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MECHANICAL DRAWING
FOR
HIGH SCHOOLS

A TEXT WITH
PROBLEM LAYOUTS

BY

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PREFACE

Industrial educators are generally agreed that a textbook is necessary for the most sucessful teaching of mechanical drawing. However, several important considerations are involved in the selection of a suitable text. It "should be more than a collection of problems. It should present the subject in a clear, orderly and logical arrangement of the divisions, explaining *why* each rule or custom is made, and illustrating with examples representing good modern practice."

A survey of mechanical drawing in high schools* recently made by the authors showed that "a system of standardization appears to be needed to give the subject the standing to which it is entitled as a cultural subject as well as a practical one, a real language to be studied and taught in the same way as any other language."

The purpose of this book is to present mechanical drawing as a definite educational subject with the following objectives:

To develop the power of visualization;

To strengthen the constructive imagination;

To train in exactness of thought;

To teach how to read and write the language of the industries;

To give modern commercial practice in making working drawings.

The standardizing of mechanical drawing by the logical arrangement of its subject matter into grand divisions will, it is believed, make both teaching and learning easier.

The first seven chapters comprise a complete textbook which may be used with any problems. The paragraphs are numbered for easy reference. The eighth chapter is a complete problem book, in which the number of problems in each division is such that a selection may be made for students of varying ability, and that a variation from year to year may be had. The problems have references to articles in the text, and the order may be

* Bulletin issued by Dept. of Public Instruction, State of Ohio.

varied to suit the particular needs of a school. Definite specifications and layouts are given for most of the problems, thus making it possible for the instructor to use his time efficiently in teaching rather than in the drudgery of detail, while the time ordinarily wasted by the pupil in getting started can be used in actual drawing.

More than enough is included for two years' work in the average high school. The authors will at any time be pleased to advise in the selection of problems or arrangement of courses.

COLUMBUS, OHIO.
July 18, 1919.

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MECHANICAL DRAWING FOR HIGH SCHOOLS

CHAPTER I

The Language of Drawing

1. Language is defined as the expression of thought. Every educated person wishes to be able to express himself readily and easily, to convey his thoughts so accurately that they cannot be misunderstood; and to be able to understand the exact meaning expressed by another person. For this reason we make an extended study of English, until we know its grammar and idioms and style. We read literature and practice composition in order to become thoroughly familiar with the language.

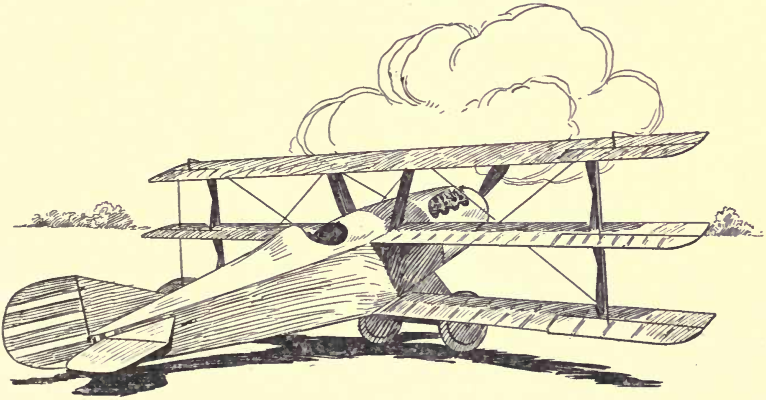


Fig. 1.—A perspective drawing.

2. But if we attempt to describe in words the appearance and details of a machine, or bridge, or building, we find it not only difficult but in most cases impossible. Here we must use another language, the universal graphic language of drawing. Thus when words fail to give a complete or accurate description we find books,

magazines and newspapers using pictures, diagrams and drawings of various kinds. For illustrative purposes perspective drawings, Fig. 1, which show the object as it actually appears to the eye are often used. A written description of a new piece of furniture would have to be very long to tell *all* about it, and even then might be misunderstood. A picture would serve the purpose much better, but the picture would not show the exact method of construction and would give only the external appearance without telling what was inside. It would be impossible to construct a locomotive or an airplane either from a word description or a picture. The pictorial methods of drawing are thus not suitable for constructive work.

3. Fortunately another form of description has been developed by which the exact shape of every detail may be defined accurately and quickly. It consists of different views of an object arranged according to a definite system, with lines and figures added to tell the sizes. This is called mechanical drawing, and it forms so important a part of all industrial and mechanical work that it is called the "language of industry."

The language of drawing has its own orthography and grammar and style, its idioms and abbreviations, and its study not only gives one the ability to express thoughts hitherto impossible but develops the constructive imagination and the habit of exact thinking.

CHAPTER II

Learning to Draw

4. The previous chapter explained the necessity for drawing in all industrial work, and that it was really a new language. Sometimes drawings are made freehand, but for accurate work it is necessary to use instruments. In learning to read and write in this language we must first learn what tools and instruments to use, and how to use them accurately, skilfully and quickly.

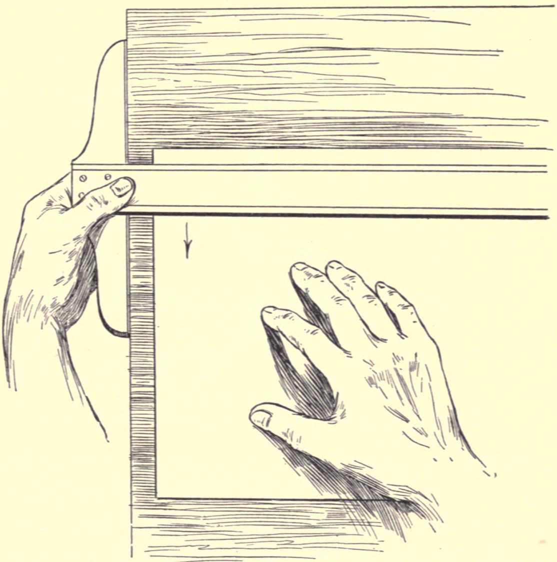


Fig. 2.—Adjusting the paper.

5. **Attaching the Paper.**—Mechanical drawings are usually penciled on fairly heavy unruled paper, either cream color or white, which is held in place on a soft pine drawing board by thumb tacks. The drawing board must have its left hand and lower edges very straight and accurately square with each other, as these are the "working edges."

In fastening the paper lay it on the board with its left edge an inch or so from the left edge of the board, place the T-square in the position of Fig. 2, and "true up" the paper with the T-square blade. Holding the paper in position, move the T-square down as in Fig. 3 and put a thumb tack through each of the corners, pushing them in until the heads clamp the paper. For sheets of firm drawing paper not larger than 12″ × 18″ the two lower tacks may be omitted.

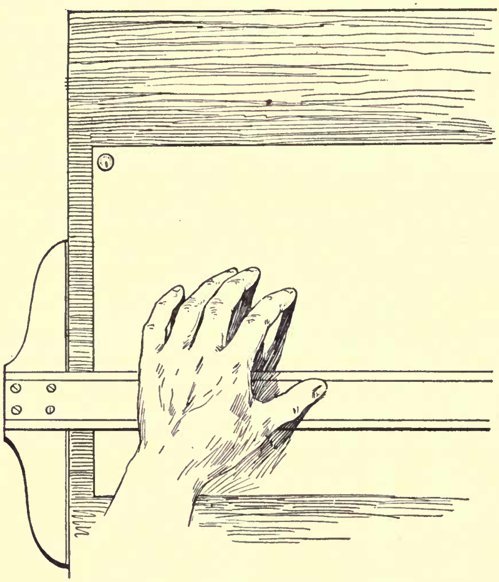


Fig. 3.—Fastening the paper.

6. **Sharpening the Pencil.**—A draftsman uses a hard pencil with a long sharp point so that his work may be very accurate. Drawing pencils are graded by letters, from 6*B* (very soft and black), 5*B*, 4*B*, 3*B*, 2*B*, *B*, *HB*, *F*, *H*, 2*H*, 3*H*, 4*H*, 5*H*, 6*H*, 7*H*, 8*H*, 9*H* (extremely hard). 4*H* and 6*H* are the usual grades of hard pencil used for drawing lines, while *H* and 2*H* are used for sketching and lettering. The ordinary No. 2 writing pencil is about the same grade as *HB* or *F*.

Sharpen the pencil by cutting away the wood at a long slope as shown in Fig. 4,*A*, being careful not to cut the lead, but exposing it about a quarter of an inch. Then shape the lead to a long conical point by rubbing it back and forth on a sandpaper pad or fine file, rotating it slowly in the fingers. Have this sharpener at hand and keep the lead sharp by frequent rubbing.

Never sharpen a pencil over the paper or drawing board.

Pencil lines must be fine, light, clear lines. Get the habit when drawing long lines of rotating the pencil so as to keep a sharp cone on the point.

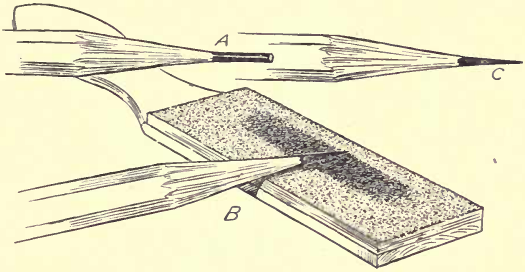


FIG. 4.—Sharpening the pencil.

The foundation of mechanical drawing is the line, so a set of the different kinds of lines used is called the alphabet of lines. These are explained in Art. 62.

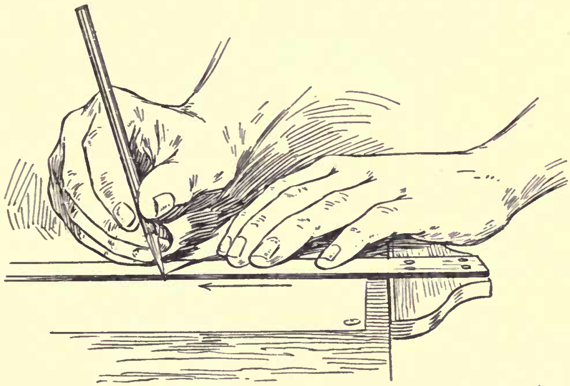


FIG. 5.—Drawing a horizontal line.

7. **Ruling Lines.**—All the lines in a mechanical drawing are made with the aid of some instrument as a guide for the pencil or pen. Horizontal lines are always drawn with the upper edge of the T-square blade as a guide. Hold the head of the T-square against the left edge of the board with the left hand,[1] and always move the pencil from left to right, Fig. 5.

[1] Left-handed persons reverse this rule, using the T-square on the right edge.

The pencil should be held about an inch from the point and inclined slightly in the direction in which the line is being drawn.

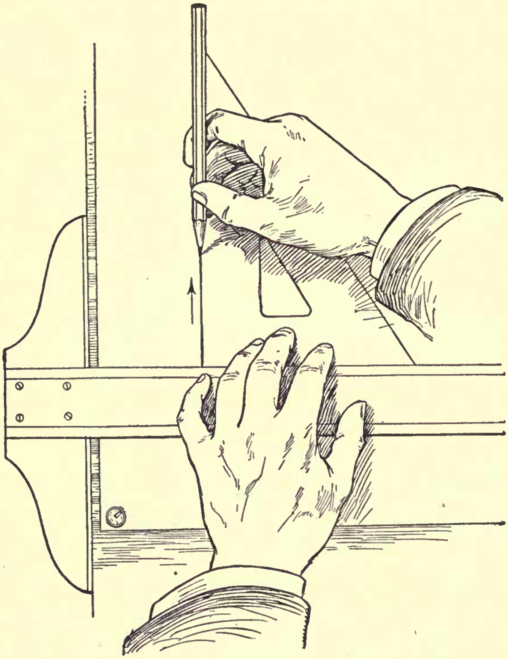


Fig. 6.—Drawing a vertical line.

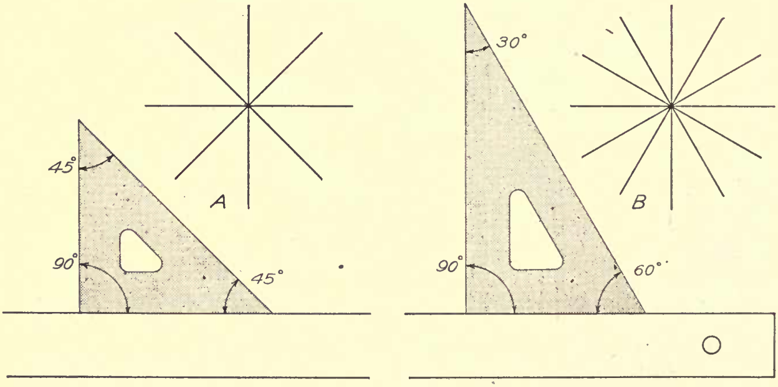


Fig. 7.—The 45 degree and 30–60 degree triangles.

Vertical lines are drawn by using a triangle held against the T-square. Always have the vertical edge of the triangle toward the left and draw up from the bottom to the top, Fig. 6.

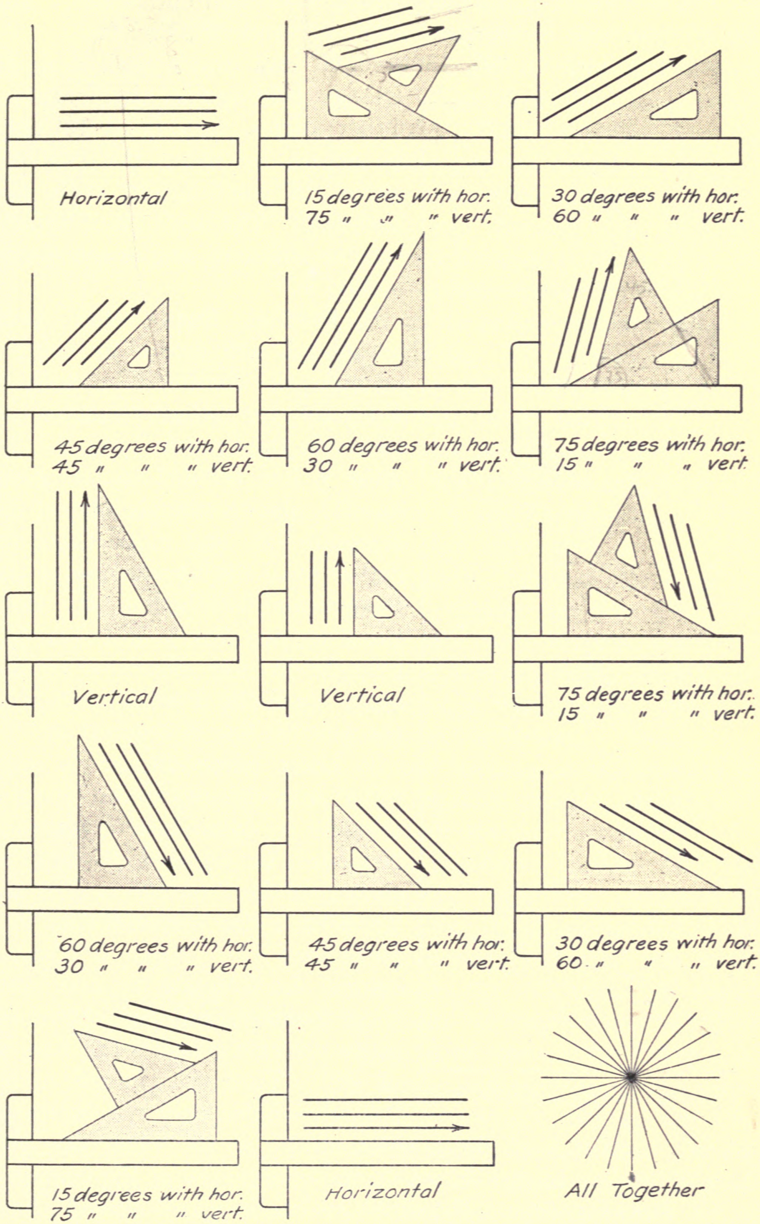


FIG. 8.—Positions of the triangles.

The 45° triangle, has two angles of 45° and one of 90°. The 30°–60° triangle has angles of 30°, 60° and 90°, Fig. 7.

Inclined lines at 30°, 45° and 60° are drawn with a single triangle held against the T-square. Other angles, varying by 15° may be drawn by using the two triangles in combination with the T-square. The methods of obtaining the different angles are shown in Fig. 8.

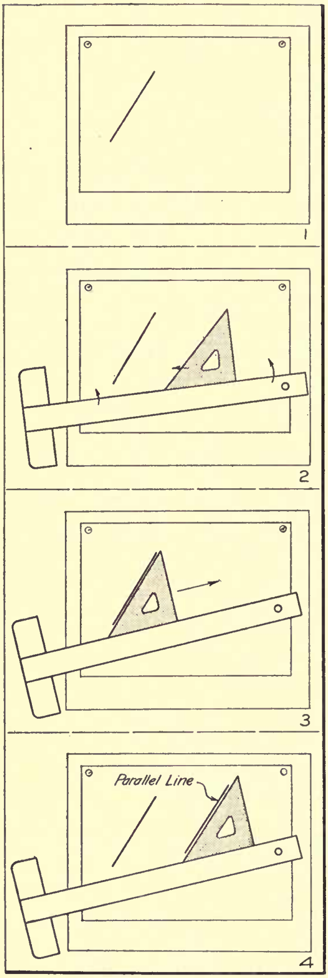


Fig. 9.—Drawing a parallel line.

8. **Parallel lines**—other than horizontal, are drawn by using a triangle in combination with a T-square (or other triangle), as shown in the "movie" Fig. 9. To draw a line parallel to the given line (1), place a triangle against the T-square (2), and move them together until the hypotenuse of the triangle matches the line (3). Hold the T-square firmly and slide the triangle in the direction of the arrow until the desired position of the parallel line is reached (4).

9. **Lines perpendicular** to each other may be drawn by using a triangle in combination with the T-square or another triangle as shown in the "movie" of Fig. 10. To draw a line perpendicular to a given line (1). Place a triangle against the T-square (2), and move them together until the hypotenuse of the triangle matches the line, as at (3). Turn the triangle about its right-angled corner as indicated at (4), until it is in the position shown at (5) when the perpendicular line can be drawn on the hypotenuse of the triangle.

10. **Drawing Arcs.**—Drawings are made up of straight lines and curved lines, the curved lines generally being circles or parts of circles. Circles larger than one and one-half or two inches

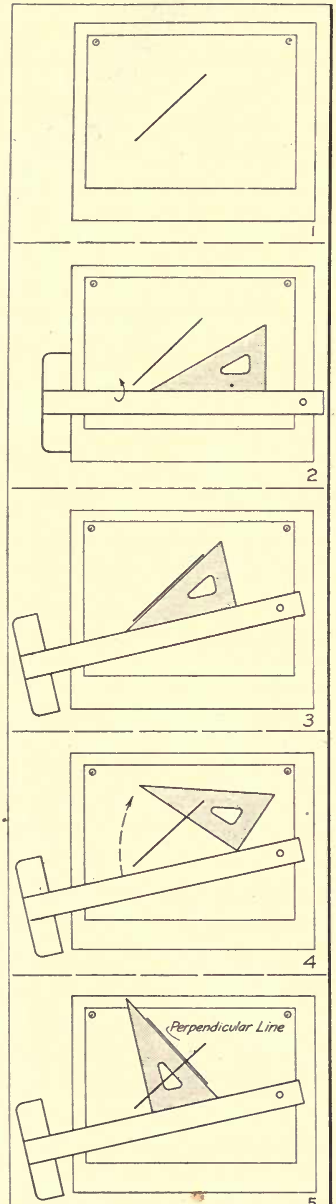


FIG. 10.—Drawing a perpendicular line.

in diameter are drawn with the large compasses. First adjust the needle point so that it is a very little longer than the pencil point, Fig. 11. Thecompasses, Fig. 12 are manipulated entirely with the right hand. They are opened by pinching between thumb and second finger (1), and set to proper radius by placing the needle point at the center and adjusting the pencil leg with first and second fingers (2). When the radius is set, raise the fingers to the handle (3), and revolve the compasses by twirling the handle between thumb and finger. Start the arc near the lower side and revolve clockwise (4), inclining the compasses in the direction of the line. Do not bore a hole at the center.

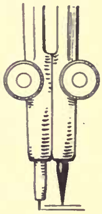


FIG. 11.

Small circles and arcs are drawn with the bow pencil. Adjust the lead and the needle, and set the radius as shown in Fig. 13. In changing the bow instruments from a small to large radius, hold the legs together with one hand and spin the nut with the other, in order to save wear on the threads, as shown at 3, Fig. 13. It is also necessary to release carefully, to prevent striking the nut and stripping the threads. Always be sure to relieve the springs of all the bow instruments when putting them away.

11. **Curves** not circle arcs are drawn with the irregular or "French" curve. These come in a number of different forms and are shifted to fit the required line. Figure 14 shows a line being drawn by finding different parts of the curve.

12. **Measuring.**—All measurements of lengths or distances on a drawing are made with the *scale.* Scales are made with different divisions for different purposes. For machine, structural, and architectural drawing the mechanical engineers' (or architects') scale of proportional feet and inches is used. For school purposes the triangular scale, Fig. 15, is much used, although the flat shapes are preferred by many draftsmen. The symbol (′) is generally used for feet

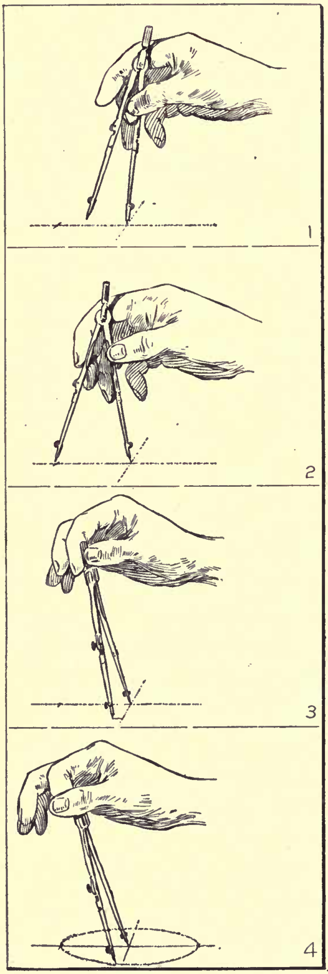


FIG. 12.—Using the compasses.

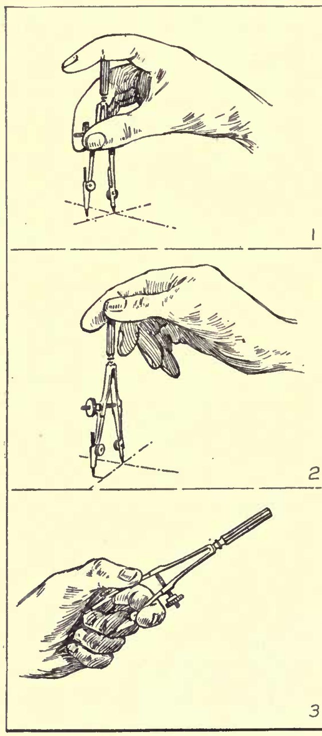


FIG. 13.—Using the bow pencil.

and (″) for inches. Thus three feet four and one-half inches is written 3′–4½″.

When the object is not too large for the paper, it is drawn in its full size, using the scale of inches and sixteenths. To lay off

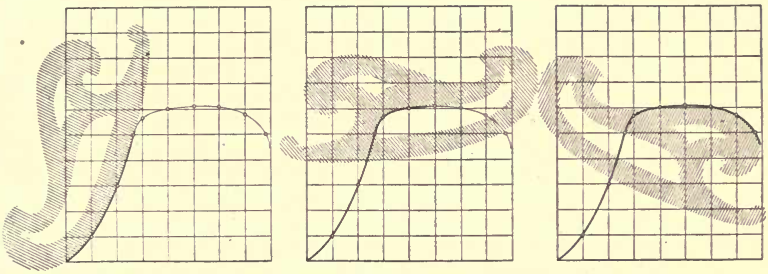


Fig. 14.—Use of the curve.

a full-size distance, put the scale down on the paper against the line to be measured. Make a short dash on the paper opposite the zero on the scale and another opposite the division represent-

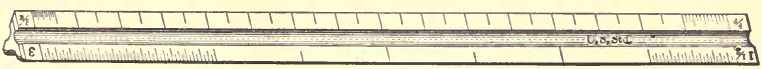


Fig. 15.—Mechanical engineers' (or architects') scale.

ing the desired distance, Fig. 16. Do not make a dot, or punch a hole in the paper.

13. If the object is too large to go on the paper in its full size, it is drawn in reduced proportion. The first reduction is to the scale of 6″ = 1′, commonly called "half-size." To measure a

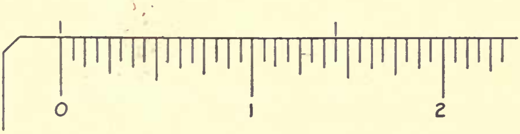


Fig. 16.—Marking a measurement.

distance at the scale of 6″ = 1′, use the full-size scale and consider each half-inch as representing an inch, each quarter inch as a half-inch, etc. Thus the 12″ scale will become a 24″ scale. Example: To lay off 3⅝″ start at the zero and count three ½ inches, and ⅝ of the next half inch, as shown in Fig. 17. Do not divide the size of the piece by two.

If the drawing cannot be made "half-size" the next scale is

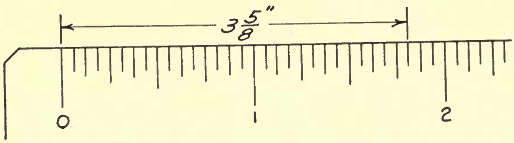


FIG. 17.—Measuring to "half-size."

3″ = 1′, often called "quarter size." Find this scale and examine it. The actual length of three inches becomes one foot, divided into 12 parts, each representing one inch, and these are

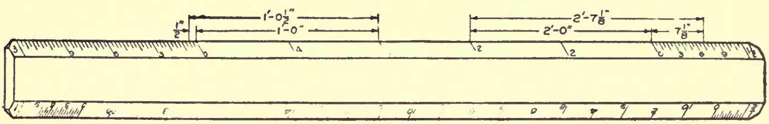


FIG. 18.—Reading the scale.

further divided into eighths. Learn to think of these as real *inches* in *reduced* scale. Example: To lay off the distance 1′–0½″, Fig. 18. Notice the position of the zero mark, placed so that

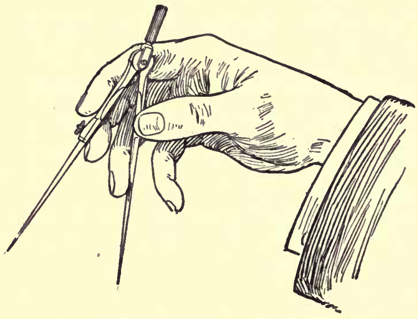


FIG. 19.—Holding the dividers.

inches are measured in one direction from it and feet in the other, as shown in the figure. Other scales found on a triangular scale are, 1½″ = 1′; 1″ = 1′; ¾″ = 1′; ½″ = 1′; ⅜″ = 1′; ¼″ = 1′; $\frac{3}{16}$″ = 1′; ⅛″ = 1′.

Take each of these scales in turn, and decide what is the longest distance that can be measured in one setting, and what is the smallest division. Measure 2′–5″ with each scale.

14. **Spacing.**—Dividing lines into spaces, and transferring distances is done with the dividers, or with the bow spacers. The dividers are held in the right hand and adjusted as shown in

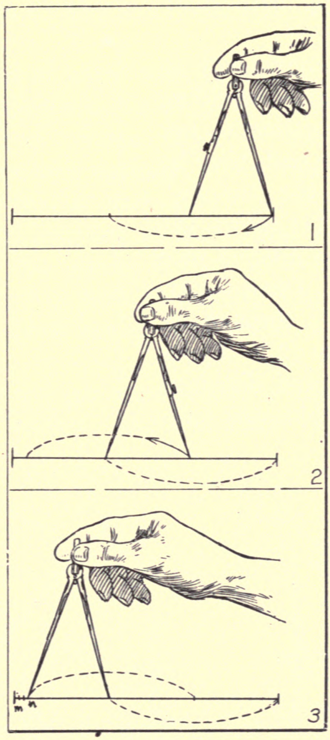


Fig. 20.—Using the dividers.

Fig. 19. The method of dividing a line into three equal parts is shown in the "movie" of Fig. 20. Adjusting the points of the dividers until they appear to be about one-third of the length of the line, place one point on one end of the line, and the other point on the line as shown at (1). Turn the dividers about the point which rests on the line as at (2), then in alternate direction as at (3). If the last point falls short of the end of the line, in-

crease the distance between the points of the dividers by an amount estimated to be ⅓ of *m–n* and start at the beginning of the line again. Several trials may be necessary. If the last point overruns the end of the line, decrease the distance between the points by ⅓ the extra distance. The bow spacers, Fig. 21, are used when working with small distances.

15. It is often convenient to use the scale as means of dividing a line. If the distance is not easily divisible, the scale may be used as shown in the "movie" of Fig. 22, where (1) shows the line which is to be divided into nine equal parts. Draw a perpendicular line *AC* through an end of the line as at (2). Apply the scale so that nine divisions of the scale (in this case half-

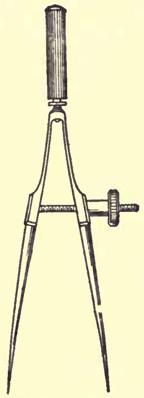


Fig. 21.

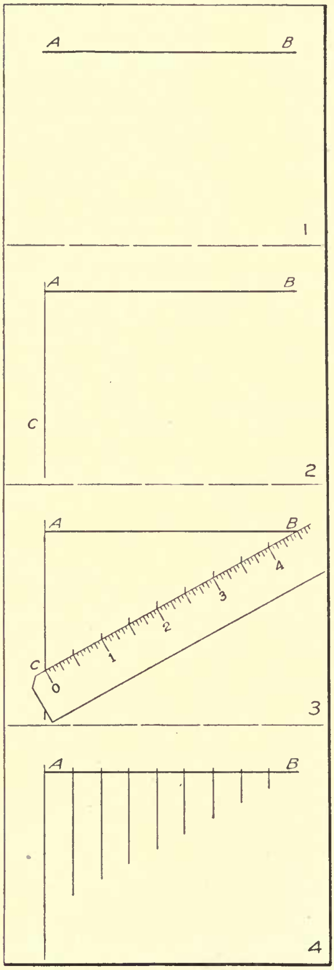


Fig. 22.—Dividing a line.

inches) are included between point *B* and line *AC* as shown at (3). Mark opposite each one-half inch and draw vertical lines, which will divide the given line into nine equal parts (4). The geometrical method upon which Fig. 22 is based is given in Art. 103.

LETTERING

16. **Lettering.**—The complete description of a machine or structure requires the use of the *graphical* language to describe shapes, and the *written* language to tell sizes, methods of making, kinds of materials, and other notes. The "written language" as used on drawings is always in the form of *lettering* and not script writing. Simple freehand lettering, perfectly legible and quickly made is an important part of modern engineering drawings.

The standard form of letter used on working drawings is the style known as single-stroke Gothic. There are two varieties, vertical, and inclined. Some concerns use vertical letters entirely, some use inclined entirely, others use vertical for titles and inclined for dimensions and notes. In the same way some schools adopt vertical lettering as the standard, and some adopt inclined lettering. The young draftsman accepting a position with a company must be able to use the standard of that company. In learning both styles it is better to take up vertical lettering first.

The ability to letter well and rapidly can be acquired only by persistent and careful practice. The forms and proportions of each

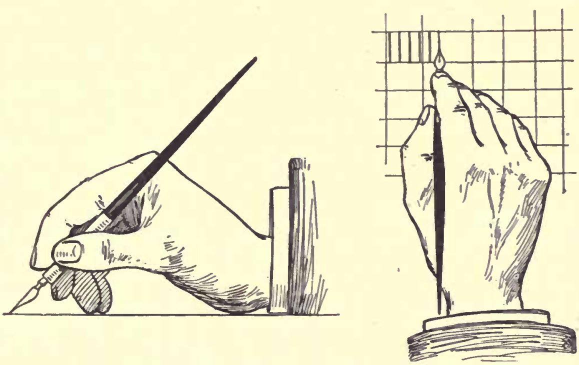


FIG. 23.—Position for lettering.

letter must be thoroughly mastered by study and practice, and the letters combined into uniform easily read words.

