewalk, a fence, and two intervening grass plots. They extend side by side and parallel to each other. Looking along the walk from any certain position, the outlines of each succeeding section of the walk, or of each succeeding picket on the fence, look different from those of the one preceding. Each successive one looks smaller, and slightly different in shape depending upon your position, until the eye can no longer distinguish one from another, and all lines merge into a blur which theoretically reduces to a point, but which practically is earlier lost to view. The illustration is a drawing in perspective. No. 83 is a sketch in perspective.

Sec. 12. The style of numerals and letters used on drawings is shown in Nos. 8, 9, 10 and

10-*a*. *Slant and spacing must be uniform.*

Sec. 13. Our standard of linear measure is the inch. A measure one inch (written 1″) in length, as shown in No. 18, has length only; and twelve of them equal one foot (written 1ft. or 2′—0″). The relation between the size of the drawing and the actual size of the object is called *scale,* and is usually expressed thus: 1″ = 12″, or, ¼″ = 12″; which means that a line 1″ long in the drawing represents a dimension 12″ long on the object, or that ¼″ in the drawing represents 12″ on the object. If a drawing is made to a certain scale, the scale should be indicated on the drawing. When a drawing or a part of a drawing is not made to scale it should be so indicated. No. 44 is not made to scale and is marked "No scale." No. 81 is drawn to scale ½″=12″, except the height of the masonry foundation which is not drawn to scale; and to show that the dimension written is not warranted by the scale it is marked "mk," which means that it is a "marked" dimension; that is, the dimension was marked on the drawing without reference to scale. Sketches and free hand drawings are made without the aid of instruments and therefore without scale.

Sec. 14.

12 inches (12″)	=1 foot (1 ft.)
3 feet (3′-0″)	=1 yard.
16½ feet	=1 rod, or pole.
25 links of 7.92 in..	=1 rod, or pole.
100 links	=1 chain.
66 feet	=1 chain.
40 rods, or poles ..	=1 furlong.

10 chains	........=	1 furlong.
8 furlongs	........=	1 mile.
80 chains	.........=	1 mile.
320 rods, or poles	..=	1 mile.
5280 feet	........=	1 mile.
1760 yards	.......=	1 mile.
2 yards or 6 feet	..=	1 fathom.
4 inches	..........=	1 hand.
39.37 inches	......=	1 meter.
69 1/6 miles	......=	1 degree on the equator.
1 11/72 miles	......=	1 knot.

Sec. 15. Surface is that which has length and breadth without thickness. Area is quantity of surface. See No 19. The illustration shows length and breadth; and two dimensions multiplied one by the other produce area. We have a figure 1″ wide and 1″ long, and therefore 1 square inch (written 1 sq. in.), which is the unit of measure in computing area or the amount of surface.

Sec. 16. A parallelogram is any plane figure of four sides whose opposite sides are parallel, and whose angles may or may not be right angles. A parallelogram whose angles are right angles is also called a rectangle. No. 40 is a parallelogram; it is also a rectangle. *The area of any parallelogram is found by multiplying its length by its breadth, or altitude* (the perpendicular distance between its parallel sides). Both dimensions should be expressed in like denominations before multiplying.

Sec. 17.	144 sq. in.	= 1 sq. ft.
	9 sq. ft.	= 1 sq. yd.
	272¼ sq. ft. ...	= 1 sq. rd. or pole.
	43,560 sq. ft. ...	= 1 acre.
	100 sq. ft.	= 1 square of roofing.
	160 sq. rds.	= 1 acre.
	625 sq. links ...	= 1 sq. rd. or pole.
	16 sq. rds.	= 1 sq. chain.
	10 sq. chains ...	= 1 acre.
	640 acres	= 1 sq. mile.
	160 acres	= 1 quarter section.

Sec. 18. A circle is a plane figure bounded by a curved line every point in which is equally distant from a point within, and this latter point is called the center. See No. 20.

a. The curved line bounding a circle is the *circumference,* and *any part* of a circumference is an *arc.* As the arc *d—e.*

b. A straight line passing through the center and terminated by the circumference is a *diameter;* and a straight line drawn from the center to the circumference at any point is a *radius* (plural radii), as *r.*

c. A straight line joining the extremities of an arc is its *chord;* as *d—e.*

d. A *tangent* is a straight line drawn from outside a circle so as to touch the circumference but not intersect it if extended; as *f—g.* Curved lines that touch but do not intersect are tangent.

e. A segment of a circle is the portion included by an arc and its chord; as by the arc *d—e* and its chord *d—e.*

f. A *zone* is the portion between two parallel chords.

g. A *sector* of a circle is the portion included by two radii and the arc which they intercept; as by the radii *h—d* and *h—e,* and the arc *d—e*.

h. Two or more circles are *concentric* when their centers are the same point, as in No. 53; they are *eccentric* when their centers are not the same point, as in No. 49.

Sec. 19. The degree is the unit of measure used in measuring the opening or difference in direction of two straight lines that meet or intersect each other; this opening is called an angle. Thus an angle is the difference of direction of two straight lines that meet, or that diverge from a common point; and this point of divergence is the vertex of the angle. Every circumference of a circle, large or small, is composed of 360 equal arcs; and each of these arcs is called a degree, and is the measure of the angle whose vertex is the center, and whose sides are the radii which include the arc. Thus, if from the vertex of an angle as the center you draw a circle, the two lines forming the angle become radii of the circle and include an arc; and this arc is the measure of the angle. An arc that is one-fourth of the circumference is an arc of ninety degrees, called a quadrant. (See No. 20.) It measures an angle of ninety degrees. An angle that is measured by an arc that is half a quadrant is an angle of 45 degrees. An angle that is one-third of a quadrant is an angle of 30 degrees. An angle that is one-fourth of a quadrant is an angle of 22½ degrees, etc. (Written thus: 45 deg., 30 deg., 22½ deg. Also, a very small circle written to the right of a number and near the top of it, is used to indicate degree or degrees. This method is employed in drawings. Observe its use in No. 20.)

a. A *right angle* is an angle measured by a quadrant, or an angle of ninety degrees.

Sec. 20. A *triangle* is a plane figure bounded by three straight lines, and having therefore three angles. In any triangle the sum of its three angles equals 180 degrees, or a half circle.

a. In No. 20 you have illustrated three triangles usually found in a draftsman's kit. What angles in each? (Sec. 19-*a*, Sec. 20).

b. In any triangle the distance measured from the vertex of any angle perpendicularly to the opposite side is the altitude upon that side as a base.

c. The area of a triangle is just half the area of a parallelogram one of whose sides is the base of the triangle and the other its altitude. The base multiplied by the altitude equals the area of the parallelogram. Therefore *the area of a triangle is half the product of the base by the altitude,* or the base multiplied by half the altitude. In No. 21. the triangle *a-b-c* is half the square *a-b-c-d*. Its area is half of (the base *a-b* multiplied by the altitude *a-d*). In No. 22 the triangle *a-b-c* is half the rectangle *a-b-d-e,* and the area of the triangle is half (the base *a-b* multiplied by the altitude *f-c*).

Sec. 21. In a right-angled triangle (See No.

21) the two sides that include the right angle are the *base* and the *perpendicular,* and the third side is the hypothenuse. *The square of the base plus the square of the perpendicular equals the square of the hypothenuse.* Therefore, *to find the hypothenuse, add the square of the base to the square of the perpendicular, and extract the square root of the sum.*

a. To find the perpendicular, subtract the square of the base from the square of the hypothenuse, and extract the square root of the remainder.

b. To find the base, subtract the square of the perpendicular from the square of the hypothenuse, and extract the square root of the remainder.

c. The square of a number is the number used twice as a factor; that is, it is the number multiplied by itself. Thus in $7 \times 7 = 49$, 7 is used twice as a factor and the result is the square of 7; 49 is the square of 7. The square root of 49 is 7. Therefore the square root of a number is one of the two equal factors of the number. To find the square root of any number observe carefully the following simple method:

Separate the number into periods of two figures each as far as practicable by commencing at the right hand figure. If the number contains an odd number of figures the left hand period will contain but one figure. If the number is a whole number and a decimal, you should begin to count off the periods at the decimal point and count in both directions. In the case of decimals you always count to the right from the decimal point; and with whole numbers you count to the left.

Then find the largest number whose square is contained in the left hand period. This number is the first figure of the root, and you place it to the right just as you do in working long division. Write its square under the left hand period and subtract from the left hand period.

Bring down the next period of two figures and write it to the right of the remainder, if there is a remainder; and thus form a *new dividend,* much as you do in division. Multiply the root already found by two and place the result to the left of the new dividend for a *trial divisor,* as in division. Divide the new dividend by this trial divisor, not including the right hand figure of the new dividend; that is, if the new dividend consists of three figures divide the trial divisor into the first two figures beginning at the left. Write the result over to the right of the first figure of the root as the second figure of the root; also write the last figure of the root to the right of the trial divisor, so that the trial divisor with this figure added may form your *true divisor.* Now multiply the true divisor by the last figure of the root and write the product under the new dividend. Subtract and annex the next period (of two figures) to the remainder for a new dividend.

Double the root now found and write the result to the left of the new dividend for a trial divisor as before; find the next figure of the root as above by dividing the trial divisor into the new dividend exclusive of the right hand figure; complete the divisor as before and proceed in the same manner until all the periods have been used.

Note 1. When the product of any divisor by the last figure of the root exceeds its corresponding dividend, the last figure of the root must be made less, remembering to change also the figure annexed to the trial divisor. Should a dividend not contain its corresponding trial divisor, a cipher must be placed in the root and also to the right of the trial divisor; then, after bringing down the next period, this last trial divisor must be used as the divisor of the new dividend.

Note 2. When there is a remainder after extracting the root of a number, periods of ciphers may be annexed as decimal places, and the figures of the root thus obtained will be decimals.

Note 3. If the number whose square root you wish to find is a whole number and a decimal, or if it is wholly a decimal, after separating into periods as above directed, you extract the root in the same manner as in the case of whole numbers, except that if the last period on the right of the decimal be incomplete you should fill it out with a cipher. The number of decimal places in the root will always equal the number of decimal periods.

Note 4. If the given number is a common fraction reduce it to its lowest terms and extract the square root of numerator and of denominator if both be perfect squares. If they are not both perfect squares, reduce the fraction to the form of a decimal by dividing the numerator by the denominator, and extract the square root of the decimal. If the given number is a mixed number, change the fraction to the form of a decimal before extracting the root.

Note 5. The problems on page 25 illustrate the above rule. Go through each operation step by step in connection with the foregoing method and the notes to which reference is made. Then make up problems and extract the square root. To prove your work, square your root or answer; that is, multiply it by itself. The problems that you make up will not likely be perfect squares, and you will not be able to find an even or exact root; but it will be sufficiently accurate if you run them out to three or four decimal places in the root. In the case of an uneven, or inexact root, of course the square of the root will not exactly equal the original number with which you started; but the difference will be only very slight if your work is accurate.

Sec. 22. A polygon is any plane figure bounded by stright lines only. A regular polygon is one whose sides and angles are equal. Triangles and parallelograms are polygons, but not necessarily regular, although they may be. We have already considered them. To find the area of any *regular polygon,* take *half the product of the perimeter by the perpendicular* from the center to one of the sides. (Perimeter means boun-

OPERATION (1)

```
     1 1'5 6 ( 3 4
      9
   6 4 ) 2 5 6
         2 5 6
```

OPERATION (2)

```
     1 7'2 2'2 5 ( 4 1 5
     1 6
   8 1 ) 1 2 2
           8 1
 8 2 5 ) 4 1 2 5
         4 1 2 5
```

OPERATION (3) (See notes 1 and 3)

```
       3 6'4 5.7 4'4 4 ( 6 0.3 8
       3 6
 1 2 0 3 ) 4 5 7 4
           3 6 0 9
 1 2 0 6 8 ) 9 6 5 4 4
             9 6 5 4 4
```

OPERATION (4) (See note 2)

```
         1'8 4'0 7 ( 1 3 5.6 7 2 4 —
         1
       2 3 ) 8 4
             6 9
     2 6 5 ) 1 5 0 7
             1 3 2 5
   2 7 0 6 ) 1 8 2 0 0
               1 6 2 3 6
 2 7 1 2 7 ) 1 9 6 4 0 0
               1 8 9 8 8 9
   2 7 1 3 4 2 ) 6 5 1 1 0 0
                   5 4 2 6 8 4
 2 7 1 3 4 4 4 ) 1 0 8 4 1 6 0 0
                 1 0 8 5 3 7 7 6
```

OPERATION (5) (See note 4)

```
       9 5 1/16
           1/16 = .0 6 2 5
       9 5 1/16 = 9 5.0 6 2 5
       9 5.0 6'2 5 ( 9.7 5
       8 1
   8 7 ) 1 4 0 6
         1 3 0 9
 1 9 4 5 ) 9 7 2 5
           9 7 2 5
```

dary or contour; hence the sum of the sides). Or:

Multiply the square of one of the sides by the number in the following table set opposite the number of sides in the polygon. The numbers in the table are *constants*.

5 sides—1.720477	9 sides— 6.181824
6 sides—2.598076	10 sides— 7.694209
7 sides—3.633913	11 sides— 9.365641
8 sides—4.828427	12 sides—11.196152

Sec. 23. The surface of a circle is less than the surface of a square whose side equals the diameter of the circle. (See No. 23). The side of the square is 1″. Its area is therefore 1 sq. in. *To find* the *area of a cicrle multiply the square of the diam. by .7854.* The diam. is 1″. The square of 1″ is 1 sq. in., and 1 sq. in. multiplied by .7854 equals .7854 sq. in., which is just a little less than four-fifths of 1 sq. in. So the area of a circle of a given diameter is just a trifle less than four-fifths the area of a square whose side equals the diameter of the circle.

To find the area of a circle, the circumference being given, square the circumference and multiply by .079577.

a. To find the *circumference* of a circle, *multiply the diameter by 3.1416.*

b. To find the *diameter, multiply the circumference by .3183;* or, the radius being given, *take twice the radius.*

c. The area of a sector of a circle equals the length of the arc multiplied by half the radius.

d. To find the area of a segment of a circle, find the area of the sector which has the same arc with the segment; also find the area of the triangle formed by the chord and the radii drawn to its extremities. Take the difference of these areas when the segment is less than half the circle, and take their sum when the segment is greater than half the circle.

Sec. 24. We come now to consider bodies having three dimensions—length, breadth or width, and thickness or height. No. 24 represents a body 1″ high x 1″ wide x 1″ long, and having therefore six equal sides; these sides are squares. Such a body we call a *cube*. This gives us our standard for measuring bodies of three dimensions. Thus the cubic foot is a cube whose dimensions are each 12″ or 1 ft. 12″ x 12″ x 12″ = 1728 cu. in. or 1 cu. ft. Therefore, *to find the contents of cubical bodies multiply together the three dimensions, expressed in the same denomination.*

a. 1728 cu. in ....= 1 cu. ft.
27 cu. ft. ....= 1 cu. yd.
128 cu. ft. ....= 1 cord of wood.
231 cu. in. ....= 1 gallon.
2150.42 cu. in. ....= 1 bushel.
2747.71 cu. in. ....= 1 heaped bushel.

1 cu. in.	wro't iron weighs	.278 lb.
1 " "	cast iron weighs	.26 "
1 " "	rolled steel weighs	.283 "
1 " "	cast steel weighs	.28 "
1 " "	brass weighs	.31 "
1 " "	copper weighs	.32 "
1 " "	bronze weighs	.32 "

1 cu. in.	lead weighs	.41	lb.
1 " "	water weighs	.036	"
1 cu. ft.	water weighs	62.5	"
1 " "	marble weighs	171.	"
1 " "	granite weighs	165.	"
1 " "	sand weighs	95.	"
1 " "	anthracite coal weighs.	54.	"
1 " "	bituminous coal weighs.	50.	"

b. An ordinary brick is 2″ x 4″ x 8¼″.
In a wall 8¼″ thick there are 14 bricks to sq. ft.
In a wall 12¾″ thick there are 21 bricks to sq. ft.
In a wall 17″ thick there are 28 bricks to sq. ft.
In a wall 21½″ thick there are 35 bricks to sq. ft.

The size of bricks varies in different parts of the country.

c.	16 oz.	=1 pound (lb.)
	100 lbs.	=1 hundred weight (cwt.)
	2,000 lbs.	=1 ton (T.)
	2,240 lbs.	=1 long ton.
	60 lbs.	=1 bushel of wheat.
	56 "	=1 bushel of shelled corn.
	70 "	=1 bushel of corn on cob.
	56 "	=1 bushel of rye.
	48 "	=1 bushel of barley.
	30 "	=1 bushel of oats.
	60 "	=1 bushel of clover seed.

Sec. 25. Sawed lumber is measured by board measure, in which the unit is a board 1 ft. square, and 1″ thick, and is called 1 ft., board measure. To find the number of feet board measure, multiply length in feet by width in inches, and that product by thickness in inches, and divide the last product by twelve; the result

will be the number of feet board measure. If the board tapers in width, take half the sum of the widths of the two ends for the width of the board.

Sec. 26. A *prism* is a solid whose ends or bases are equal, similar and parallel polygons, and whose sides are parallelograms. (See No. 25.) We have here a square prism, or one whose ends or bases are squares. To find the contents of a prism, *multiply the area of one of the bases by the perpendicular distance between them.* In the illustration the base is 1″ x 1″, and its area is 1 sq. in., which multiplied by the length or perpendicular distance between the bases = 1 sq. in. x 1½″ = 1½ cu. in., the contents of the prism.

Sec. 27. A *cylinder* is a round body of uniform diameter whose bases or ends are circular and parallel to each other. No. 60 represents a cylinder. To find the contents of a cylinder, *multiply the area of the base or end by the altitude, or perpendicular distance between the bases.* In No. 26 we have a cylinder whose diameter is 1″ and whose length is 1″. The area of one end is 1 x 1 x .7854 = .7854 sq. in. (See Sec. 23) and .7854 x 1″ (long) = .7854 cu. in., the contents of the cylinder.

a. If you imagine that you cut the lateral surface of a prism, or the convex surface of a cylinder from end to end, and spread it out on a flat surface, you would have a parallelogram one dimension of which would be the distance around the prism or the cylinder, and the other would be the altitude of the prism or the altitude of the cylinder; and to find the area of the parallelogram you would multiply one dimension by the other. (Sec. 16). Therefore to find the lateral surface of a prism, *multiply the perimeter of the base by the altitude.* To find the convex surface of a cylinder, *multiply the circumference of the base by the altitude.*

Sec. 28. A solid having a circle for its base and tapering uniformly to a point called the vertex is called a *cone.* (See No. 28). The slant height of a cone is a straight line drawn from the vertex to the circumference of the base. The altitude of a cone is a line drawn from the vertex perpendicular to the plane of the base.

a. To find the convex surface of a cone, *multiply the circumference of the base by half the slant height.*

b. To find the contents of a cone, *multiply the area of the base by one-third the altitude.*

Sec. 29. A pyramid is a solid having for its base a polygon and for its sides triangles meeting in a common point called the vertex. (See No. 30). The slant height of a pyramid is a straight line drawn from the vertex to the middle of one of the sides of the base. The altitude of a pyramid is a line drawn from the vertex perpendicular to the plane of the base.

a. The lateral surface of a pyramid is found by multiplying the perimeter of the base by half the slant height.

b. The contents of a pyramid equal the area of the base multiplied by one-third the altitude.

Sec. 30. The frustum of any solid is the part that remains after cutting off the top by a plane parallel to the base, as the frustum of a cone shown in No. 29, and the frustum of a pyramid shown in No. 31.

a. To find the convex surface of a frustum of a cone, *multiply half the sum of the circumference of the two bases by the slant height.*

b. To find the lateral surface of a frustum of a pyramid, *multiply half the sum of the perimeters of the two bases by the slant height.*

c. To find the contents of a frustum of a cone, or of a frustum of a pyramid, *multiply the areas of the two bases together, and extract the square root of the product; to this root add the two areas and multiply the sum by one-third the altitude.*

Sec. 31. A *sphere* is a solid bounded by a *curved surface* every part of which is equally distant from a point within called the center. (See No. 27).

a. The surface of a sphere equals the diameter multiplied by the circumference.

b. The contents of a sphere equal the cube of the diameter multiplied by .5236.

Sec. 32. In comparing similar surfaces, they are to each other as the squares of their like (or similar) dimensions.

Sec. 33. In comparing similar solids, they are to each other as the cubes of their like dimensions.

SIMPLE APPLICATIONS IN DRAWING.

Sec. 34. "Mr. Lumberman:—Please send me twenty-one pieces of hemlock lumber 1″x 12″x 3′-6″. Make a drawing showing the plan, an elevation of one side and an elevation of one end. (See No. 40). Use scale 1″=12″. Make up a similar problem, using different dimensions, and make drawing to scale. (See No. 35-g-wood section).

Sec. 35. "Mr. Millman:—I want nine pieces of hemlock lumber delivered at the bridge that I am building at the Bend. They must be No. 1 in quality, 3″x 12″x 2′-8″. There must be a wedge-shaped piece cut off one edge of each joist. At a point on one end 9″ from one edge start cutting this wedge-shaped piece, running out 14 inches up on the other other edge." Make drawings to scale 1½″=12″. Show side elevation, plan and right and left end elevations. A joist rests on one edge when in place, therefore you conceive the plan to be a view of the top edge, the cut having been made on the bottom edge. Change the size of the joist and make drawings to scale. (See No. 41.) End wood is always shown as in section (Sec. 10).

Sec. 36. "Mr. Foundryman:—Please cast for me as early as you can two corner plates, making the pattern at my expense and as cheap as possible. These castings are to be of soft iron, and in shape they will resemble a carpenter's square, with one leg 11″ long and the other 7″ long, while both are to be 3″ wide and 1″ thick.

At the end of each leg there is to be a hole drilled ¾″ in diam., the center of the hole to be 1″ from the end and in the center of the width; also there is to be a hole drilled, same diam., in the corner 1½″ from each outside edge. I enclose drawing." Make drawing to scale 3″=12″. (See No. 42). Show plan and end and side elevations. Make up similar problem, make drawing using different scale, and show plan and elevations of the four sides in relation to the plan. (See Secs. 4, 5 and 9).

a. "Also please make for me a cast iron, square, open end wrench with jaws opening 2¼″ and 2¼″ deep, to fit a standard 1⅛″ or 1¼″ square nut. Make it 16″ long over all, 1″ thick and having a handle 2″ wide and rounded at the end. Make the head of the wrench 4¾″ wide across the jaws at the widest part, rounding the outside edges of the jaws with a 2⅜″ radius centered ⅜″ from the bottom of the jaws and midway between them; and then by reversing the curve with the same radius gracefully merge into the straight lines of the handle. Complete the curve at the end of each jaw with a ½″ radius. Make the pattern and include the cost of it in your bill."

b. Make a drawing of the wrench for the pattern maker. (No. 52). In reversing the curve with a 2⅜″ radius as required, you may locate its center on the outside by placing the pivot leg of your compasses at the point in the curve where you wish the reverse curve to begin and describe an arc; then place the pivot leg at the point where you wish the reverse curve to merge into the straight line of the handle, and describe an arc intersecting the other. From the point of intersection as a center describe the arc that shall be your reverse curve. Make the drawing half size, that is 6″=12″. The handle may be drawn full length if desired, or it may be broken to save space. (Sec. 7).

c. In making castings a certain amount of contraction takes place in the metal as it cools, and this must be provided for by making the pattern enough larger than the casting is to be to allow for this contraction or shrinkage. The shrinkage of cast iron is about ⅛″ in 12″; and in making a pattern for an iron casting the pattern maker uses a rule in which the foot is ⅛″ longer than standard, and thus he provides for the shrinkage. The shrinkage of steel is about twice that of iron, and in different metals the shrinkage varies, so that the pattern maker must use different "shrink rules" in making patterns for the different metals.

Sec. 37. "Mr. Machinist:—I would like you to make for me twenty eccentric collars of steel, ¼″ thick, outside diameter 1½″, and having an inside diameter of 1″, the center of which shall be 3/16″ from the center of the outside diameter, making the outer circle and the inner circle eccentric (Sec. 18-*h*.). Finish the collars all over."

a. Make the drawing with care; and make other drawings of eccentric circles and concentric circles, and be sure that you have well fixed in your mind the difference.

Sec. 38. "Mr. Contractor:—Please quote me your best price on 100 second quality pine frames as follows: The material is to be planed on both sides, and when assembled it is to have a priming coat. The stock is to be 1½"x 2", and is to be made up the flat way, outside dimensions of the frames to be 12"x 2'- 2". The short sticks are to be as long as the width of the frame, so they will be 12" long; and the long sticks are to be as long as the frame, or 2'- 2". Each end of each stick will be cut out for 2" by half the thickness of the stick across the entire width; or in other words, a piece will be cut out of each end of each stick ¾" x 2" x the width of the stick, both cuts to be on the same side of the stick. This will enable a joint to be made the same thickness as the stick." Make drawing showing elevation of side of frame and end elevation, (See No. 43), scale 3" = 12". (See Sec. 7 and Sec. 10, *g*). Note that end wood is shown in these illustrations where it appears in elevation just as it would be shown in section (See No. 35). End wood is always shown with the sectional cross hatching as shown in No. 35. The metals are shown only in section and not in elevation (See Sec. 4 and Sec. 6). Change dimensions and make the drawings, using any scale that you think will be most convenient.

Sec. 39. "Mr. Contractor:—Please make for me twenty-four boxes of 1" surfaced pine lumber, securely nailed together, for use in my delivery wagon. Make them 12" wide x 18" long x 10" deep, outside measurement. A strip of wood for a handle, ⅝″ x 2″ x 4″, should be nailed on crosswise 1″ down from the top in the center of the ends." Make a sketch in perspective. (See No. 44). Read again Sec. 11 and Sec. 13, the latter part. Dimensions are marked on a sketch without using "mk," because being a sketch there is not supposed to be any reference to scale.

Sec. 40. "Mr. Carpenter:—There are two shelves much needed in our kitchen, and they must fit exactly in place in order to look well, so please make them according to the following exact requirements: Each shelf is to be 8½″ wide x 3′-6″ long. Facing the front edge of the shelf, start at the left hand end and measure up 9″ along the back edge, and then cut out a piece 6½″ long x 2¼″ deep; then measure 7″ more along the same edge and cut out another piece same length and depth; then, starting at the opposite end, on the same edge, cut out a piece 6½″ long x 2⅝″ deep. Still facing the same way the left hand corner on the front edge is to be rounded off to a 2½″ radius. Material to be ⅞″ thick, white pine, and smooth." Make drawing, scale 1½″ = 12″. (See No. 45). Write new specifications, changing the requirements, and make drawings to scale.

Sec. 41. "Mr. Blacksmith:—Kindly make for me two cold chisels of good ¾″ hexagon tool steel. They should be ⅞″ wide along the cutting edge when finished and 9″ long." Make a sketch. (See No. 50).

a. "Also please make a good poker for our furnace, of ⅝″ round iron, and four feet over all. At one end bend the iron around so as to form a hand hold and an oblong hole to slip the fingers through in grasping it. This opening should be 1½″ x 4″, and the latter dimension should extend in a direction at a right angle to the direction of the shaft; make a right angle bend 4″ over all on the other end of the shaft, bending the iron in the direction of the length of the handle or hand hold, and flatten the end of the bent portion." Make a sketch of the poker. (See No. 46). Practice making sketches.

Sec. 42. "Mr. Carpenter:—Please make for me a dog house of surfaced 1″ yellow pine boards with tongue and groove to make tight joints. The dimensions over all are to be—width 24″, length 3′-0″, height of sides 18″, length of roof 3′-6″, slant height of roof 2′-1″ from eaves to apex, height to apex of roof 2′-6″, and the two sides of the roof to form an angle of 90 deg. Use 3″ nailing strips 1″ thick around the inside at the bottom and lay the floor on them; and similarly use them around the inside at the top of the sides, and use one at the apex of the angle of the roof on the inside. The outside edge of the tops of the two sides should be chamfered off with the direction of the roof back to the inside edge of the nailing strip. In the center of one end make an opening 10″ wide and 11″ high above the floor, making the top of the opening an arc of a circle with a radius of 5″." (See No. 51). (Also see Sec. 18, *a* and *b*,, and Sec. 19). Make drawings, scale 1″ = 12″. Show front elevation and side elevation in relation to it. Also draw a plan of the dog house without the roof and the floor. Draw a plan with roof and elevations of the sides and ends in relation to the plan; also draw them in relation to each other; draw an inverted plan in relation to the front elevation. (See No. 34, Sec. 8; also Sec. 9, *a* to *e*). Draw a rear elevation, or any other elevation, in an independent position. Study this relation of elevations, plan and inverted plan until you have mastered it. Independent elevations are much used also, *especially for rear views.* Study carefully the use of dotted lines to show outlines that cannot be seen because they are behind something else (Sec. 3-*e*). Observe the proper use of dotted lines in drawing these several views.

Sec. 43. "Mr. Foundryman:—Please make for me four cast steel quoits having an outside diam. of 5¾″ and an inside diam. of 3½″, leaving the width of the circular ring 1⅛″. Both edges are to be rounded on the outside as well as on the inside of the ring, which is to be ⅛″ thick at the outside edge and ⅜″ thick at the inside. Also the ring is to rest on its outside edge, so that when it rests on the ground the top of the inside of the ring will be ⅝″ above the ground. On the outside edge there is to be a slight rounded indentation for a finger notch 3/16″ deep by 11/16″ across. I enclose drawing for the use of your pattern maker." (See No. 53). Make drawings. The scale is half size, 6″ = 12″. Observe the lines in the section to indicate material. (See No. 35).

Sec. 44. "Mr. Cement Stone Maker:—Please make for me a cement stepping stone, or carriage step, 12″ high, 20½″ wide and 3′-0″ long. Make the ends round with a 10¼″ radius, and chamfer off the edge around the top down to a line on each side 1″ from the edge." Make drawing showing plan and side elevation, scale 1″=12″.

a. "Also please make for me a cement tie-post 12″ square at the bottom and 8″ square at the top, and 6′-6″ high or long. 4″ down from the top in the center of the width of one of the sides, make a 2″ hole coming out in a like position on the opposite side. Beginning three feet from the bottom the edges or corners should be chamfered off to a depth of 1″ back on each face and running thus uniformly to the top. Also in like manner chamfer off the edge around the top." Make elevation drawing, plan and sectional plan (Secs. 4, 5 and 6). A sectional plan is a view taken as though a section were made by a horizontal plane, and you were looking down at the exposed surface from a point directly above it. Show material (concrete) in the section (See No. 48). Change the dimensions and make drawings to suit, scale 1″ = 12″.