The term "single stroke" means that the width of the stem of the letter is the width of the stroke of the pen. Two satisfactory pens are Hunt's 512 for titles and large letters, and Gillott's 404 for ordinary dimensions and notes. The pen should be held in the position shown in Fig. 23, the strokes drawn with a steady even motion and a slight uniform pressure on the paper, not enough to spread the nibs of the pen. Lettering in pencil should be done lightly with a softer pencil than used for drawing.

Guide lines, ruled lightly with a sharp pencil should always be drawn for the tops and bottoms of each line of letters.

17. **Single-stroke Vertical Capitals.**—In Fig. 24 the vertical capitals are arranged in "family order," first the straight letters,

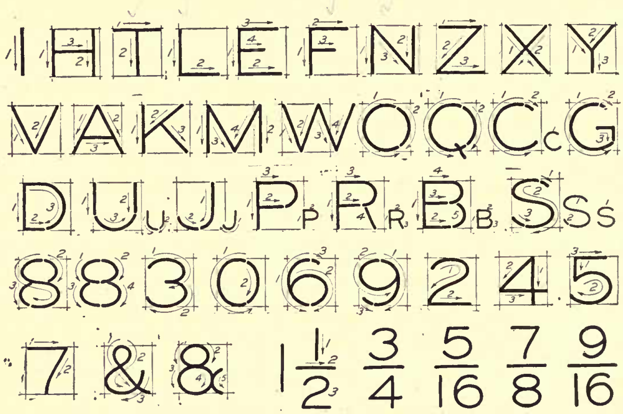


FIG. 24.—Single stroke vertical capitals.

then the slant line and curved letters. Each letter is shown in a square, so that the proportion of its width to height may be easily learned. In this style many of the letters just about fill the square. The arrows and figures give the order and direction

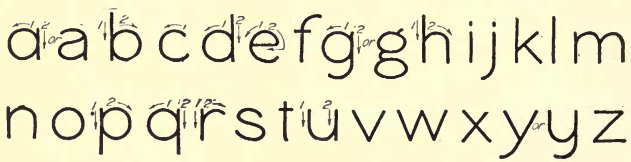


FIG. 25.—Single stroke vertical lower case.

of strokes, which must be learned for each letter. Vertical strokes are all made downward and horizontal strokes from left to right.

Special care and practice must be given to the numbers. Notice that the shapes of the figures are just as different from those used in ordinary figuring as the letters are from ordinary writing.

Particularly is this true of the 2, 4, 6, 8 and 9. Fractions are always made with a horizontal division line with figures two-thirds the height of the whole numbers and a clear space above and below the division line.

18. Single-stroke Vertical Lower Case.—Words lettered in lower case or "small" letters are easier to read than when made in capital letters. The single-stroke lower-case alphabet as used with the capitals of Fig. 24 is shown in Fig. 25. These letters are made with bodies two-thirds the height of the capitals, the ascenders (*b*, *d*, *f*, etc.) extending up to the cap line and the descenders (*g*, *p*, *q*, etc.) dropping the same distance below. They are based upon the combination of circle and straight line, Fig. 26. The "monogram" in the figure contains eighteen of the twenty-six letters.

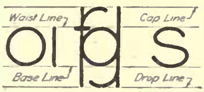


FIG. 26.

19. Single-stroke Inclined Caps.—In making inclined letters there are two things to watch, first, to keep a uniform slope, second, to get the rounded letters of the correct shape.

Slanting "direction lines" should be drawn either with a lettering triangle (of about 67½°) or by setting a slope of 2 to 5 by marking two units on a horizontal line and five on a vertical line, and using T-square and triangle as shown in Fig. 27. The form taken by the rounded letters when inclined is illustrated in Fig. 28, showing that the curves are sharp in the upper right-hand and lower left-hand corners and flattened in the other two corners.

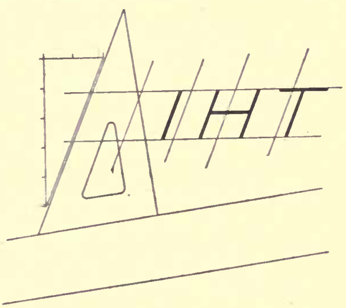


FIG. 27.

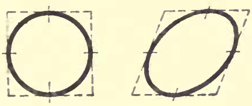


FIG. 28.

FIG. 29.

The letters *H*, *A*, *V* and *W* are shown enlarged in Fig. 29. Note particularly that the lines of *A*, *V* and *W* must make equal angles on each side of the sloping direction lines.

The alphabet and numerals are given in family order in Fig. 30.

20. Single-stroke Inclined Lower Case.—This letter, sometimes called the Reinhardt letter, is in general use for notes on drawings as it is very legible and effective and can be made very rapidly. The bodies are two-thirds the height of the capitals,

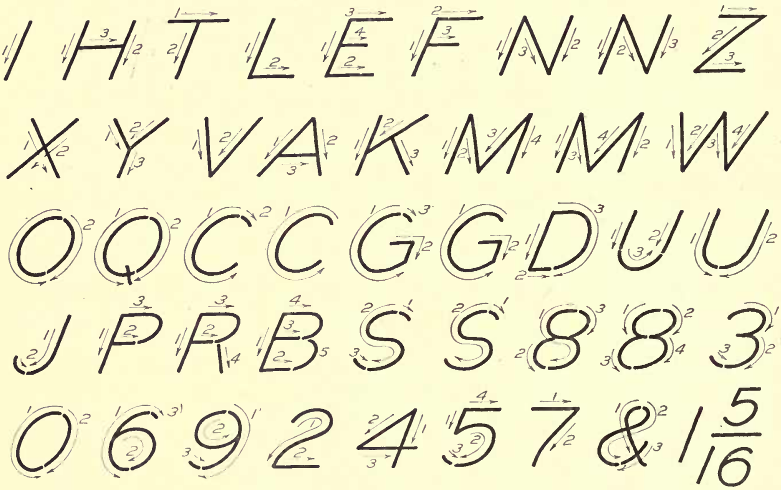


FIG. 30.—Single stroke inclined capitals.

with the ascenders extending to the cap line, and the descenders dropping the same distance below the base line.

For study, the letters may be divided into four groups:

Group I, *i j k l t v w x y z*
Group II, *a b d f g p q*
Group III, *h m n r u y*
Group IV, *c e o s*

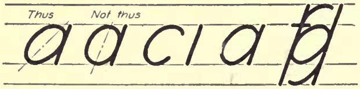


FIG. 31.

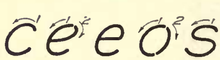


FIG. 32.

Group I contains the straight letters. Be particularly careful about the slant of the angle letters *v w x y* and *z*.

The letters of Group II are made up of a partial ellipse whose axis slants 45 degrees, and an inclined straight line, Fig. 31. The hook letters of Group III are made with a part of the same ellipse. The monogram of Fig. 31 illustrates this group also.

The letters of Group IV are made with the same ellipse as the capitals, Fig. 32.

The alphabet with order and direction of strokes is given in Fig. 33.

a b c d e f g h i j k l m

n o p q r s t u v w x y z

Fig. 33.—Single stroke inclined lower case.

21. **Composition.**—Composition in lettering means the selection of appropriate styles and sizes of letters, and their arrangement and spacing. After the shapes of the separate letters have

LETTERING COMPOSITION
involves the spacing of letters in words,
the spacing of words and lines, and the
choice of appropriate styles and sizes.

Fig. 34.—An example of spacing.

been mastered the entire practice should be on words and sentences. Letters in words are not spaced at equal distances along

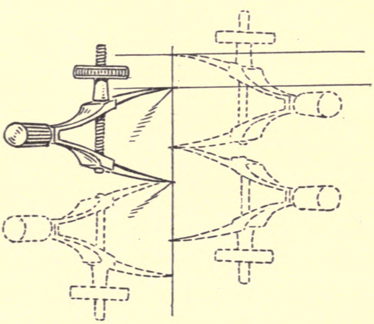


Fig. 35.—Spacing guide lines.

the guide lines, but so that the areas of white spaces between the letters are approximately equal, making them appear to be spaced uniformly. Figure 34 is an illustration of composition.

In spacing words the clear distance between them should be about equal to the height of the letters. The clear distance between lines varies from one-half to one and one-half times the height of the caps. Figure 35 illustrates a method of spacing guide lines for tops and bottoms when several lines of letters are to be

Fig. 36.—Single stroke Roman.

made. Mark the height of the letter on the first line, then set the dividers to the distance wanted between base lines and step off the required number of lines. With the same setting step down again from the upper point.

The composition of titles is referred to in Art. 68. An alphabet of single-stroke Roman letters for use in architectural drawing is given in Fig. 36.

CHAPTER III

Theory of Shape Description

22. There are two things which a designer, inventor or builder must be able to do; first, he must be able to *visualize,* or to see clearly in his mind's eye what an object looks like without actually having the object; second, he must be able to describe it so that it could be built. A few lines properly drawn on paper will describe an object more accurately and clearly than a picture or a written description. To describe the true shape of an object by means of lines, and to be able to read and understand such descriptions requires a thorough knowledge of the theory upon which this method is based.

23. **Describing Objects by Views.**—For the graphical description of an object we have available the paper, pencil and instruments explained in Chapter II. On the paper we can make measurements in a single plane only, while all objects have dimensions perpendicular to the paper as well as parallel to it. A picture can be made which would show just as a photograph would do, the general appearance of the object, but it would not show the *exact* forms and relations of the parts of the object. It would show it as it *appears* and not as it really is.

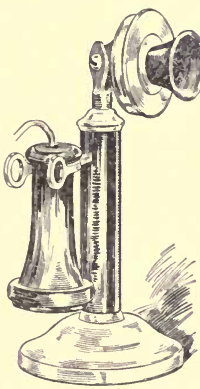


Fig. 37.

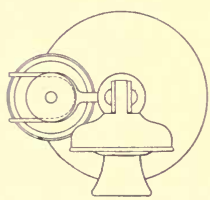


Fig. 38.—Top view.

Our problem then is to represent solid objects on a flat sheet of paper in such a manner as to tell the exact shape. This is done by drawing a system of "**views**" of the object as seen from different positions, and arranging these views in a definite manner.

A picture of a telephone, Fig. 37, shows the instrument as it ordinarily appears to us, but it does not show the true shapes of the parts. The base appears as an ellipse, although we know that it really is circular. If we look down at the instrument from directly above we obtain a *view* showing the exact shape of the base, and the outline of the other parts as seen from above. This is called a *top view* or *plan*, Fig. 38. This view does not tell us the height of the instrument, so it is necessary to take another view from a position directly in front or else from the left or right side. In this way either a *front view* or *side view* to show the

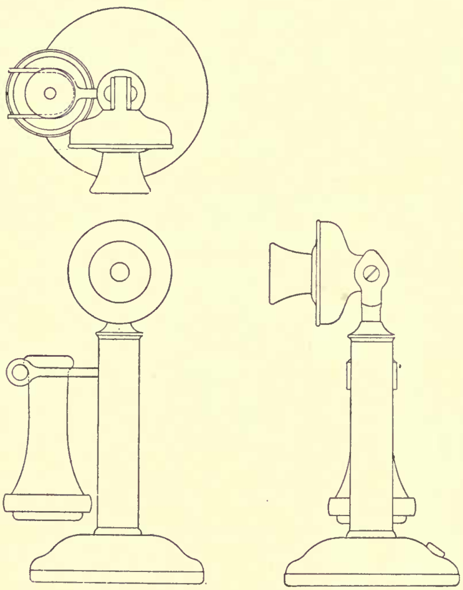


FIG. 39.—The three views.

height, is added, Fig. 39. Often, as in this case, both front view and side view in addition to top view are needed to describe the object.

Since the bottom of the base is level it will show as a straight line in the front and side views, as will the bottom of the receiver and all other horizontal circles. The front view shows the circular shape of the transmitter, while the side view shows the true shape of the connection between transmitter and post.

The three views taken together completely define the shapes of all the parts of the instrument and their exact relations to each other.

It is evident that the front and side views are exactly the same height. When drawn they are placed directly across from each other. The top view is placed directly above the front view, and the three views together appear as in Fig. 39.

Sometimes a left side view describes the object more clearly than the right side would do. Fig. 40 shows the top, front and left side views.

Notice in Figs. 39 and 40 that the mouthpiece is toward the front in the top views, and also toward the front view in both the right and left side views.

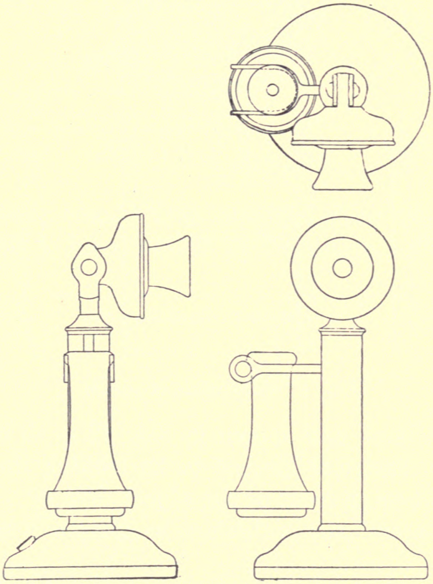


FIG. 40.—Top, front and left side views.

As a further explanation of the relation of the three views, study the drawing of the chair shown in Fig. 41. Notice that the magazine holder is at the right in the top and front views and therefore shows in the right side view. The front of the chair is toward the front view in the top and two side views.

24. **Theory of the Relation of Views.**—The principle of representing an object by different views, as just described, is called *Orthographic Projection*, and is the basis of all kinds of industrial drawing. The real theory of orthographic projection must be well understood before complicated or difficult drawings can be made or read.

The following definition has been given: "*Orthographic projection is the method of representing the exact form of an object in two or more views on planes generally at right angles to each other, by dropping perpendiculars from the object to the planes.*"

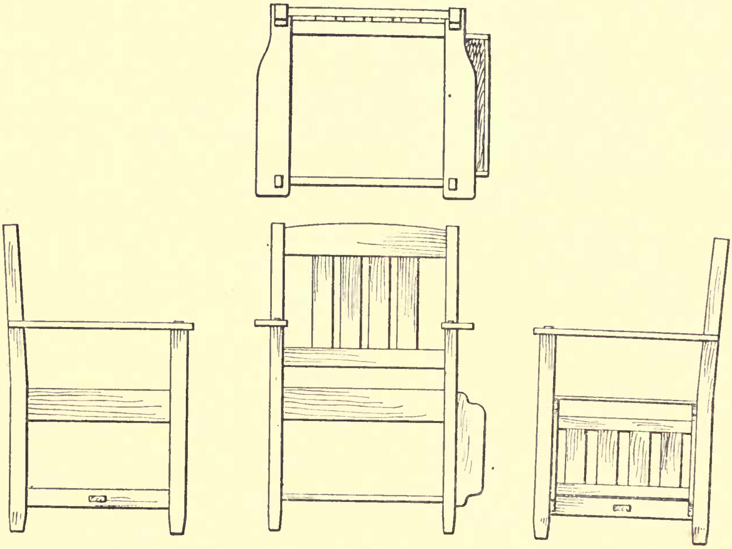


Fig. 41.—Relation of views.

Suppose the book end shown in Fig. 42 is to be represented. The draftsman imagines himself to be looking through a transparent plane set up in front of the object, Fig. 43. If from every point of the object perpendiculars be imagined as extended or

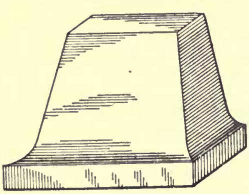


Fig. 42.

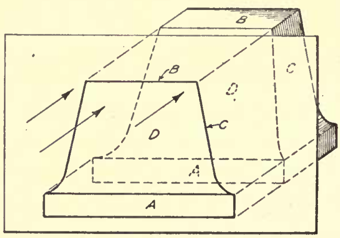


Fig. 43.—The vertical plane.

projected to the plane, the result on the front of the plane would be the *projection* on the plane, called the *vertical projection*, or *front view*, or in architectural drawing the *front elevation;* and would show the true height and length of the object.

Suppose now that a horizontal plane is hinged at right angles to the first plane, the observer looking through it at the top of the object. Perpendiculars from the object to this plane will give the *horizontal projection*, or *top view*, or as called in architec-

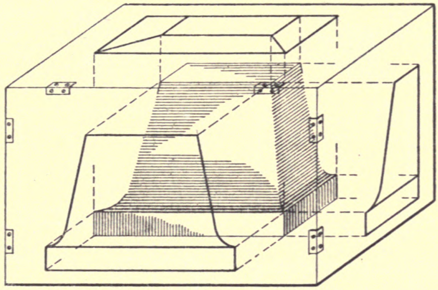


FIG. 44.—The glass box.

tural drawing, the *plan*. This view will show the width of the object from front to back, as well as the length already shown on

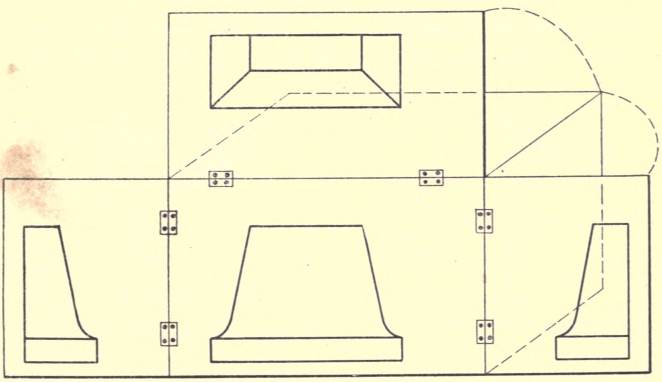


FIG. 45.—The box opened.

the front view. These two planes represent the drawing paper, and if the horizontal plane be imagined as swung up on the hinges until it lies in the extension of the front plane, the two views will be shown in their correct relationship as they would be drawn on the paper, and together give the length, breadth and height. This explains the reason for the statement made in the preceding section, that the top view is always drawn directly over the front view.

The *side view* or *side elevation* is imagined as made on a plane perpendicular to both top and front planes. Thus the object may be thought of as being inside of a glass box, or show case, as in Fig. 44. The projections on the sides of this box would be

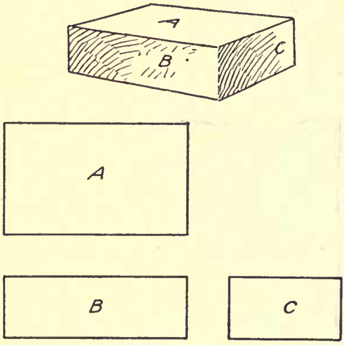


Fig. 46.

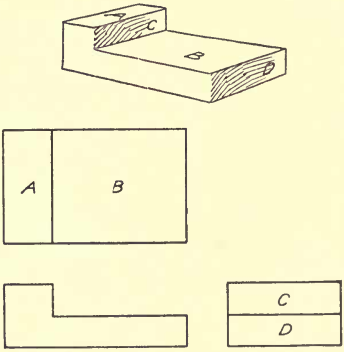


Fig. 47.

the *views* which we have discussed, and when these sides are opened up into one plane, the views take their relative positions as on the paper, with the top view directly over the front view and the side views directly across from the front view, Fig. 45.

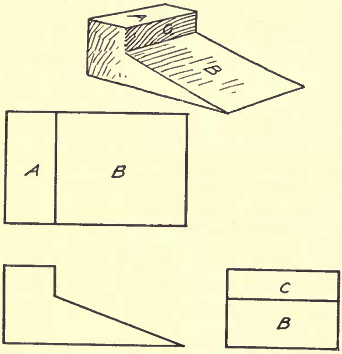


Fig. 48.

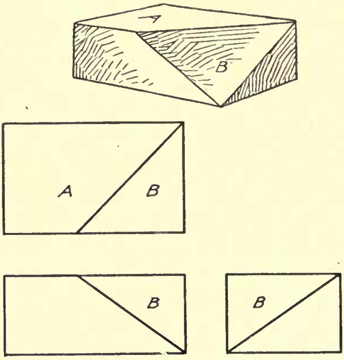


Fig. 49.

25. From a study of these projections the following principles will be noted:

1. A face parallel to a plane of projection is shown in its true size, as *A* on the front view, Fig. 43.
2. A face perpendicular to a plane of projection is projected as a line; as *B* and *C*, Fig. 43.

3. A surface inclined to a plane of projection shows foreshortened, as *B*, Fig. 48.

Similarly—

4. A line parallel to a plane of projection will show in its true length.

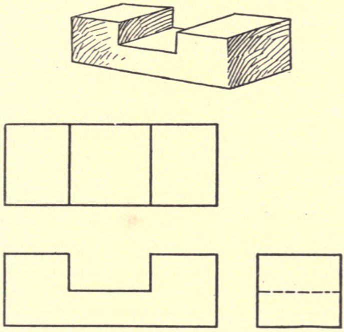


FIG. 50.

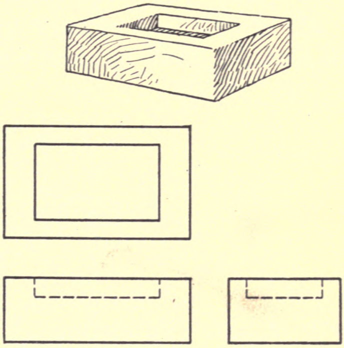


FIG. 51.

5. A line perpendicular to a plane of projection will be projected as a point.
6. An inclined line will have a projection shorter than its true length.

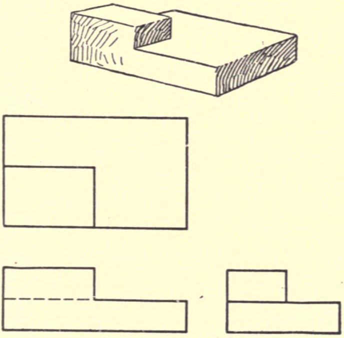


FIG. 52.

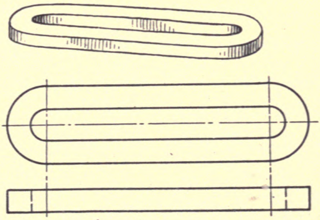


FIG. 53.

26. As a further explanation of how the theory of projection is applied, study the drawings of the objects in the following figures. In Fig. 46 each view represents a single surface. In Fig. 47 the top view shows two surfaces *A* and *B* at different levels, and as shown by the front view, surface *A* is above surface *B*. In the side view the surfaces *C* and *D* are shown. In Fig. 48 the surface *B* is inclined and shows slightly foreshortened in

the top view and very much foreshortened in the side view. To obtain the true size of the surface *B*, its length must be taken from the front view and its width from the top or side view. A surface which is inclined in three ways is illustrated in Fig. 49 where the corner of the block has been cut away.

27. Since it is necessary to describe every part of an object, all surfaces must be represented whether they can actually be

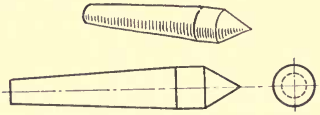


Fig. 54.

seen or not. To distinguish surfaces which cannot be seen in the views, they are represented by dotted lines as in Figs. 50, 51 and 52. Notice that a dotted line touches the line from which it starts, that dots touch at corners, but that if a dotted line is the continuation of a full line, a space is left between the full line and the first dot of the dotted line.

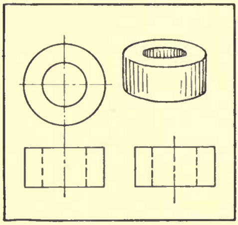


Fig. 55.

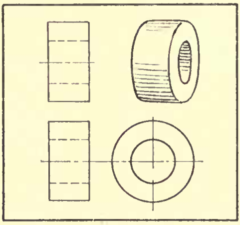


Fig. 56.

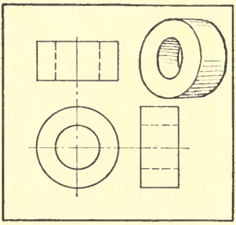


Fig. 57.

28. The fact that curved surfaces do not show as curves in all views is illustrated in Figs. 53 and 54. A cylinder appears as a circle in one view and as a rectangle in the others, as in Figs. 55, 56 and 57, which show three views of a cylinder when placed in different positions.

Figure 58 shows a bearing made up of flat and curved surfaces and requiring visible and invisible lines. Note that surface *A* of the side view is shown by a full line *a-a* in the front view and by a dotted line *a-a′* in the top view.

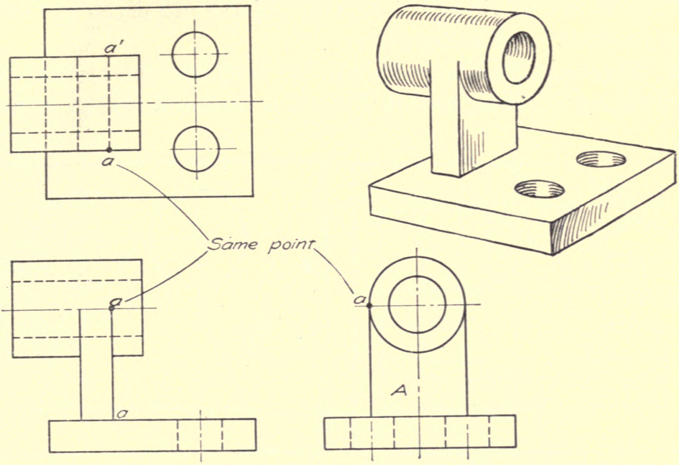


FIG. 58.—A bearing.

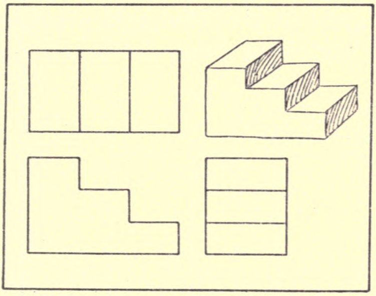


FIG. 59.

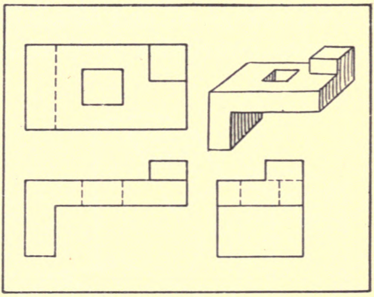


FIG. 60.

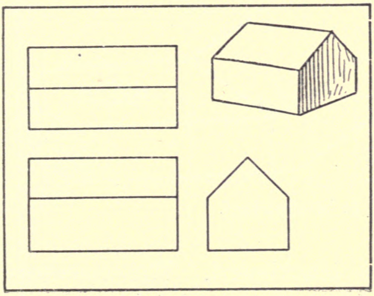


FIG. 61.

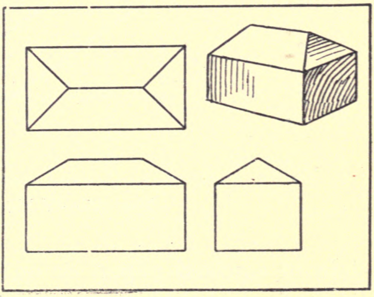


FIG. 62.

Pictures and drawings of several objects are given in Figs. 59 to 64 for study and comparison.

29. **Freehand Studies.**—In Fig. 65 is shown the picture of an overhanging *V* block, and in Fig. 66 a freehand sketch in pencil

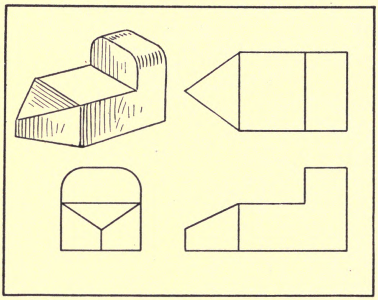


FIG. 63.

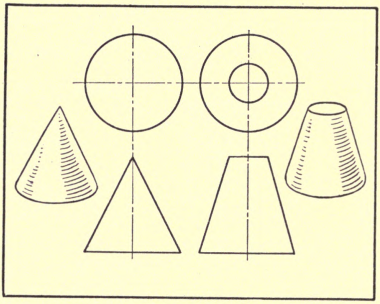


FIG. 64.

of the views required for describing its shape. The objects shown in Figs. 67 and 68 are designed to give the pupil practice in shape description by freehand sketching either in pencil on

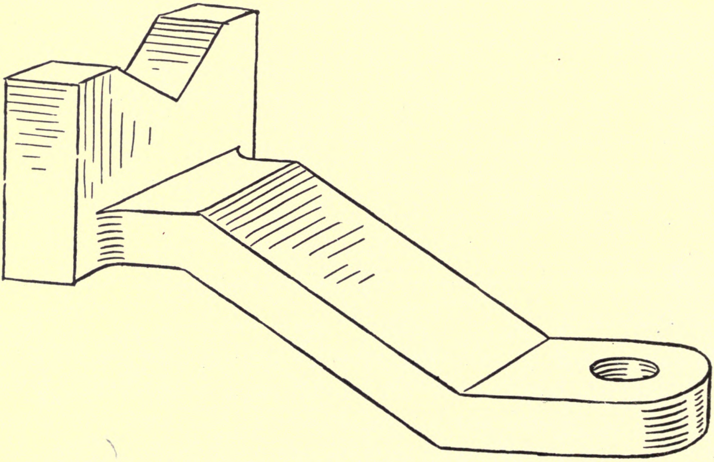


FIG. 65.—V block, to be sketched.

plain or squared paper, or on the blackboard. The necessary views of selected objects are to be blocked in and brightened as in Fig. 66. The pictures are not to be copied.

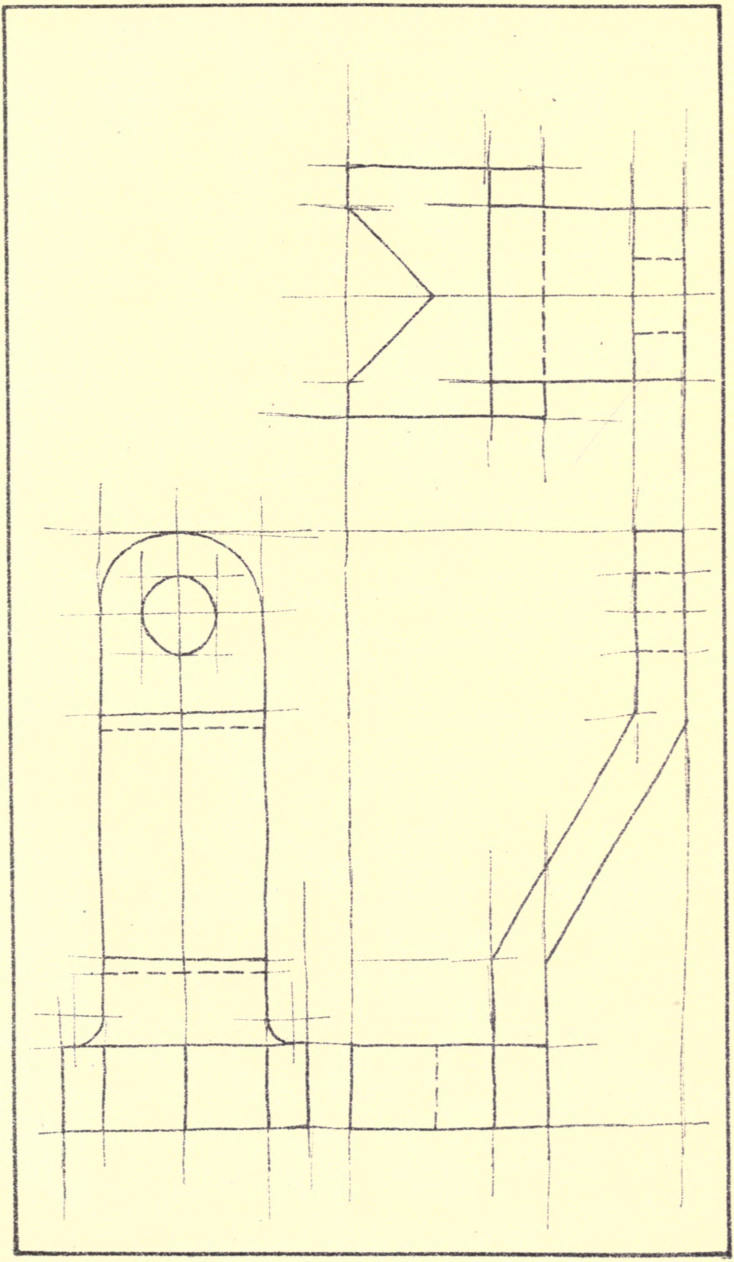


FIG. 66.—A freehand sketch.