APPLICATIONS AND PROBLEMS.

Sec. 45. (See No. 60). We have here a round steel shaft 2″ diam. and 20′-0″ long, to find its contents, its weight and its entire surface. The set collar with set screw in it is represented in broken line (Sec. 3, *g.*) because it is not in place on the shaft. Therefore it is represented in broken line. It shows its relation to the shaft as it would be if in place. It has nothing to do with our problem. Make the drawing scale 6″=12″, except in length which may be broken to save space. Show a side elevation and a section, indicating material in the latter (Sec. 10).

a. The figure is that of a cylinder. (See Sec. 27). All dimensions must be considered in the same denomination; that is, all must be inches or all must be feet. To find the contents of a cylinder we must find the area of one end and multiply by the length. The end being a circle, to find its area we must square the diam. and multiply by the constant .7854, (See sec. 23.) which gives us 2 x 2 x .7854 = 3.1416 sq. in. The length is 20 ft. or 240″. The area of one end, 3.1416 sq. in. x 240″ = 753.984 cu. in., the contents of the shaft.

b. The material is steel (rolled), and rolled steel weighs .283 lb. to the cu in. (See sec. 24, *a.*) 753.984 x .283 lb. = 213.377 lbs. There are 16 oz. in a pound. The decimal, .377 lbs. x 16 = 6 oz., and we have 213 lbs. 6 oz., the weight of the shaft. Note that the weight of iron in its several forms is approximately one quarter of a pound to the cubic inch, and that the total weight in pounds is approximately one fourth the number of cubic inches of metal. Remember this.

c. The entire surface is the area of the ends plus the area of its convex surface. We find above (*a.*) that the area of one end is 3.1416 sq. in. The area of both ends is 6.2832 sq. in.

The convex surface = circumference x length. (See sec. 27, *a.*) We have the diam. and must find the circumference (See sec. 23, *a.*) Circumference = diam. x 3.1416; 2″ x 3.1416 = 6.2832″, circumference. 6.2832″ x 240″ (length) = 1507.968 sq. in., convex area. Adding to this the area of the two ends we have 1514.25 sq. in. Reduce to square feet by dividing by 144 = 10.5 sq. ft. = 10 sq. ft. 72 sq. in., the entire surface of the shaft.

d. Take a shaft of different dimensions, draw it to scale in broken elevation and section, and perform the same calculations. Do not pass a reference without looking it up, and always work out calculations in detail.

Sec. 46. (See No. 61.) The elevation shows the side of a bar and the section shows that its four sides are equal and its ends square, and that it is made of wro't iron. (See No. 35, *b.*) The short dimension on the elevation is not necessary because it is shown on the section. In drawing it should be left off. The same is true of No. 60. The bar is 4″ x 4″ x 20′-0″; we wish to find its weight and surface. Make the drawing to scale 3″ = 12″, except in length. When the object drawn is long, in order to save space on the sheet and to save the time of the draftsman, it is frequently done as in No. 61 without making a break in the elevation. You will notice that the drawing is not made to scale as regards the length. It is made any convenient length and the correct dimension is written with the letters "mk.", which means that the dimension is marked on the drawing without reference to scale. Nos. 62. 65, 67 and 68 are also examples of this practice.

a. To find its weight we must first know its cubical contents. It is a square prism (See sec. 26.) and its contents = the area of its end x its length. 4″ x 4″ = area of end; therefore 4″ x 4″ x 240″ (length) = 3840 cu. in., the contents. A cubic inch of wro't iron weighs .278 lb. (See sec. 24, *a*). 3840 x .278 lb. = 1067.5 lbs. = 1067 lb., 8 oz., the weight of the bar.

b. Its surface is the area of its four sides and its ends. Each side is 4″ wide; the sum of the widths of the four sides is 16″ = the perimeter (Sec. 27-*a*) or "girth." Therefore 16″ x 240″ = 3840 sq. in., area of four sides. The area of the two ends (See *a.*) is twice 16 sq. in. = 32 sq. in., which added to the area of the sides = 3872 sq. in., the entire surface of the bar.

c. Change the dimensions of the bar and draw to scale. Note which are drawing lines, which dimension lines, which witness lines and which center lines, and make the proper distinctions.

Sec. 47. (See No. 62.) The drawing shows a bottom plan or inverted plan and a section of a half round hand-rail of brass (See No. 35*d*). The section shows us that the figure is that of a hollow cylinder cut by a plane passing longitudinally through its center, one-half being shown The outside diam. is 2″, the length 10′-0″ and the thickness of the wall 3/16″ to find the weight of brass in the hand rail and its convex surface.

Make the drawing to scale 6″ = 12″, using a marked dimension for the length.

a. If the drawing showed the hollow cylinder completed the section would show a circular ring, and the area of the ring multiplied by the length would give the contents of the wall of the hollow cylinder. The area of the ring is the difference of the areas of the two concentric circles (Sec. 18, *h.*) which form the ring. The diam. of the outer circle is 2″; the diam. of the inner circle is 2″ less twice the thickness of the wall; 2″ — (2 x 3/16″) = 2″ — 3/8″ = 1 5/8″. The area of a circle being the square of the diam. multiplied by .7854, it follows that *the difference between the areas of two given circles must be the difference of the squares of their diameters multiplied by .7854.* We have the diameters 2″ and 1 5/8″ or 1.625″; their squares are 4 sq. in. and 2.64 sq. in., and the difference of their squares multiplied by .7854 is (4—2.64) x .7854 = 1.36 x .7854 = 1.068 sq. in., the area of the circular ring. 1.068 sq. in. x 120″ (length) = 128.16 cu. in. in the wall of the hollow cylinder. Half of 128.16 cu. in. = 64.08 cu. in. of brass in the hand-rail. A cubic inch of brass weighs .31 lb. 64.08 cu. in. of brass weighs 64.08 x .31 lbs. = 19.86 lbs., weight of hand-rail. (Sec. 24 *a.*)

b. The convex surface of the hollow cylinder whose diam. is 2″ = circumference x length (Sec. 27, *a*). Circumference = diam. x 3.1416 (Sec. 23, *a.*). 2″ x 3.1416 = 6.2832″, circumference. 6.2832″ x 120″ = 753.98 sq. in., convex surface of hollow cylinder. Half of 753.98 sq.

in. = 377 sq. in., convex surface of hand-rail.

Note. Half the area of the circular ring multiplied by the length would give the contents of the hand-rail; and half the circumference of the hollow cylinder multiplied by the length would give the convex surface of the hand-rail. Also the contents of the outer cylinder less the contents of the inner cylinder = the contents of the hollow cylinder. Get the principles involved in this problem firmly fixed in your mind before you leave it. Make up a similar problem using different dimensions; make the drawing to scale, except the length, and work the problem. Observe that No. 62 presents a concave surface with the light falling on it from an upper left hand direction. The upper portion of the concave surface is shaded showing that it is in the shadow. No. 60 represents a convex surface, and for a like reason the lower portion is shaded. Think this over carefully. Have in mind clearly the difference between a concave surface and a convex surface and where the shadow would be.

Sec. 48. No. 64 shows simply a sheet of Russia iron, to find its weight, 1 sq. ft., .03″ thick, weighing 1.21 lbs. The sheet is 24″ x 72″, or 2′-0″ x 6′-0″and contains 12 sq. ft. 12 x 1.21 lbs. = 14.5 lbs. = 14 lbs. 8 oz. Both views are broken.

Sec. 49. No. 65 shows a steel channel of special design, its weight to be figured from its dimensions. Note that the drawing shows an end view and not a section, and that the material is not indicated on the end view. When the material is a metal it is shown only on a section. Note also that in the side elevation we are looking at the back of the channel. The dotted lines show the lines of the flanges on the other side. One dimension is marked.

a. The channel is composed of two flanges and a web (the part between the flanges), and both flanges and web are ½″ thick. The flanges are 2½″ over all, and the web is 6″ over all, and between the flanges it is 5″ long; so in figuring the area of the end we have three parts, two flanges each 2½″ and a web 5″, making a total of 10″ long by ½″ wide, or 5 sq. in., the area of the end. The length is 20′-0″ or 240″. 5 sq. in. x 240″ = 1200 cu. in. of steel in the channel. It is rolled steel, and not cast steel. Its weight would therefore be 1200 x the weight of a cubic inch of rolled steel = 340 lbs.—(Sec. 24, *a.*) Change the dimensions and draw to scale showing an elevation of the front or channel side with an end elevation (End view means the same.) Note that the flange ends would point toward the side elevation. (See sec. 9, *c* and *e.*) Be sure that this is clear to you before you leave it. Use a marked dimension for the length and show a section at the right.

Sec. 50. (See No. 67.) In the drawing we have represented the back view of a special angle beam of rolled steel and an end view. Figure the weight from the dimensions. To find the area of the end, the web is 3¼″ long and the flange is 1½″ over all, and it projects 1½″ less ⅜″, or 1⅛″. We have a total length of

3¼″ added to 1⅛″, or 4⅜″ x ⅜″ wide = 1.64 sq. in., the area of the end, which multiplied by the length = 1.64 sq. in. x 216″ = 354.24 cu. in. of steel in the beam. 354.24 x .283 lb. = 100 lbs. 4 oz., the weight of the beam. Draw a front view of the beam with a right hand end view. The flange would point the same way that it does in No. 67.

Sec. 51. No. 66 shows a broken side view and an end view of a wro't iron tube. Note that the material is indicated on the section but not on the end view. The inside and the outside diameters and the length are shown. It is required to find the weight of the tube. The thread shown will be discussed farther on in the course.

a. The figure is that of a hollow cylinder, and we will find the area of the circular ring shown by the end view. Its outside diam. is 8.625″ and its inside diam. is 7.982″. The difference of their squares x .7854 = area of circular ring. (See sec. 47-*a.*) The square of 8.625″ = 74.3906 sq. in. The square of 7.982″ = 63.7123 sq. in. The difference is 10.6783 sq. in., and 10.6783 sq. in. x .7854 = 8.3867 sq. in.—the area of the circular ring, or of the end of the tube. The area of the end x the length = the contents. 8.3867 sq. in. x 120″ = 1006.404 cu. in. of wro't iron in the tube, weighing .278 lbs. to the cu. in. 1006.404 x .278 lbs. = 279.78 lbs. = 279 lbs. 12½ oz., the weight of the tube.

b. Assign new dimensions to the tube, make the drawings to any convenient scale, and find the weight of the tube. Observe to hold your instruments correctly in drawing.

Sec. 52. (See No. 69.) The drawing represents a cast steel roller comprising three parts, two cylinders and a square prism, to find its weight. The diam. of the smaller cylinder is 5″, and 5″ x 5″ x .7854 = 19.63 sq. in., the area of the end of the smaller cylinder. 19.63 sq. in. x 2½″ (length) = 49 cu. in., the contents. The diam. of the larger cylinder is 6″, and in like manner 6″ x 6″ x .7854 x 3½″ = 99 cu. in., the contents of the larger cylinder. The square prism is 2½″ square by 2″ long; its contents must be 2½″ x 2½″ x 2″ = 12.5 cu in. The total contents of the roller are the sum of 49 cu. in., 99 cu. in. and 12.5 cu. in., or 160.5 cu. in. Cast steel weighs .28 lb. to the cubic inch (Sec. 24, *a.*). 160.5 x .28 lb. = 44.9 lbs., the entire weight. Note the left hand end view, and the right hand end view showing only half the view on account of lack of space, and observe the use of dotted lines to represent the outlines that could not be seen from the view point. Can you explain the differences of those end views or elevations? Assign new dimensions to the roller and make a drawing to scale. Show a horizontal section. The drawing will be a sectional plan. The outlines will be just the same as those of the side elevation in No. 69, except for the changed dimensions.

Sec. 53. No. 63 shows a broken elevation and a section of a wro't iron bridge link 1″ thick, 6″ wide and 4′-6″ long over all, having the ends rounded off to a 3″ radius and a 2″

hole drilled in each end in the center of the width and 3″ from the end. What is the weight of the bridge link? Make the drawing to scale.

The link being just 6″ wide a 3″ radius will describe an arc of 180 degrees, or a half circle (Sec. 19.) in rounding the ends, and the portion of the link between these half circles will have the form of a prism whose dimensions are 1″ x 6″ x 4′-0″, or 1″ x 6″ x 48″ = 288 cu. in. in that portion of the link. The half circles on the ends having each a radius of 3″ are equal to a circle having a diameter of 6″, which forms the end of a cylinder 1″ long, whose contents = 6″ x 6″ x .7854 x 1″ = 28.27 cu. in., contents of the ends. Add this to 288 cu. in., and the total is 316.27 cu. in. Now deduct the holes. They are 2″ in diam. and 1″ deep or long, so their form is that of a cylinder (Sec. 27.), and the contents of each one is 2″ x 2″ x .7854 x 1″ = 3.14 cu. in. 2 x 3.14 cu. in. = 6.28 cu. in., contents of two holes. Subtract 6.28 cu. in. from 316.27 cu. in. = 310 cu. in., contents of link. 310 x .278 lb. = 86.18 lbs. = 86 lbs. 3 oz., the weight of the link. Make up a similar problem, work it out and make drawing.

Sec. 54. (See No. 68.) We have an elevation of a side and a section (taken at A A) of a steel I beam (No. 35, c.) that is 6½″ high, 7″ wide and whose flanges and web are each 1″ thick, and which is 30′-0″ long. We wish to find its weight. The rule for finding the contents of prisms (Sec. 26.) and cylinders (Sec. 27.) applies to bodies of any shape whose ends are equal, similar and parallel, and a cross section of which at any point would be equal and similar to the ends; that is, the area of the end multiplied by the length equals the cubical contents. See how this applies to the preceding numbers on Sheet No. 3, and get the principle firmly fixed in your mind.

a. The top and bottom flanges are each 1″ x 7″, and the web, or the part that connects the flanges, is 1″ thick x 6½″ long less twice the thickness; that is, it is 1″ x 4½″. Putting these together, the two flanges and the web are 7″ and 7″ and 4½″ = 18½″ long by 1″ wide = 18½ sq. in., area of the end of the I-beam. 18½ sq. in. x 360″ (30′-0″) = 6660 cu. in. of steel, weighing .283 lb. to the cubic inch = 1885 lbs. Would an end view have the shading lines to indicate material? (Sec. 49.) Change the dimensions, making the beam larger and draw it to scale or to a smaller scale, and find its weight.

Sec. 55. No. 70 shows a plan and a side elevation of a cast iron tamping head having a square base and a hollow cylinder with a hole through its sides to receive and fasten the handle. Figure its weight from the drawing. First make the drawing one quarter size; that is, 3″=12″. The base is a rectangular prism, 6″ square by 2″ high, and contains 6″ x 6″ x 2″ = 72 cu. in. Then the cylindrical part, regarding it as being solid, is 3″ in diam. and 3″ high. (Sec. 27.) Its contents must be 3″ x 3″ x .7854 x 3″ long, or high = 21.21 cu. in., which added to the base makes 93.21 cu. in. Now deduct the 2″ hole for the handle and the ⅞″ core hole for fastening the handle. The 2″ hole is 3½″ deep. Its shape is that of a cylinder, so its contents must be 2″ x 2″ x .7854 x 3½″ = 11 cu. in. The ⅞″ hole penetrates the wall of the hollow cylinder in two places. This wall is ½″ thick (½ of 3″—2″), and the hole through it is ⅞″ diam. by a depth or length of ½″. Its ends are equal, similar and parallel (although curved), and it is a cylinder. Its contents must be ⅞″ x ⅞″ x .7854 x ½″ = .3 cu. in.; and two such holes contain .6 cu. in., which added to the contents of the 2″ hole makes 11.6 cu. in. Deducting 11.6 cu. in. from 93.21 cu. in., we have 81.61 cu. in. of cast iron weighing .26 lb. to the cubic inch, or 21 lbs. 3.5 oz., the weight of the tamping head.

a. Increase the dimensions, draw to any scale and figure the weight. Explain the use of dotted lines in the drawing.

Sec. 56. (See No. 71.) We have two views of a cast iron pole link and a section of the middle part, which connects the two hollow cylinders, taken at *C—C* as indicated on the drawing. You will notice that where the middle portion connects with the hollow cylinders the corners are filled in so as to make a curve instead of an angle in the outline. You will notice the same thing in No. 72 where the middle portion connects with the bases. It is a rounding of inside corners by filling in to a curved line, and this filling in of a corner is called a fillet. For the purpose of this course we will make allowance for the fillet approximately, as is usually done in practice. We wish to figure the weight of this pole link.

a. The two hollow cylinders on the ends are each 6″ diam. outside and 4″ inside. (See sec. 47, *a.*) The area of the circular ring is the difference of the areas of these two circles, and the difference of their areas is the difference of the squares of their diameters multiplied by .7854. Therefore (6 x 6)—(4 x 4) x .7854 = the area of the circular ring = 15.7 sq. in. 15.7 sq. in. x 3″ (length of hollow cylinder) = 47.1 cu. in., and this multiplied by 2 equals 94.2 cu. in., the contents of the two hollow cylinders. Now take the middle part which is 2½″ x 3″ x its length. We find that the length from one hollow cylinder to the other along the center line is 4″ (by deducting the radii of the two outer circles from the dimension from center to center.). Keeping in mind the scale of the drawing as we study it, an allowance of ¼″ to be added to the length of this middle portion seems to be sufficient to cover the material in the fillets, so we will consider the length of the middle portion along its center line to be 4¼″. 2½″ x 3″ x 4¼″ = 31.9 cu. in. Add 94.2 cu. in. and we have 126.1 cu. in., the total contents, weighing .26 lb. to the cubic inch, or 32 lbs. 12½ oz., the weight of the pole link. Change the dimensions and draw to scale and work out the problem.

Sec. 57. No. 72 shows a side elevation and an inverted plan (Sec. 8.) of a cast iron pedestal having one round base and one square base connected by a cylindrical portion, through one side of which there is a slotted hole communicating with a round hole that extends through the center of the pedestal along its longitudinal axis. The inverted plan shows whether the round base is at the bottom or at the top. Where is it? How can you tell? Make the drawing to scale 3″ = 12″. Find the weight of the pedestal.

a. We have to figure the contents of the round base, the square base and the cylinder, and deduct the contents of the slotted hole and the round hole. The square base is at the top. It is 7½″ square by 1″ thick, and its contents = 7½″ x 7½″ x 1″ = 56.25 cu. in. The round base is at the bottom, and its contents = area of end x length or thickness. The area of the end or face of the round base is 7½″ x 7½″ x .7854 = 44.18 sq. in., and this multiplied by the thickness = 44.18 cu. in., contents of round base. The middle portion has the form of a cylinder. (Sec. 27.) Its contents = area of base x length. Its diam. is 4″ and its length is 9¾″, (Find these dimensions from those given), and 4″ x 4″ x .7854 x 9¾″ = 122.52 cu. in., its contents. Adding to this the two bases we have 222.95 cu. in., total contents. Now the round hole through the center of the pedestal is 11¾″ long by 2½″ diam. Its contents must be 2½″ x 2½″ x .7854 x 11¾″ = 57.68 cu. in., contents of round role. The slotted hole is 1½″ wide x 7 ¾″ long x thickness of the wall through which it is cut. From the dimensions given we find that this wall is half the difference of the diameters of the round hole and the outer cylinder, or ¾″. Therefore the contents of the slotted hole = ¾″ x 1½″ x 7¾″ = 8.72 cu in. Adding 57.68 cu. in. we have 66.4 cu. in., which we subtract from the gross contents, 222.95 cu. in., and have 156.55 cu. in. of cast iron in the pedestal, or 40 lbs. 11 oz.

b. Draw a plan of the top of the pedestal to scale. Also draw an elevation of the side opposite the side that is shown, or the rear. Draw a right hand elevation. Be careful to use dotted lines correctly, to show outlines that cannot be seen from your point of observation in drawing any elevation or plan. Draw a section and indicate on the drawing where it is taken. (See No. 71.)

Sec. 58. No. 74 shows two views of a cast steel lever, to find its weight, approximating exactness closely enough for practical purposes. You will see that we have a hollow cylinder and a bar of uniform thickness but tapering in width. We will deduct the key way shown in the hollow cylinder, but we will disregard the fillet where the latter joins the bar, and we will also disregard the rounding of the edges of the bar, allowing this to offset the fillet. The hollow cylinder is 2½" diam. outside by 1½" diam. inside by 2" long. (See 47,*a*.) Its contents must be (2½" squared)—(1½" squared) x .7854 x 2" (the length), or 6.25 sq. in.—2.25 sq. in. x .7854 x 2" = 6.28 cu. in. The length of the bar or handle along its center line to the hollow cylinder is 27" less the radius of the outside diam. of the hollow cylinder, or 25¾" long. At the wide end it is 2½" wide and at the other end it is 1¾" wide. The average width is half the sum of the end widths, or 2⅛", average width. So the handle is ¾" (thick) x 2⅛" x 25¾" = 41 cu. in., contents of handle. Adding

6.28 cu. in. we have a total of 47.28 cu. in. The key way in the hollow cylinder is ¼″ x ½″ x 2″ = ¼ cu. in., or .25 cu. in. Subtracting from 47.28 cu. in. we have 47.03 cu. in. of cast steel weighing .28 lb. per cubic inch, or 13.17 lbs. = 13 lbs., practically, because of the approximations.

a. Notice that the section is not drawn exactly to scale and is so marked. Increase the dimensions and draw to scale, and figure the weight.

Sec. 59. (See No. 73.) The drawing shows a cast iron cleaning door, having a depressed panel containing two bosses on its front and a panel in relief, or raised panel, on its back. The drawing comprises a front elevation, a right hand elevation, a vertical section taken along the vertical center line, and a sectional plan bisecting one of the bosses. Study the drawing and the dimensions very carefully until you have in your mind a clear conception of just what the draftsman means to show; then find the weight of the door. We will regard the door as being 1″ thick x 8″ wide x 10″ long or high; we will add the raised panel on the back, deduct the depressed panel on the front, add the two bosses and deduct the core holes. The contents of the door = 1″ x 8″ x 10″ = 80 cu. in. The raised panel on the back is ¼″ x 7″ x 9″ and contains 15.75 cu. in., which added to the door = 95.75 cu. in. The depressed panel on the front contains ½″ x 5″ x 8″ = 20 cu. in. Deducting 20 cu. in. we have 75.75 cu. in. The two bosses are each 2″ in diam. by ½″ high. Regarding them as solid each contains 2″ x 2″ x .7854 x ½″ = 1.57 cu. in. And both contain 2 x 1.57 cu. in. = 3.14 cu. in. Adding this we have 78.89 cu. in. Now deduct the core holes (two). They are ⅞″ diam. by 1¼″ long or deep. Each contains ⅞″ x ⅞″ x .7854 x 1¼″ = .75 cu. in., and in both there are 1.5 cu. in. Deducting this there is left 77.39 cu. in. of cast iron in the door, weighing 77.39 x .26 lb. = 20 lbs. 2 oz.

a. Make the drawing to scale, and add an inverted plan of the lower edge of the door. Make an elevation of the back of the door and place it independently. Double the dimensions and make drawing to same scale and figure the weight. Core holes are made when the metal is cast. They are not drilled.

Sec. 60. Nos. 75, 76, 77, 78 and 79 are part of the detailed drawings that go with the roof truss on Sheet No. 5, as they represent parts of that construction. They are introduced here to further illustrate methods and processes in shop arithmetic.

a. We will now take up No. 75. It shows a cast iron washer, being 3″ in diam., ⅞″ thick and having a core hole ⅞″ in diam., so that it will easily slip over a ¾″ bolt. It is called a ¾″ washer. We will figure the material in it and its weight. You will at once recognize that in form it is a hollow cylinder, and the square of 3″ minus the square of ⅞″ x .7854 x ⅞″ = the contents; or, (9— 49/64) x .7854 x ⅞″ = 5.658 cu. in., weighing .26 lb. to the cu. in, or a total weight of 1 lb. 7½ ozs.

b. No. 76 shows a cast iron bevel washer, also ¾″ size. It is 3″ in diam. and has a ⅞″ core hole. It is beveled off from a thickness of 1¾″ down to ¼″. We must figure it in two parts. First figure the hollow cylinder whose diameters are 3″ and ⅞″ and whose length is ¼″; then figure half of a hollow cylinder whose diameters are the same and whose length is 1½″. The contents of the former are (3″ squared—⅞″ squared) x .7854 x ¼″ = 1.617 cu. in. The contents of the latter are ½ of (3″ squared —⅞″ squared) x .7854 x 1½″ = 4.85 cu. in., which added to 1.617 cu. in. = 6.467 cu. in. This multiplied on the weight of a cu. in. of cast iron = 1 lb. 11 ozs., the weight of the washer.

c. No. 77 shows a 1″ cast iron washer having a diam. of 4″, a core hole of 1⅛″ and a thickness of 1″. Figure its weight. The method has already been illustrated a number of times. See sec. 60-*a*.

d. No. 78 shows a peak washer to be used on an inch bolt at the top or peak of a roof truss having a fifty per cent. rise, or a rise of 6″ in 12″ or 3″ in 6″. We have two views, a plan and a side elevation. The dimensions being shown, we desire to find its weight. We must figure it in three parts—the middle part and the two sides or wings. We must make a drawing so that from it a pattern for a casting may be made that will fit to the rafters of the truss; and the angle or direction of the sides must conform to the direction of the rafters. In drawing the view of the side of the washer as you have it in your mind, draw the lines *a*—*b* and *c*—*d* representing the upper and lower edges of the middle part of the washer. Then from the point *d* draw *d—h* perpendicular to *c—d* and representing a length of 3″. From *h* draw *h—i* perpendicular to *d—h* and representing a length of 6″. The points *d* and *i* give you the direction for drawing the line *d—e* so that the washer will fit the truss. You can then complete the wing *d-e-f-b*. Draw the other wing in the same manner.

To find the contents of the washer we must find the area of the side as shown and multiply by the width; then deduct the core hole. The area of the middle part *a-b-c-d* is 1¼″ x 4″ = 5 sq. in. The two wings are alike, so we will consider *b-d-e-f*. It is not a parallelogram, but the sides *b—d* and *e—f* are parallel, and its area is half the sum of its parallel sides multiplied by the perpendicular distance between them; *b—d* is 1¼″ and *e—f* is ⅞″; the perpendicular between them is 3″. ½ of (1¼″ plus ⅞″) x 3″ = 3 3/16 sq. in., the area of side of one wing; area of two wings = 6⅜ sq. in. Adding 5 sq. in. and 6⅜ sq. in. we have 11⅜ sq. in., the area of the side of the washer; and multiplying by 6″, the width, we have 68¼ cu. in., from which we must deduct the hole. The hole is 1⅛″ in diam. and 1¼″ deep or long. In shape it is a cylinder. Its contents must be the square of 1⅛″ x .7854 x 1¼″ = 1¼ cu. in. (1.25 cu. in.) Deducting 1.25 cu. in from 68¼ cu. in. (68.25 cu. in.) we have 67 cu. in. of cast iron weighing .26 lb. to the cu. in., or a total weight of 17.4 lbs.

Be sure that you understand the method used to find the angle of the lines representing the under side of the wings to make them fit rafters having a rise of 3″ in 6″. Draw another peak washer to fit on rafters having a rise of 4″ in 12″; and another for rafters having a rise of 8″ in 12″. Draw them to any convenient scale and find their weight.

e. No. 79 shows a plan, a side view and an end view of a toe plate for the roof truss shown on Sheet No. 5. It is the plate on which the lower end of the rafter rests, made so that the rafter cannot slip. The plate is 1″ x 6″ x 12″, and having three projections or ribs running across its width, two on one side and one on the other. We wish to know how much cast iron is in it. The body of the plate being 1″ x 6″ x 12″ contains 72 cu. in. Two of the ribs are 1″ wide x 1″ high x 6″ long, and each contains therefore 6 cu. in., and two of them contain 12 cu. in. The third rib is 1″ high on one side and ½″ high on the other and 1″ wide. The area of its end multiplied by its length = its contents. The sum of its parallel sides is 1″ plus ½″, and half their sum is ¾″ which multiplied by 1″, the perpendicular distance between them, = ¾ sq. in., the area of the end; multiplying by the length, 6″, we have 4½ cu. in., the contents of the third rib. Adding 72 cu. in. and 12 cu. in. and 4½ cu. in., we have 88½ cu. in., the contents of the toe plate, less the hole. The hole is ⅞″ wide and 3″ long, having rounded ends. The two rounded ends are each a half circle and if put together would make a circle ⅞″ in diam. whose area is the square of ⅞″ x .7854 = .6

sq. in. The parallelogram between these semi-circular ends is 7/8" x 2 1/8" and contains 1.86 sq. in. Adding the ends we have 2.46 sq. in., the area of the hole. Multiply this by the depth of the hole or 1" and we have 2.46 cu. in., the contents of the hole. Subtract this from 88 1/2 cu. in. (88.5 cu. in.) and we have 86.04 cu. in., weighing .26 lb. to the cu. in., or a total weight of 22 lbs. 6 oz. In the drawing the hole is not made to scale, and is so indicated. In drawing it to scale the ends should be rounded to a 7/16" radius, making the diam. 7/8".

Sec. 61. No. 82 represents a pile of coal against a side wall in a cellar up to the height of the bottom of the window frames from one end wall to the other and extending out from the base of the side wall uniformly a distance of 12'-0". How many tons of anthracite coal are in the pile? The drawing shows an inside elevation of the side wall of the cellar and the face of the coal pile, and a section of both. The scale is 1/4" = 12". Make the drawing first. We find from the drawing that the coal pile is in the form of a triangular prism (Sec. 26); its bases, or ends, are equal and parallel triangles whose altitude is 7'-6", and whose base is 12'-0". The area of an end of the coal pile is therefore 1/2 of (12'-0" x 7 1/2') = 45 sq. ft. (Sec. 20, *c.*), and 45 sq. ft. x 16'-0" = 720 cu. ft. of coal. A cubic foot of anthracite coal (Sec. 24,*a.*) weighs 54 lbs. Therefore 720 x 54 lbs. = 38,880 lbs. = 19T. 880 lbs. of coal in the pile.

a. How many square feet of surface in the face of the pile? This surface is a parallelogram whose length is 16′-0″, and whose width is the slant height of the pile, or the hypothenuse of the right-angled triangle which forms the outline of the end of the pile or of a section. The hypothenuse (Sec. 21.) of a right-angled triangle = the square root of the sum of the squares of the other two sides. The base of the triangle is 12′-0″, and the altitude is 7½′; the squares of these numbers are 144 sq. ft. and 56.25 sq. ft.; and their sum is 200.25 sq. ft. The square root of 200.25 sq. ft. is 14.15 ft., the width of the face of the coal pile. The width x the length = 14.15 ft. x 16 ft. = 226.4 sq. ft., the surface of the face of the coal pile.

b. Note the stone walls shown in section, and also the coal pile. (See No. 35-*h*.) Also note how the glass in the cellar windows is shown, and also the face of stone in walls not shown in section, as indicated in the upper part of No. 35-*h*. (See also Nos. 81, 83, 84 and 86.) Give the problem new dimensions and make a new drawing and new calculations, putting great care on the details of the drawing.