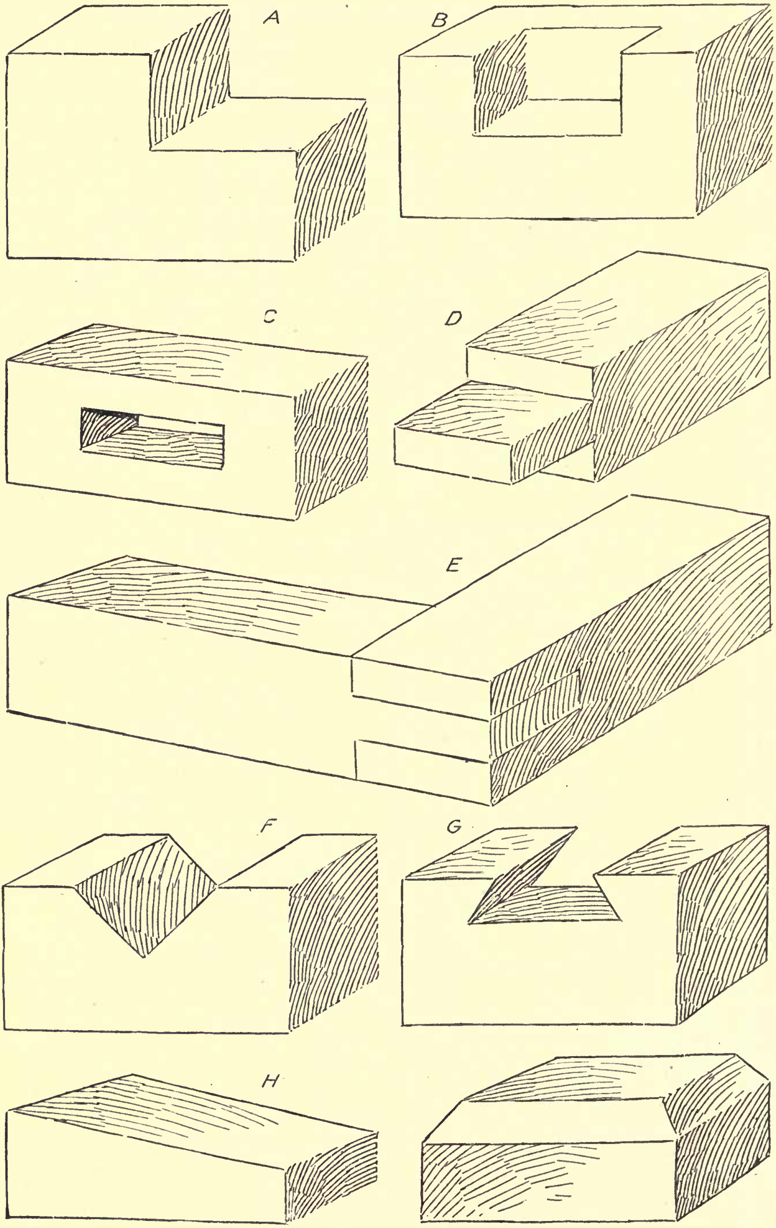


FIG. 67.—Problems for freehand sketching.

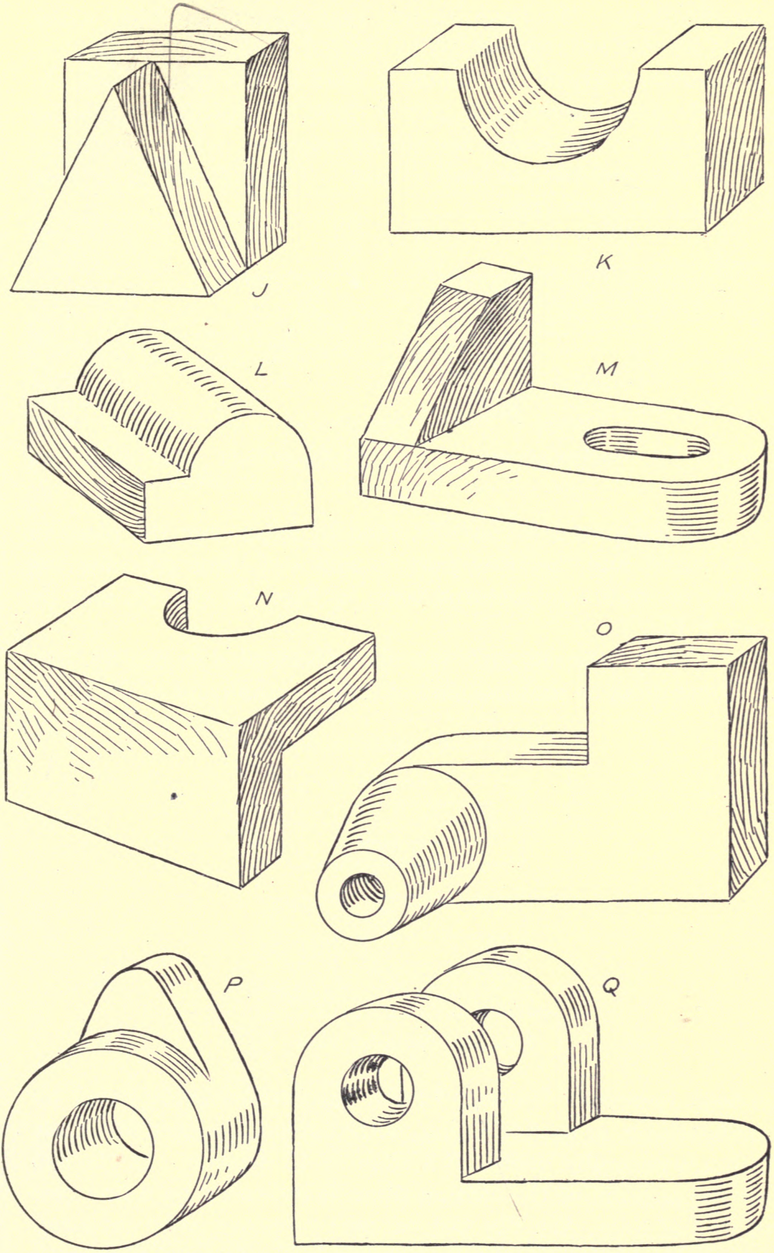


FIG. 68.—Problems for freehand sketching.

30. Sections.—We have learned that parts of an object which cannot be seen are represented by dotted lines, and this method is satisfactory where the object is solid or the interior simple. There are many cases, especially if there is considerable interior detail, or if several pieces are shown together, when the dotted lines become confusing or hard to read. This difficulty is avoided by using a *sectional view.*

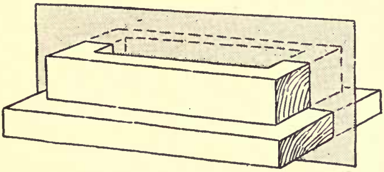


FIG. 69.—Cutting plane.

FIG. 70.—Object after front half removed.

A sectional view is a view obtained by supposing the piece to be cut apart and the front portion removed, thus exposing the interior, as shown in pictorial form in Figs. 69 and 70, and by views in Fig. 71.

The plane of the cut surface is shown extended in Fig. 69. In Fig. 70 we imagine that the part of the object in front of the plane

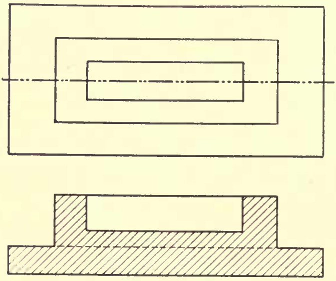


FIG. 71.—Sectional view.

has been removed. In Fig. 71 the cut surface is indicated by cross-hatching, or section lining, with uniformly spaced fine lines, which are generally drawn at a slope of 45 degrees. In the top view the position of the cutting plane is indicated by a line (see alphabet of lines, Art. 62) but the part supposed to be cut away is not left out. Study each piece shown in Fig. 72 until the reason for every line is clear.

The cutting plane need not be continuous but may be taken so as to show any desired details of the interior.

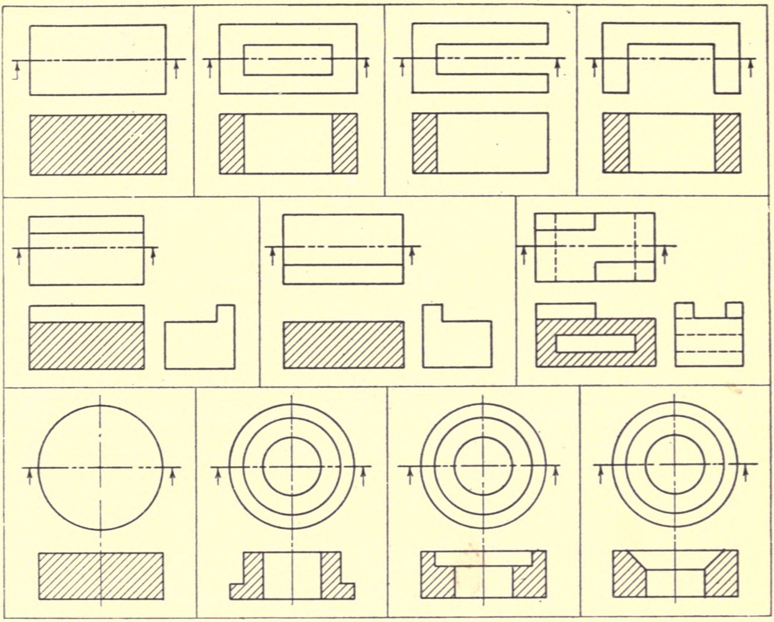


FIG. 72.—Sections for study.

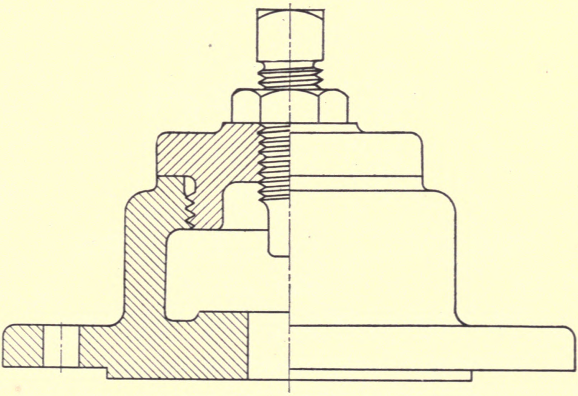


FIG. 73.—A half section.

A full section is the view obtained when the cutting plane extends clear through the object, whether continuous or not, Fig. 71.

A half section is a view obtained when the cutting plane extends only halfway through the piece, that is when one quarter of the piece is imagined to have been removed, Fig. 73. This method is used to advantage when a machine or construction is symmetrical, as it shows both the interior and the exterior. The dotted lines are generally left out on both sides of the center line.

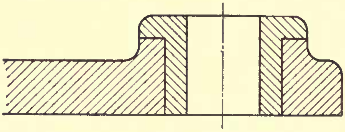


FIG. 74.

For simple pieces all lines beyond the plane of the section, both full and dotted are drawn.

Any piece must have the section lines in the same direction on all parts of its cut surface. When two pieces are shown together they are sectioned in different directions, Fig. 74.

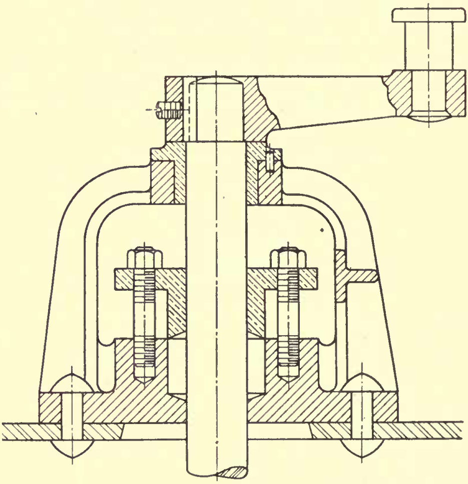


FIG. 75.—Bolts, shafts, etc., on sectional views.

It is not necessary to cut through all the parts of a machine. Such parts as bolts, nuts, screws, keys, shafts, etc., are not sectioned, Fig. 75.

Different materials are sometimes indicated by varying the kinds of section lines and the spacing between them. A system for this purpose is shown in Fig. 159, page 81. As there are other standards such symbols should not be depended upon alone as a means of specifying the material. Always use a note for this purpose.

The spacing of section lines should be such as will give the effect of an even tint. For most purposes the distance between lines is about 1/16 inch, spaced entirely by eye. Uneven spacing

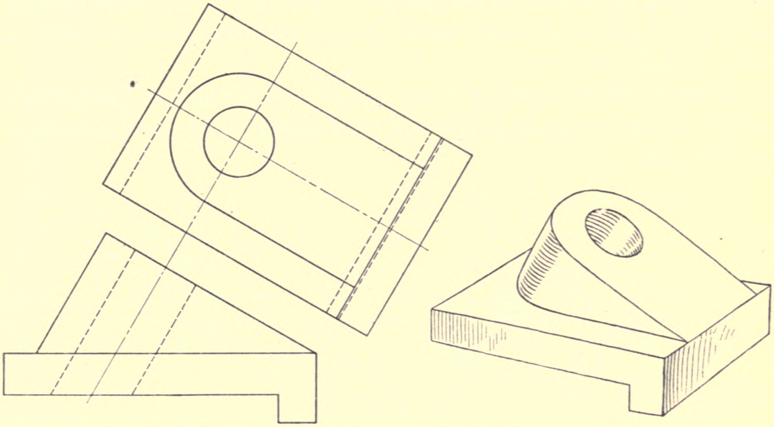


FIG. 76.—An auxiliary view.

will ruin the appearance of a drawing and make it harder to read. Very small pieces require somewhat closer spacing than large ones.

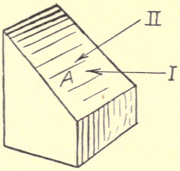


FIG. 77.

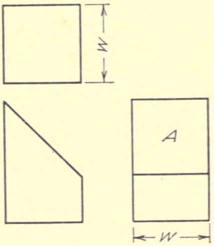


FIG. 78.

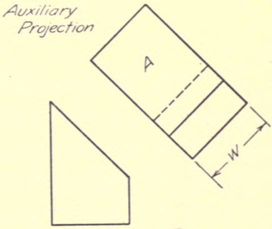


FIG. 79.

31. **Auxiliary Views.**—We have found, Art. 26, Fig. 48, that slanting surfaces are foreshortened when represented in the usual views. It is sometimes necessary or desirable to show a slanting surface in its true shape, especially when it has an irregular outline. Such a view can be drawn by looking directly at the slanting surface. When this is done all the regular views do not have to be drawn, Fig. 76.

The object shown in Fig. 77 would ordinarily be drawn as in Fig. 78, obtaining the side view by looking in the direction of arrow I. The face *A*, does not show in its true size in Fig. 78. However, if we look in the direction of arrow II perpendicular to face *A* the object would be drawn as in Fig. 79, and instead of the usual side view we would have an *auxiliary view* placed as shown, and giving the true size and shape of face *A*. The auxiliary view of Fig. 77 has thus been made on an auxiliary plane parallel to face *A*, Fig. 79.

When making working drawings for practical use, the whole object is not generally projected, part views being used instead as in Fig. 80.

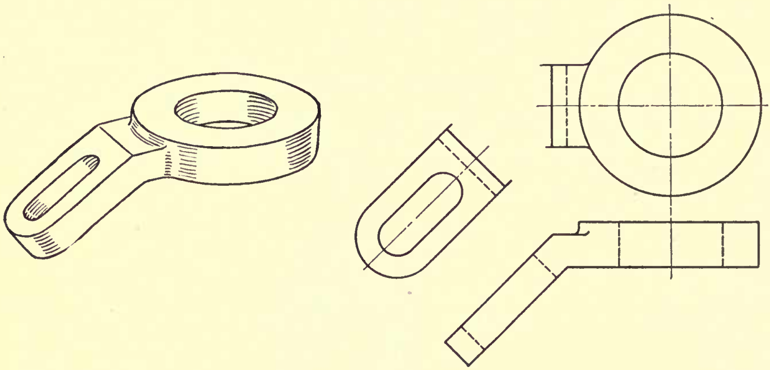


Fig. 80.—An auxiliary part view.

32. The usual method of drawing an auxiliary view is by making use of a center line. To obtain an auxiliary view of the cut surface of the hexagonal prism, Fig. 81, draw a horizontal center line in the top view and another center line parallel to the cut face at any convenient distance from it. Draw projecting lines perpendicular to the cut face from each point. On each of these lines locate points by measuring on each side of the auxiliary center line, distances obtained from the top view. Distances *a* and *b* are toward the front of the object as shown in the top view and therefore are measured toward the front in the auxiliary view. In Fig. 82 the entire object has been projected to the auxiliary plane, using the method just described.

The auxiliary view of the cut surface of a cylinder is shown in Fig. 83. In this case the vertical center line of the end view corresponds with the inclined center line. Select a convenient number of points on the front view of the inclined surface and draw perpendiculars from them to the parallel center line. Locate the points in the end view by projecting from the front

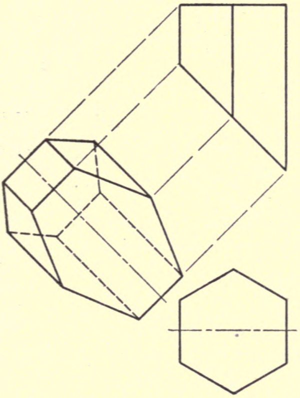


FIG. 81.

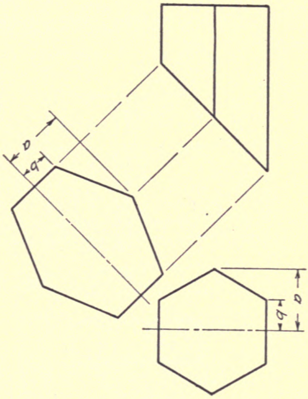


FIG. 82.

view, thus obtaining the distances to measure toward the front or back from the inclined center line.

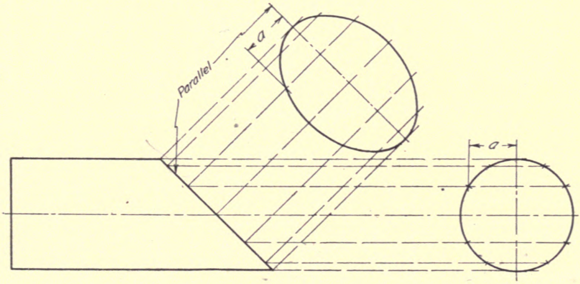


FIG. 83.

Similar methods are used for obtaining the auxiliary projections of cones, pyramids and other objects.

33. **Revolutions.**—It is generally possible to place an object in a simple position so that most of its lines show in their true length or can be easily located on the planes of projection. Ordinarily, drawings are made in this way. However, it is, of course, possible to represent an object tipped about one of its edges or resting on one of its corners. To obtain the views of an object

in such an unnatural position draw it first in its natural position, then revolve to the new position about one or more imaginary axes taken perpendicular to the planes of projection.

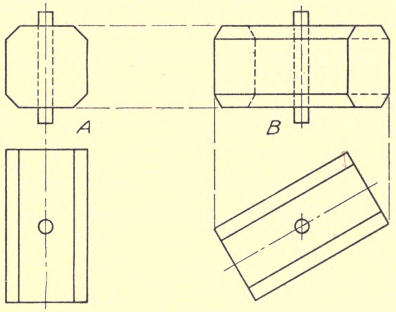


FIG. 84.—Revolutions.

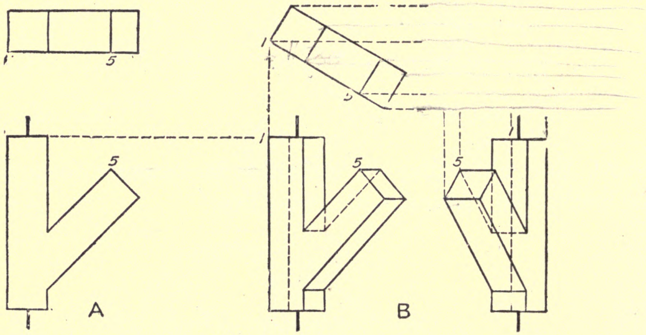


FIG. 85.

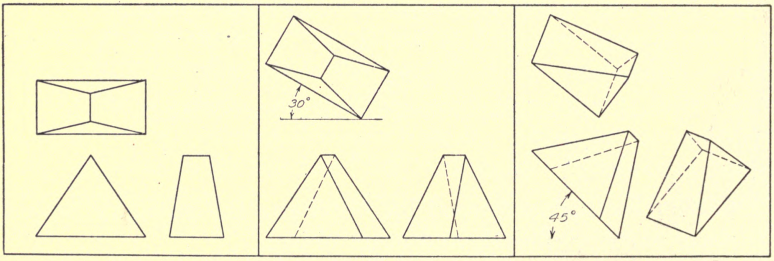


FIG. 86.—Double revolution.

At *A* in Fig. 84 we have two views of an object in a natural position. Suppose a hole is drilled through from the front and a shaft inserted as shown. The object might be revolved about the shaft or *axis* into a new position as at *B*. It will be observed

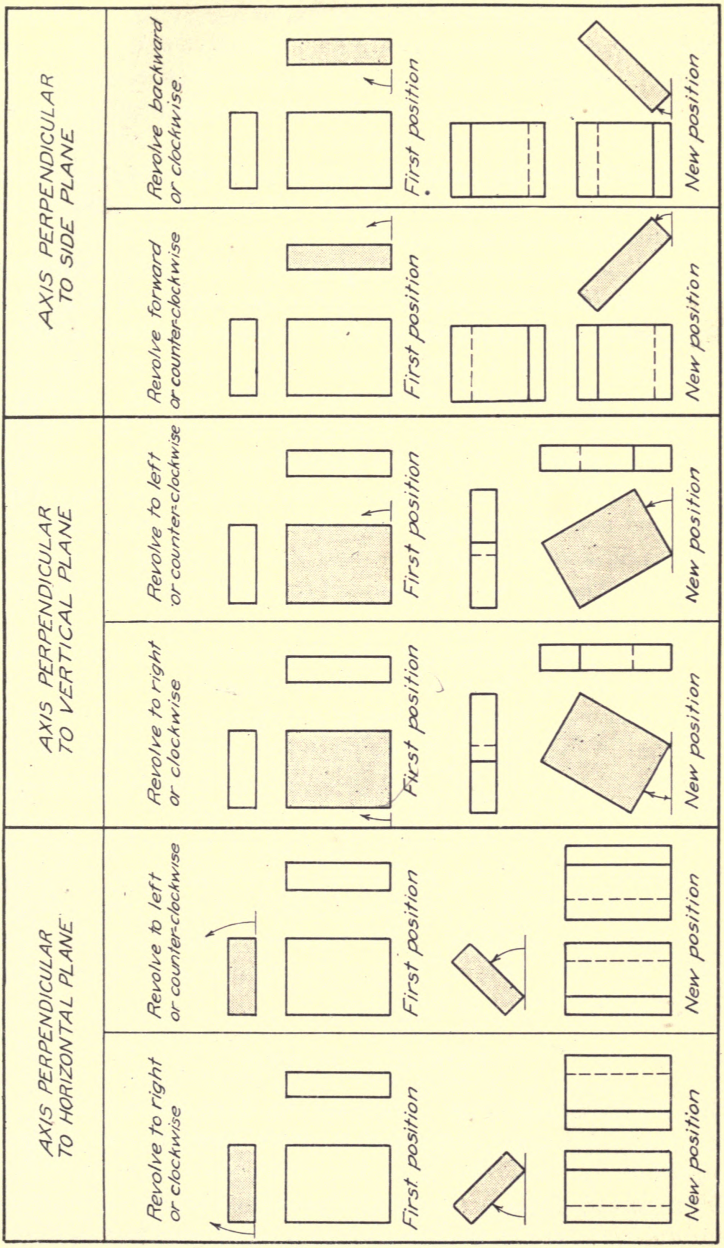


FIG. 87.—A revolution chart.

that the front view of *B* is the same as the front view of *A* except that its position has been changed. The top view of *B* is obtained by projecting up from the new front view, and across from the top view of *A*. The rule of revolution may now be stated:

First.—*The view perpendicular to the axis of revolution is unchanged except in position.* Second.—*Distances parallel to the axis of revolution are unchanged.*

In Fig. 85 the method of drawing an object when revolved about a vertical axis is shown. Given the two views as at *A*, it is required to draw three views after the piece has been revolved through 30° about a vertical axis. First draw the top view in its new position, *B*. Since the axis is vertical, the height has not been changed, so a horizontal projecting line may be drawn from point 1, of *A* and a vertical projecting line from the top view of *B*. The intersection of the two lines just drawn will locate the position of point 1 in the new front view. Proceed in the same way for each point and join the points to complete the view. The side view is obtained from the front and top views in the usual manner.

After an object has been revolved about an axis perpendicular to a plane it may be revolved about an axis perpendicular to another plane. This is double or successive revolution and is illustrated in Fig. 86, where the piece has been revolved about a vertical axis through 30°, and from this position about an axis perpendicular to the vertical plane through 45°.

An object may be revolved to the right or to the left about an axis perpendicular to the horizontal or vertical plane, or it may be revolved forward or backward about an axis perpendicular to the profile or side plane. The various positions are illustrated in Fig. 87. The view which is unchanged in size and shape is shown slightly tinted in each case.

Pictorial Drawing

34. **Pictorial Drawing.**—Thus far we have studied shape description by the exact method of separate views, or orthographic projection. In addition to a knowledge of this method it is very necessary for a draftsman to be able on occasion to make a pictorial view, either freehand or with instruments.

By those familiar with the subject, sketches are often made in *perspective*, showing the object as it would actually appear to the eye. An easier way, although the result is not so pleasing in appearance as a well-made perspective, is to use one of the pictorial methods of projection, of which the commonest are *isometric drawing*, *oblique drawing*, and *cabinet drawing*. These all show three faces in one view and have the advantage that the principal lines can be measured directly. While similar in effect, these three methods must not be confused.

35. **Isometric Drawing.**—This simple method is based on revolution, Fig. 88. If a cube be imagined as tilted up on one corner to such an angle that its front view shows three faces equal in shape and size it is said to be in *isometric*[1] *projection.*

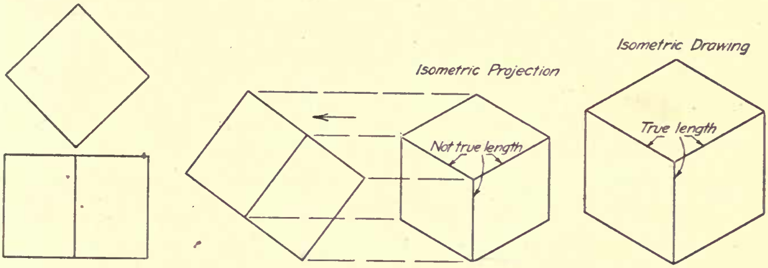


FIG. 88.—The isometric cube.

In this position the edges would evidently not show in their true length. An *isometric drawing* of the same cube is the same shape but a little larger in size as the edges are drawn in their true length instead of in the foreshortened length.

Isometric drawings are thus built on a skeleton of three lines representing the three edges of the cube. These three lines form three equal angles of 120° and are called the isometric axes. One is drawn vertically, the others with the 30° triangle as shown in Fig. 89. The intersection of these lines would be the front corner of a block with square corners. Measuring the length, breadth and thickness of the block on the three axes, and drawing through these points lines parallel to the axes will give the isometric drawing of the block. It is often better to start with the axes in the "second position," representing the lower corner as in Fig. 90.

Any line on the object parallel to one of these edges is drawn parallel to it and is called an *isometric line*. The first rule of

[1] Isometric—equal measure.

isometric drawing is: *Measurements can be made only on isometric lines.* The second rule is: *Remember the isometric cube.*

36. **Non-isometric Lines.**—Lines not parallel to one of the isometric axes are called non-isometric lines. Such lines will not show in their true length and cannot be measured, but must be drawn by locating their two ends.

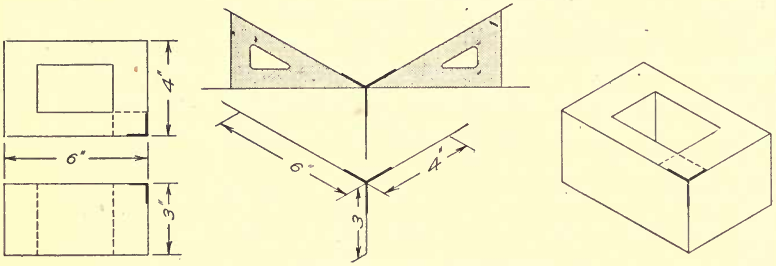


FIG. 89.—Isometric axes. First position.

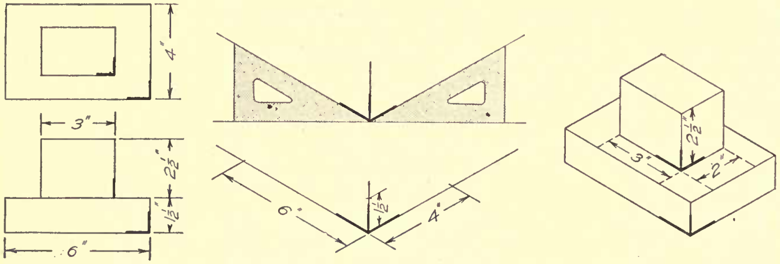


FIG. 90.—Isometric axes. Second position.

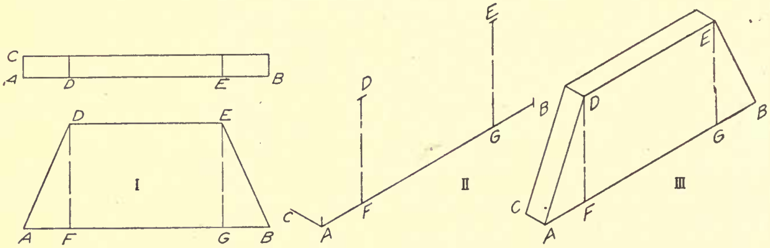


FIG. 91.—Construction for non-isometric lines.

37. **Angles** between lines on isometric drawings do not show in their true size, and cannot be measured in degrees. All the angles of a cube are right angles but in the isometric drawing some would measure 120° and some 60°. In drawing angles other than 90°, the lines forming them must be transferred from the orthographic views as shown in Fig. 91. To make an iso-

metric drawing of the packing block shown at I, first drop perpendiculars on the front view from the points D and E, giving the construction lines DF and EG. Then draw the two isometric axes, AB and AC as at II, and measure the distances AF and BG. Draw vertical lines at F and G equal to the corresponding lines in the front view. The non-isometric lines AD and BE can then be drawn and the angles at A and B will be represented correctly. Finish the figure as at III.

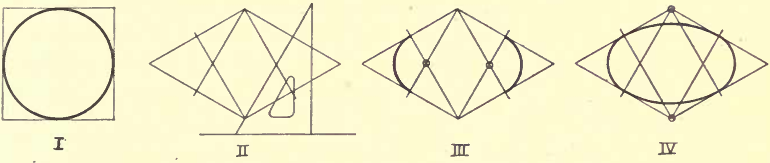


FIG. 92.—Construction of isometric circle.

38. **Circles** will appear as ellipses in isometric drawing, but instead of drawing a true ellipse a four-centered approximation is usually made. To draw an isometric circle, first make the isometric drawing of the square which will contain it, Fig. 92. From the points of tangency draw perpendiculars. Their inter-

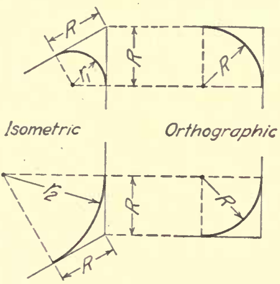


FIG. 93.—Isometric arcs.

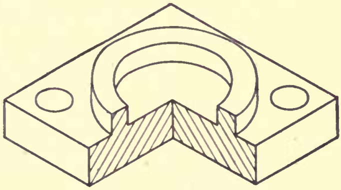


FIG. 94.—Isometric half-section.

sections will give four centers for arcs tangent to the sides of the square. Two of these centers will fall at the corners of the square, as shown at II. Thus the entire construction may be made with the 60° triangle. The construction for quarter rounds is the same, as shown in Fig. 93, where the radius is measured from the corner and actual perpendiculars of 90° drawn to find the required center.

39. **Sections.**—Isometric drawings are generally made as outside views, but sometimes a sectional view is needed. The section is taken on an "isometric plane," that is, on a plane parallel

to one of the faces of the cube. Figure 94 shows a half section and Fig. 95 a full section of the same piece.

40. **Making an Isometric Drawing.**—Problem: Make an isometric drawing of the guide, Fig. 96. First, draw the axes *AB*, *AC* and *AD*, in second position, Fig. 97.