Sec. 62. In No. 81 we have an elevation and the plan of a concrete cone on a stone foundation. Find how many cu. yds. of masonry are in the foundation; how many cu. ft. of concrete in the cone; and the cost of painting the cone at ½ cent a sq. ft. The base is in the form of a cylinder (Sec. 27.) whose diam. is 4′-8″ and whose length is 3′-6″. The area of the end of the cylinder (Sec. 23.) is 4⅔′ x 4⅔′ x .7854 = 17.1 sq. ft., which multiplied by 3½′ (length or height) = 59.8 cu. ft., or 2.18 cu. yds. of masonry in the foundation.

a. Now we consider the upper portion, or the cone (Sec. 28.) The area of the base of the cone is 17.1 sq. ft. as we found above, since the base of the cone coincides with the end of the cylinder which forms the foundation; 17.1 sq. ft. x (1/3 of 4′-0″) = 17.1 sq. ft. x 4/3 ′ = 22.8 cu. ft. of concrete in the cone. (Sec. 28,*b.*) The painted surface will be the convex surface only, and the convex surface equals circum. of base x 1/2 of slant height (Sec. 28, *a.*). The circumference equals diameter x 3.1416 (Sec. 23, *a.*). 4 2/3′ x 3.1416 = 14.66′, the circumference; and this multiplied by (1/2 of 4′-7″) (or 14.66′ x 55/24′) = 33.6 sq. ft. of surface to paint at 1/2 cent a sq. ft. = 17 cents, cost of painting. Make drawing to scale, as given; then change dimensions, make drawing to scale and work problem. Study references and learn rules.

Sec. 63. No. 80 shows a small concrete pier whose ends are parallel squares and whose sides are slanting. Its form is that of a frustum (Sec. 30.) of a pyramid (Sec. 29.) We have shown a side elevation and the plan, with dimensions, to find the cubic feet of concrete in it, and the cost of painting the exposed surface (standing on its larger base) at 1/2 cent a sq. ft. Make the drawing first.

a. We are to find the contents of the frustum (See Sec. 30,*c*). The lower base is 18″ square, and the upper base is 12″ square. Their areas (Secs. 15 and 16) are respectively 324 sq. in. and 144 sq. in., and the product of their areas is 46,656. Extracting the square root, we have 216, to which we add 324 and 144 = 684 sq. in. Multiply by ⅓ of 22″ (or 684 sq. in. x 7⅓″) = 5016 cu. in. = 2.9 cu. ft. of concrete in the pier. (For square root see Sec. 21-*c*.)

b. To find the surface of the sides we must know the slant height, which would be the shortest distance between the edges of the bases measured at the middle of a side. In this case the sides being equal, the slant height of the sides is the same. If you could drop a perpendicular line from the edge of the upper base it would touch the lower base 3″ from its edge, and you would have a right angled triangle whose base is 3″, perpendicular 22″ and whose hypothenuse is the slant height of the frustum. We must find the hypothenuse (Sec. 21.) The square of 3″ added to the square of 22″ = 493 sq. in., and the square root of 493 sq. in. = 22.2″, the slant height. The area of each side would be half the sum of its parallel sides or ends multiplied by the slant height or shortest distance between them; so the area of the four sides must be half the sum of the perimeters of the bases multiplied by the slant height. (Perimeter means the distance around, or the sum of the four sides.) The sum of the perimeters of the bases is 120″, and half of this, or 60″ x 22.2″ = 1332 sq. in., the area of the four sides; add the area of the top or upper base, and we have 1476 sq. in. = 10.25 sq. ft. of surface to be painted, at ½ cent per sq. ft. = 5 cents, cost of painting.

Make a similar problem by changing dimensions; make the drawing and work the problem.

c. Draw a figure having two round bases instead of square ones. It will be a frustum of a cone. Add the dimensions according to scale, and find the contents and convex surface. The principles are the same as in above problem.

Sec. 64. In No. 89 we have the plan, an end elevation and a side elevation of a chest of bins, in each of which are four upright corner pieces for nailing strips, made by ripping diagonally 3″ square sticks. *A* is filled with shelled corn, *B* with wheat and *C* with oats. What weight of grain is in the chest? How many square inches of tin will it require to line the sides and bottom of the chest on the inside? Make the drawing to scale with great care.

a. We must first find the contents of each bin without considering the corner pieces, and then deduct the corner pieces. *A* is 3′-0″ x 4′-0″ x 3′-0″ and contains 36 cu. ft., or 62,208 cu. in. The corner pieces are triangular prisms (Sec. 26.) The area of an end of a corner piece (Sec. 20,*c*) is half of 3″ (base) x 3″ (altitude) = ½ x 3″ x 3″ = 4½ sq. in., and multiplying by the length or 36″ gives us 162 cu. in. in each corner piece. There are four of them in a bin, or 648 cu. in. of corner pieces in each bin. 62,208 cu. in. less 648 cu. in. = 61,560 cu. in. In each bin there is a batten or cleat on the under side of the lid which must be deducted. The batten is 1¼″ x 8″ x 3′-1″, and contains 370 cu. in. 61,560 cu. in. less 370 cu. in. = 61,190 cu. in. of shelled corn in *A*, or

28.45 bu. of shelled corn weighing 1593.2 lbs. (Sec. 24-*a*-*c*.) *B* is the same size and contains 61,190 cu. in., or 28.45 bu. of wheat, weighing 1707 lbs. *C* is 2′-0″ x 3′-0″ x 4′-0″ and contains 41,472 cu. in. less the corner pieces and the batten. The corner pieces contain 648 cu. in. and the batten contains 370 cu. in., as found above. Together they contain 1018 cu. in. 41,472 cu. in. less 1018 cu. in. = 40,454 cu. in., or 18.8 bu. of oats, weighing 564 lbs. in *C*. And in all three bins there is a total of 3864 lbs. of grain.

b. Now we want to know how many square inches of surface there are to be lined with tin. The sides, the end and the bottom of the chest are to be covered, and we assume that it is done before the partitions are put in. The four corner pieces of the chest must be in place in order to nail the chest together, and they will therefore be in place when the lining is put in. The end walls are each 42″ long between corner pieces and 36″ high, and contain 1512 sq. in. In the two end walls there are 3024 sq. in. The sides are 92″ long between corner pieces and 36″ high, and contain 3312 sq. in. each. In the two sides there are 6624 sq. in. The bottom is 98″ long and 48″ wide and contains 4704 sq. in., from which we must deduct the ends of the four corner pieces. We have found (*a*) that the area of the end of a corner piece is 4.5 sq. in., and four corner pieces would cover 18 sq. in. of the bottom of the chest. 4704 sq. in. less 18 sq. in. = 4686 sq. in. to be covered. The exposed face of each corner piece must be covered. The end of any of the corner pieces is in the form of a right angled triangle whose base and perpendicular are each 3″. The hypothenuse of the triangle is the width of the exposed surface of the corner piece. (See sec. 21.) The sum of the squares of the two sides that enclose the right angle is (3″ x 3″) plus (3″ x 3″) = 18 sq. in. and the square root of 18 sq. in. is 4.24″, the hypothenuse, or the width of the exposed surface of a corner piece. 4.24″ x 36″ = 152.64 sq. in., the exposed surface of a corner piece; and on four corner pieces there is a surface of 610.5 sq. in. Adding the exposed surfaces of ends, sides, bottom and corner pieces, we have a total of 14,944.5 sq. in. of surface to be covered with tin.

c. Note the use of dotted lines in the drawing to show outlines that cannot be seen from the view point of the drawing. Assign new dimensions to the bins and make a drawing to scale, and work the same problem.

Sec. 65. No. 85 represents a hoisting bucket made of ¼″ sheet steel, to figure its weight when filled level full of sand. Study the drawing until you know the construction of the bucket, then make the drawing, using dotted lines where proper to use them.

a. First we will figure the material in the bucket. The four sides are made of one sheet riveted together with a lap of 1½″. The length of this sheet is 4 x (24″ plus ¼″) plus 1½″ = 98½ long by 21″ wide, containing 2068.5 sq. in. The bottom is made of a square sheet with its four sides bent up so as to form a pan, a piece having been cut from each corner. The bottom of the pan is 24″ x 24″ (outside) and contains 576 sq. in. The sides of the pan form a strip 95″ long by 2¼″ wide (its height inside), containing 213.75 sq. in., which added to the bottom = 789.75 sq. in. of material in the pan. The top band is 99″ long by 2″ wide, and contains 198 sq. in. Adding the sides, bottom and top band together we have 3,056.25 sq. in. of sheet steel ¼″ thick, or 764.06 cu. in. of steel. Now we must add the handles or bails. We find that the handles are made of a 1″ round bar flattened for 6″ on each end, the round part between being bent so that the center line of the shaft forms a half circle with a radius of 2″. This center line is the length of the round portion. The diam. of the circle of which it forms an arc of 180 degs. (Sec. 19) is 4″, and its circumference is 4″ x 3.1416 = 12.566″ (Sec. 23,*a*). Half the circumference, or an arc of 180 degs. is 6.283″, the length of the round portion along its center line. Add to this the 6″ on each end that has been flattened and we have a round bar 18.283″ long, and the two handles would form a bar 36.566″ long by 1″ diam. (Sec. 27.) (1″ x 1″ x .7854) x 36.566″ = 28.72 cu. in. Adding 764.06 cu. in. we have 792.8 cu. in of steel in the bucket, weighing 792.8 x .283 lb. = 224.36 lbs., weight of bucket.

b. The inside dimensions of the bucket are 24″ x 24″ x 21″ = 12,096 cu. in., less the sides of the pan in the bottom, which we have found (a) contains 213.75 sq. in.; and this multiplied by ¼″ (thickness) = 53.44 cu. in. 12,096 cu. in.—53.4 cu. in. = 12,042.56 cu. in. of sand contained in the bucket, = 6.969 cu. ft., weighing 95 lbs. per cu. ft. = 662.05 lbs. of sand in the bucket. Add the weight of the bucket, 224.36 lbs., and we have a total of 886.4 lbs. in the loaded bucket. (See sec. 24,*a*.)

c. How can you tell from the drawing that the turned-up sides on the bottom are fitted inside and not outside the walls of the sides of the bucket? In what way does the drawing of the band around the bottom differ from that around the top? What does the dotted line at the bottom indicate? Change the dimensions to 26″ square inside by 23″ deep outside; make the top band and the bottom turn-up each ½″ wider, and the radius of the center line of the handle 2½″. Draw to scale and figure the weight of bucket and load of sand.

b. Section *AA* shows a section of the joint taken at *AA*. It shows the rivet in place, and is introduced here to show how the joint is made and how the rivet is applied.

Sec. 66. No. 87 shows an ordinary kitchen tank, to figure the gallons and weight of water it holds. Make the drawing. Note the dotted lines and what they mean. The tank is round, of uniform diam., and its ends or bases are parallel, the lower being concave and the upper equally convex. It is a cylinder, 24″ diam. by 61″ long. Its contents are 24″ x 24″ x .7854 x 61″ = 27,595.8 cu. in. of water (Sec. 27.) weighing .036 lb. per cu. in. (Sec. 24,*a*) = 993.45 lbs. of water. Also, dividing 27,595.8

cu. in. by 231 cu. in., we have 115 gals., the contents of the tank, there being 231 cu. in. in a gallon. (Sec. 24,*a*.)

a. Observe carefully the use of dotted lines and why they are used. Note that the plan is broken outside the center line, which may be done. Take the dimensions of your own hot water tank, make a drawing to scale and find the weight of a tank full of water.

Sec. 67. In No. 84 we have represented a stone culvert, to find the number of cubic yards of masonry in it. The area of the end of the walls of the culvert multiplied by its length must give us the contents of the walls. The walls are 14″ thick (minimum), and any projections beyond that thickness on the outside are not considered. The arch begins 4′-0″ above the base, so that the length of the faces of the side walls from the base to the arch is 8′-0″. The length of the face of the base is 4′-0″ plus 14″ plus 14″ = 6⅓′. Adding the length of the faces of the side walls we have a face 14⅓′ x 1 ⅙′ (or 14″), containing 16.722 sq ft. The face of the arch is half of a circular ring whose inside radius is 2′-0″ and whose outside radius is 24″ plus 14″ = 3 ⅙″. Each of these radii describes an arc of 180 degs., or two half circles whose diameters are respectively 4′-0″ and 6⅓′ and half the difference of the areas of these circles is the area of half the circular ring, hence the area of the face of the arch. (See sec. 47-*a*.) The difference of the squares of these diameters is 361/9 sq. ft. less 16 sq. ft. = 217/9 sq. ft., which multiplied by .7854 = 18.9368 sq.

ft., or the area of the circular ring; half this area is 9.468 sq. ft., the area of half the circular ring or the area of the face of the arch. Adding the face of the walls below the arch we have 26.19 sq. ft., the area of the face of the walls of the end of the culvert; this area multiplied by the length of the culvert gives us the contents of the walls of the culvert. 26.19 sq. ft. x 126 ft. = 3299.94 cu. ft., or 122.22 cu. yds.—practically 122¼ cu. yds. of masonry.

a. The drawing shows end and side elevations, the latter being broken so as to show only the ends of the side. Make the drawing carefully, giving much attention to details. Change the dimensions and make another drawing to any convenient scale, and find contents of the masonry.

Sec. 68. No. 83 shows a pile of wood drawn in perspective (Sec. 11.) The drawing shows a lot of wood cut in 30″ lengths and piled carefully in three parallel rows abutting each other, and supported on one end by the side of a building and on the other by a fence. How many cords of wood in the pile? Make the drawing with care in perspective. The width of the pile is 3 times 30″ = 7½′.

The contents of the pile equals 5′-0″ x 7½′ x 14′-0″ = 525 cu. ft. But some wood has been taken from the pile, and we estimate the depression to be an average of 12″ deep for a distance of 5′-0″ along the pile; so it would contain 1′-0″ x 2′-6″ x 5′-0″ = 12.5 cu. ft. 525 cu. ft.—12.5 cu. ft. = 512 cu. ft., practically, or four cords (Sec. 24,*a.*)

a. Practice sketching and perspective drawing of objects at hand. Draw a woodpile of your own conception and find how much wood in it.

Sec. 69. No. 88 represents a discharge pipe of a mine pump, showing an elevation of a side of the pipe between the connection for the discharge elbow and that for the pump elbow, these two elbows being shown in broken line. We wish to figure the weight of water and the pressure to the square inch, either downward or in a lateral direction, at the level of the pump elbow connection when the water stands in the pipe at the level of the discharge elbow connection. The pipe is 18″ in diam. and 280′-0″ high between these two levels. The area of a section of the column of water in the pipe is 18″ x 18″ x .7854 = 254.47 sq. in., which multiplied by the height in inches (280′-0″, or 3360″) = 855,019 cu. in of water, weighing .036 lb. per cu. in., or 30,780 lbs., or 15.39 T. (Sec. 24-*a*). *The pressure due to gravity, either in a downward direction or in a lateral direction, on a square inch of surface at any point is the weight of a column of water 1″ square by the height of water above that point.* The column of water in the pipe being 3,360 in. high, the pressure per sq. in. at the level of the pump elbow connection is the weight of a column of water 1″ square and 3,360″ high, or 3,360 cu. in. of water weighing .036 lb. per cu. in. 3,360 x .036 lb. = 121 lbs. pressure per square inch at the bottom or on a square inch of the side of the pipe at the level of the bottom. Also observe that *the height of water in feet multiplied by .433 = the number of pounds pressure per square inch.* 280 ft. x .433 = 121 lbs. pressure per sq. in. Note that the number of pounds pressure per square inch at any point is just a little less than half the number of feet of water above that point. In any given tank the total pressure on the bottom depends upon the area of the bottom and the height of water, and is independent of the shape of the tank or the quantity of water. The pressure on the bottom may thus be greater than the weight of water in the tank, or it may be less. Draw three vessels as follows: let *A* be a vessel having straight sides, in the form of a cylinder resting on one end; let *B* be a vessel in the form of a frustum of a cone resting on its larger end (Sec. 30); and let *C* be a vessel in the form of a frustum of a cone resting on its smaller end. Let all be filled with water to the same height. The pressure per sq. in. on the bottom of all three vessels will be the same because it depends upon the height of water in the vessel; and this pressure is the same on *any* square inch and on *every* square inch of the bottom of each vessel. The pressure on each bottom, therefore is the pressure per sq. in. multiplied by the number of square inches in the bottom. In *A* this total pressure will be just the weight of the water in the vessel; in *B* it will be more than the weight of the water; and in *C* it will be less than the weight of the water. You will observe that pressure and weight are not necessarily the same, although they may be. Think this subject over carefully, and apply these principles to vessels of different shapes.

a. The walls of the pipe are 1½″ thick, and the sections 14′-0″ long. On each end of each section there is a flange for connecting the sections; and these flanges are 1¾″ thick and have an outside diam. of 26″. Figure the weight of the pipe. The inside diam. of the pipe is 18″; the outside diam. is 21″. The contents of the walls of the pipe = the area of the circular ring shown by a section of the pipe, multiplied by the length of the pipe. The square of 21″ minus the square of 18″ x .7854 = 91.8918 sq. in., the area of the end of the pipe, not including the flange. 91.8918 sq. in. x 3360″ (length) = 308,756.45 cu. in. of cast iron in the pipe, not including the flanges. Regarding the flanges as separate from the pipe, each flange has an outside diam. of 26″ and an inside diam. of 21″. The area of the face of one side = the square of 26″ minus the square of 21″ x .7854, or 184.57 sq. in. 184.57 sq. in. x 1¾″ (thickness of flange) = 323 cu. in. of metal in one flange. There are twenty sections of pipe, each having two flanges, or forty flanges. 323 cu. in. x 40 = 12,920 cu. in. of cast iron in the flanges. Adding 308,756.45 cu. in., we have 321,676.45 cu. in. of cast iron, weighing (Sec. 24-*a*) 83,635.9 lbs., or 41.8 tons.

b. Beginning at the first joint below the top, what is the water pressure per square inch at each joint, the pipe being full?

Sec. 70. No. 86 shows a plan, an end elevation and a side elevation of a brick powder house with stone foundation walls, to figure cubic yards of masonry in foundation, and number of brick in the walls of the building. Make drawing to scale. Note dotted lines and why used. In drawing pay careful attention to details.

a. The base of the foundation extends 6″ on either side of the 18″ wall above it. (See front elevation). This base is 2′-6″ wide and 6″ high. Figuring the length of this base across the front and the rear, and on the sides between the end bases, we have 13′-0″ plus 13′-0″ plus 6′-0″ plus 6′-0″ = 38′-0″ long by 2½′ wide by ½′ high = 47.5 cu. ft. in the base. Now, figuring the wall above the base in the same way, we have 12′-0″ plus 12′-0″ plus 7′-0″ plus 7′-0″ = 38′-0″ long by 4′-0″ high by 1½′ wide = 228 cu. ft., which added to 47.5 cu. ft. = 275.5 cu. ft. = 10.2 cu. yds. of masonry in the foundation walls. Where walls are exposed and corners have to be dressed, stone masons figure the contents of the wall by taking the outside measurements from corner to corner as the length of the wall on any side or end.

b. The brick wall is 12¾″ thick and has 21 bricks to the square foot (See sec. 24-*b*.). The distance around the wall of the building less four times the thickness of the wall gives us the actual length of wall; and the length multiplied by the height gives us the surface for this length. The distance around is 44′-0″. 4 x 12¾″ = 51″ = 4¼′. 44′-0″ — 4¼′ = 39¾′ = 39.75′ .Multiplied by the height (10′-0″), we have 397.5 sq. ft. to which we must add the gables. They are two triangles having a 12′-0″ base and altitude of 3′-0″. The area is half their product, or 18 sq. ft., and in two gables there are 36 sq. ft. Adding to 397.5 sq. ft., we have 433.5 sq. ft. Now deduct the door. It is 3′-6″ wide and 5′-3″ high to the foot of the arch. We will add half the height of the arch for an average height, and we have 5′-6″ for the height of the door. Its area will be 3.5′ x 5.5′ = 19.25 sq. ft. Subtracting from 433.5 sq. ft. we have a wall surface of 414.25 sq. ft. having 21 bricks to a square foot, or 8,700 bricks.

c. In figuring the cost of laying bricks at so much per thousand, ordinary doors and windows are not deducted; neither is the thickness of the wall taken off at the corners; the distance around the outside of the wall is considered the length of wall. Make a drawing of some familiar building and figure the number of bricks in the walls, and also how many thousand bricks would be charged for in the bricklayer's bill for laying the walls.

Sec. 71. In No. 100 we have a comparative illustration of roof angles, showing those most commonly used. At the top is shown a 45 deg. pitch, in which the rise is 12″ in 12″. The angle of 45 deg. is the angle formed by the roof line and the horizontal across the building—the angle at the eaves. The roof pitch is designated either by the measure of this angle or by the rise per foot; that is, the number of inches of rise for every foot of length of the horizontal from the outside edge of the building to the center line. In the case of a 45 deg. pitch, if the length of the horizontal from the outside edge to the center line is 12′-0″, the perpendicular from the center line to the apex will be 12′-0″. In the case of the 8″ pitch the perpendicular will be 8′-0″. In the 30 deg. pitch the angle with the base or horizontal is an angle of 30 deg. In a 6″ pitch the rise is 6″ for every foot of length of the horizontal to the center line; that is, the perpendicular upon the center line will be half the length of the horizontal to the center line. In a 22½ deg. pitch the angle with the horizontal is one-fourth of a quadrant, or 22½ deg. A ⅓ pitch means that the perpendicular is one-third the length of the horizontal to the center line; and a ¼ pitch means that the perpendicular is ¼ the horizontal.

a. The length of the horizontal to the center line being known, and the pitch being decided, you determine the length of the perpendicular from the center line to the apex of the roof; and with the perpendicular and the horizontal, or base, you can find the hypothenuse (Sec. 21), and that will be the length of the rafter from the apex to the outside end of the horizontal; add the length of the projection for the eaves and you will have the length of the rafter. In small buildings, carpenters generally find the length of the rafter by making a pattern or triangular frame, the base and perpendicular having been determined as above; they can then measure the hypothenuse and get the length of rafter.

Sec. 72. Nos. 101-*a* to 108 show a general drawing of a 6″ pitch wooden roof truss. It is a general drawing because it shows the parts in place. No. 101 is the chord of the truss; No. 102 is a rafter, of which there are two; No. 103 is a strut, of which also there are two; No. 104 is the king bolt, and 105 is a square nut; No. 106 is a strut bolt; No. 107 is a toe bolt, there being two of each. No. 108 is a square nut. Nos. 104 and 105, and Nos. 106, 107 and 108 are shown also in detail. Nos. 3-75, 3-76 and 3-77 are cast iron washers, and these numbers refer to Nos. 75, 76 and 77 on Sheet No. 3, where the items are shown in detail. Likewise No. 3-78 and 3-79 refer to Nos. 78 and 79 on Sheet No. 3. No. 78 is a peak washer and No. 79 is a toe plate. Note carefully the details of these numbers on Sheet No. 3; draw washers and toe plates of different dimensions to scale. Draw the completed truss—a general drawing, all parts being shown in place.

Sec. 73. No. 112 shows a steel taper pin, side and end views. It is introduced here principally for the purpose of affording a practical illustration of the use of converging shading lines representing a convex surface. They should be drawn with care. Note the difference between the shading lines on No. 112 and those on No. 69. No. 112 represents a frustum of a cone (Sec. 30) and the shading lines are not parallel. Draw frustums of different cones, and carefully draw the shading lines to show where the shadow lies on the frustum, and that the surface is convex.

Sec. 74. We come now to the screw, always an interesting subject in drawing. A cylinder grooved or threaded in an advancing spiral on its outer surface, also a hollow cylinder having such a groove or thread on its inner surface are forms of the screw.

The former is ordinarily called a screw and the latter a nut. The threads of the nut are adapted to turn on the threads of the screw. Nos. 104, 105, 106, 107 and 108 present common forms of screws and nuts. Nos. 114 to 122 inclusive show various styles of machine screw heads and points with their respective names. You should become familiar with them all. Any desired point may go with any desired head, so that from the styles shown a great number of combinations of heads and points may be made.

a. Nuts are ordinarily either square or hexagon shaped. The end view of No. 124 shows a ⅝″ hexagon nut, and also in broken line a ⅝″ square nut for the purpose of comparison. Nuts are designated by their greatest inside diam.; that is, by the outside diam. of the screw which they were made to fit. Notice that the distance over flats is the same on both nuts. It is a standard dimension and a wrench that will fit one nut will fit the other. The square nut requires a circular turning space 1.502″ in diam., while the hexagon nut will turn in a circular space 1.227″ in diameter. In No. 138 at the top of Sheet No. 5 there are shown two views of a special form of hexagon nut called a safety nut. Observe that a hollow cylinder ⅛″ long is turned on one end of the nut, and that three slots ⅛″ wide and ⅛″ deep are made diametrically across the end of the hollow cylinder. In the end of the screw or bolt there is made a round hole to receive a cotter pin or split pin (No. 139). When the safety nut is in place on the bolt the cotter pin is inserted in one of the slots in the nut and is pushed through the hole in the bolt, thus preventing the turning of the nut. In No. 128 you see a pair of hexagon lock nuts. They may be locked in any position on the screw by holding one nut and turning the other tightly against it. Another name for them is jamb nuts.

b. There are three styles of thread ordinarily used in making screws. They are the U. S. standard thread, as shown on the left end of No. 127; the square thread, as shown on the right end of 127; and the 29 deg. Acme thread, as shown on No. 140 and No. 141. The U. S. standard thread is the thread most commonly used. In U. S. standard threads the number of threads on each inch of the screw depends upon the diameter of the screw, the number increasing as the diameter decreases, as follows: 1″ diam.—8 threads per inch; 7/8″ diam.—9 threads; 3/4″ diam.—10 threads; 5/8″ diam.—11 threads; 1/2″ diam.—13 threads; 3/8″ diam.—16 threads; 5/16″ diam.—18 threads; 1/4″ diam.—20 threads. Automobile manufacturers have agreed upon a special standard of threads per inch for use in automobile construction, requiring finer threads and more threads per inch. No. 123 represents a machine stud, threaded at both ends. It is 5/8″ in diam. and there should be 11 threads per inch, U. S. standard. No. 124 is the nut in place. The thread on the other end is cut just slightly larger than U. S. standard, so that it may be screwed very solidly into a U. S. standard tapped hole. No. 125 is a machine bolt differing from a machine stud in that it has a head on one end. Notice that the threads on Nos. 123 and 125 are not pictured; they are simply indicated. This method of representing threads is very generally used in order to save time. The number of lines and spaces used to represent a thread bears no relation to the number of threads per inch. No. 136 is a special automobile bolt, 24 threads per inch. The drawing simply shows that the bolt is threaded; the lines do not indicate the number of threads. Observe that the head on No. 125 is square. The angle or corner of the nut is represented as being toward you. The square nuts on Nos. 104 and 106 are drawn the same way. Please note that carefully. Now observe No. 126. It is a representation of a square nut shown as if you were looking directly at one of its sides or faces. Square nuts or heads are often drawn in this manner.

c. No. 127 shows a cross feed screw of a lathe, having a square thread on the right hand end. Each thread is ⅛″ wide, and each groove is ⅛″ deep and ⅛″ wide; a section of either thread or groove would be ⅛″ square, practically, and a thread and a groove occupy ¼″ of the length of the screw; so we say there are four threads to the inch, measuring the width of a thread and a groove for the width of a thread. At the end of the square thread there is a shoulder. That this shoulder is round is shown by the fact that its one dimension is given as a "diameter"—"1½″ dia." Note that carefully. That the shank next to the shoulder is round is shown also by the dimension "7/8″ dia." A U. S. standard thread is cut on a portion of this 7/8″ shank. There are nine threads to the inch, the portion of thread shown having 4½ threads to a half inch. The standard for a 7/8″ screw is nine threads per inch.