Measure from *A*, the length 3″ on *AB*
Measure from *A*, the width 2″ on *AC*
Measure from *A*, the thickness ⅝″ on *AD*

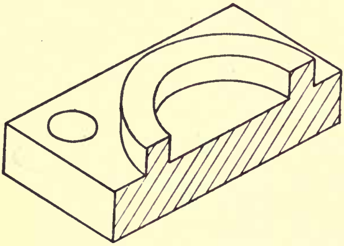


FIG. 95.—Isometric section.

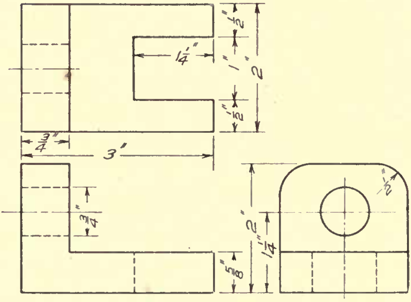


FIG. 96.—Problem for isometric drawing.

Through these points draw isometric lines, blocking in the base. Second, block in the upright, making two measurements only, 2″ and ¾″. Third, locate center of hole, and draw its center lines as shown. Block in a ¾″ isometric square and draw the hole

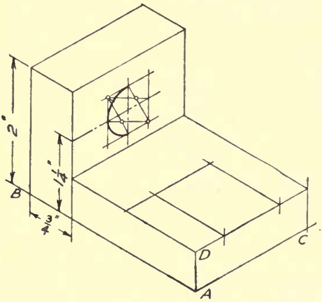


FIG. 97.—First stage.

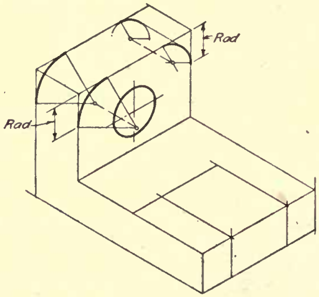


FIG. 98.—Second stage.

as an approximate ellipse by Art. 38. At the upper corners measure the one-half inch radius on each line, Fig. 98, and draw real perpendiculars to find the centers of the quarter circles. Fourth, finish the drawing as in Fig. 99.

41. **Making a Freehand Isometric Drawing.**—Freehand isometric sketches are of great help in reading orthographic views

and in explaining objects or parts of construction. The principles of isometric drawing form the basis of isometric sketching, but since sketches are not made to scale, their appearance is improved by flattening, that is, giving the axes an angle less than 30° with the horizontal, and by slightly converging the lines, as well as foreshortening the lengths, thus avoiding the distortion and giving the effect of perspective. This is sometimes called "fake perspective."

Always block in construction squares before sketching circles or arcs, and remember that the long axes of ellipses representing circles on the top face are horizontal.

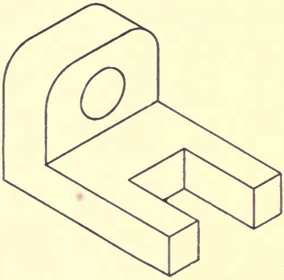


FIG. 99.—Completed drawing.

42. **Oblique Drawing.**—This form of pictorial drawing is based upon the theoretical principle that the object is placed parallel to the plane of projection and projected to it by oblique projecting lines instead of perpendicular ones. Practically it is drawn on three axes, just as isometric, but two of the axes always make right angles with each other, that is, one axis is drawn vertically, one horizontally and the third at any convenient angle, Fig. 100.

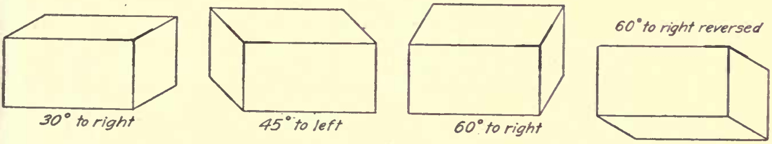


FIG. 100.—Axes in oblique drawing.

The same methods and rules as used in isometric apply to oblique, but compared with isometric it has the distinct advantage of showing one face without distortion. Thus objects with irregular outlines can be drawn by this method much more easily and effectively than in isometric, and many draftsmen prefer it for practically all pictorial work.

The first rule in oblique drawing is: *Place the object so that the irregular outline or contour faces the front.*

If there is no irregular outline the second rule should be followed: *Always place the object so that the longest dimension shows in the front.*

43. **Circles.**—On the front face circles and curves show in their true shape. On the other faces they are drawn as in isometric, by drawing perpendicular lines from the tangent points.

44. **Making an Oblique Drawing.**—Problem: Make an oblique drawing of the bearing, Fig. 101. First, draw the axes for the

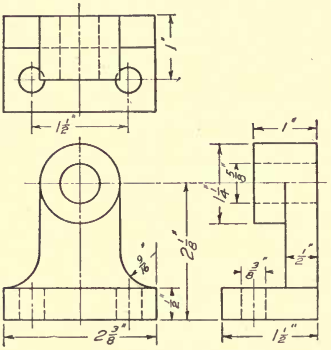


FIG. 101.—Problem for oblique drawing.

base, *AB*, *AC*, and *AD*, in second position, and measure on them the length, width and thickness of the base, Fig. 102, *A*. Draw the base and on it block in the upright omitting the projecting

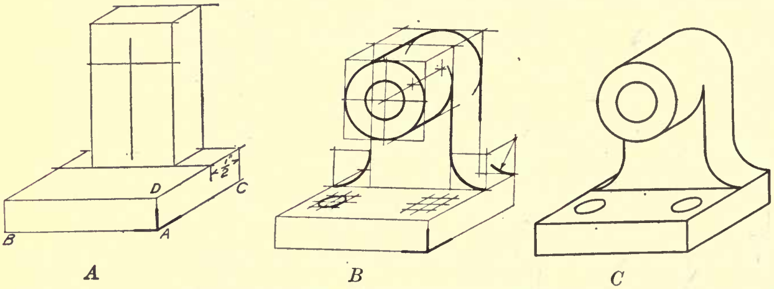


FIG. 102.—Stages in oblique construction.

boss, as shown in the figure. Second, block in the boss, as at *B* and find the centers for all circles and arcs. Third, draw the circles and circle arcs. Fourth, finish the drawing as at *C*.

45. **Cabinet Drawing.**—In this form of drawing the axes are taken the same as in oblique drawing but all measurements parallel to the oblique or cross axis, or in other words all thickness measurements from front to back, are reduced one-half. It is used sometimes in making drawings of wood construction.

46. **Perspective Drawing.**—Perspective drawing is the representation of an object as it actually appears to the eye. A sketch made in perspective thus gives the best pictorial effect. The elementary principles of perspective are familiar to most students

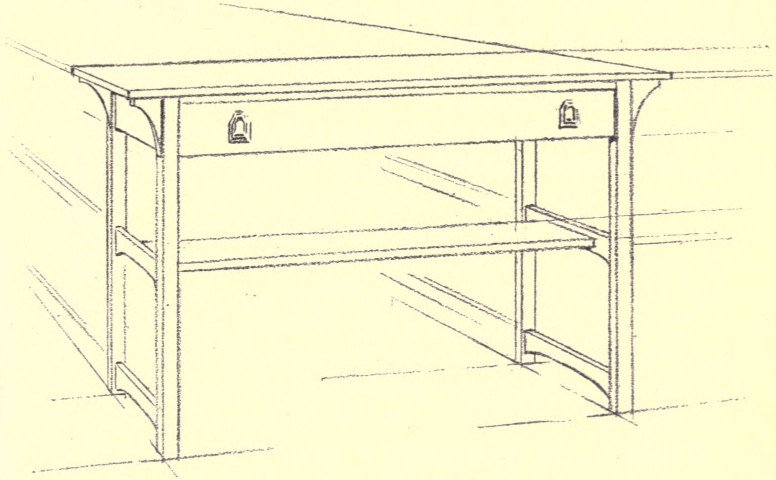


FIG. 103.—Angular perspective.

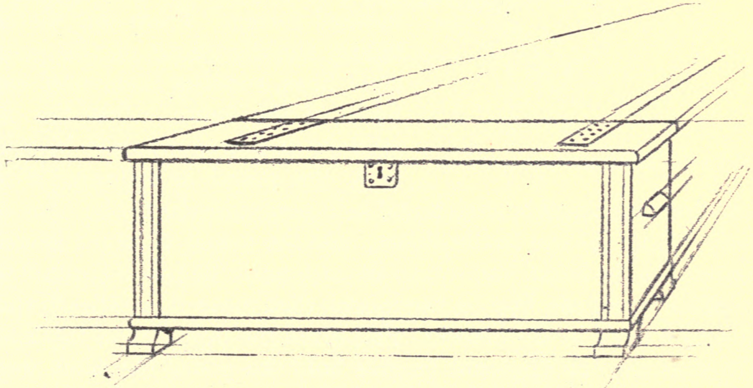


FIG. 104.—Parallel perspective.

through the study of freehand drawing and they will find this knowledge of value in studying shape description.[1]

[1] In the scope of this book the interesting subject of mechanical perspective construction cannot be taken up. With a knowledge of its methods perspective drawings can be made from working drawings, as for example when an architect makes a picture of a proposed building, the result being as accurate as a photograph of the building.

In the perspective sketch, Fig. 103, it will be noted that the vertical lines remain vertical and that the two sets of horizontal lines each converge toward a point called the vanishing point. These two vanishing points lie on a horizontal line at the level of the eye called the horizon. The first rule is, *all horizontal lines vanish on the horizon.*

When the object is turned at an angle as in Fig. 103, the drawing is said to be in angular or "two point" perspective.

If the object is turned so that one face is parallel to the front plane, the horizontal lines on that face, or parallel to it, remain horizontal and have no vanishing point. This drawing is called parallel or "one point" perspective, Fig. 104.

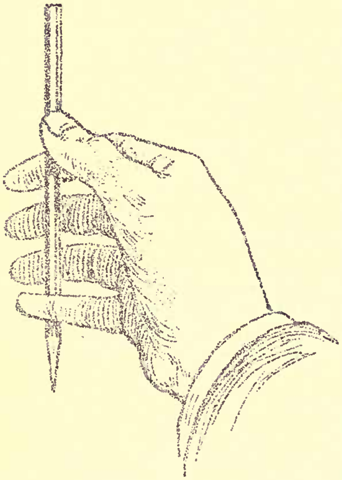


Fig. 105.—Estimating proportions.

47. Making a Perspective Sketch.—In sketching from the object, place it below the level of the eye (unless very large) and so as to show the outline of shape to the best advantage. Start by drawing a line for the nearest vertical corner. From this sketch lightly the directions of the principal lines, running them past the limits of the figure. Test the directions and proportionate lengths with the pencil as follows: With the drawing board or sketch pad held *perpendicular* to the "line of sight" from the eye to the object, hold the pencil at arm's length *parallel* to the board and rotate the arm until the pencil appears to coincide with the line on the model, then move it parallel to this position back to the board. This gives the direction of the line. To estimate the apparent lengths hold the pencil the same way and mark with the thumb, Fig. 105, the length of the pencil which covers the line. Rotate the arm with the thumb held in position until the pencil coincides with another line and estimate the proportion of this measurement to the second line.

Block in the enclosing squares for all circles and circle arcs and carry on the figure. Work with light free sketchy lines and do not erase any lines until the whole sketch is blocked in. Draw main outlines first, then add details. Finally, brighten the sketch with heavier lines.

CHAPTER IV

Principles of Size Description

48. We have learned that the two things to be told about an object are its shape and its size. In the previous chapter we studied the methods of representing the shape. When information regarding the *size* is added to the shape description, the two together give the complete working drawing of the object.

While working drawings are always made to scale, it would require too much time to take off distances by applying a scale to the drawing. Furthermore, the chances of making a mistake would be numerous especially with small distances or for drawings made to small scale.

For convenience in using, insuring accuracy, and saving time, the size description is given in the form of dimensions and notes, arranged on the drawing in a definite manner.

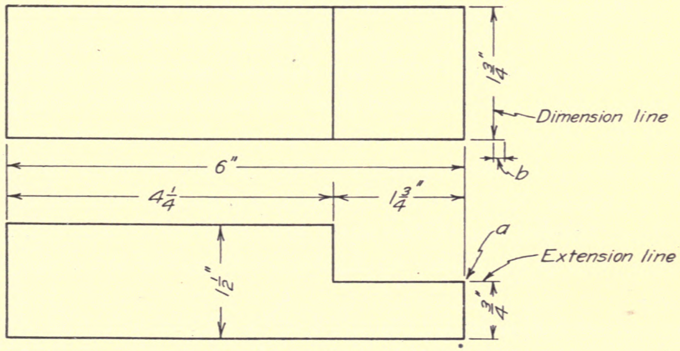


Fig. 106.—Dimension lines.

49. **Lines, Figures, Arrows, Etc.**—Certain conventional lines and symbols are used and the draftsman to make a successful drawing must not only be familiar with these but must know the principles of dimensioning and be acquainted with the shop processes which will be used in building or making the object represented.

The dimension line is made a light full line, in contrast with the heavier shape outline. See Alphabet of Lines, Art. 62. The line is terminated by long pointed arrow-heads, Fig. 106. Great care must be taken to have all arrow-heads the same size, and correctly shaped, Fig. 107.

A space is left in the dimension line for a figure to tell the actual distance on the full-size piece. When the dimension is placed outside of the outline of the view *extension* or *witness* lines are drawn from the view to show the points or surfaces measured on the object. Extension lines are fine lines drawn from the outline and extending past the arrow-head. Since extension lines are not part of the shape they should not touch the outline, see Fig. 106.

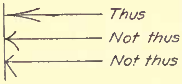


FIG. 107.

Figures must be carefully made and of a size easily readable but not so large as to overbalance the drawing. In general make them about $\frac{1}{8}''$ high. To avoid crowding, extension lines should be $\frac{3}{16}''$ or more from the lines of the drawing and from each other. A fraction is *always* made with a horizontal division line. Figures for fractions are made about two-thirds the height of whole numbers, see Fig. 24.

50. Placing Dimensions.—In placing dimensions the important thought is for the man who has to read the drawing and make the piece from it. It is necessary to think of the actual piece in space. Since the shape is already defined, select the view which tells most about the piece and give two dimensions of each part. One of the other views must be used to tell the third distance. In general it is better to place the dimensions between the views so as to be near both views. Horizontal dimensions must always read from the bottom of the sheet and vertical dimensions from the right side of the sheet, no matter what part of the sheet they are on.

Inches are indicated by ($''$) and feet by ($'$) and a dash is always placed between feet and inches thus, $5'\text{–}7\frac{1}{2}''$, or $0'\text{–}9\frac{1}{4}''$. When the drawing is dimensioned entirely in inches, the inch marks may be omitted. When the space is too small to admit of arrow-heads and figures, one of the methods of Fig. 108 is used.

When there are few lines within the outline, dimensions may be placed inside, making it unnecessary to draw extension lines.

Dimension lines should never cross extension lines. Larger dimensions should be placed outside of smaller dimensions.

51. **Theory of Dimensioning.**—The theory of dimensioning

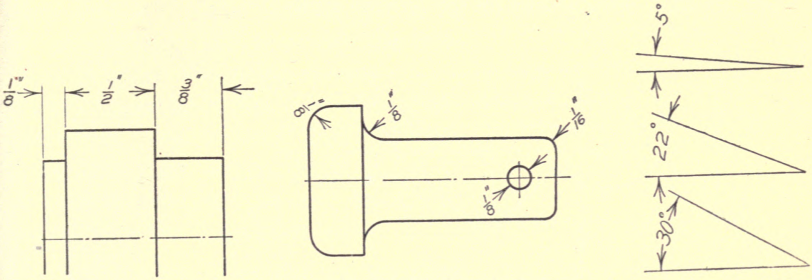


FIG. 108.—Dimensioning in limited space.

is based upon the idea of considering any object as made up of a number of simple shapes. When the size of each simple piece is defined and the relative positions given, the size description is complete. When a number of pieces are assembled, each piece is first considered separately and then in relation to the other pieces. In this way the size description of a complete machine, of a piece of furniture or of a building is no more difficult than the dimensioning of a single piece.

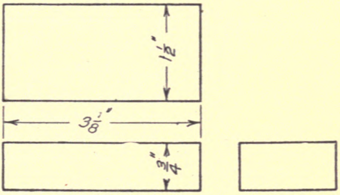


FIG. 109.—The first shape.

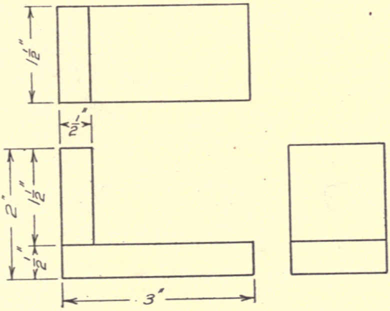


FIG. 110.—First rule applied.

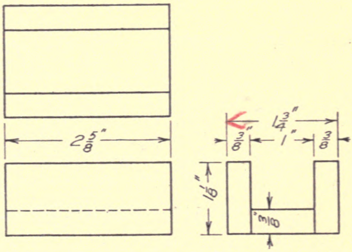


FIG. 111.—First rule applied.

52. The first shape is a flat piece, requiring the length, breadth and thickness, Fig. 109. Such an elementary shape may appear in a great many ways, a few of which are shown in Figs. 110 and 111.

Flat pieces of irregular shape are dimensioned in a similar way, Figs. 112 and 113.

Rule.—*For any flat part give the thickness in one of the edge views and all other dimensions on the outline view.*

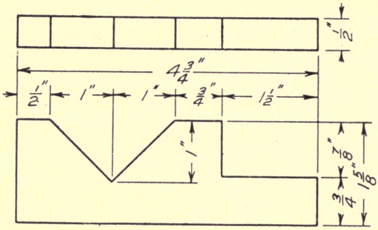


FIG. 112.—An irregular flat shape.

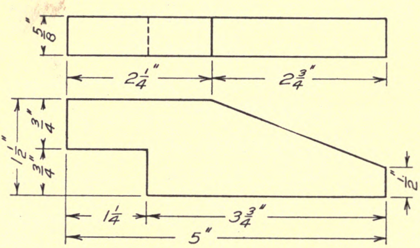


FIG. 113.—An irregular flat shape.

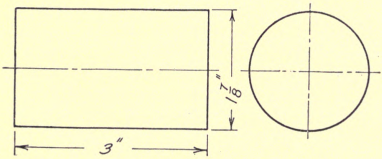


FIG. 114.—The second shape.

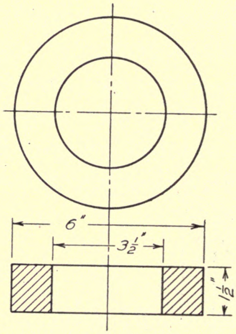


FIG. 115.—Second rule applied.

The second shape is the cylinder, requiring two dimensions, the diameter and length, Fig. 114. A washer may be thought of as two cylinders, Fig. 115, requiring two diameters and one length.

Rule.—*For cylindrical pieces give the diameter and length on the same view.*

Combinations of the first and second shapes are shown in Figs. 116 and 117. The dimensions *A*, *B*, *C* and *D*, Fig. 117, establish the relation between the single shapes.

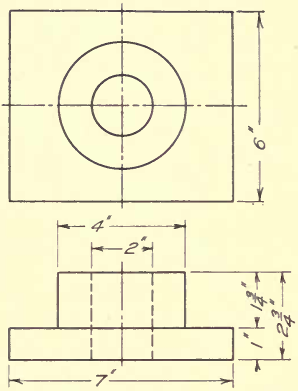


FIG. 116.—First and second shapes.

53. **General Rules.**—In the application of dimensioning there are certain practices which have come to represent good form to such an extent as to have the force of rules.

1. Regardless of location on the sheet, dimensions must read in line with the dimension line and either from the lower or right-hand side of the sheet.

2. On machine drawings detail dimensions up to 24″ should be given in inches. Above this feet and inches are generally used, except for gear drawings, bore of cylinders, length of wheel bases, etc.

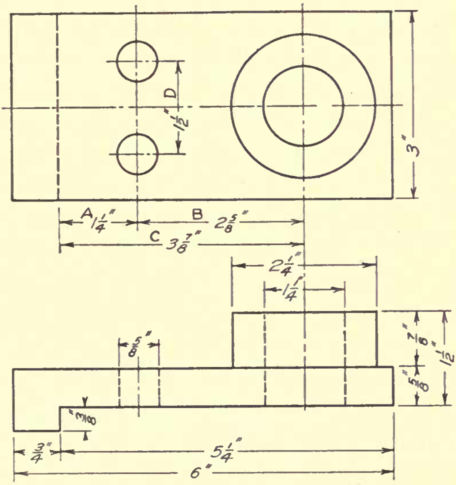


FIG. 117.—First and second shapes.

3. On architectural and structural drawings, dimensions of 12″ and over are given in feet and inches.

4. Sheet metal drawings are usually dimensioned entirely in inches.

5. Furniture and cabinet drawings are usually dimensioned in inches.

6. Feet and inches are designated thus, 7′–3″, or 7 ft.–3 in. Where the dimension is in even feet it is indicated thus, 7′–0″.

7. The same dimension is not repeated on different views unless there is a special reason for it.

8. When it is necessary to place a dimension within a sectioned area do not run the section lines across the number, Fig. 118.

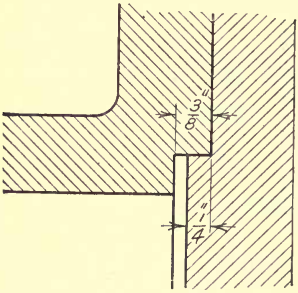


Fig. 118.

9. Dimensions should be given from or about center lines. Finished surfaces are always located from other finished surfaces or from center lines.

10. Never use a center line as a dimension line.

11. Never use a line of the drawing as a dimension line.

12. Never have a dimension line a continuation of a line of the drawing.

13. Never place a dimension so that it is crossed by a line.

14. Always give the diameter of a circle, not the radius.

15. Always give the radius of an arc. The abbreviation R or Rad. is used when necessary, Fig. 108.

54. **Use of Decimals.**—Dimensions are given in feet, inches and fractions of an inch. In ordinary work binary fractions

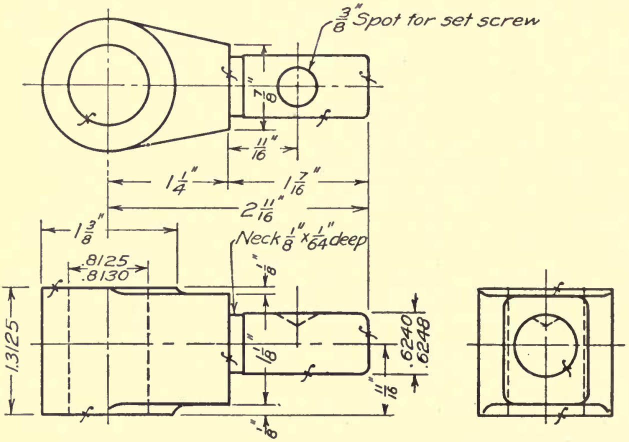


Fig. 119.—Dimensioning with limits.

such as ½″, ¼″, ⅛″, 1/16″, 1/32″, 1/64″ are used. For parts which must fit very accurately the dimensions are given in decimals instead of the usual fractions, and the workman is required to work within a certain fixed limit of accuracy. The number of thousandths or ten-thousandths of an inch which will be allowed as variance from the absolute measurement is called the tolerance. The limits between which the measurement must come are given as in Fig. 119, which shows that the diameter of the hole must not be over .8130″ nor under .8125″.

55. **Dimensioning Assembled Parts.**—The drawing of a separate part is called a detail drawing. When the different parts of a machine or structure are shown together in their relative positions the drawing is called an assembly drawing. The rules and methods given for dimensioning apply to all cases where a complete description of size is required.

Drawings of complete machines, pieces of furniture, etc., are made for different uses and have to be dimensioned to serve the purpose desired of them. If the drawing is simply to show the arrangement of parts all dimensions are left off. When it is desired to tell the space required, give "*over-all*" dimensions. Where it is necessary to locate parts in relation to each other without giving all of the detail dimensions, it is usual to give center distances and size of parts which might affect putting together the machine or construction. Assembly drawings may be completelv dimensioned, either with or without extra part views, see Fig. 163. Such drawings serve the purpose of both detail and assembly drawings.

For furniture and cabinet work the major dimensions only are sometimes given, such as length, breadth, height, and sizes of stock, leaving the details of joints to the cabinetmaker. This is common practice where machinery is used and where many details of construction are standardized.

56. **Sketching and Measuring.**—Sketching as a means of shape description and study has been considered in Chapter III. When sketches are made from machine or furniture parts, to be used in making drawings it is necessary to define the size, the material, the kinds of surfaces, either "finished" or "rough," the limits of accuracy and all information that might have any possible future value.

57. After sketching the views of a piece, add *all* necessary dimension lines in exactly the same way as for a drawing. The piece should now be examined, the kind of material noted, together with the kinds of finish and the location of all finished surfaces. When everything else is done it is time to measure the piece and fill in the figures, telling the size. For this purpose

various measuring tools will be required. A two-foot rule, a steel scale and a pair of calipers will be found sufficient for most measurements. Other machinists' tools are often necessary or convenient and the pupil should know something about the tools which are available and how to use them.

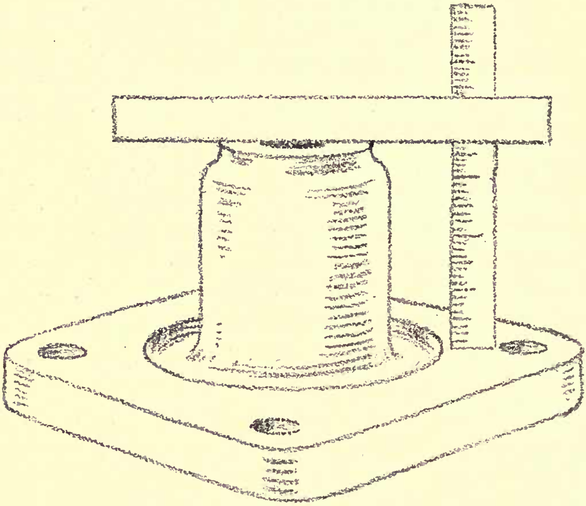


FIG. 120.—Taking a measurement.

58. The flat scale or the steel scale and straightedge can be used in many ways, as suggested in Fig. 120 and the distances read directly.

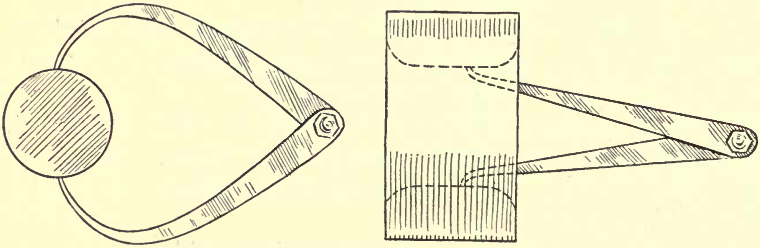


FIG. 121.—Outside and inside calipers.

Whenever possible, always take measurements from finished surfaces. Inside and outside calipers with their use illustrated are shown in Fig. 121. The distance between the contact points is read by applying the calipers to a scale, Fig. 122.

When the calipers cannot be removed from a thickness, the plain calipers may be used by inserting an extra piece or "filler" Fig. 123; or the "transfer" calipers, Fig. 124, may be used. The distance x must be subtracted from the total distance to obtain

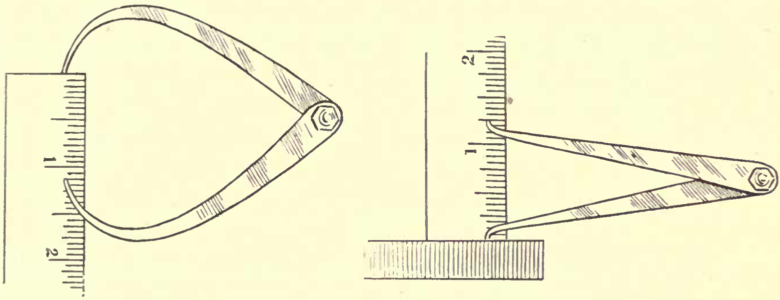


FIG. 122.—Reading the calipers.

the desired thickness t when a filler is used. The transfer calipers are provided with a false leg which is set so that the calipers may be opened and then brought back to the same position after removing from the casting.

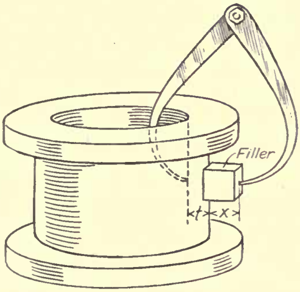


FIG. 123.—Use of filler.

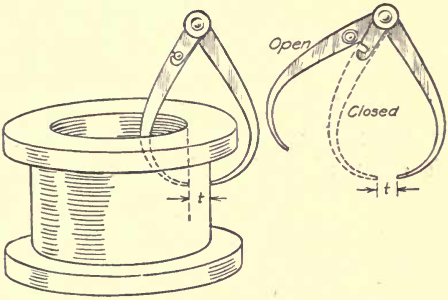


FIG. 124.—Use of transfer calipers.

All measurements of wood construction can generally be obtained with sufficient accuracy by using the two-foot rule.

For very accurate measurements vernier calipers and micrometer calipers, Figs. 125 and 126 are used. Other tools which are useful if at hand are the steel square, try square, combination square, surface gauge, depth gauge, radius gauges, protractor, etc.

When a pictorial sketch is dimensioned the only additional consideration is to use care to see that all extension lines are either in or perpendicular to the plane on which the distance is being given, Fig. 127.

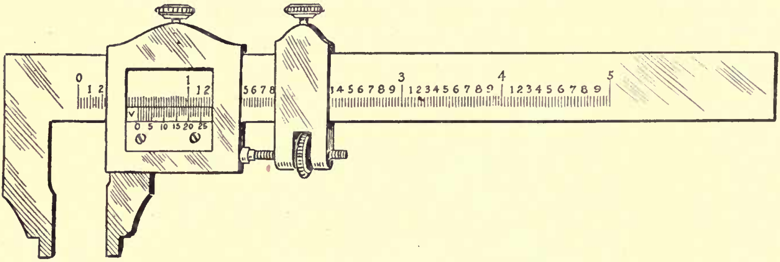


FIG. 125.—Vernier calipers.

59. **Notes and Specifications.**—Information which cannot be represented graphically must be given in the form of lettered

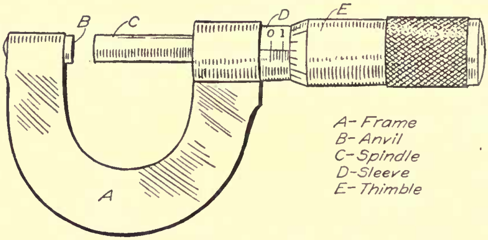


FIG. 126.—Micrometer calipers.

notes and symbols. Generally understood trade information is often given in this way. Such notes include the following

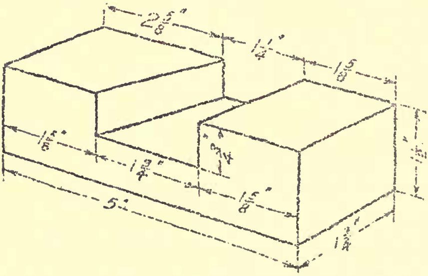


FIG. 127.—Dimensioning a pictorial sketch.

items: Number required, material, kind of finish, kind of fit, method of machining, kinds of screw threads, kinds of bolts and nuts, sizes of wire, thickness of sheet metal, etc.

The materials in most general use are wood, cast iron, wrought iron, steel and brass. All parts which go together must be of the proper size so they will fit. Some pieces are left in the rough and others must have a smooth "finish." The wood used for making a piece of furniture is first shaped with wood-working tools. Cast iron and brass are given the required form by moulding, casting, and machining. First a wooden "pattern" of the shape and size required is made. This pattern is placed in sand to make an impression or mould, into which the melted metal is poured. Wrought iron and steel are made into shapes by rolling or forging in the rolling mill or blacksmith shop. Some kinds of steel may be cast as described for cast iron.

There are many interesting ways of forming metals for special purposes, and many special alloys, that cannot be described in a drawing book, but the pupil will learn much by observing the shapes of parts of machinery and the materials of which they are made.

After a part is cast or forged it must be "*machined*" on all surfaces which are to fit other surfaces. Round surfaces are generally formed on a lathe. Flat surfaces are finished or smoothed on a planer, milling machine, or shaper. For making holes drill presses, boring mills or lathes, are used.

Extra metal is allowed for surfaces which are to be finished. To specify such surfaces a small "*f*" is placed on the lines which represent the surfaces. If the entire piece is to be finished a note such as "*fin. all over*" may be used and all other marks omitted.

Specifications as to methods of machining, finish and other treatment are given in the form of notes, as spot face, grind, polish, knurl, core, drill, ream, countersink, hardened, case-hardened, blued, and tempered.

It is often necessary to add notes in regard to assembling, order of doing work or other special directions.

60. **Checking a Drawing.**—After a drawing has been completed it must be very carefully examined before it is used. This is called checking the drawing. It is very important work, and should be done by someone who has not worked on the drawing.

Thorough checking requires a definite order of procedure, and consideration of the following items:

1. See if the views completely describe the shape of each piece.
2. See if there are any unnecessary views.
3. See that the scale is sufficiently large to show all detail clearly.

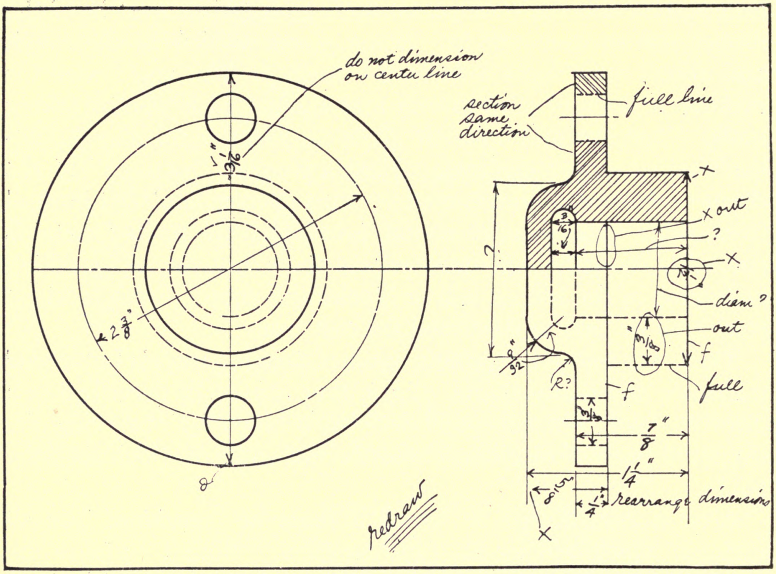


FIG. 128.—An incorrect drawing. To be redrawn.

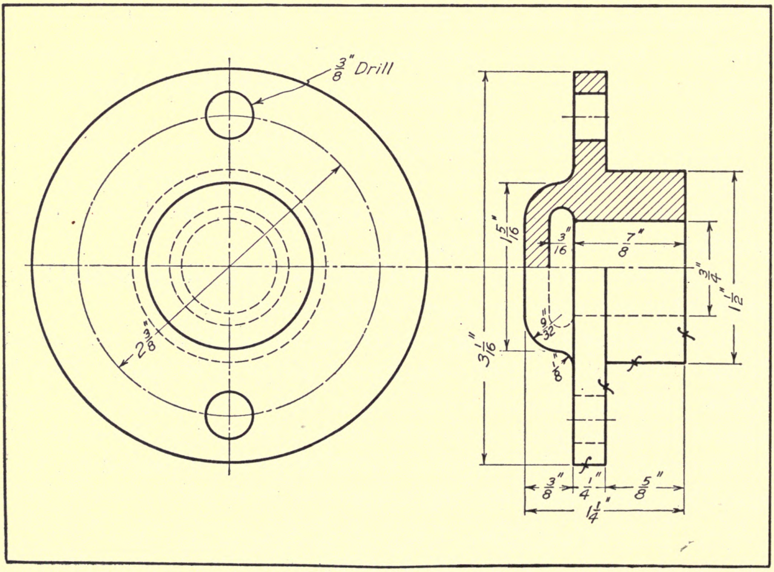


FIG. 129.—The drawing corrected.

4. See that all views are to scale and that correct dimensions are given.

5. See that sufficient dimensions are given to define the size of all parts completely.

6. See that the kind of material and the number required of each part is specified.

7. See that the kind of finish is specified, that all finished surfaces are marked and that finish is not called for where not needed.

8. See that all necessary explanatory notes are given, and that they are properly placed.

An incorrect drawing with some of the mistakes noted on it is shown in Fig. 128, and the same drawing when corrected in Fig. 129.

CHAPTER V

Technic of the Finished Drawing

61. We have had it impressed upon us that in the language of drawing an object is described by telling its shape and its size. All drawings whether for machinery, structural work, buildings or ships are made on the same principles.

Sometimes an unfavorable comparison is made between a *student's* drawing and a *real* drawing. The finished appearance of a real drawing as made by a draftsman or engineer is due to a thorough knowledge of the technic of commercial drafting. The correct order of going about the work and some of the conventional representations in common use are described in this chapter. The pupil must become thoroughly familiar with this practice if his drawings are to have the style and good form which are so desirable and necessary.

62. **Alphabet of Lines.**—The kinds of lines in general use in

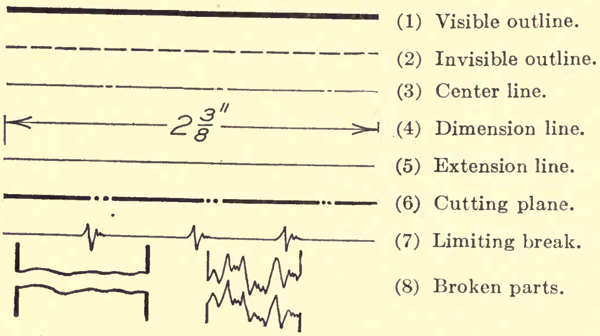


Fig. 130.—The alphabet of lines.

making drawings are given in Fig. 130. Each line is used for a definite purpose and must not be used for anything else. Detail drawings should have fairly heavy outlines, with light center lines and dimension lines so that the drawing will have contrast and be easy to read. If all the lines are the same weight the drawing will have a *flat* appearance making it hard to read.

63. **Order of Penciling.**—After learning about shape and size description the most important thing for the young draftsman to get is good form, a systematic method of working. The order of making the different parts of the drawing is the first item. A drawing is started by drawing center lines and base lines, which form the skeleton for the views. The views should be carried along together. Do not attempt to finish one view before making another. Learn the following order of penciling and follow it as nearly as possible in every drawing.

1. Lay off the sheet to proper size, and block in the title space or record strip.
2. Plan the arrangement of views.
3. Draw the primary center and base lines.
4. Lay off the principal measurements.
5. Block in the views by drawing the preliminary and final "blocking-in" lines.
6. Lay off the detail measurements.
7. Draw the center lines for details. See that two intersecting center lines are drawn to locate all circles, and that there are center lines for the axes of all cylinders.
8. Draw all complete circles and the preliminary and final lines for details.
9. Draw part circles, fillets and rounded corners.
10. Draw such lines as could not be previously drawn.
11. Draw all extension and dimension lines.
12. Put on dimensions and notes.
13. Cross-hatch all sectioned surfaces.
14. Put on title.
15. Check drawing.

64. **Inking and Tracing.**—Finished drawings are generally inked, either by going over the pencil lines with drawing ink or more commonly by putting a piece of tracing cloth or paper over the pencil drawing and tracing it in ink. From such tracings blueprints can be made for use on the work. The method of procedure is the same for paper or cloth.

All straight lines are inked with the ruling pen. Hold the pen point downward and fill by touching the quill on the ink bottle cork to the inside of the pen blades. The nibs of the pen are set to the desired width of line by turning the adjusting screw, using the thumb and second finger of the pen hand. Then hold the pen against the T-square or triangle in the position of Fig. 131.

Note the following:

Do not hold the pen over the drawing while filling.

Keep the blades parallel to the direction of the line.

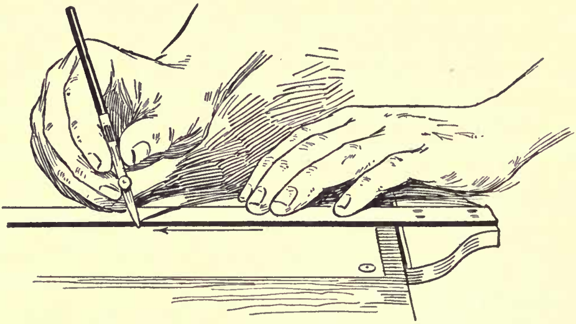


FIG. 131.—Correct position of pen.

Do not press too hard against the T-square.

Do not screw the nibs of the pen too tight.

Have a pen wiper at hand.

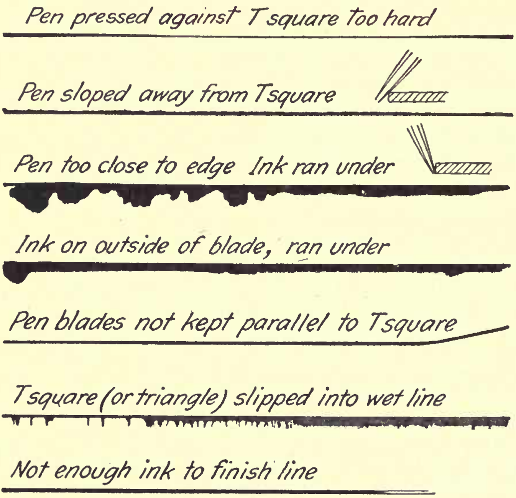


FIG. 132.—Faulty lines.

Keep the pen clean. Always wipe it out carefully after using.

Never dip the pen into the ink bottle or allow ink to get on the outside of the blades.

Do not put too much ink in the pen. (Not over ¼ inch.)

Faulty lines occur from different reasons. The pen may need dressing or sharpening. The beginner should not attempt to do this but should ask the teacher to do it for him. Figure 132 shows some of the common faults and suggests the remedy.

The irregular curve, Fig. 14, is used for guiding the pen when inking curves other than circle arcs. It is used by matching a portion of the curved line and drawing a piece of the line, then moving the curve to a new position. The new position must always match a part of the line already inked.

For inking circles the compasses and bow pen are used. Remove the pencil leg from the compasses and insert the pen leg, adjusting the needle point until it is very slightly longer than the pen.

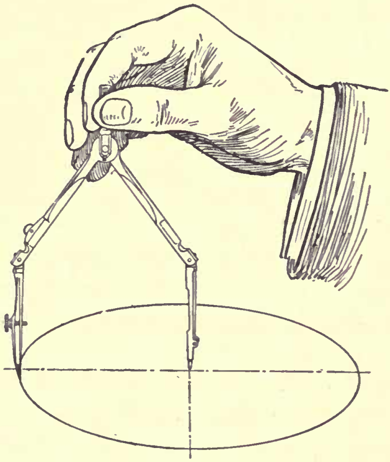


FIG. 133.—Inking a circle.

The joints of the compasses should be adjusted so that the legs are perpendicular to the paper. Always draw a circle in one stroke, inclining the compasses in the direction of the line and rolling the handle between the thumb and finger, Fig. 133. Small circles are drawn with the bow compasses.

65. **To Make a Tracing.**—First tear off the selvage and tack the cloth down smoothly over the pencil drawing. Most draftsmen place the dull side up. Dust the surface with chalk and rub over with a cloth to remove all traces of grease so as to obtain smooth ink lines. Be sure to remove all dust before starting to ink. With the tracing cloth in position and properly prepared inking is done in exactly the same way as on paper.

As tracing cloth is very sensitive to atmospheric changes and will stretch if left over night, no view should be started which cannot be finished on the same day. When work is again started the cloth should be restretched.

66. **Order of Inking.**—Good inking is the result of two things, careful practice and a definite order of working. Smooth joints and tangents, sharp corners and neat fillets not only improve the appearance of a drawing but make it easier to read.

1. Ink center lines.
2. Ink small circles and arcs.
3. Ink larger circles and arcs.
4. Ink irregular curves.
5. Ink horizontal full lines.
6. Ink vertical full lines.
7. Ink inclined full lines.
8. Ink dotted circles and arcs.
9. Ink dotted lines.
10. Ink extension and dimension lines.
11. Ink arrow-heads and figures.
12. Ink section lines.
13. Letter notes and title.
14. Ink border lines.
15. Check drawing.

67. **Erasing.**—The ideal way of course is to complete a drawing or tracing without having to do any erasing. Sometimes, however, it is necessary to make an erasure on account of a change or a mistake. Ink lines may be removed by rubbing rather hard with a pencil eraser, which does not abrade the surface of the paper or cloth as does an ink eraser. Do not use a knife or scratcher. An erasing shield is very convenient. One can be made by cutting a slot in a card or piece of drawing paper. Pencil lines are removed with artgum or a pencil eraser.

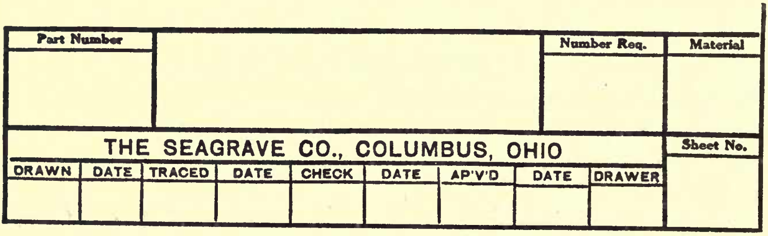


FIG. 134.—A boxed title form.

68. **Titles.**—Every sketch and drawing must have some kind of title. The form, completeness and location vary. On work-

ing drawings the title is usually "boxed" in the lower right-hand corner, Fig. 134, or as part of a record strip extending across the bottom or end of the sheet, Fig. 135.

The title gives as much as is necessary of the following information:

1. The name of the construction.
2. The name of the part shown (or simply "details").
3. Manufacturer; company or firm name and address.
4. Date; usually date of completion of tracing.
5. Scale, or scales.
6. Drafting-room record; names or initials of draftsman, tracer, checker, and approval of chief draftsman, engineer or superintendent.
7. Numbers, of the drawing; of the order.

In larger drafting rooms the title is often printed in blank on the paper or cloth used.

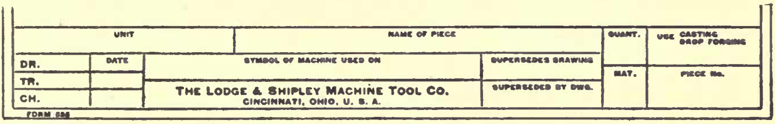
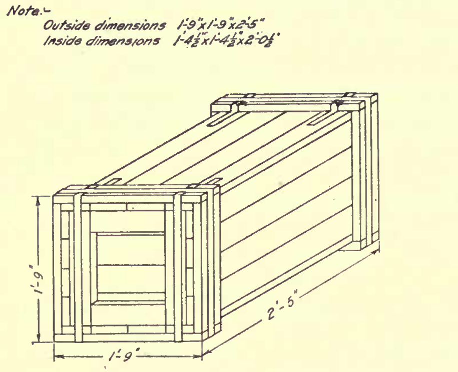


Fig. 135.—A record strip title.

69. **Bill of Material.**—Drawings may have the name of the part, material, number required, part number, etc., given in a note near the views of each part. Another method often used is to place the number of the part in a circle near the views and then collect all the information in a tabulated list, called a bill of material, or material list. Sometimes this list is placed on the drawing over the title, and sometimes it is typewritten on a separate sheet. If for wood construction the bill will give the stock sizes, kind and quality of wood, board measure, and number of each part required, Fig. 136. Sometimes the cost is added. Bolts and other metal parts are often specified and marked with an identification number or mark.

70. **Screw Threads.**—The use of screw threads is so frequent that the common forms and methods of representation must be understood. The most familiar occurrence of screw threads is on the ordinary wood screw, and common bolt, Figs. 137 and 138.

The form of thread generally used in this country for machine bolts and metal constructions is the United States Standard, shown in Fig. 139. Wood screw threads have a space between them to allow for the difference in strength of wood and metal.



BILL OF MATERIAL REQUIRED FOR ONE BOX

No. Pcs.	Size	Description	Remarks
	LUMBER		
8	1⅛" x 4⅛" x 2'-5"	Side Plank	
4	1⅛" x 5¼" x 2'-5"	Top & Bott Plank	
4	1⅛" x 4⅛" x 2'-5"	Top & Bott Plank	
8	1⅛" x 4⅛" x 1'-4⅛"	End Plank	
4	1⅛" x 3" x 1'-4½"	End Batten Vert.	
4	1⅛" x 3" x 10½"	End Batten Hor.	
4	1⅛" x 3" x 1'-6¾"	End Vert Cleat	
4	1⅛" x 3" x 1'-9"	End Hor Cleat	
	HOOP IRON		
2	1" x #20 Gauge x 7'-4"	Cross Tie	
4	1" x #20 Gauge x 3'-3"	End Tie	
	NAILS		
72	10d x 3" Nail		
180	8d x 2½" Nail		

BOX FOR
OVERSEAS SHIPMENT

Fig. 136.—Drawing with bill of material.

Other forms of threads used to meet various requirements are illustrated and named in the figure.

To draw a true representation of a screw thread it is necessary to draw the projection of a cylindrical helix. A cylindrical helix

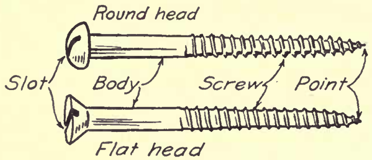


Fig. 137.—Wood screws.

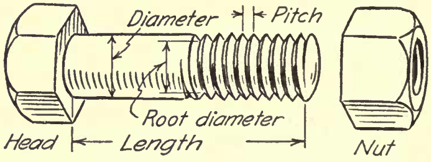


Fig. 138.—Hex head bolt and nut.

is a curve generated by a point moving uniformly around a cylinder and uniformly lengthwise of the cylinder at the same time. The hypotenuse of a right triangle will form one turn of a helix if it is wrapped around a cylinder, as in Fig. 140. The base of the triangle is equal to the circumference of the cylinder and the altitude is the pitch of the helix.

71. **To Draw the Projection of a Helix.**—Draw two projections of the cylinder, divide the top view into a number of equal parts and the pitch into the same number of parts as at *A*, Fig. 141. From each point in the top view drop perpendiculars to meet horizontal lines drawn through the same numbered division of the front view as at *B*. A smooth curve drawn through the points found will give the projection of the helix, as at *C*.

The application of the helix is shown in Fig. 142, which is the actual projection of a square thread. Such drawings are seldom made as they require too much time and are no better practically than the conventional representations commonly used. For diameters of more than one inch the representations of Fig. 143 may be used. The order of drawing the lines for V threads is shown in Fig. 144.

For small diameters the representation is further conventionalized to one of the forms of Fig. 145. The pitch or distance between threads is not measured but the lines are spaced so as to look well, as indicated in the figures. The simple form shown at *C* is generally satisfactory and is easily and quickly made.

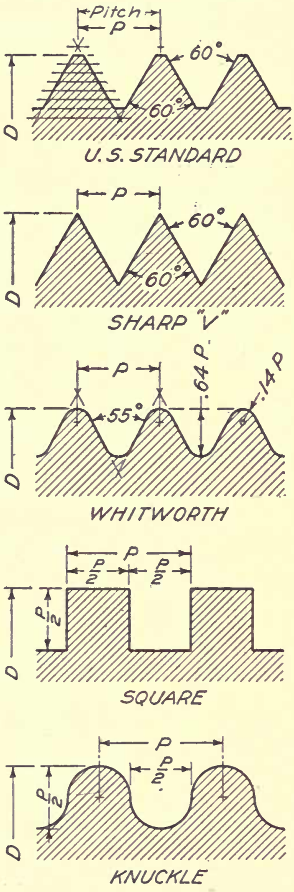


Fig. 139.—Threads.

Screw threads in section are shown in Fig. 146. Threaded holes in plan, elevation and section may be drawn as in Fig. 147. Any one of the plan representations may be used with any of the elevations or sections. A small threaded hole is called a "tapped" hole and a note such as "tap for ⅝" U. S. Std. Thread" placed on the drawing. If a threaded hole does not go clear

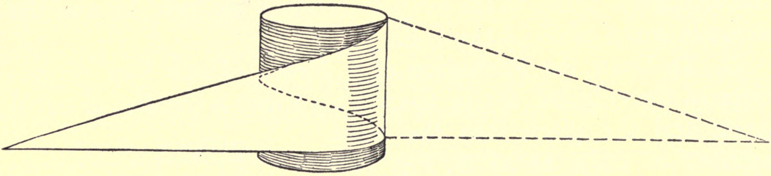


FIG. 140.—Helix.

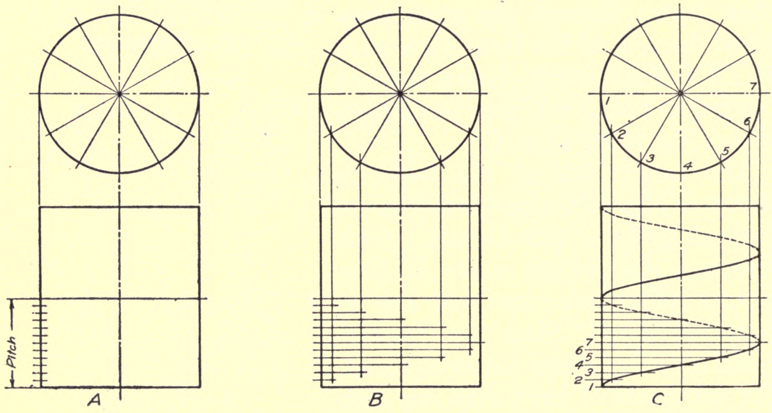


FIG. 141.—Drawing a helix.

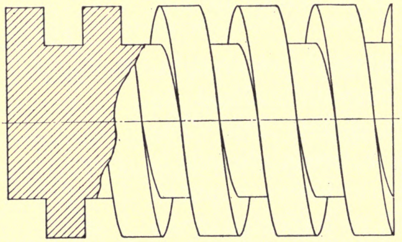


FIG. 142.—True projection of square thread.

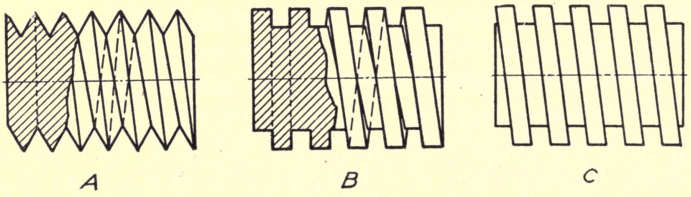


FIG. 143.—Straight line thread representations.

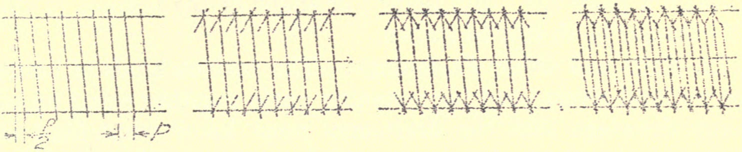


FIG. 144.—Order of drawing a V thread.

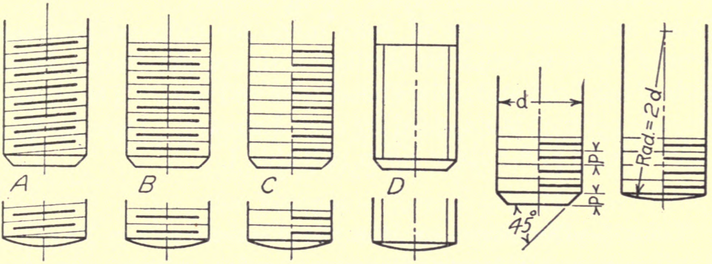


FIG. 145.—Usual methods of drawing threads.

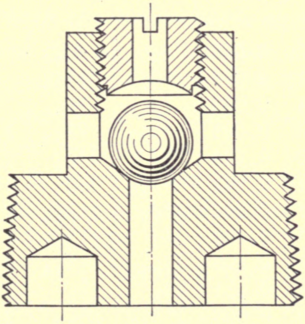


FIG. 146.—Threads in section.

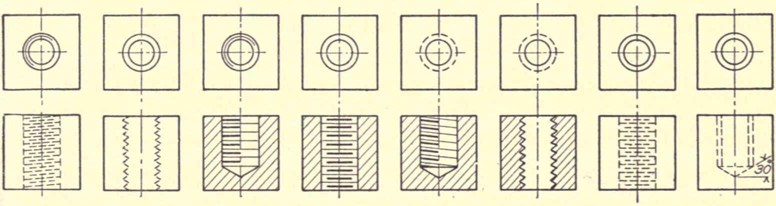


FIG. 147.—Various methods of drawing threaded holes.

through a piece the "drill point" or shape of the bottom of the hole should be drawn as shown.

72. **Bolts and Other Fastenings.**—The various kinds of bolts, screws, and rivets used for fastening parts together occur on so many drawings that the draftsman must know what kind of fastenings to use and how to represent them conventionally. In the previous paragraphs the methods of representing threads conventionally have been shown. These are always used on shop drawings on account of the saving of time.

There are many forms of bolts made for different purposes. The ones which we must be familiar with are the United States Standard hex head and square head bolts and nuts. The number of threads per inch is standard for each diameter. Data for U. S. Standard bolts and nuts is given in Table I.

TABLE I.—DIMENSIONS OF U. S. STANDARD BOLTS AND NUTS

Diam. of bolt, in.	Threads per inch	Diam. at root of thread	Area at root of thread	Distance across flats, in.	Distance across corners		Thickness	
					Hexagon, in.	Square, in.	Nut, in.	Head, in.
1/4	20	0.185	0.026	1/2	37/64	23/32	1/4	1/4
5/16	18	0.241	0.045	19/32	11/16	27/32	5/16	19/64
3/8	16	0.294	0.068	11/16	51/64	31/32	3/8	11/32
7/16	14	0.345	0.093	25/32	29/32	1 7/64	7/16	25/64
1/2	13	0.400	0.126	7/8	1 1/64	1 1/4	1/2	7/16
9/16	12	0.454	0.162	31/32	1 1/8	1 3/8	9/16	31/64
5/8	11	0.507	0.202	1 1/16	1 15/64	1 1/2	5/8	17/32
3/4	10	0.620	0.302	1 1/4	1 29/64	1 25/32	3/4	5/8
7/8	9	0.731	0.420	1 7/16	1 43/64	2 1/32	7/8	23/32
1	8	0.838	0.551	1 5/8	1 7/8	2 19/64	1	13/16
1 1/8	7	0.940	0.693	1 13/16	2 3/32	2 9/16	1 1/8	29/32
1 1/4	7	1.065	0.889	2	2 5/16	2 53/64	1 1/4	1
1 3/8	6	1.159	1.054	2 3/16	2 17/32	3 3/32	1 3/8	1 3/32
1 1/2	6	1.284	1.293	2 3/8	2 3/4	3 23/64	1 1/2	1 3/16
1 3/4	5	1.490	1.744	2 3/4	3 3/16	3 57/64	1 3/4	1 3/8
2	4 1/2	1.711	2.300	3 1/8	3 39/64	4 27/64	2	1 9/16

Both hex and square forms have the same dimensions "across flats," which is equal to one and one-half times the diameter of the bolt plus 1/8", or $S = 1\frac{1}{2}\,d + \frac{1}{8}''$.

The thickness of a bolt head is one-half the distance across flats or $= \frac{S}{2}$. The thickness of a nut is equal to the diameter, $= d$.

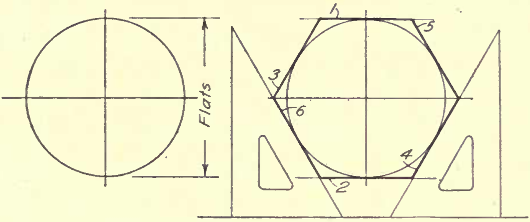


FIG. 148.—To draw a hexagon.

73. To Draw a Bolt.—The easiest way to understand a bolt head is to draw the top and front views. Since the hexagonal form is oftenest used we must know how to draw a regular hexagon.

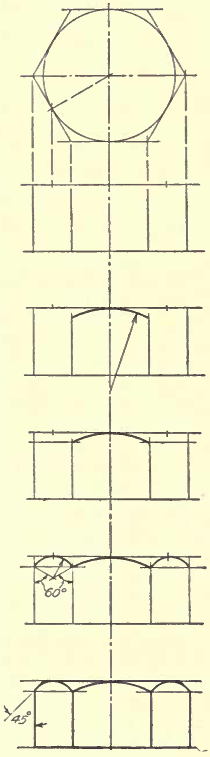


FIG. 149.

To Draw a Hexagon.—Given the distance between two sides, called the short diameter, or "distance across flats," Fig. 148. First draw horizontal and vertical center lines. With the intersection as a center, draw a circle having a diameter equal to the distance across flats. With the T-square and 30°–60° triangle, draw lines tangent to the circle in the order given.

A hex bolt head is a hexagonal prism with the corners chamfered as shown in the picture of Fig. 138.

74. To Draw a Bolt Head.—Start the top view by drawing the chamfer circle with a diameter equal to one and one-half times the diameter of the bolt plus one-eighth of an inch. $S = 1\frac{1}{2}\, d + \frac{1}{8}''$. About this circle draw a hexagon as just described. For the front view draw a horizontal line representing the under side of the head. The thickness of the head is $\frac{S}{2}$, or the radius of the chamfer circle. Draw top line and project from top view to obtain edges. Complete the front view by drawing three circle arcs as shown in Fig. 149. The middle arc has a radius equal to d and the side arcs are of such radius as to line across with the middle one. Their centers may be found by the construction shown, but draftsmen often draw the arcs by trial, without construction.

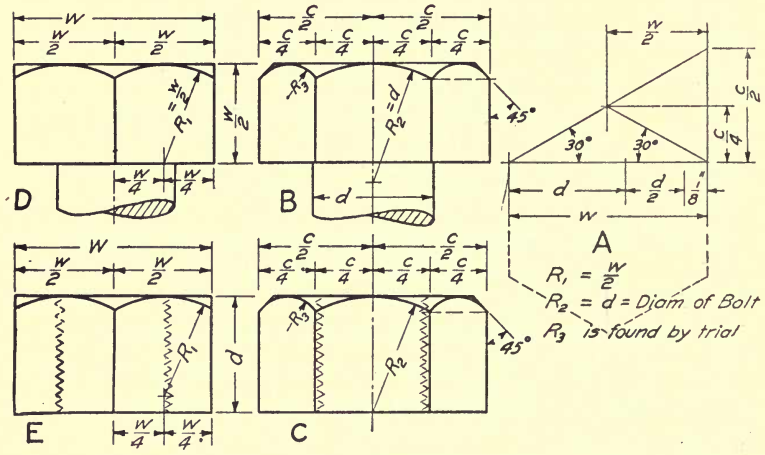


Fig. 150.—To draw a U. S. Standard hex head and nut.

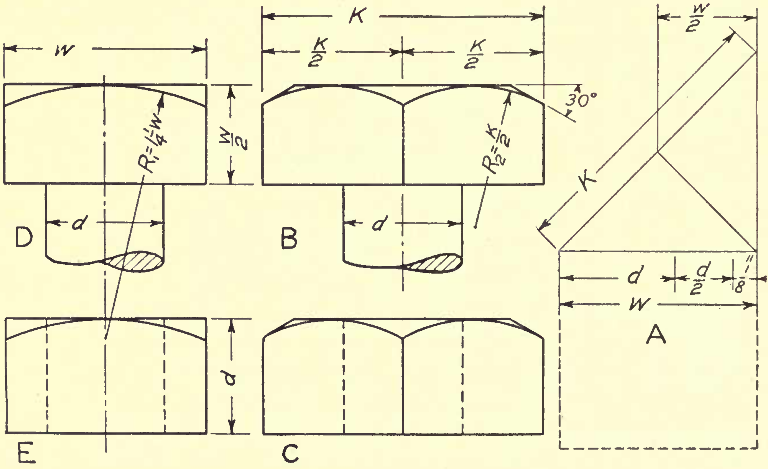


Fig. 151.—To draw a U. S. Standard square head and nut.

75. In drawing a bolt head or nut it is not necessary to draw the top view. A convenient method of drawing bolts and nuts is illustrated in Fig. 150, where a simple diagram is used to obtain

the dimensions. To draw the diagram shown at *A*, lay off on a horizontal line the diameter of the bolt, half the diameter of the bolt and ⅛″. From one end of the line draw a 30° line with the triangle and from the other end draw a vertical line. Complete the diagram as shown. The distances are marked on

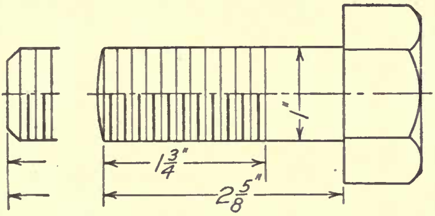


Fig. 152.—Dimensioning a Standard bolt.