(*b*) No. 128 shows two hexagon nuts working one against the other and called jamb nuts or lock nuts. By holding the nut nearest the shoulder and tightening the other against it, the distance to the shoulder may be definitely fixed and regulated so that the part of the mechanism that is to be held between the nuts and the shoulder may be held without any lost motion and yet not so tightly that the screw may not turn readily. Beyond the U. S. standard thread the shaft is turned down to a diam. of ¾″, and four flat faces are cut on it, making it almost square, to receive a handle or a handwheel, as is shown by the section.

d. No. 140 shows a 29 deg. Acme thread cut on a 1½″ shaft, there being two threads to the inch, and the thread is called a right hand thread. No. 141 shows a left hand thread of the same kind. All screws are made with right hand threads unless left hand threads are specified for some particular use. Note that No. 141 shows the screw without the shading lines, which is often done to save time.

e. No. 66, Section *AA*, on Sheet No. 3, shows a section of a pipe thread. Iron pipes are regularly threaded so as to form a tapering screw; that is, the diameter of the screw becomes gradually less as the end of the pipe is approached. This taper is for the purpose of making tight joints. No. 66 shows it slightly exaggerated.

f. No. 111 shows a sectional view of a U. S. standard thread. The distance between centers of adjacent threads is called *pitch,* and in the view shown the pitch is ½″, or two threads to the inch. The sides of a U. S. standard thread form an angle of 60 deg. with each other. The thread is flat, top and bottom, and the width of this flat is ⅛ of the pitch.

g. The thread diagram, No. 113, is full size, and shows how to draw a U. S. standard thread. The screw is to be 1¼″ in diam.; there must therefore be seven threads to the inch. The pitch must be 1/7″. To draw the thread, first draw the center line *c;* then with your bow-dividers open ⅝″ locate two points that distance on either side of the line *c,* and through these points draw the lines *a* and *b* parallel to the line *c.* They will be 1¼″ apart; and this dimension represents the outside diameter of the screw. Now take your bow-dividers and adjust them so as to divide an inch into seven equal parts. The length of one of these parts is the pitch of the thread, 1/7″. With the bow-dividers thus adjusted divide the line *a* into equal spaces. In No. 113 we have some of these division points shown greatly exaggerated. In practice the puncture made in the paper by the bow-dividers should be a sufficient mark to indicate the division points. Now see No. 20, Sheet No. 1. Select your triangle having in it an angle of 30 deg. Set its shorter base on the upper edge of the T-square, and draw the short lines *e* through all the division points in the line *a*. Then turn over the triangle and draw the short lines *d* through the same division points. The intersections *o* of these short lines *e* and *d* in the division points in the line *a* mark the centers of the tops of the threads. Their intersections *f* below the line *a* mark the centers of the root of the thread. Now from one of these root centers *f* draw a line *v* perpendicular to the line *b;* it will intersect it at *g*. From *g* as a starting point divide the line *b* into equal spaces representing the pitch of the thread, the same as you divided the line *a*. Through these division points (*g*) in line *b* draw the short lines *h* and *k* in like manner as you drew *e* and *d*. Then draw the lines *p* from the intersections *o* to the intersections *g;* and also draw the lines *m* from the intersections *f* to the intersections *r*. Having drawn all of these lines as directed in pencil you are ready to "ink in." Ink the lines *e* and *d* only from intersections *o* to intersections *f*, and ink the lines *h* and *k* only from intersections *g* to intersections *r*. Ink the lines *p* and the lines *m*, and also ink the center line *c*. You have now a thread drawn to scale, full size, and you are ready to erase the pencil lines. If you inked only the lines, *a, b, c, p*. and *m,* you would have an *indicated* thread drawn to scale, full size.

h. In drawing an indicated thread you will find it very helpful to draw the pencil lines *s* and *t* at such distances from *a* and *b* respectively as would represent the depth of the thread. The lines *a* and *b* become the limits of the lines *p* representing the top of the thread, and the lines *s* and *t* become the limits of the lines *m* representing the root of the thread. The lines *s* and *t* should not be inked; they should be erased after inking the lines *a, b, c, p* and *m*. As the object in indicating a thread is usually to save time, it may or may not be drawn to show the true number of threads to the inch. But in any event you must first determine the number of threads you will show to the inch to make your work look well, and divide the line *a* into equal spaces accordingly. You will then proceed as above to locate the lines *p* and *m,* having first drawn the lines *s* and *t* through the intersections *f* and *r* respectively.

Sec. 75. Nos. 143, 144 and 145 present another use of the spiral in the form of spiral springs. No. 143 is a conical compression spring, made to occupy the least possible space when compressed. It may be compressed until its height or length is no more than the thickness of the wire of which it is made.

a. No. 144 is the most common form of spiral compression spring, called a cylindrical spiral. It is an open spiral. It may be compressed until the coils lie one upon another. The virtue of Nos. 143 and 144 lies in their ability to resist compression, and to return to their original position as the compressing force is released. The property which tends to cause a return to the original position is called *elasticity.*

b. No. 145 presents a closed cylindrical spiral. It tends to resist being pulled open, and to return to its closed position upon being released. It is called a tension spring. A common use of a spiral tension spring is in an ordinary spring balance. Its virtue lies in its elasticity, or its ability to return to a closed position upon being pulled open.

Sec. 76. By way of illustrating a subject requiring greater detail we have introduced drawings of a familiar bit of modern mechanism—an automobile piston, connecting rod and crank shaft. No. 129 shows the piston, presenting a side view showing the end of one of the wrist pin bearings. The piston is round, turned all over. There are three grooves each ¼″ wide, turned around the outside of the piston to receive the expansion rings shown in No. 130. We have two views of the ring. Observe that the inside circumference and the outside circumference are not concentric; their centers are not at the same point; they are eccentric, and the ring is thicker at one side than at the other. Notice that there is a cut through the ring where it is thinnest, and that this cut is 5/16″ long and that it passes through the ring from one side to the other at an angle of 45 deg. with the side line of the ring. The grooves around the piston are machined to gauge—to an exact width; and the rings are machined to an exact width to correspond. The grooves are slightly deeper than the thickness of the rings at their thickest part. The rings are sprung open and slipped over the end of the piston and moved along until each springs into its groove. Then they are compressed as the piston enters the cylinder; so that their tendency to expand keeps the outer surface of the rings in close contact with the inner surface of the cylinder. No. 131 presents an end view of the piston showing in outline the brass bushings that receive the wrist pin (shown in No. 132 at the upper left hand corner of the sheet). The wrist pin is finished all over and is fitted carefully into the bushed bearings made to receive it in the piston. Note that there is a concave cut made in one side of it, and that it has a screw slot in one end. The latter is for the purpose of being able to turn the wrist pin in its bearings so as to bring the concave cut to the right place so that it will be occupied by the clamp bolt when in place, thus preventing the wrist pin from moving toward either end, and keeping it from contact with the inner wall of the cylinder.

a. Nos. 133, 134, 135, 136, 137 and 138 show a general drawing of the connecting rod and also detailed drawings of its parts. We have a side elevation of the connecting rod with a section, a plan, an end elevation and another section. No. 133 shows the plan of the connecting rod, and below it is a side elevation. They show on the wrist pin end of the connecting rod the chamber bored out for the wrist pin and the cylindrical boss bored and tapped for the clamp bolt (No. 136), and also a 1/16" milled cut through the upper wall of the wrist pin chamber and through the boss. This milled cut allows the clamp bolt, when in place, to be drawn up so as to pull together the walls of the cut, tightening the chanber around the wrist pin like a clamp. The side elevation shows also how the clamp bolt occupies the concave cut in the side of the wrist pin and prevents its moving in the direction of either end. In the other end of the connecting rod is the crank shaft bearing showing the babbitt in the bearing and the cap bolts (No. 137) and the safety nuts (No. 138) in place. The side elevation, plan, section and end view show four different views of this end of the connecting rod. The bearing is in two parts, the division being along the line of the vertical center line as shown in the drawing. The detached piece is called the cap, and when the journal of the crank shaft is in place in its connecting rod bearing the cap is securely fastened on by means of the two cap bolts No. 137, shown also in detail at the top of the sheet. One side of the heads of the cap bolts is cut off so that the straight edge thus formed prevents the cap bolt from turning by its contact with the shoulder shown in the section of the connecting rod. The safety nuts (See Sec. 74-*a*) are shown in place and with the cotter pins (No. 139) also in place, so that the nuts cannot turn and become loosened. The section *D-D* is a section of the cap, as though the lower half of the cap were cut off at *D-D* and you were looking up at the exposed surface remaining. No. 134 is the cap and No. 135 is the babbitt within. The curved dotted line shows a shoulder made by providing clearance for the nuts No. 138.

b. No. 142 shows an automobile crank shaft to go with the connecting rod shown. It has three main journals, the two on the ends being each 1¼″ diam. x 3″ long, while that in the middle is 1¼″ diam. x 2¼″ long. There are four connecting rod journals each 1¼″ diam. x 1½″ long, having a two inch throw, which is just half the piston stroke. The center lines of all the journals are within the same plane. This is shown by the end views. The view from the left hand end shows the lines of the long arms and of the short arms, while the section at *A-A* shows the sectional outline of the long arms and that at *B-B* shows the sectional outline of the short arms. Both end views show the coupling flange on the right hand end. It is made to be attached by six bolts to a gear coupling. The dotted circles indicate the main journals and their shoulders. The two small dotted circles in the left hand end view show the outlines of the connecting rod journals within the lines of the shoulder or flange at each end of the journal.

Sheet No. 5 is full of practical work in drawing and in reading drawings. You should not leave it until you can draw well any number on it. The spirals—the screw thread and the spiral springs should receive plenty of attention. When you have mastered the work on this sheet you will be able to draw any screw thread, double threads excepted. Study the piston, connecting rod and crank shaft drawings until you absolutely understand every line and why it is there—until you can see the mechanism before your eyes by looking at the drawings. *Then you will* *have read the drawings.* It will be fine practice to present this subject in full size and half size drawings. Draw from original subjects. Select simple subjects and make different views of them. Gradually take up subjects having more detail. Do your best on everything you attempt to draw and do not leave it until you know that you have done it well. In the meantime do not fail to apply your mensuration wherever you can get data on which to base a problem. The mathematical end of your work is very important. Drawing without mathematics makes a one handed man—not very useful anywhere. Combine the two with ability to think and unceasing application, and you will overcome all obstacles.

Sec. 77. We come now to consider the lever, because it enters into so many mechanical constructions. There are three classes of levers, and three elements to be considered in connection with the lever:—the fulcrum is the point about which the lever turns, as *F* (No. 164); the weight or resistance to be moved or overcome, as *W*; and the power or force applied, as *P*. When the fulcrum is between *P* and *W* the lever is of the first class. Resistance or weight and power or force are measured in pounds; and when the power multiplied by its distance from *F* equals the weight multiplied by its distance from *F*, the power and the weight will balance each other. Therefore *P* x distance *P-F* = *W* x distance *W-F;* and three of these four elements being known, the fourth can be found. In No. 164, if the weight of the boy is 100 lbs., and the distance from the middle point between his hands to the point where the crow bar rests on the block is 36″, and the distance between this point (fulcrum) and the point where the crow bar touches the big stone is 6″, 100 lbs. x 36 = 3,600 lbs.; divide by 6 and we find that the boy can exert a lifting force of 600 lbs. To move the stone one inch the boy's hands will have to travel six inches, and the power will move six times as fast as the weight; hence also, the power multiplied by the distance it travels must equal the weight multiplied by the distance it moves, and three of these elements being known, the fourth can be found as in the above problem.

a. No. 165 represents a lever of the second class, the weight being between the power and the fulcrum. Suppose the boy exerts a lifting force of 100 lbs., and the distance from the middle point between his hands (*P*) to the point where the crow bar rests on the ground (fulcrum) is 42″, and the distance from that same point (fulcrum) to the point where the stone rests on the crow bar is 6″; 100 lbs. x 42 = 4,200 lbs., and dividing by 6 we find that the boy can exert a lifting force of 700 lbs. on the stone. To move the stone one inch the boy's hands will have to travel seven inches, and the power will move seven times as fast as the weight.

b. When the power is exerted between the weight and fulcrum the lever is of the third class (No. 166). Suppose the boy wishes to lift a two-pound fish from the water; the weight is where the line is attached to the rod; if he holds his right hand stationary it becomes the fulcrum; and if he lifts with his left hand it becomes the power. If the distance from fulcrum to weight is 42″, and from fulcrum to power is 6″, then the weight, 2 lbs., x 42 = 84 lbs., and dividing by 6 we find that the left hand must exert a lifting force of 14 lbs. to lift that 2-pound fish. In raising the left hand (power) one inch the fish (weight) will be moved seven inches.

c. *In levers of the first and second classes power is gained and motion is lost; in levers of the third class power is lost and motion is gained.* Look around you for examples of the different kinds of levers. They are everywhere. Consider their application. Make up problems and work them out. A pair of scissors is an application of levers of the first class. A lemon squeezer is an application of levers of the second class. Revolve a lever about its fulcrum; the power would describe a circle, and the weight would describe another circle; and so we have the principles of the lever applied in wheels, pulleys, gears, etc.

Sec. 78. Pulleys are wheels used to transmit motion and power by means of belts. No. 153 represents the smaller pulley as being a driving pulley communicating motion and power to the larger. Motion or speed will be lost and power will be gained. If the driving pulley is 36″ in diam. and runs 100 revolutions per minute, at what rate of speed will it drive a 48″ pulley? 100 x 36, and this product divided by 48 gives us the number of revolutions per minute of the

48″ pulley, or 75 revolutions. *To find the speed of a "follower," or following pulley, multiply the r. p. m. (revolutions per minute) of the driving pulley by its diameter and divide by the diameter of the follower. The result is the r. p. m. of the follower. Likewise to find what must be the diameter of a follower to give it a certain speed, multiply diam. of driving pulley by its r. p. m. and divide by the required r. p. m. of the follower. The result will be the diam. of the follower.* No. 154 represents a train of pulleys introduced for the purpose of illustrating their use in transmitting increased or diminished power and motion, and for changing the direction of the latter. Let the 48″ pulley *A* be the driving pulley running 100 r. p. m. It drives a 36″ pulley *B*, which we find (See above rule.) will run at the rate of 133⅓ r. p. m. With the pulley *B* there are the 30″ pulley *C* and the 8″ pulley *D*, all on the same shaft; and being tight pulleys (turning with the shaft), they all have the same r. p. m. The pulley *D* therefore makes 133⅓ r. p. m., and it drives a 36″ pulley *E*. 8 x 133⅓, divided by 36 = 29.6 r. p. m. of pulley *E*. On the same shaft with the pulley *E* an 8″ pulley *F* runs at the same rate and drives a 24″ pulley *G* with a reversed motion. Show by the same method that the pulley *G* runs at the rate of 9.8 r. p. m., and that the 8″ pulley *H* revolves with it in the same direction and at the same rate. Now going back to the 30″ pulley *C*, it makes 133⅓ r. p. m. and drives an 8″ pulley *I*. Applying the rule we find that the pulley *I* makes 500 r. p. m. The 24″ pulley *J* with it drives an 8″ pulley *K* giving it a speed of 1500 r. p. m. The idler pulley *L* does not transmit motion or power. It is simply a belt tightener, capable of being moved against the belt or away from it.

a. If the driver is an 18″ pulley making 300 r. p. m., what size pulley must be put on the line shaft to give it 250 r. p. m.? (See rule above). 18 x 300, divided by 250 = 21.6″ diam. From this same line shaft running at the rate of 250 r. p. m., it is desired to run a jointer 3,500 r. p. m. The pulley on the jointer is 5″ in diam. Select a pulley of suitable size to be the driving pulley on the line shaft, and then find what size follower and driver on the counter-shaft will give the required speed approximately. You can find plenty of practical examples. Reduce them to figures. Arrange a mill room, starting with an engine running 250 r. p. m., and put in a line shaft and counter shafts with machines. Assign desired speeds to the machines, and then arrange your pulleys so as to secure the desired speeds, while at the same time trying to avoid running your counter shafts at high speeds.

b. In studying levers we learned (Sec. 77-*c*) that when motion is lost power is gained, and when motion is gained power is lost. Since pulleys and gears are applications of levers, the same principles apply. The power transmitted is in an inverse ratio to the motion transmitted. In No. 153 the driver makes 100 r. p. m. and the follower makes 75 r. p. m. The motion transmitted is 75/100 of the motion of the driver, or

$\frac{3}{4}$. The power transmitted to the follower is $\frac{100}{75}$ or $1\frac{1}{3}$ times the power of the driver; that is, a certain power exerted upon the shaft of the driver will exert $1\frac{1}{3}$ times as much force upon the shaft of the follower, due to the advantage of the leverage in the larger wheel, but in gaining that advantage the wheel will run slower and motion or speed is lost.

Sec. 79. We come now to consider the transmission of motion and power by means of gears—gear-wheels or cog-wheels (Nos. 155 to 163). The usual form of a gear is that of a wheel having transverse teeth or cogs on its face, made to mesh with similar teeth on another gear. Perfectly formed teeth are made to roll upon each other with little or no sliding friction when gears are running in mesh. This requires that the face of the tooth should have just the proper curve. When gears are in mesh the depth to which the teeth of one enter between those of the other is called *working depth.* (See No. 155—Gear Diagram). *G* is the working depth of the tooth. The bottom of the trough between the teeth is spoken of as the *bottom* of the *tooth.* You will notice that when the teeth are in mesh the end of the tooth of one gear does not quite touch the bottom of the tooth of the other gear. The space between is called *clearance;* also, when the working surfaces of teeth in mesh are in contact, between the opposite or idle surfaces there is a slight space, and this space is likewise called *clearance.* In No. 155 these two clearances are shown at F. and F. Divide the working depth of a tooth into two equal parts as measured along its center line, and draw a circle from the center of the gear through this division point. This is the *pitch circle* of the gear, as H. When two gears are in mesh their pitch circles just touch but do not intersect each other. Note that the pitch circles of the gears shown in mesh in the drawing are always tangent to each other—they touch but do not intersect. The distance between the pitch circle and the end of a tooth, measured along a radius of the gear, is called *addendum;* and in practice this name has come to be applied to that part of the tooth which lies outside of the pitch circle. In like manner that part of the tooth lying within the pitch circle is called *dedendum.* In No. 155, *A* is the addendum and *B* is the dedendum. The distance measured along the pitch circle from the center line of any tooth to the center line of the next tooth is called *circular pitch. E* represents the circular pitch of the teeth of the diagram. Thickness of tooth is the thickness of any tooth measured along the pitch circle, as is shown at *D.* The diameter of the pitch circle is called *pitch diameter,* as I. The *outside diameter is* the diameter of a circle drawn from the center of the gear and passing through the end lines of the teeth, as J in No. 155; or, it is the diameter of the gear from end of tooth to end of tooth, as J in No. 156-*a.* The distance measured along a radius of a gear from the end of a tooth to the bottom of the tooth, or from the circle of the outside diameter to the bottom of the tooth, is called *whole depth* of tooth, as is shown at *C* in No. 155. The working surface of the tooth outside of the pitch circle is called the *face* of the tooth; and that part of the working surface of the tooth inside of the pitch circle is called the *flank* of the tooth. All of these various terms and the relation of the things they represent should be carefully learned.

a. Nos. 156-*a,* 157, 158, 159, 156-*b,* 160 and 156-*e* show a train of gears, of which 160 and 156-*e* are not in the same plane as the others; they are behind 159 and 156-*b.* 156-*b* and 156-*e* are loose gears turning on journals; they do not turn shafts. Their office would be to transmit motion and power to other gears in the train not shown. 159 and 160 are on the same shaft and both are tight gears, so that the gears and the shaft all turn together. The key-way is shown, indicating that they are to be keyed tightly on the shaft. 156-*a* and 158 are also tight gears. 157 is a gear cut on a shaft, as is indicated by its being shown in section. The section *A A* is taken at *A A* through the vertical center line of 159 and 156-*b.* The section *B. B.* is taken at *B B* through the center lines of 160 and 156-*e.* It is an inclined section represented in a vertical position in order to show the gears in proper relation. The journal for 156-*e* is shown in place. That it is a journal and not a tight shaft is shown by the crossed diagonal lines, wihch are always used to indicate journals. Likewise the shaft in 159 and 160 is shown to be a tight shaft by the absence of the diagonal lines, and also by the key-way shown on the side of the shaft.

b. The gears in the drawing are half size.

The diameter of the pitch circle of 158, or its *pitch diameter,* is 3″; the pitch diam. of 159 is 6″. Their *gear centers* are 4½″ apart, or half the sum of their pitch diameters. The gear centers of 159 and 156-*b* are 5″ apart; and the gear centers of 156-*a* and 157 are 3″ apart. In 156-*a,* having a pitch diam. of 4″, there are 16 teeth; in 157, pitch diam. 2″, there are 8 teeth; in 158, pitch diam, 3″, there are 12 teeth; in 159, pitch diam. 6″, there are 24 teeth; in 160, pitch diam. 3½″, there are 14 teeth; in 156-*b,* pitch diam. 4″, there are 16 teeth; and in 156-*e,* pitch diam. 4″, there are 16 teeth. It will be seen that in each gear in the train the number of teeth is four times the pitch diameter, or 4 teeth for each inch in the pitch diameter. In any gear the number of teeth per inch of pitch diam. is called *diametrical pitch;* so in this train of gears the diametrical pitch is 4; which means that the number of teeth is 4 x the pitch diam. In any train of gears the diametrical pitch must be uniform in all the gears; and what this diametrical pitch should be in any train of gears depends upon the circumstances and conditions of their use.

c. In this train of gears we will assume that 158 is the driving gear. 158 transmits motion to 157, and 157 in turn transmits motion to 156-*a.* Observe the direction of the motion of 158 as shown by the arrow, and note that when 158 turns it will turn 157 in the opposite direction; 157 in turn will impart motion in the opposite direction to 156-*a,* and the direction of 156-*a* will be the same as that of 158. Thus we see that numbers one, three, five, etc., in a train of gears, or the odd numbers, all turn in the direction of No. one—the driving gear; while the even numbers of gears turn in the opposite direction.

d. The pitch diameter of 156-*a* is the same as that of 156-*b*, and they each have 16 teeth. 158 transmits motion to 156-*a* through 157 having 8 teeth; 158 also transmits motion to 156-*b* through 159 having 24 teeth. 158 has 12 teeth. Now observe that when 158 turns the thickness of a tooth it turns 157 one tooth, and 157 turns 156-*a* one tooth; and when 158 turns 12 teeth or one revolution, 156-*a* turns 12 teeth also, or 12/16 or 3/4 of a revolution. Also, when 158 turns one tooth it turns 159 one tooth, and 159 turns 156-*b* one tooth; and when 158 turns 12 teeth or one revolution, 156-*b* also turns 12 teeth, or 12/16 3/4 of a revolution. One revolution of 158 has turned 156-*a* and 156-*b* exactly the same, or 3/4 of a revolution, whether the motion was transmitted through a small gear or a large gear. So you see that the size of the go-between or intermediary gear has nothing to do with the rate of motion transmitted to the next gear. *The intermediary transmits to the follower a motion of as many teeth as it receives from the driver.* Now let us suppose 156-*a* to be the driver transmitting motion through 157, 158 and 159 to 156-*b*. When 156-*a* moves one tooth 156-*b* will move one tooth; and when 156-*a* makes one revolution 156-*b* will make one revolution. Neither the number of intermediaries nor their size affects the relative speed of any gear in a train as compared with that of any other. *The relative speeds of any two gears in a train depend solely upon their relative number of teeth respectively.* Again supposing 156-*a* to be the driver, when 156-*a* makes one revolution 157 will make two because it has half as many teeth as 156-*a;* 158 will make one and a third revolutions, and 159 will make two thirds of a revolution. While 157 is making one revolution 159 makes one third of a revolution, and 157 turns three times while 159 turns once.

e. We have seen that while 158 makes one revolution, 159 makes half a revolution because 159 has 24 teeth while 158 has 12 teeth. We have seen also (*a*) that 159 and 160 are both tight gears on the same shaft, both turning with the shaft and both turning together; when 159 makes a revolution 160 also makes a revolution. 160 has 14 teeth and it meshes with 156-*e* having 16 teeth. Now, when 158 makes one revolution, 159 makes half a revolution; 160 also makes half a revolution, and it moves seven teeth; it transmits a motion of seven teeth to 156-*e,* or 7/16 of a revolution. 156-*e* and 156-*b* have each 16 teeth; and we have seen that one revolution of 158 turns 156-*b* 12/16 of a revolution, while 156-*e* is turned 7/16 of a revolution. The difference is effected by the device of using two tight gears on the same shaft as an intermediary, one of them receiving the motion and the other transmitting it to 156-*e.* It will be seen readily that by varying the relative sizes of these two tight gears acting as an intermediary, any desired change can be effected in the relative speeds of 158 and 156-*e*.

f. In transmitting power the intermediary gear transmits just what it receives, except of course a certain loss due to friction. *If motion or speed is lost in transmitting, power is gained; and if speed is gained power is lost.* In a train of two gears, 158 and 159, 158 makes one revolution while 159 makes half a revolution. The speed transmitted to 159 is just half the speed of 158; but the power transmitted to 159 is double the power of 158. Add 156-*b* to the train of gears making 159 an intermediary; the power transmitted to 156-*b* is just the same as if 158 were directly in mesh with 156-*b* except for a certain loss by friction due to the intermediary. *The power transmitted is in an inverse (reversed) ratio to the motion or speed transmitted.* We have seen that the speed transmitted to 156-*b* is 12/16 of the speed of 158; the power transmitted to 156-b is therefore 16/12 of the power of 158. In other words, if 156-*b* were a tight gear on a shaft, its shaft would exert 1¾ times as much force as is exerted upon the shaft of 158, but it would turn only ¾ as fast as the shaft of 158.

Sec. 80. Nos. 150, 151 and 152 show general and detailed drawings of a frame garage with a bench across the width of the room under the window at the rear. This subject is introduced here not with the object of showing particular methods of construction. The purpose is rather to show how to *indicate* construction in drawing—*any* construction that it is desired to follow. The several views and sections show pretty clearly just what the construction is to be in this case; and that is the whole purpose of making a drawing. For the purpose of this Course the foundation work is omitted from this study, having already included a drawing of a foundation. The drawings show a front elevation, a rear elevation and a left hand side elevation in relation to the front elevation, and a sectional plan; a front elevation, plan and right hand side elevation of the window viewed from the outside; a section of sash mullion, sections of bottom and side of window frame, two sections of doors and door frame, section of siding, section of a corner and two views of the bench construction. In the rear view and the left hand side view the siding and the roof are broken out that the frame and the bench in place may be shown. The encircled numbers on the drawing indicate parts of the construction, as follows:

(1) Sills under sides, (2) sills under ends, (3) side plates, (4) end plates, (5) stud (six of them), (6) stud (four of them), (7) stud (fourteen of them), (8) rafters (twenty of them), (9) rafter peak board, (10) header over door, (11) corner boards (eight of them), (12) roof edge (all around), (13) roof boards, (20, 21, 22 and 23) siding, (25) cap (two of them), (26) legs (four of them), (27) tie (two of them), (28) bolts (four of them), (29) bolts (two of them), (30) plank, (31) boards, (32) filling pieces (four of them), (34) end supports (two of them), (40) sash (upper and lower),

(41) window sill, (42 and 43) window casing, (44 and 45) window jamb, (46, 47, 48 and 49) window stops, (50) right hand door, (51) left hand door, (52) door stop (top), (53) door jamb (top), (54) door casing (top), (55) weather strip(top of door), (56) door casing, upright (two of them), (57) door jamb, sides (two of them), (58) door stops, sides (two of them), (59) finishing piece under door, (60) hinges hardware, (61) hasp and staple, (62) lock.

a. Although these garage drawings are for a rather small and unimportant building, they present quite sufficient detail for the first subject in architectural drawing. Study the drawings carefully in connection with the foregoing explanation of the numbers until you are able to name and know how to place every piece of lumber in the building. Give very careful attention to the sections as a means of showing exactly how every construction is to be made; and note with care all details shown in all the drawings. Having studied the drawings until you understand every line in them, you are ready to reproduce them. Make a complete set of drawings of your own, and allow for them about twice as much space as they occupy on this sheet, if you draw them to the same scale. They are necessarily crowded together here. You can make your work present a better appearance by giving it more space on the sheet. Pay very close attention to what may seem to you to be small things, and omit not the slightest detail. When you have mastered thoroughly this subject it will not be difficult for you to make drawings for a larger building.

b. Having completed the drawings, the next step is to prepare what is called a "bill of material" for the building. It is simply an itemized statement of all materials required and the quantity of each. The bill of material with a percentage added for labor cost forms the basis for your preliminary estimate of the cost of the building. The cost of materials is not the same in all parts of the country; and the percentage to be added for labor cost varies even more. Go over the plans carefully and verify the following bill of material. Find the cost of the materials at the prevailing local prices, and add to that an estimate of the labor cost according to the best information you can get, for your estimate of the cost of the garage, not including the foundation. To find the cost of the foundation, you must first determine from the nature of the ground what will be necessary to make the foundation sufficiently secure. Then you can decide what material shall be used, and figure the number of cubic yards and the probable cost. The following is the bill of material (Sec. 25):—

ROUGH LUMBER—YELLOW PINE.

		(board measure)
(1) Sills	2 pcs., 4 x 6 x 18 =	72 ft.
(2) Sills	2 pcs., 4 x 6 x 12 =	48 ft.
(3) Plates	2 pcs., 4 x 6 x 18 =	72 ft.
(4) Plates	2 pcs., 4 x 6 x 12 =	48 ft.
(5) Studs	6 pcs., 6 x 6 x 10 =	180 ft.

(6) Studs .... 4 pcs., 4 x 6 x 10 = 80 ft.
(7) Studs ....14 pcs., 3 x 6 x 10 = 210 ft.
(8) Rafters ....10 pcs., 3 x 6 x 18 = 270 ft.
(9) Peak board .... 1 pc., 1 x 8 x 18 = 12 ft.
(10) Header over
door .... 1 pc. 4 x 6 x 10 = 20 ft.
(13) Roof boards, 357 sq.ft. plus waste = 380 ft.
(32) Filling pcs. bench, 1 pc., 2 x 4 x 8 = 5 ft.
(34) End suppports
bench .... 1 pc., 2 x 6 x 8 = 12 ft.

Total ....1409 ft.

FINISHED LUMBER—YELLOW PINE.

(20-21-22-23) Siding, exposed surface 650
sq. ft., 20 per cent. allowance for lap
and waste .... = 780 ft.
(12) Roof edge ....4 pcs., 1x6x8′-6″= 17 ft.
(12) Roof edge ......4 pcs., 1x6x12″ = 24 ft.
(11) Corner boards ...8 pcs., 1x7x12 = 56 ft.
(53) Door frame (top) 1 pc., 1x4x10 = 3 ft.
(57) Door frame (sides) 2 pcs., 1x4x 8 = 6 ft.
(52) Door stop (top)..1 pc., 1x3x 8 = 2 ft.
(58) Door stop (sides).2 pcs., 1x3x8 = 4 ft.
(54-56) Door casing ..3 pcs., 1x7x10 = 18 ft.
(55) Door weather strip, 1 pc., 1x3x10 = 2 ft.
(59) Door finishing pc. 1 pc., 1x3x10 = 3 ft.
(30) Bench plank ....1 pc., 3x12x12 = 36 ft.
(31) Bench boards...1x17 (total) x 12 = 17 ft.

Total ....968 ft.

MILL WORK—YELLOW PINE.

(50 Door, right hand, as per drawing.
(51) Door, left hand, as per drawing.

(151) Window frame and sash, as per drawing.
(152) Two bench frames complete as per drawing, without Nos. 30-31-32.

OTHER MATERIAL.

(60) Hinges—4 prs.—2 doz. 1½″—No. 14 screws.
(61) Hasp and staples. (62) Lock.
Nails—10d. (penny), 5 lbs.; 8d., 25 lbs.
Roofing paper—4 rolls. Paint—2½ gals.

There have now been presented to you the facts, principles, rules and practices which constitute a basic knowledge of Mechanical Drawing and a general knowledge of the Arithmetic of Measures as applied to a wide range of shop problems. If you have followed with fidelity the suggestions contained in our foreword to the student, this knowledge is yours to a greater or to a less degree, according to your ability to grasp ideas readily and to apply them practically. However it would be expecting too much to assume that you have mastered the Course, that you have exhausted the subject and have absorbed all that is taught herein by going over it just once. A second trip over the same route should prove very interesting and profitable, and a third for review will convince you that you have yet some work to do before you can feel sure that every element in this Foundation Course has been applied in your own foundation preparation for life's work.