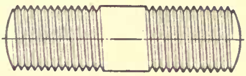


Fig. 153.—A stud.

the diagram to correspond with the same distances on the bolt head and nut.

Figure 151 shows the same method applied to a square head bolt and nut, in which the diagram is constructed with a 45° angle instead of 30°.

The proportions of bolt heads and nuts are so well standardized that they are not dimensioned on a drawing. For a bolt it is only necessary to specify three dimensions, the diameter, length from under side of head to end of bolt; and length of thread, as in Fig. 152.

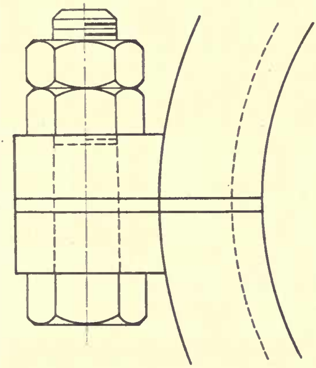


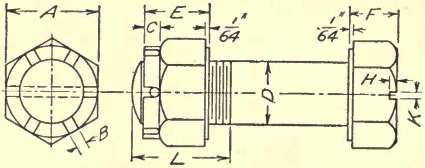
Fig. 154.—Locknuts.

A *stud* or stud bolt, Fig. 153, has threads on both ends and is used where bolts are not suitable and for parts which must be removed often. One end is screwed permanently into a tapped hole and a nut is screwed on the projecting end.

Various arrangements are used to prevent nuts from working loose under vibration. Locknuts such as illustrated in Fig. 154, are the commonest.

76. S. A. E. Standard Bolts.—Bolts used for automobile work have finer threads, and smaller heads and nuts than U. S. Standard. A pin through the bolt is used to prevent loosening of the "castle nut" and the head is slotted for the use of a screw driver. The dimensions for the standard of the Society of Automotive Engineers is given in Table II.

Table II.—Dimensions of S. A. E. Standard Bolts and Nuts

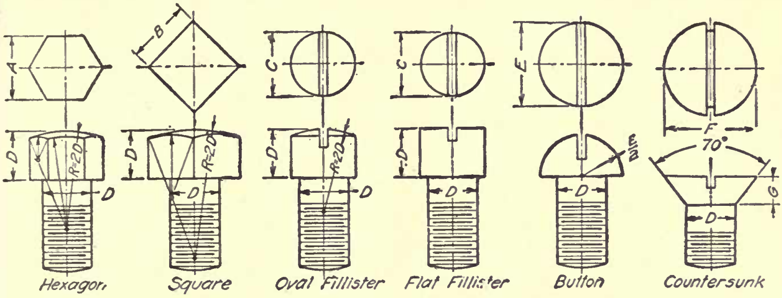


D	Threads	A	B	C	E	F	H	K	L
1/4	28	3/8	5/64	3/32	9/32	3/16	3/32	1/16	3/8
5/16	24	1/2	5/64	3/32	21/64	15/64	7/64	1/16	15/32
3/8	24	9/16	1/8	1/8	13/32	9/32	1/8	3/32	9/16
7/16	20	11/16	1/8	1/8	29/64	21/64	1/8	3/32	21/32
1/2	20	3/4	1/8	3/16	9/16	3/8	1/8	3/32	3/4
9/16	18	7/8	5/32	3/16	39/64	27/64	1/8	3/32	27/32
5/8	18	15/16	5/32	1/4	23/32	15/32	1/8	3/32	15/16
11/16	16	1	5/32	1/4	49/64	33/64	1/8	3/32	1 1/32
3/4	16	1 1/8	5/32	1/4	13/16	9/16	1/8	3/32	1 1/8
7/8	14	1 1/4	5/32	1/4	29/32	21/32	1/8	3/32	1 5/16
1	14	1 7/16	5/32	1/4	1	3/4	1/8	3/32	1 1/2

77. **Cap screws** have various forms of heads and are used for fastening two pieces together by passing through one and screwing into a tapped hole in the other. The usual range of sizes and dimensions for drawing are given in Table III.

Machine screws are used where small diameters are required, they are specified by number and run from No. 0 (.06″ diam.) to No. 30 (.45″ diam.). They are similar to cap screws in appearance.

TABLE III.—DIMENSIONS OF CAP SCREWS



D	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4
A	...	...	7/16	1/2	9/16	5/8	3/4	13/16	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
B	...	...	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1 1/8	1 1/4	1 3/8	1 1/2
C	3/16	1/4	3/8	7/16	9/16	5/8	3/4	13/16	7/8	1	1 1/8	1 1/4		
E	7/32	5/16	7/16	9/16	5/8	3/4	13/16	15/16	1	1 1/4				
F	1/4	3/8	15/32	5/8	3/4	13/16	7/8	1	1 1/8	1 3/8				
G	3/32	9/64	5/32	7/32	17/64	17/64	17/64	5/16	23/64	7/16				

Set screws, Fig. 155, are used for holding two parts in a desired position relative to each other by screwing through a threaded hole in one piece and bearing against the other.

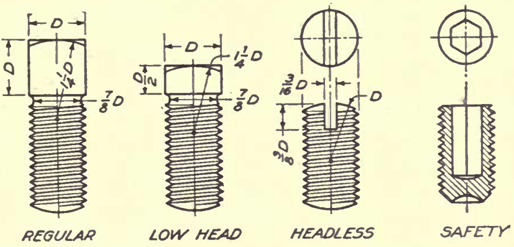


FIG. 155.—Set screws.

78. **Wood screws** are made of steel or brass, and are finished in various ways. Steel screws may be bright (natural finish), blued, galvanized or copper plated, while both steel and brass are sometimes nickel plated. Round head screws have the head above the wood while flat head screws are set flush, or countersunk. They are drawn as in Fig. 156. Wood screws are specified by length, style of head, number, and finish. Length of

flat head screws is measured over all and round head screws from under head to point. A lag screw, drawn as in Fig. 157, is used for fastening machinery to wood supports and for heavy wood constructions when a bolt cannot be used. It is similar to a machine bolt but has wood screw threads. The head may be either square or hexagonal. Lag screws are specified by diameter and length from under side of head to end of screw.

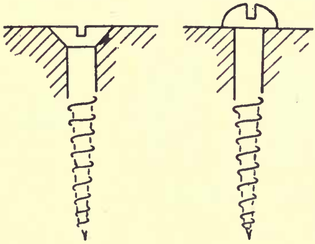


FIG. 156.—Wood screws, as drawn.

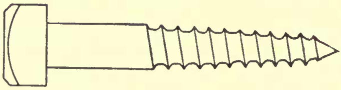


FIG. 157.—Lag screw.

Several other forms of screws and bolts are drawn as in Fig. 158. Screw hooks and screw eyes are specified by diameter and length over all.

79. **Conventional Symbols.**—There are a number of commonly accepted symbols used on drawings. The symbols for representing the cut surfaces of sectional views as given by a committee of the American Society of Mechanical Engineers are shown in Fig. 159. For showing the cross-section of long, uniformly shaped pieces and for "breaking out" parts the representations of Fig. 160 are used.

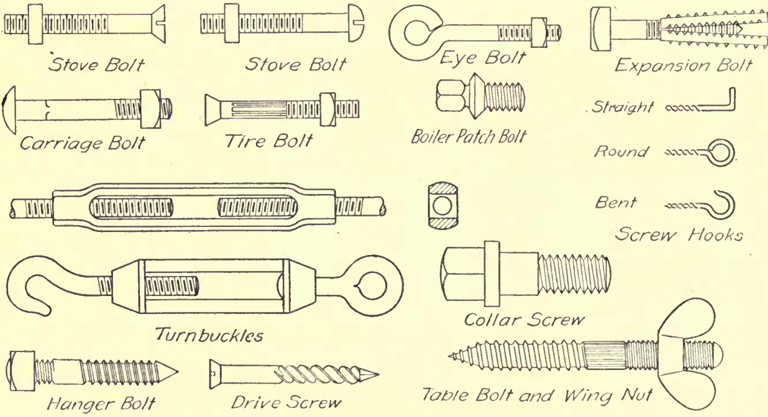


FIG. 158.—Various bolts and screws

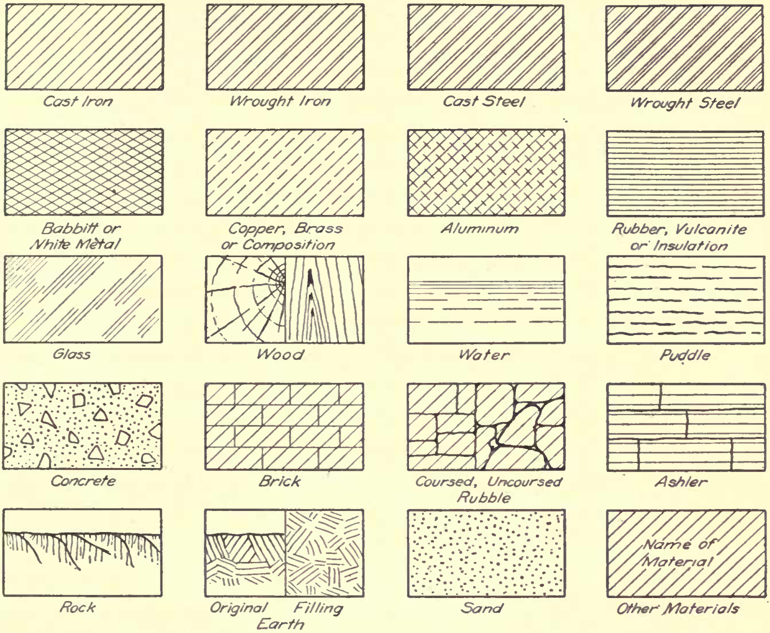


FIG. 159.—Symbols for materials in section (A. S. M. E.).

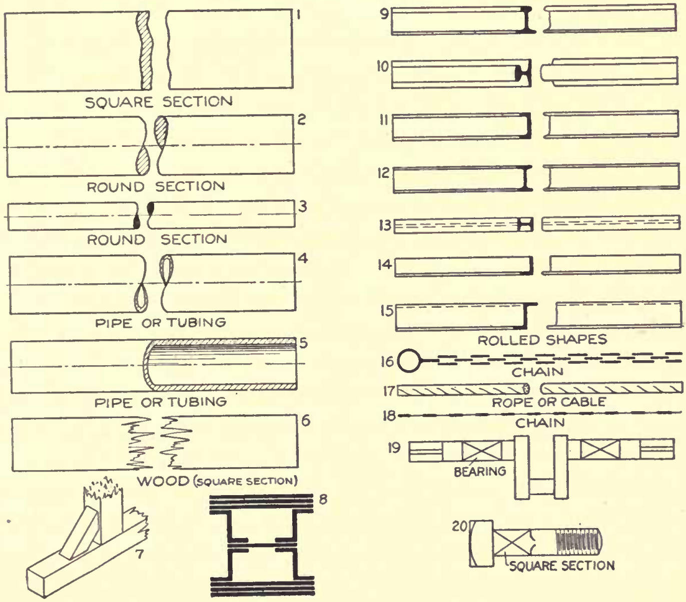
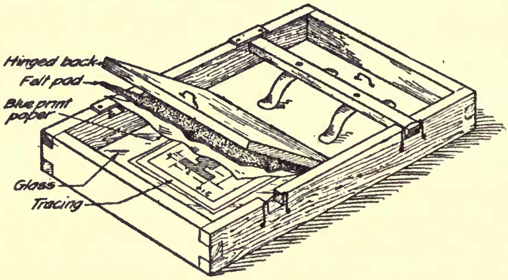


FIG. 160.—Conventional breaks and other symbols.

80. Blueprinting.—Practically all work in shops or on structures is done from blueprints, which are copies made from a tracing, on chemically treated paper, giving white lines on a blue background. As many copies as desired can be made from a single tracing. Blueprints can be made from pencil or ink drawings on tracing cloth, tracing paper or bond paper. The original drawing is never allowed to go into the shop but is kept in the files of the drawing room. Blueprint paper is usually bought ready sensitized and may be had in different degrees of rapidity, when fresh it is of a yellowish green color and an unexposed piece should wash out perfectly white, with age or exposure to light or air it turns to a darker gray blue color, and spoils altogether in a comparatively short time.



Blue-print frame.

81. To Make a Blueprint.—Place the tracing in a blueprint frame with the inked side next to the glass and lay a sheet of blueprint paper with the sensitized side next to the tracing. Put the back of the frame in place and lock it in position so as to hold the tracing and paper. Expose to sunlight or electric light for from 30 seconds to several minutes, depending upon the sensitiveness of the paper. The yellowish green color of the unexposed paper will turn to a grayish color. Take the paper from the frame and wash in a bath of running water for five or ten minutes. This fixes the blue color and washes the lines to a clear white. Hang up until dry. The prints may be improved in color and clearness by dipping in a dilute bath of sodium bichromate or hydrogen peroxide and rinsing after taking from the original bath. Changes may be made on blueprints by using any alkaline solution in a writing or drawing pen.

Nineteen Nevers

1. **Never** begin work without wiping off table and instruments.
2. **Never** use the scale as a ruler.
3. **Never** use a dull lead pencil.
4. **Never** draw with the lower edge of the T-square.
5. **Never** put either end of a pencil into the mouth.
6. **Never** take dimensions by setting the dividers on the scale.
7. **Never** run backward over a line either with pencil or pen.
8. **Never** try to use the same thumb tack holes when putting paper down a second time.
9. **Never** use a blotter on inked lines.
10. **Never** leave the ink bottle uncorked.
11. **Never** dilute ink with water. If too thick throw it away.
12. **Never** put a writing pen which has been used in ordinary writing ink, into the drawing-ink bottle.
13. **Never** scrub a drawing all over with the eraser after finishing. It takes the life out of the inked lines.
14. **Never** cut paper with a knife and the edge of the T-square as a guide.
15. **Never** use the T-square as a hammer.
16. **Never** jab the dividers into the drawing board.
17. **Never** use the dividers as reamers or pincers or picks.
18. **Never** put instruments away without cleaning. This applies with particular force to pens.
19. **Never** put bow instruments away without opening to relieve the spring.

CHAPTER VI

DRAFTING, MECHANICAL AND ARCHITECTURAL

82. **Working Drawings.**—A working drawing is a drawing which completely describes the shape and size, and gives specifications for the kinds of material, methods of finish, accuracy required and all other information necessary for making a single part, or a complete machine or structure.

Working drawings are based upon orthographic projection, Chapter III, with dimensions and notes added as described in Chapters IV and V. A working drawing may be made for a separate piece, for a group of pieces, or for a completely assembled construction.

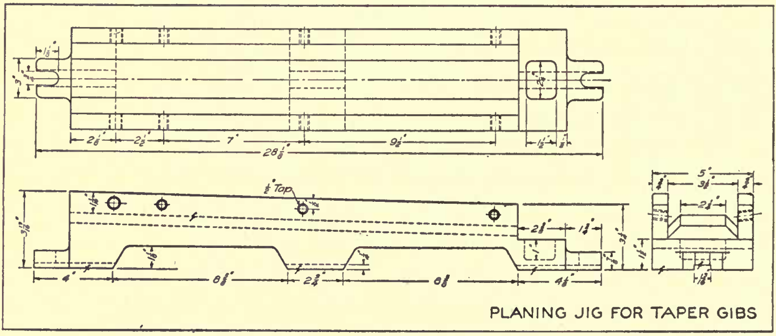


FIG. 161.—A detail drawing.

83. **Detail Drawings.**—A drawing of a single piece which gives all the information necessary for making it is called a detail drawing. This is the simplest form of working drawing and must be a very complete and accurate description of the piece, with carefully selected views and well-located dimensions. Sometimes separate detail drawings are made for the use of different workmen, as the patternmaker, blacksmith, machinist, etc. Such drawings have only the dimensions and information needed by the workmen for whom the drawing is made.

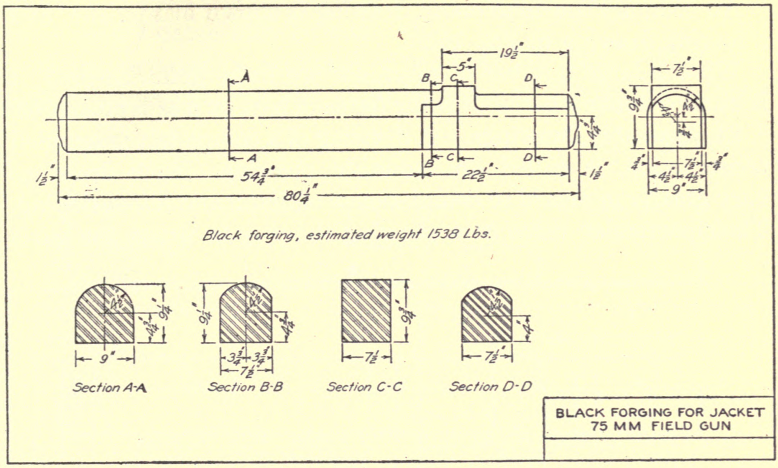


FIG. 162.—A forging drawing.

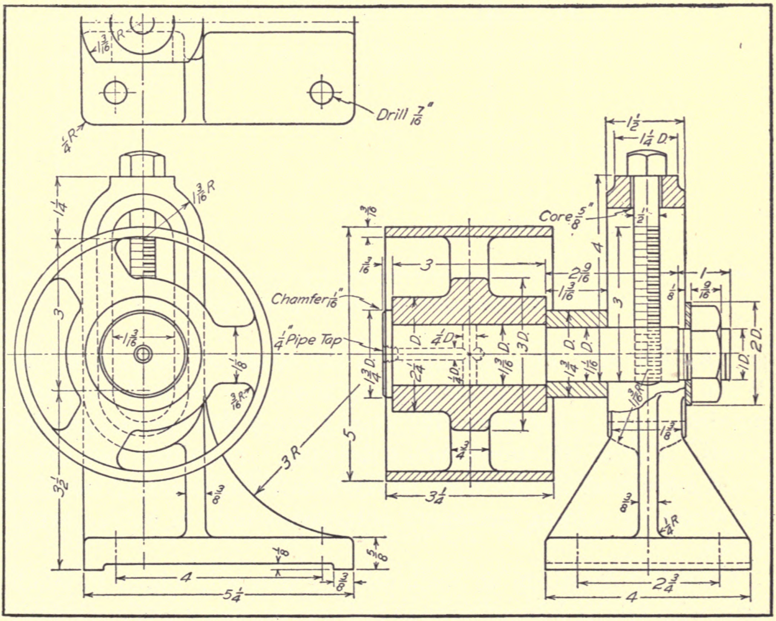


FIG. 163.—An assembly working drawing.

An ordinary machine detail drawing is shown in Fig. 161, and a forging drawing in Fig. 162.

When a large number of machines are to be manufactured, it is usual to make a detail drawing for each part on a separate sheet.

84. Assembly Drawings.—A drawing of a completely assembled construction is called an assembly drawing. Such drawings vary greatly in regard to completeness of detail and dimensioning. Their particular value is in showing the way in which the parts

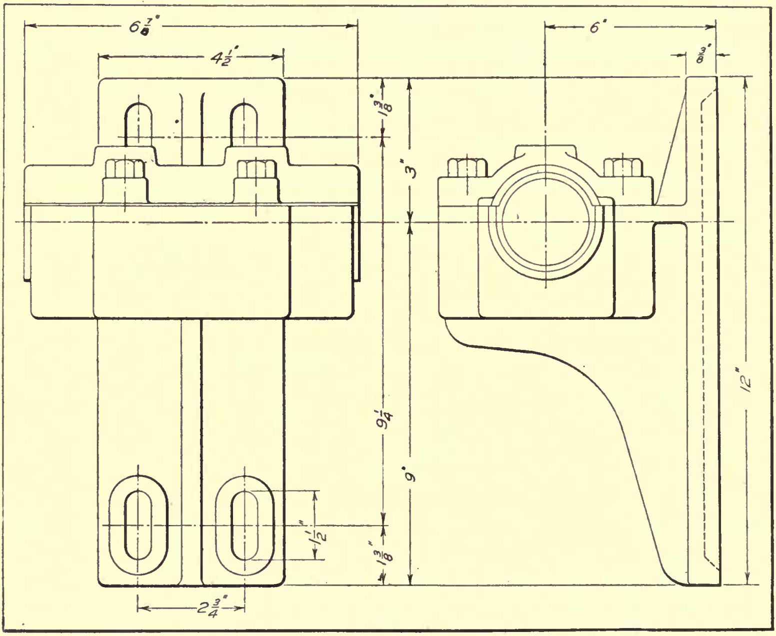


FIG. 164.—An outline assembly drawing, with shade lines.

go together and the appearance of the construction as a whole. When complete information is given they may be used for working drawings. This is possible when there is little or no complex detail. Figure 163 shows such a drawing. Furniture and other wood constructions can often be represented in assembly working drawings by adding necessary enlarged details or extra partial views.

Assembly drawings of machines are generally made to small scale with selected dimensions to tell over-all distances, important center-to-center distances and location dimensions. All or almost all hidden lines may be left out and if to very small scale unnecessary detail may be omitted.

Either exterior or sectional views may be used. When the general appearance is the main purpose of the drawing, only

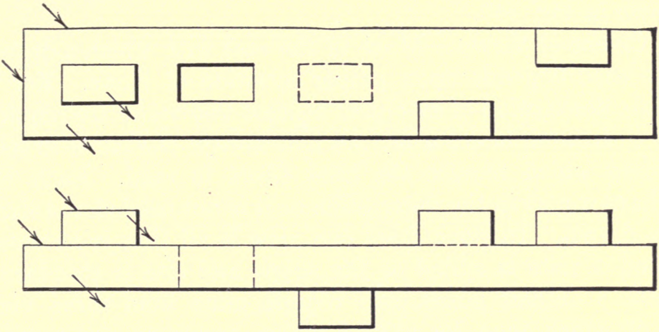


FIG. 165.—Conventional shade lines.

one view or two views may be used, sometimes with "shade lines" to bring out the shape more clearly, Fig. 164.

85. **Shade Lines.**—When shade lines are used the simple conventional method is to shade the lower and right-hand lines of each part in all views. Assume parallel rays of light at

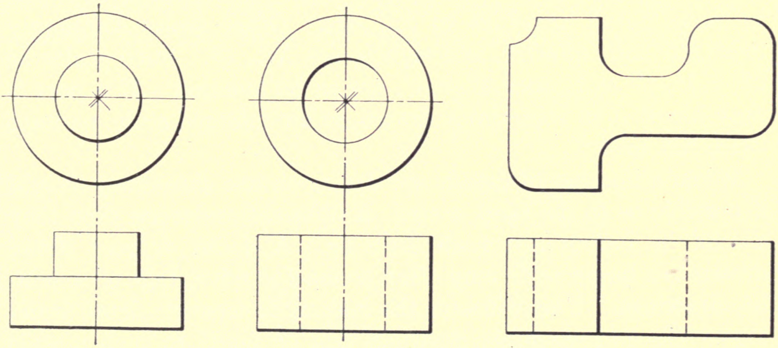


FIG. 166.—Shade lines on circles and arcs.

an angle of 45° in the direction shown in Fig. 165. Each view is considered by itself. Edges over which the rays of light pass are shaded. Dotted lines are never shaded. Light lines are made very fine. Shade lines are made at least three times the width of fine lines. The extra thickness of line is added outside the boundaries of the view.

A circle is shaded by moving the center of the compasses on a 45° line toward the lower right-hand corner a distance equal to the thickness of the shade line, and drawing a tangent semi-circle as shown in Fig. 166.

86. **Choice of Views.**—Much of the ease with which a drawing can be used depends upon proper selection of views. For the complete description of an object at least two views are required. While a drawing is not a picture it is always advisable to select the views which require the least effort to read. Each view must have a part in the description or it is not needed and should not be drawn. In some cases one view is all that is necessary, provided a note is added or the shape and size is standard or evident. Complex pieces may require more than three views, some of which may be partial views, auxiliary and sectional views. The reason for making the drawing must always be kept in mind when a question arises. The final test of the value of a drawing is its clearness and exactness in giving the complete information necessary for making the piece.

87. **Choice of Scale.**—The choice of scale for a detail drawing is governed by three things—the size necessary for showing all details clearly, the size necessary for carrying all dimensions without crowding and the size of paper used. It is always desirable to make detail drawings to full size. Other scales commonly used are half, quarter, and eighth, see Art. 13. Such scales as $2'' = 1'$, $4'' = 1'$, and $9'' = 1'$, are to be avoided. If a part is very small it is sometimes drawn to an enlarged scale, perhaps twice full size.

When a number of details are drawn on one sheet they should if possible be to the same scale. If different scales are used they should be noted near each drawing. A detail or part detail drawn to a larger scale may often be used to advantage on assembly drawings. This will save the making of separate detail drawings. General assembly drawings can be made to such a scale as will show the desired amount of detail and work up well on the size of paper used. Sheet-metal pattern drawings for practical use are always made full size, although practice models may be constructed from small scale layouts.

88. **Grouping and Placing Parts.**—When a number of details are used for one machine only, they are often grouped on a single

sheet or set of sheets. A convenient arrangement is to group the forging details together, the brass details together and similarly for other materials. In general it is well to represent parts in the position which they will have in the assembled machine, with related parts near each other. Long pieces, however, such

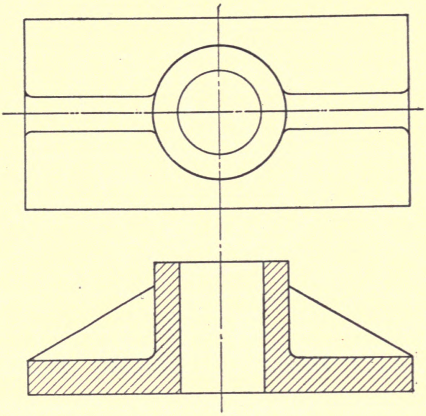


FIG. 167.—Rib in a section.

as shafts, bolts, etc., are drawn with their long dimensions horizontal.

89. **Conventional Representation.**—The principles upon which the description of shape by means of views is based have been explained and they form the basis for working drawings. In

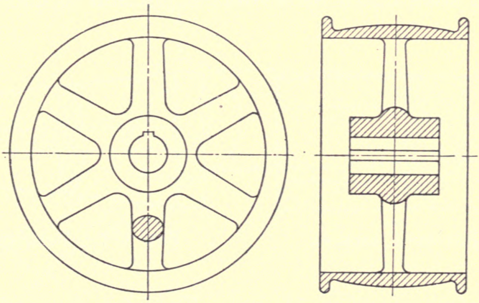


FIG. 168.—Pulley in section.

the actual use of mechanical drawing it has been found desirable under certain conditions to violate the rules previously given.

90. **Sections Through Ribs, Arms, Etc.**—When the plane of a section passes through a rib or pulley arm the drawing is made

as in Figs. 167 and 168, where the plane is thought of as being just in front of the rib or arm. A true section would give the idea of a very heavy solid piece. When a section or elevation of a drilled flange is drawn, the holes are shown at their true distance from the center regardless of where they would project, Fig. 169.

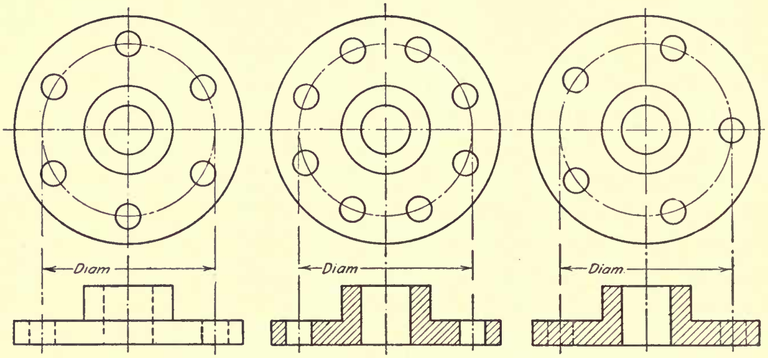


FIG. 169.—Flanges, in elevation and section.

A revolved or *turned* section is sometimes inserted in a view to show the shape, as in Figs. 170 and 171.

91. **Rule of Contour.**—*In general preserve the characteristic contour of an object.* Sections or elevations of symmetrical pieces are sometimes hard to read when drawn in true projection. It is usual in such cases to revolve a portion of the object until

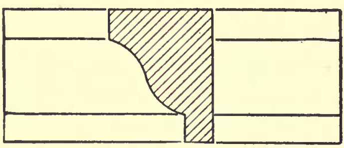


FIG. 170.—Revolved section.

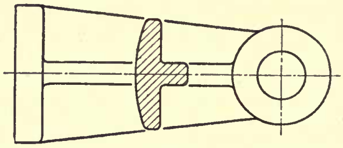


FIG. 171.—Revolved section.

the characteristic contour shows. This has been done in Fig. 172, which is the correct method of drawing the object shown.

It is always desirable to show true distances even though the views do not project. This may be illustrated by bent levers and similar pieces which are represented by revolved or stretched out views as in Fig. 173

92. **Gears.**—If two wheels are in contact and keyed to parallel shafts, both will revolve if either one of the shafts is turned, Fig. 174. If the driven shaft turns hard the wheel will slip. To

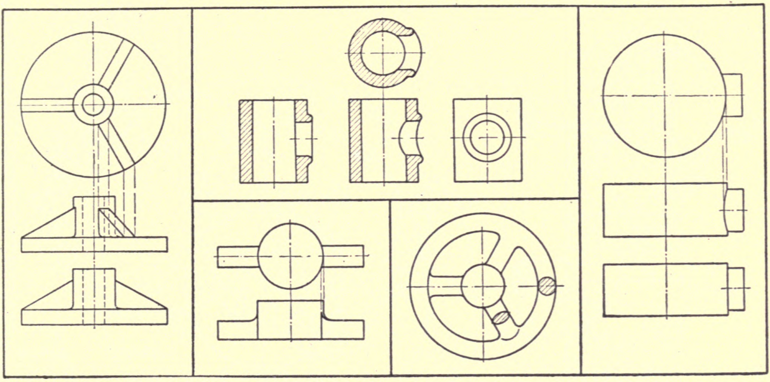


Fig. 172.—The "rule of contour."

prevent slipping, teeth are added to the wheels. The shape of these teeth is such that the same kind of motion as with the rolling wheels is obtained. Gearing is a separate study but the student should know how to show a gear on a drawing. Spur

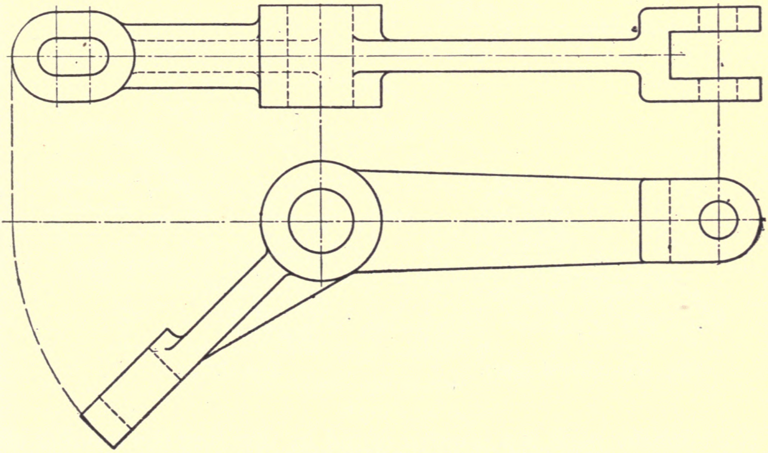


Fig. 173.—A stretched out view.

gears and bevel gears, Figs. 175 and 176 are the most common forms. A small gear used with a large one, or with a "rack" is called a "pinion." The parts of gear teeth have names as given in Fig. 177. There are three diameters and two kinds of pitch to remember. The three diameters are indicated on the figure. The *circular pitch* is the distance from a point on one tooth to the same point on the next tooth, measured along the pitch circle.

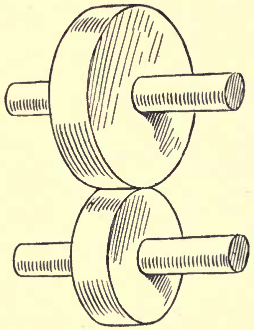


Fig. 174.

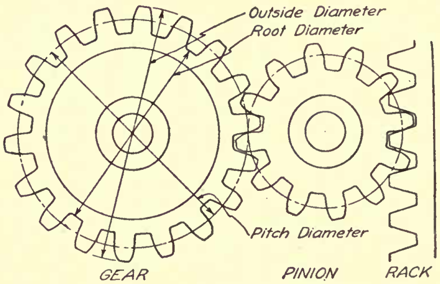


Fig. 175.—Spur gears.

Let N = number of teeth
D = diameter of pitch circle
P_c = circular pitch
P = diameter pitch

$$\text{Addendum} = \frac{1}{P}$$

$$\text{Dedendum} = \frac{1}{P} + \frac{0.157}{P}$$

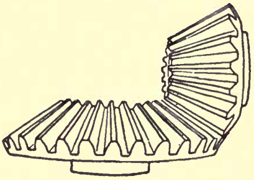


Fig. 176.—Bevel gears.

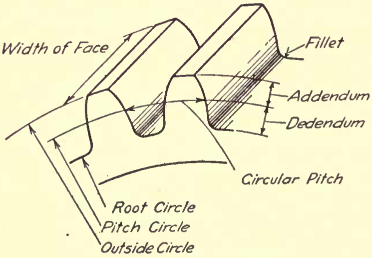


Fig. 177.

The *diameter pitch* is a number found by dividing the number of teeth by the diameter of the pitch circle.

It is not necessary to draw the actual teeth when making working drawings of gears. Cut spur and bevel gears are drawn as in Figs. 178 and 179, which show "gear blanks" with notes to give required information. The representations of Fig. 180 are used on assembly drawings.

93. **Cams.**—A cam is a machine element used to obtain an irregular or special motion not easily obtained by other means.

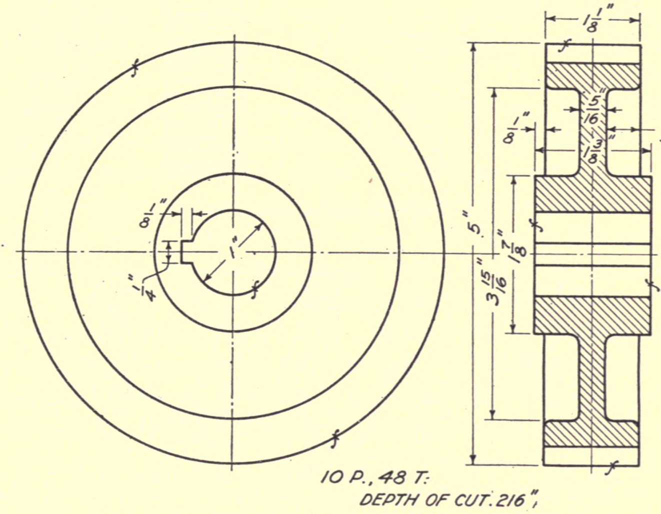


FIG. 178.—Working drawing of a cut spur gear.

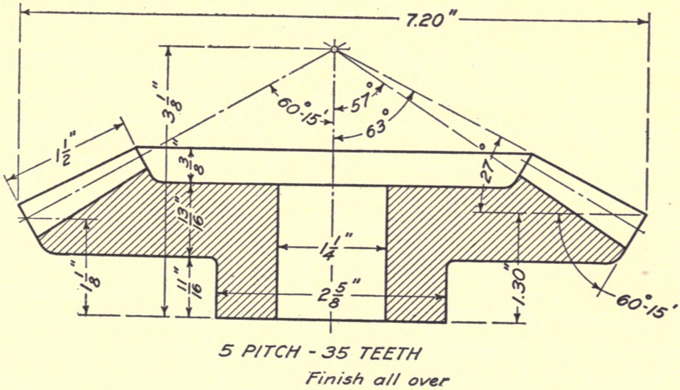


FIG. 179.—Working drawing of a cut bevel gear.

The shape of a cam is derived from the motion required of it. One form of plate cam is shown in Fig. 181. A cylindrical cam is shown in Fig. 182.

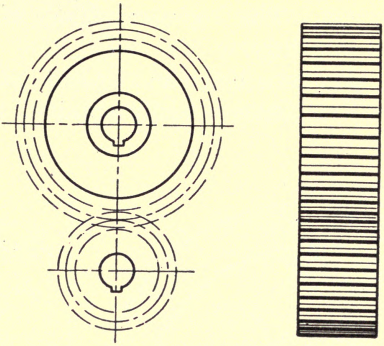


Fig. 180.—Gears in elevation.

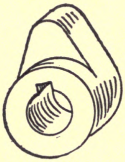


Fig. 181.

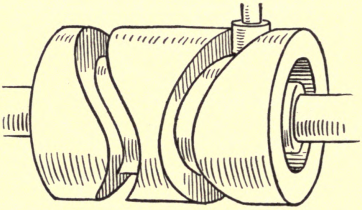


Fig. 182.—A cylindrical cam.

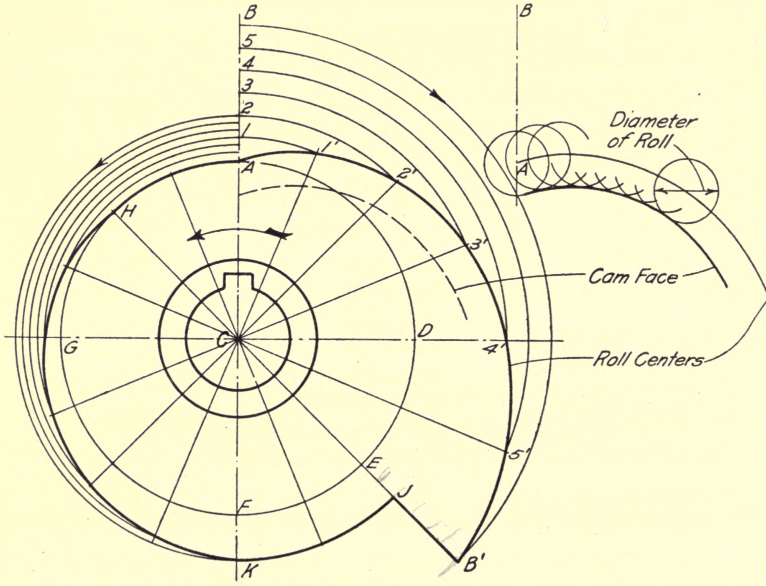


Fig. 183.—Drawing of plate cam.

To find the cam outline, Fig. 183, given point C, the center of the shaft and point A, the lowest position of the center of the roller. It is required to raise the center of the roller with uniform motion during three-eighths of a revolution of the uniformly revolving shaft, allow it to drop two-thirds of the way down instantly, remain at rest for one-eighth of a revolution, drop uniformly during three-eighths of a revolution, and remain at rest for the remaining one-eighth of a revolution.

Divide the rise into a number of equal parts. Divide the arc ADE into the same number of equal spaces as there are spaces in the rise, and draw radial lines. With C as a center and radius $C1$ draw an arc intersecting the first radial line at $1'$. In the same way locate points $2'$, $3'$, etc., and draw a smooth curve through them. If the cam is revolved in the direction of the arrow, it will raise the roller with the desired motion. Draw $B'J$ equal to two-thirds of AB. Draw arc JK with radius CJ. Divide $A2$ into six equal parts and arc FGH into six equal parts. Circle arcs drawn as shown will locate points on the cam outline. Draw arc HA with radius CH to complete the cam. This outline is for the center of the roller, allowance for which may be made by drawing the roller in its successive positions and then drawing the tangent curve as shown in the auxiliary figure.

Architectural Drawing

94. **Architectural Drawing.**—All kinds of technical drawing are based upon the same general principles. Architectural drawings have to do with the representation and specification of buildings. The drawing of a building has to be made to a very small scale as compared with a machine drawing, which makes it necessary to use conventional symbols for the different parts. They differ also in that only one view usually is drawn on a sheet.

There are three general classes of architectural drawings:

1. Preliminary sketches: These are freehand studies of the arrangement of rooms, first made as very small "thumb-nail" sketches without using the scale, and when a satisfactory scheme is decided upon, worked up in larger freehand sketches to approximate scale.

2. Display and competitive drawings: These are more or less elaborate preliminary drawings of a proposed building, often

including a perspective, and are rendered in water-color, pen-and-ink, or pencil to make them legible and attractive.

3. Working drawings: These form the most important class, and include *plans, elevations, sections* and *detail drawings* which when read with the *specifications* for details of materials and

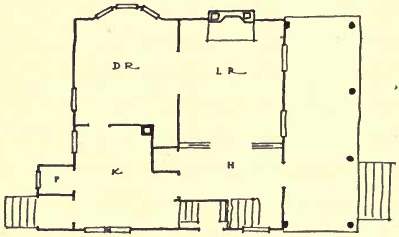


Fig. 184.—Sketch plan.

finish, give the working information for the erection of the building.

95. **Plans.**—A floor plan is a horizontal section taken above the floor represented. It shows all the walls with their doors and windows, gives the location of lighting, heating and plumbing

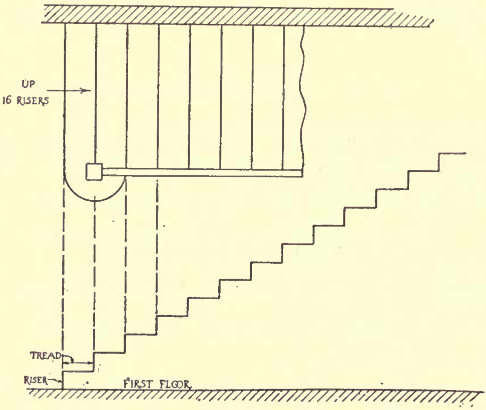


Fig. 185.

outlets, and shows part of the stairways starting up or down from the floor. A plan is always laid out with the front of the building at the bottom of the sheet. Ordinary house plans are drawn to the scale of $\frac{1}{4}'' = 1'$.

Fig. 184 is a freehand sketch plan of the first floor of a house.

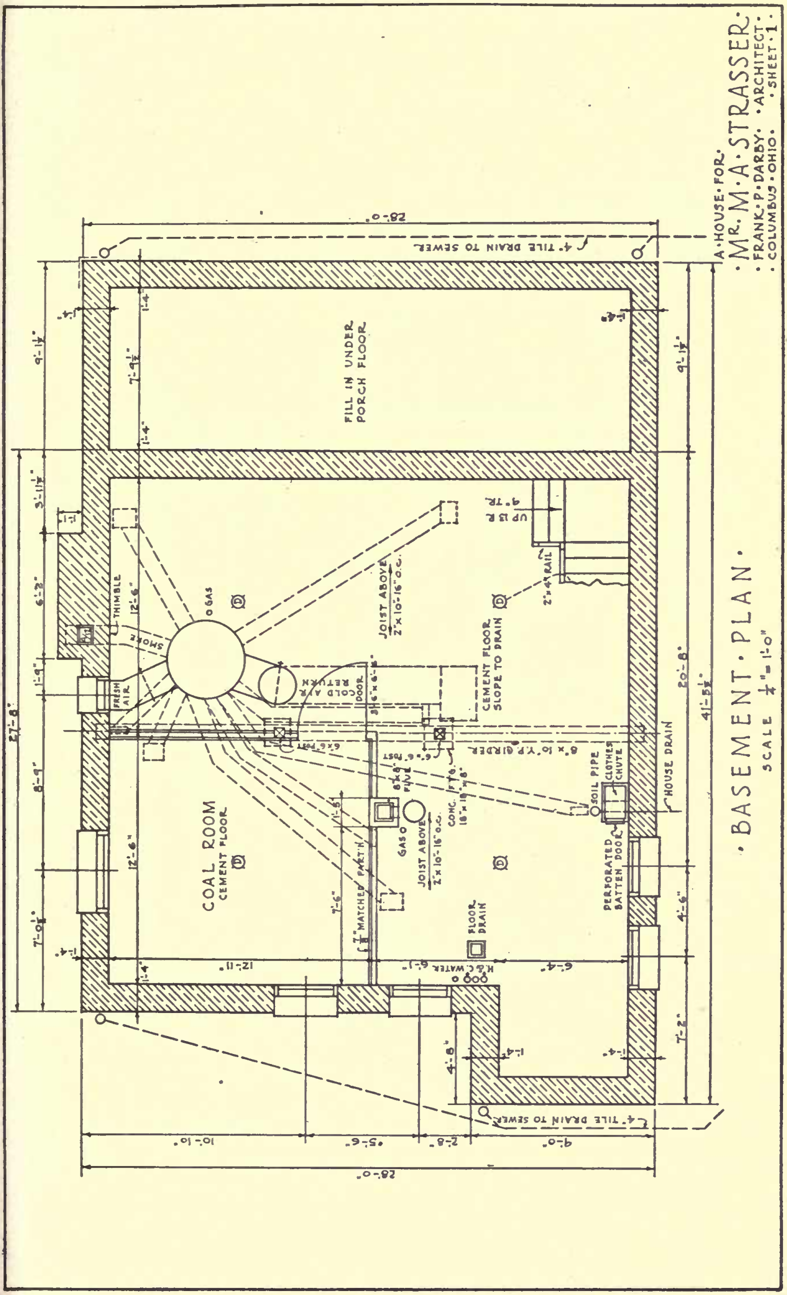


FIG. 186.—Basement plan.

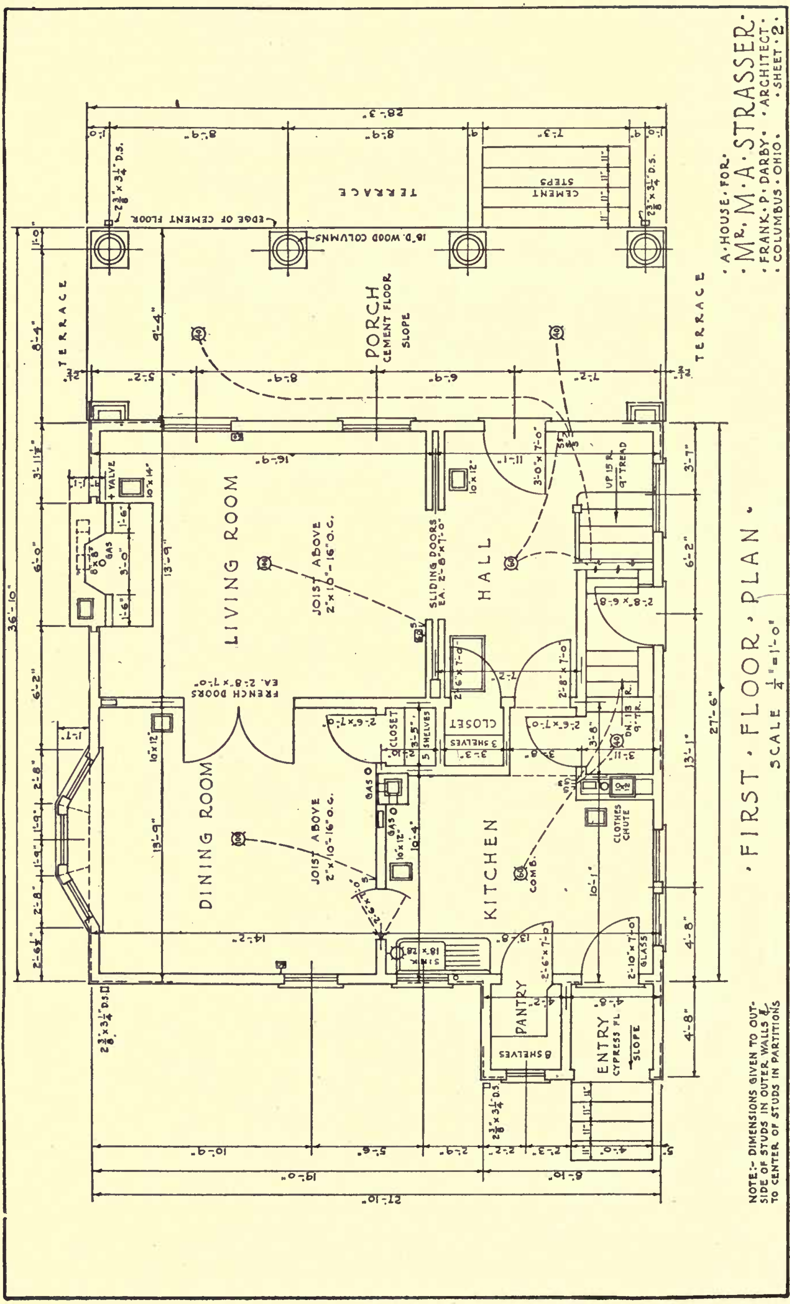


FIG. 187.—First floor plan.

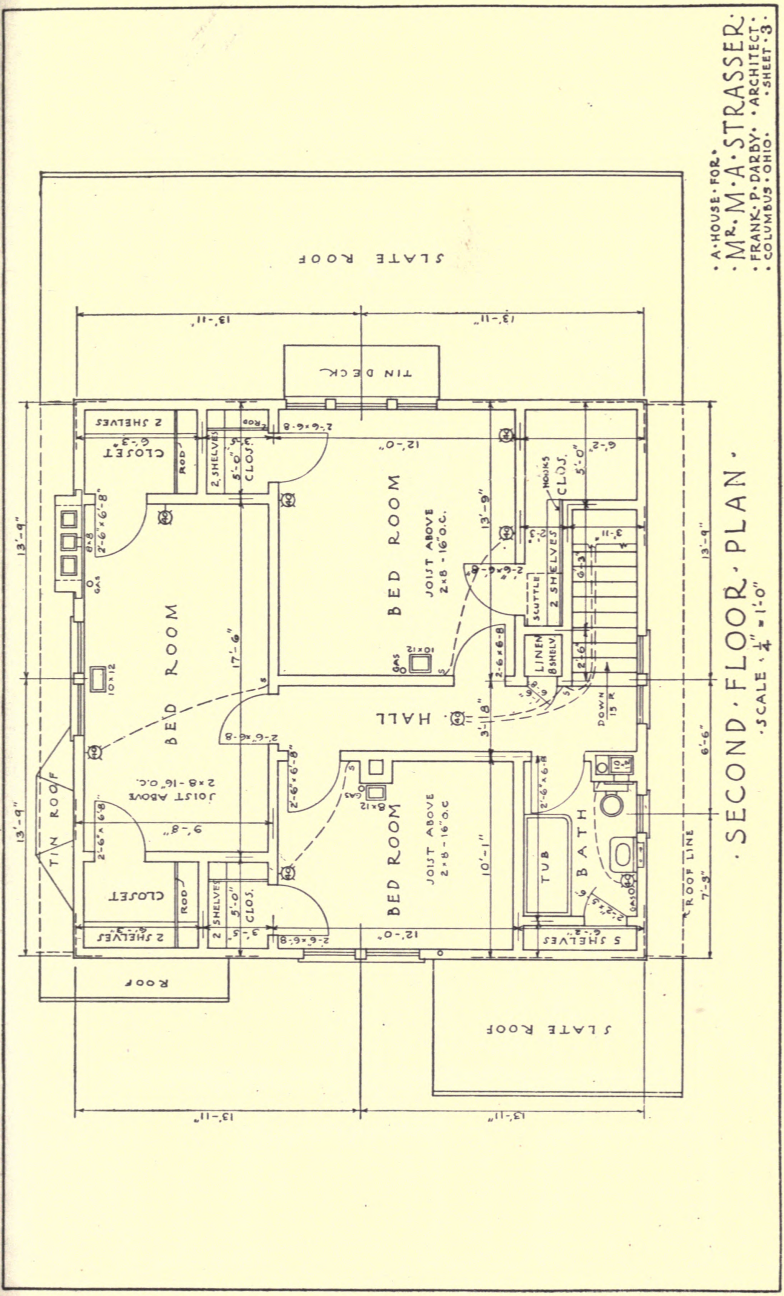


FIG. 188.—Second floor plan.

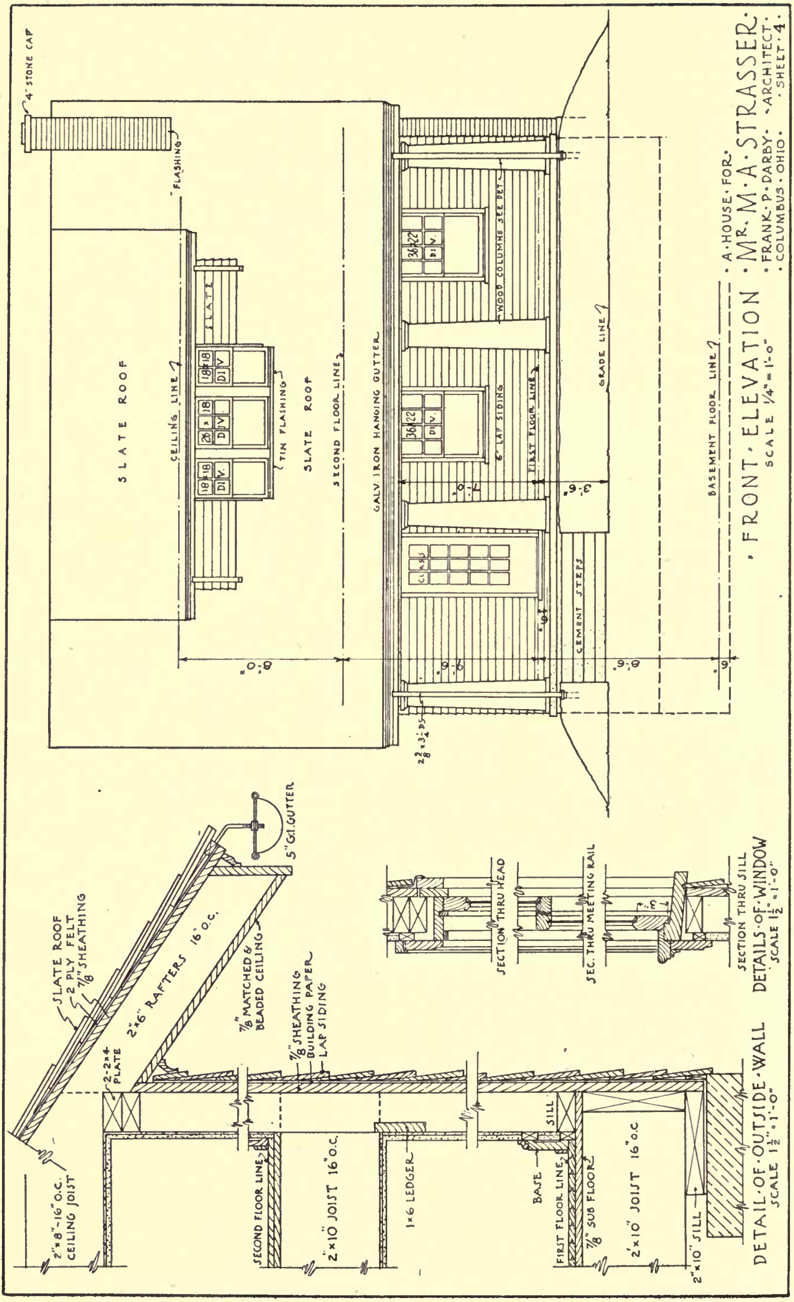


FIG. 189.—Front elevation.

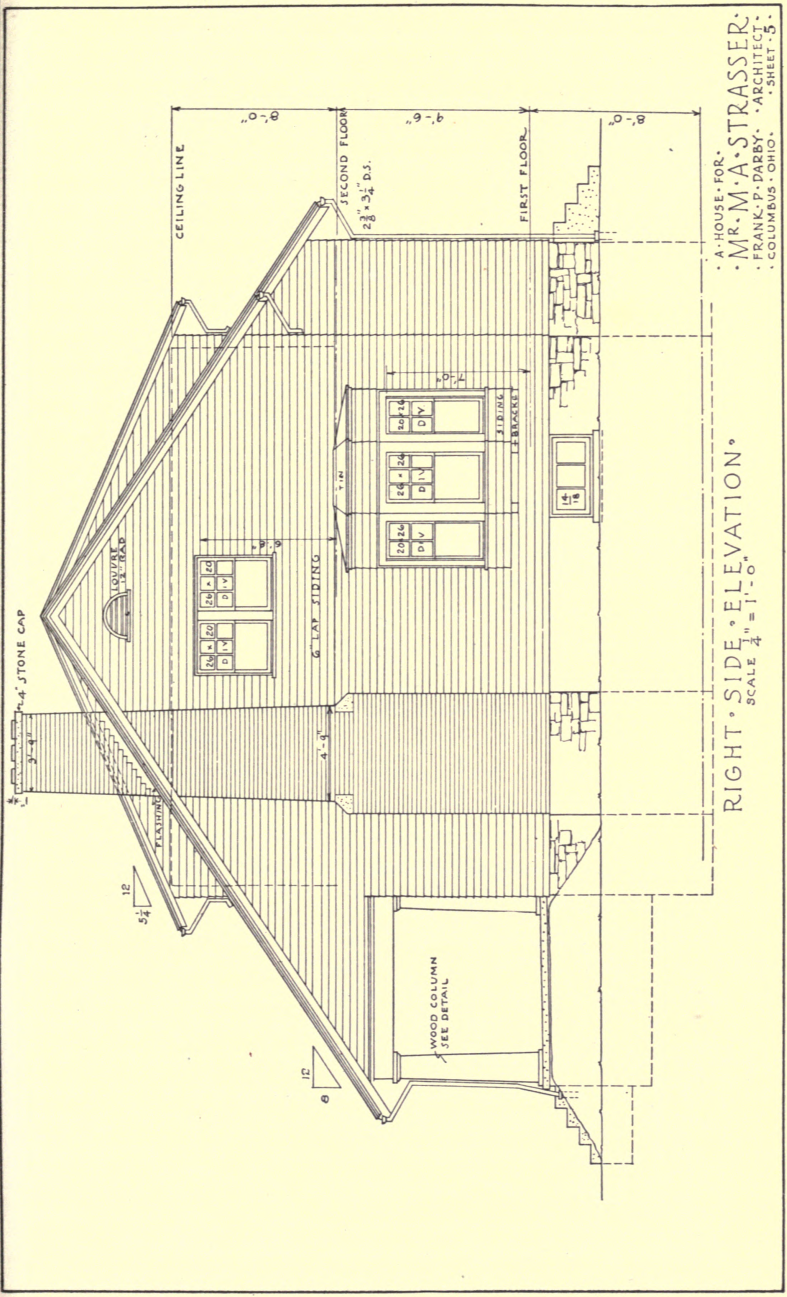


Fig. 190.—Side elevation.

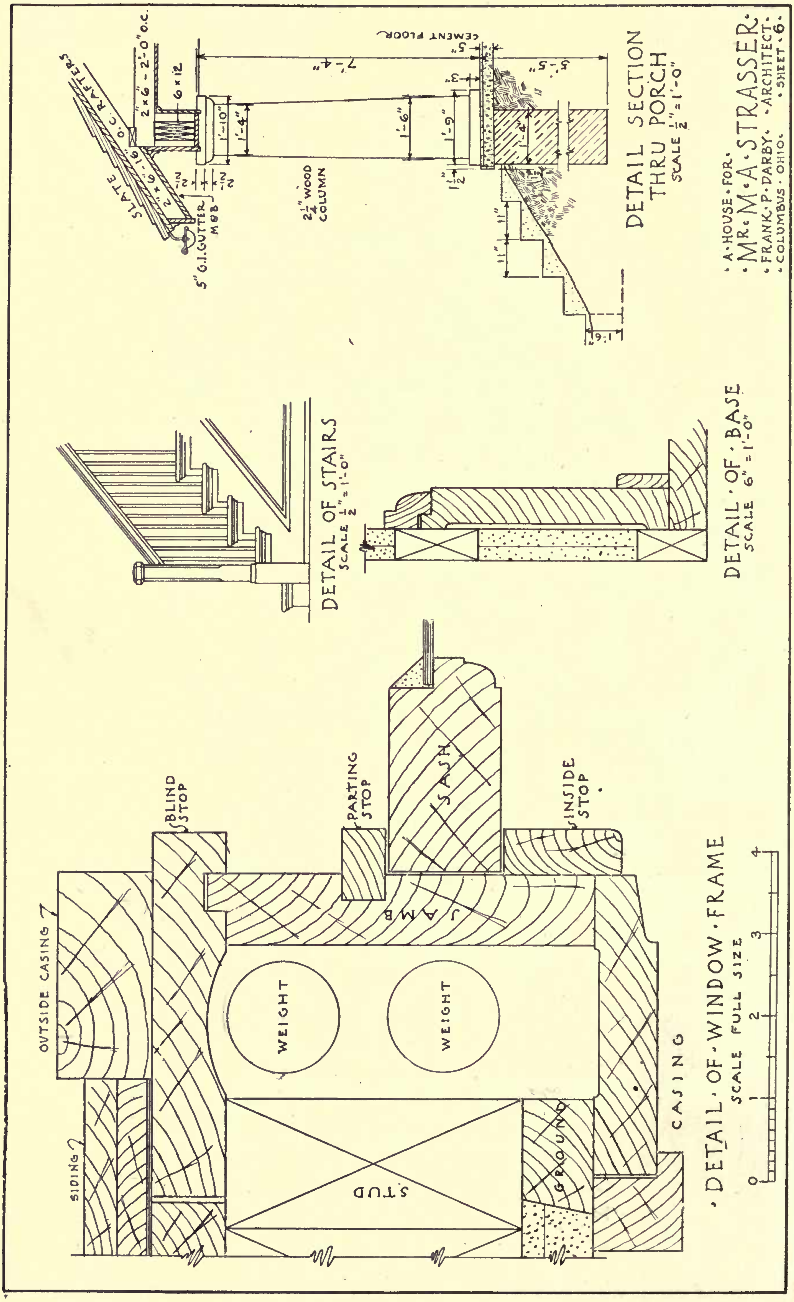


Fig. 191.—Details.

With this as a basis it is required to draw the plans of the house. The first floor as shown in Fig. 187, is drawn first, then the second floor and basement plans. Draw a horizontal line representing the outside face of the front wall. Complete the exterior walls and interior partitions. Frame walls are drawn 6″ thick.. Locate doors and windows and draw them with the conventional symbols as shown.

96. In drawing the stairway first make a diagram to find the number of steps and space required. The rise, or height from one step to the next, is from 6½″ to 7½″ and the tread so that the sum of rise and tread is about 17½ inches. On the plan the lines drawn represent the edges of the risers and are drawn as far apart as the width of the tread, as shown in Fig. 185. The entire flight is not drawn on the plan but is broken so as to show what is on the floor under it. The other end is shown on the plan of the floor above.

97. The second floor for a two story house is best planned by laying a piece of tracing paper over the first floor plan. Trace the exterior walls and locate stairways and chimney flues. The interior partition walls need not be continuous with the first floor. See that closets are provided for every room. Note that the second floor, Fig. 188, is for a cottage type and account must be taken of headroom under the roof.

The basement plan is shown in Fig. 186. It should be completely dimensioned as the construction of the house is started with this plan. Windows should be under the first floor windows. The furnace should be near the center of the house.

98. **Elevations and Sections.**—A front and one side elevation are shown in Figs. 189 and 190. In a complete set of plans the other side and rear elevations should be drawn. In drawing elevations start with the grade line as a base line. The figures show the information usually given on elevations. A wall section to a larger scale is shown in Fig. 189.

99. **Details.**—In addition to the quarter-inch scale drawings, larger scale drawings are made of such parts as cannot be shown with sufficient detail on the small scale drawings. Figure 191 is a typical sheet of details. As the building progresses the architect furnishes full size drawings made with soft pencil, for millwork and other details.

100. **Symbols.**—The usual symbols for doors, windows, fireplaces, etc., have been shown on the plans. Different building

materials are indicated in section as shown in Fig. 192, and some of the standard wiring and lighting symbols in Fig. 193.

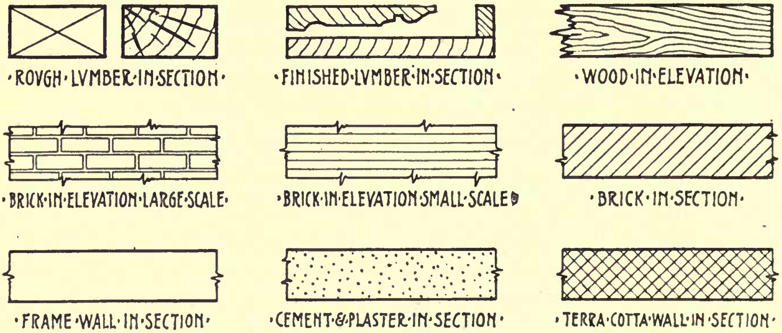


Fig. 192.—Symbols for building materials.

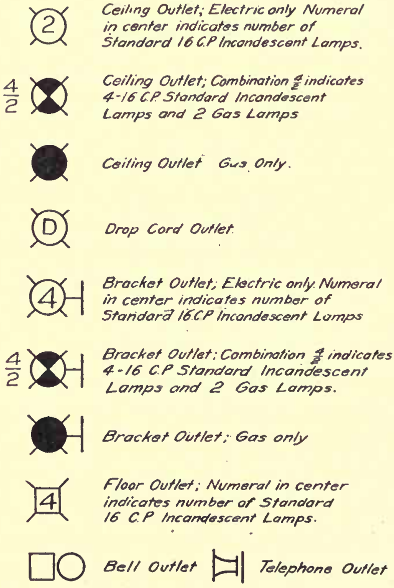


Fig. 193.—Symbols.

Lettering on architectural drawings is usually done in light single-stroke Roman as shown in Fig. 36.

CHAPTER VII

Graphic Solutions and Sheet-metal Drafting

101. Our study of drawing in the preceding chapters has considered two main purposes—shape and size description of space constructions. There are, however, many other ways of using drawing as a means of solving the problems which arise in industrial work. Graphic solutions require a working knowledge of some geometrical constructions as the basis for the "laying out" of wood and metal work as well as for sheet-metal drafting.

102. **Lines.**—A line may be divided into two equal parts by measurement with the scale, by trial with the dividers, or geometrically as in Fig. 194. Given the line AB. Draw arcs with A

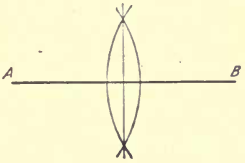


Fig. 194.—To bisect a line.

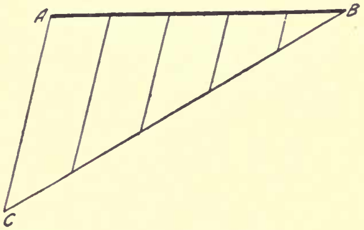


Fig. 195.—To divide a line.

and B as centers and a radius greater than one-half AB. A line drawn through the intersections of the arcs will be perpendicular to AB and will divide it into two equal parts, or "bisect" it.

103. A line may be divided into any number of equal parts by trial with the dividers, as described in Art. 14, or by using the scale as described in Art. 15. Another way is by the geometrical method of Fig. 195. To divide the line AB into *five* equal parts. From B draw another line at an angle. On it step off *five* equal spaces of any convenient length. Connect the last point (c) with A. Through the other points draw lines parallel to CA, using triangle and T-square as shown in Fig. 9.

104. Sometimes it is necessary to reduce or enlarge linear dimensions from one size to another. A special scale for this purpose may be made geometrically on the well-known theorems of proportional triangles. Draw two parallel lines at a convenient distance apart, one, AB, to the given scale and the other,

CD, to the desired length, either shorter, Fig. 196, or longer, Fig. 197. Lines through *AC* and *BD* will intersect at point *O*. Draw lines from point *O* through each division of the given scale *AB*. These will divide *CD* into proportional spaces, thus making a new scale, Figs. 198 and 199, from which the desired measurements can be taken.

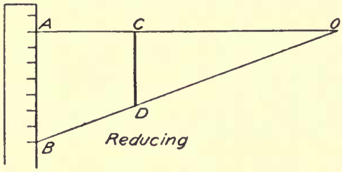


FIG. 196.

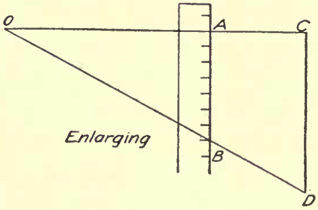


FIG. 197.

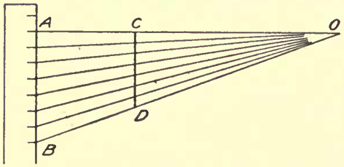


FIG. 198.

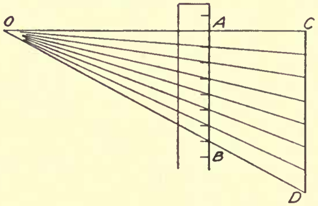


FIG. 199.

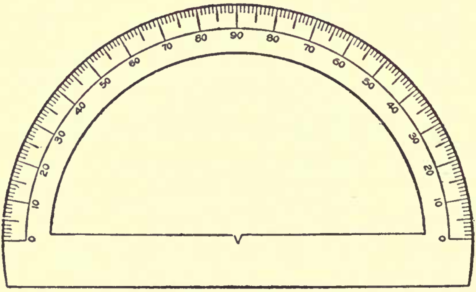


FIG. 200.—A protractor.

105. **Angles.**—When two lines meet at a point they form an angle. Lines which are perpendicular to each other form right angles. If a right angle is divided into 90 equal parts, each part is called a degree. A circle contains 360 degrees. An angle is measured in degrees.

In Art. 7 we learned that angles varying by 15 degrees may be constructed with the 30–60 and 45° triangles.

For measuring and laying out angles an instrument called a protractor is used. The usual form is semicircular as shown in Fig. 200.

106. An angle of 90° may be readily bisected by using the 45° triangle or trisected with the 30–60° triangle. To bisect any angle, Fig. 201. With O as a center and any radius, draw an arc cutting the sides at A and B. With A and B as centers and any radius greater than one-half AB, draw intersecting arcs. A line through this intersection and point O will bisect the angle.

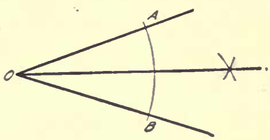


Fig. 201.—To bisect an angle.

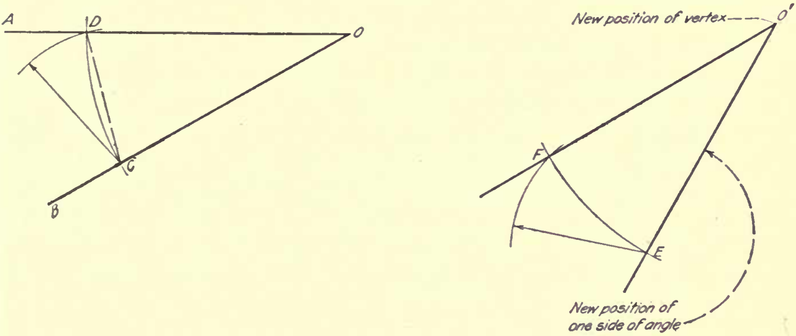


Fig. 202.—To copy or transfer an angle.

107. To copy an angle, Fig. 202. Given the angle AOB. Draw an arc with O as a center and any convenient radius. With the same radius and center at new position O', draw another arc. With radius equal to chord DC and center at E draw an arc giving an intersection at F through which a line may be drawn to the vertex to complete the angle in its new position.

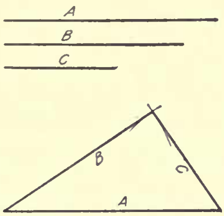


Fig. 203.—To construct a triangle.

108. **Triangles.**—To construct a triangle, having given the three sides, Fig. 203. Given the lengths A, B and C. Draw one side A in the desired position. With its ends as centers and radii B and C draw two intersecting arcs as shown. An *equilateral* triangle has three equal sides. It may be constructed by drawing one side in the desired

position and drawing intersecting arcs with the ends as centers and the length of the side as a radius, Fig. 204. Another method is to draw 60° lines from each end of the base, using the 30–60° triangle.

An *isosceles* triangle has two equal sides, Fig. 205. It may be constructed by locating the base and drawing intersecting arcs from each end, using one of the equal sides as a radius.

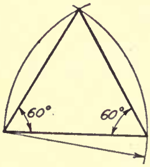


Fig. 204.—Equilateral triangle.

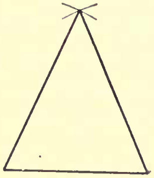


Fig. 205.—Isosceles triangle.

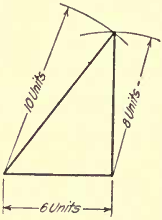


Fig. 206.—Right triangle.

A *right* triangle is one which has a right angle. A right triangle may be easily constructed by the "6–8–10 method." Draw a line 6 units long. From one end draw an arc with a radius 10 units long and from the other end with a radius 8 units long. Complete as shown in Fig. 206.

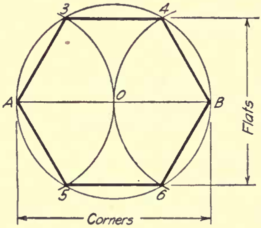


Fig. 207.—Hexagon.

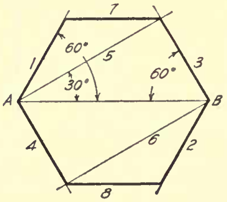


Fig. 208.—Hexagon.

109. **The Hexagon.**—The regular hexagon can be drawn in a number of ways and has already been explained in Art. 73. If the distance across corners *AB* is given, draw a circle with *AB* as a diameter, Fig. 207. With *A* and *B* as centers and the same radius draw arcs and connect points. A hexagon may be constructed directly on line *AB*, without using the compasses, by drawing lines with the 30–60° triangle in the order shown in Fig. 208.

110. **The Octagon.**—To draw an octagon, first draw a square, Fig. 209. Draw the diagonals of the square. With the corners as centers and a radius of half a diagonal draw arcs cutting the sides of the square, and connect these points.

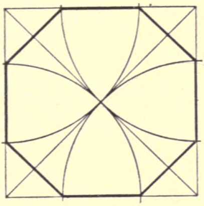


FIG. 209.—Octagon.

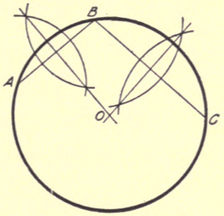


FIG. 210.—Circle.

111. **Arcs and Tangents.**—A circle may be drawn through any three points which do not lie in a straight line. To draw a circle through points *A*, *B* and *C*, Fig. 210. Draw lines *AB* and *BC*. Using the method of Art. 102 bisect these lines. Where the bisectors cross at *O* will be the center for the required circle for which *OA*, *OB* and *OC* are radii.

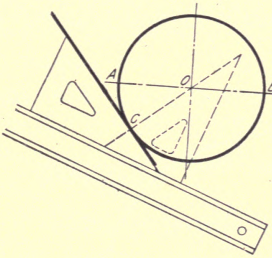


FIG. 211.—To draw a tangent.

112. To draw a tangent to a circle at a given point, Fig. 211. Arrange a triangle in combination with the T-square (or another triangle) so that its hypotenuse passes through center *O* and point *C*. Holding the T-square firmly in place, turn the triangle about its square corner, move it until the hypotenuse passes through *C*, and draw the tangent.

113. To draw an arc tangent to two lines, Figs. 212 and 213. Given two lines *AB* and *CD* and radius *R*. Draw lines parallel to *AB* and *CD* at a distance *R* from them. The intersection of

these lines will be the center of the required arc. The points of tangency are found by drawing a line through the center of the arc and perpendicular to the tangent lines.

114. To draw an arc tangent to two lines at right angles, Fig. 214. This case frequently occurs in drawing fillets and

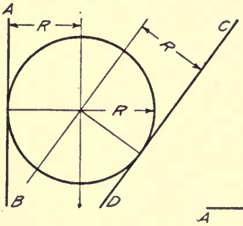


FIG 212.

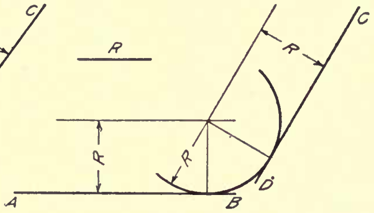


FIG. 213.

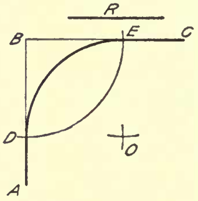


FIG 214.

To draw an arc tangent to two lines.

rounds. It is desired to round the corner *ABC* with an arc having a radius equal to *R*. With *B* as a center and radius *R*, draw an arc cutting the two lines. With the points *D* and *E* thus found as centers and the same radius as before draw arcs intersecting at *O*. An arc drawn with center *O* and radius *R* will be tangent to the straight lines at points *D* and *E*.

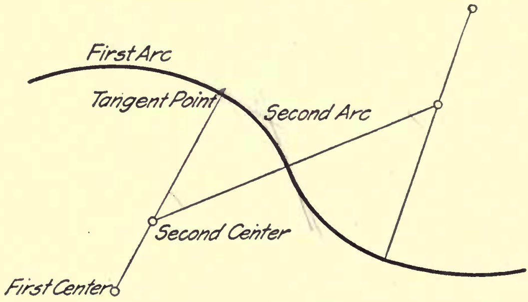


FIG. 215.—To draw tangent arcs.

115. Sometimes a smooth curve is made up of circular arcs having different radii. In such cases we must be very careful to have the arcs join at a point of tangency. The two centers and the point of tangency are in the same line, as shown in Fig. 215.

116. To lay off on a straight line the approximate length of a

circle arc, Fig. 216. Given the arc *AB*. At *A* draw the tangent *AD*. Set the dividers to a small space. Starting at *B* step along the arc to the point nearest *A*, and *without lifting the dividers* step off the same number of spaces on the tangent, as shown.

117. A reverse or "ogee" curve is shown in Fig. 217, joining lines *AB* and *CD*. Join *B* and *C* by a straight line. Draw pert pendiculars at *B* and *C*. Arcs tangent to lines *AB* and *CD* mus- have their centers on these perpendiculars. Point *E* through which the curve is to pass may be taken any place along *BC*.

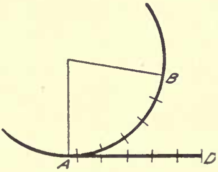


FIG. 216.—Length of an arc.

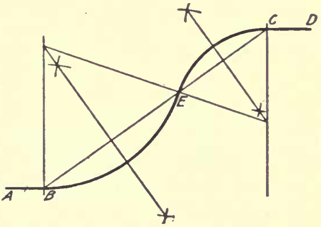


FIG. 217.—An ogee curve.

Draw perpendiculars at the middle points of *BE* and *EC*, Art. 102. Any arc to pass through *B* and *E* must have its center on a perpendicular at the middle point. The intersection therefore of these perpendiculars with the two first perpendiculars will be the centers for arcs *BE* and *EC*. The construction may be checked by drawing the line of centers, which must pass through *E*.

118. **The Ellipse.**—If a circle is parallel to a plane its projection on the plane will be a circle. If it is perpendicular to the plane its projection will be a straight line. If it is at an angle its projection will be an ellipse. A square card with a circular hole, drawn in different positions as in Fig. 218 illustrates the above statements. An ellipse is defined as a curve generated by a point moving so that the sum of its distances from two fixed points, called the foci, is constant, and is equal to the longest diameter or major axis.

A line through the center perpendicular to the major axis is called the short diameter or minor axis. To find the foci, draw an arc with center at one end of minor axis and radius equal to one-half the major axis. This arc will cut the major axis at the foci, F_1 and F_2, Fig. 219.

There are a number of ways of constructing an ellipse, two of which are given.

119. The easiest method for large work is the pin-and-string method. Given the major and minor axes, Fig. 220. Locate

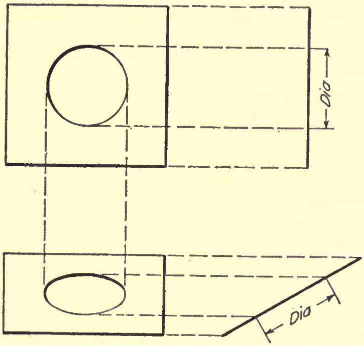


Fig. 218.—Circle projected as ellipse.

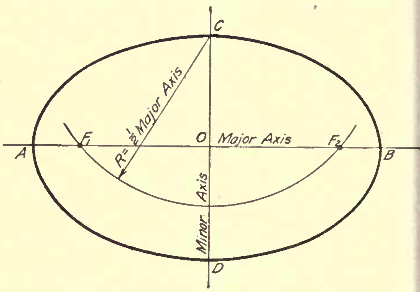


Fig. 219.—Ellipse.

the foci by the method just described. Drive pins at points F_1, C, and F_2, and tie a cord tightly around the three pins. If the pin C be removed and a marking point moved in the loop, keeping the cord taut, it will describe a true ellipse.

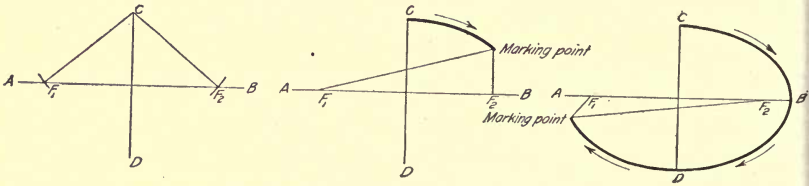


Fig. 220.—To draw an ellipse by pin-and-string method.

120. A very accurate method for finding the points on an ellipse is by concentric circles, Fig. 221. Draw two circles about the center of the desired ellipse, one with a diameter equal to the minor axis and the other with a diameter equal to the major axis. Divide the large circle into a number of equal parts, and draw radii OP, OQ, intersecting the small circle at P', Q', etc. From P and Q draw lines parallel to OD, and from P'

and Q' lines parallel to OB. Where the lines through P and P' cross is one point on the ellipse. The lines through Q and Q' give another point. In this way each radial line will locate a point on the ellipse. For accuracy extra points should be taken close together toward the ends, where the curve is changing rapidly. The curve is sketched in very lightly freehand before drawing it in with the irregular curve. A tangent at any point H may be drawn by dropping a perpendicular from the point to the outer circle at K, and drawing the auxiliary tangent KL cutting the major axis produced, at L. From L draw the required tangent LH.

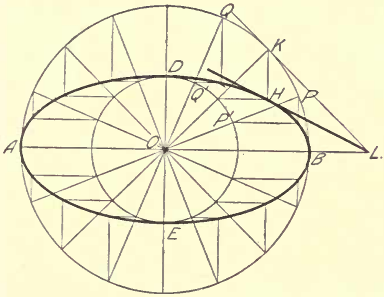


FIG. 221.—Two circle method.

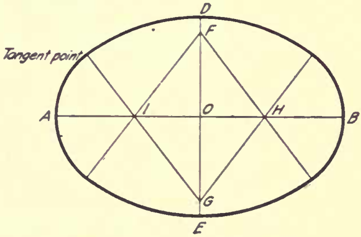


FIG. 222.—Approximate ellipse.

121. Approximate ellipses may be drawn with arcs of circles. When the minor axis is at least two-thirds of the major axis, the four center approximation shown in Fig. 222 is satisfactory. Make OF and OG each equal to AB minus DE. Make OH and OI each equal to three-fourths of OF. Draw FH, FI, GH and GI, extending them as shown. Draw arcs through points D and E with centers at G and F, and through A and B with centers I and H.

SHEET-METAL DRAFTING

122. **Sheet-metal Drafting.**—There is a large class of metalwork made from thin sheets of metal, formed into the required shape by bending or folding up and fastening by rivets or seams or soldering. In this kind of work the drawings consist of the representation of the finished object, and the drawing of the shape of the flat sheet, which when rolled or folded and fas-

tened will make the object.[1] This second drawing is called the development or pattern of the piece and making it comes under the term, sheet-metal pattern drafting.

123. **Development.**—There are two general classes of surfaces, plane surfaces and curved surfaces. The six faces of a cube are plane surfaces. The bases of a cylinder are plane surfaces, while the lateral surface is curved.

It is possible to cut out a piece of paper so as to fold it up into a cube, as in Fig. 223. The shape cut out would be the *pattern*

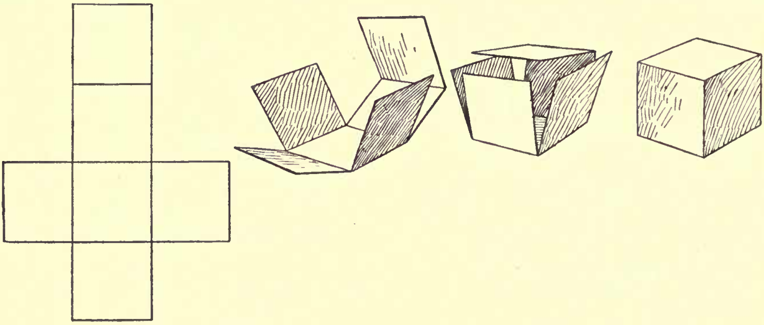


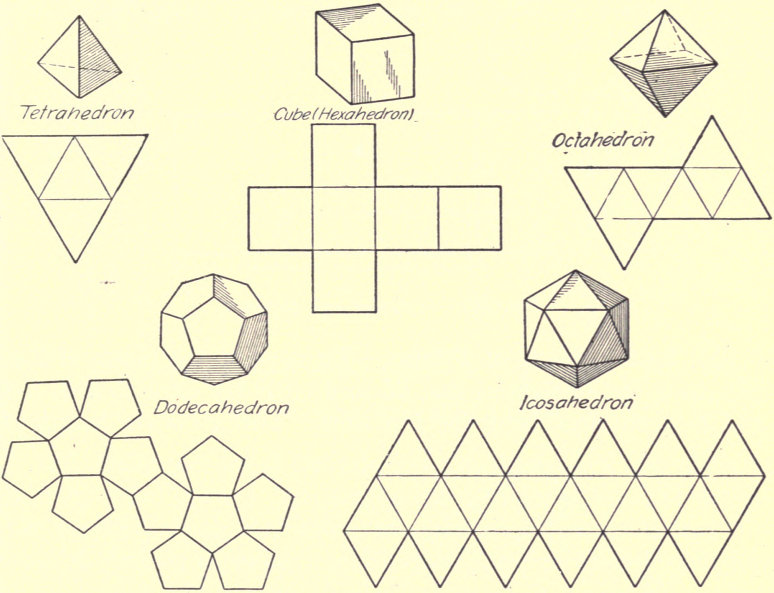
FIG. 223.—Pattern for a cube.

of the cube. Those who have studied solid geometry recall that there are five regular solids and that their patterns are made as shown in Figs. 224 to 228. A good understanding of the nature of developments may be had by laying out the above patterns and folding them to form the figures.

Thus the pattern for any piece which has plane surfaces may be made by first deciding where the seam is to be, then opening up each face in order, showing it in its true size. One example, the development of a square prism, is illustrated in Fig. 229. The light lines on the pattern are called folding or crease lines. The dotted lines on the second figure are to indicate extra material to allow for lap in making joints.

[1] A great many thin metal objects are formed without seams by die-stamping or pressing a flat sheet into shape under very heavy presses. Examples range from brass cartridge cases to steel wheelbarrows. Still another division is made by "spinning," as brass and aluminum ware. In stamped and spun work the metal is stretched out of its original shape, and making blanks for it depends upon much technical knowledge and experience.

In geometry we learn that a cylinder may be thought of as a prism with an infinite number of sides. The development of a cylinder then would be a rectangle having a width equal to



Figs. 224, 225, 226, 227, 228.—The five regular solids.

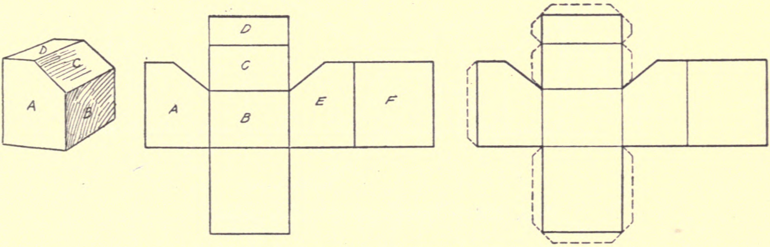


Fig. 229.—A pattern, showing lap.

the height of the cylinder and a length equal to the distance around the cylinder, Fig. 230.

The length of the pattern of a prism or cylinder is measured on a straight line called the *stretchout line.* This line is the stretched out length of the shortest distance around the figure. When the base is perpendicular to the axis it will roll out into a straight line and form the stretchout. If the prism or cylinder does not have a base perpendicular to the axis, a "right section" must be taken in order to get a straight stretchout.

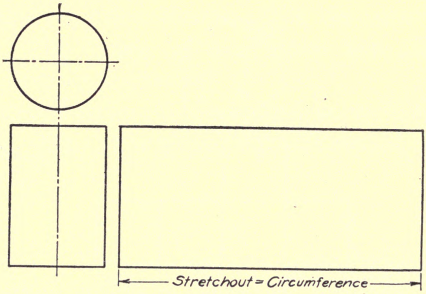


FIG. 230.—Cylinder and pattern.

124. Development of Prisms.—To develop the prism of Fig. 231 draw the stretchout line *SL* and on it lay off 1–2, 2–3, 3–4 and 4–1, obtained from the top view. This gives the length of

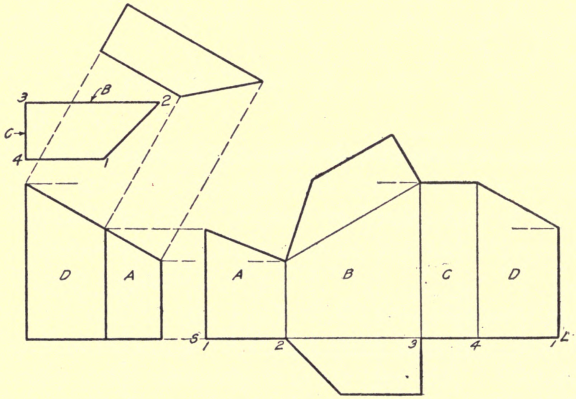


FIG. 231.—Development of a prism.

the stretchout and the true distances between the vertical edges. At points 1, 2, 3, 4, 1 on the stretchout draw vertical "crease lines" equal in length to the corresponding edges of the prism. These lengths may be easily projected across from the front view. The true size of the inclined surface is found by the method of auxiliary projection, Art. 31, and attached to one of the sides in its proper relation. The development of the bottom may be added if desired.

To develop the lateral surface of the triangular prism, Fig. 232, draw the stretchout line *SL* and lay off the distances 1–*a*, *a*–2, 2–3, 3–*b*, *b*–1, taken from the top view. Points *a* and *b* do not locate crease lines but are required to find the line of the cut. Such extra "measuring lines" are often necessary.

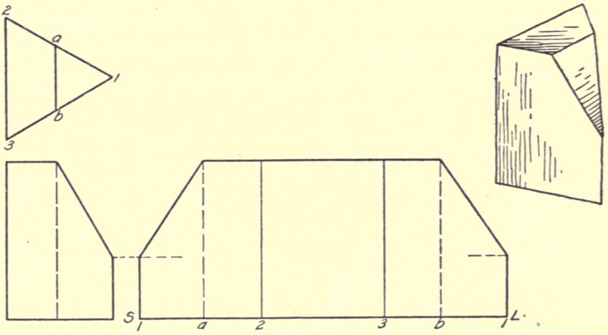


FIG. 232.—Development of a prism.

125. **Development of Cylinders.**—Consider a cylinder as being a many-sided prism. To develop the cylinder of Fig. 233 assume the position of any convenient number of imaginary edges. For ease of working these are equally spaced, which makes it possible

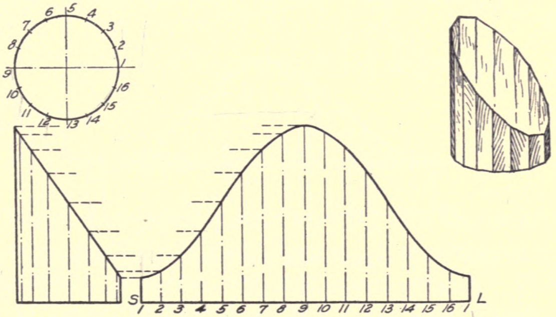


FIG. 233.—Development of a cylinder.

to obtain the length of the stretchout by taking as many spaces along *SL* as there are spaces in the top view. At each point on the stretchout draw a vertical "measuring line." Project the length of each imaginary edge across from the front view and draw a smooth curve through the points.

Since the surface is curved, the stretchout as obtained is only approximate. The more edges assumed the closer will be the approximation, but it is seldom necessary to have the points less than ¼" apart. The accuracy in length of the stretchout may be tested by measuring on it the figured length of the circumference, which equals the diameter × 3.1416, or πd.

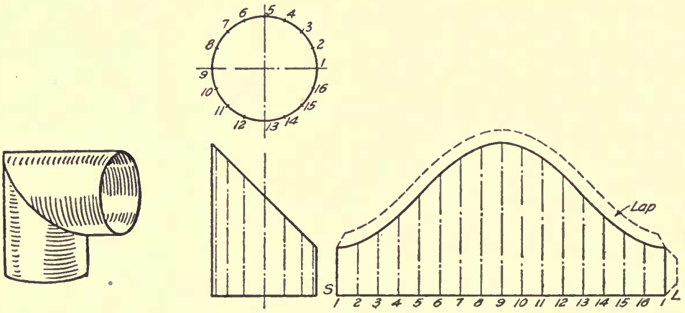


FIG. 234.—Pattern for square elbow.

126. To draw the pattern for a two-piece, or square, elbow Fig. 234. This elbow consists of two cylinders cut off at 45 degrees, so only one need be developed. The explanation of Fig. 233 applies to this figure except that lap must be allowed as indicated.

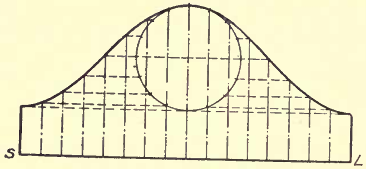


FIG. 235.—Square elbow pattern, short method.

Sheet-metal workers use short-cut methods for many problems when laying out directly on the metal. The square elbow pattern can be constructed as in Fig. 235, where a circle is drawn with a diameter equal to the diameter of the pipe and divided into a number of equal parts. These parts are spaced along the stretchout *SL*. Horizontal lines from the points on the circle and vertical lines from the points on the stretchout will cross at points on the desired curve.

127. The development of a four-piece elbow is illustrated in Fig. 236. To draw the elbow, first draw arcs having the desired inner and outer radii as shown at I. Divide the outer quarter circle into six equal parts. Draw radial lines from points 1, 3 and 5 to locate the joints. Draw tangents to the arcs at points 2 and 4 and complete the figure as shown at II, by tangents to the inner quarter-circle. With this view completed we are ready to start the development. Draw a circle representing the cross-section of the pipe (one-half of this view is sufficient). Divide

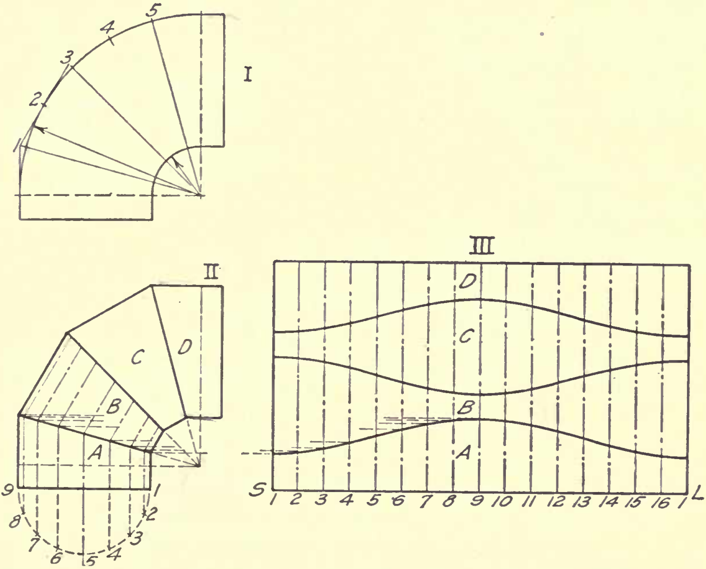


FIG. 236.—Patterns for four-piece elbow.

it into a number of equal parts, and lay out the stretchout line with the same number of equal parts. From the circle project to the elevation to locate the imaginary edges. The pattern for the first section is obtained by projecting across from the elevation in the same way as Fig. 233.

The patterns for the four pieces may be cut without waste from a rectangular piece if the seams are made alternately on the inside or throat line and outside line. To draw the pattern for the second section extend the measuring lines of the first section and with the dividers take off the lengths of the imaginary edges on the front view, starting with the longest one. The third and fourth sections are made in a similar way. Since the curve is the same for all sections one only need be plotted.

128. Galvanized iron mouldings and cornices are made up of a combination of cylinder and prism parts. A practical problem in developments is making the pattern for a piece mitered to "return" around a corner as shown in the sketch of Fig. 237. An inspection of the figure shows the method of working to be the same as Fig. 233, the section of the moulding taking the place of the top view and having its length laid out on the stretchout line.

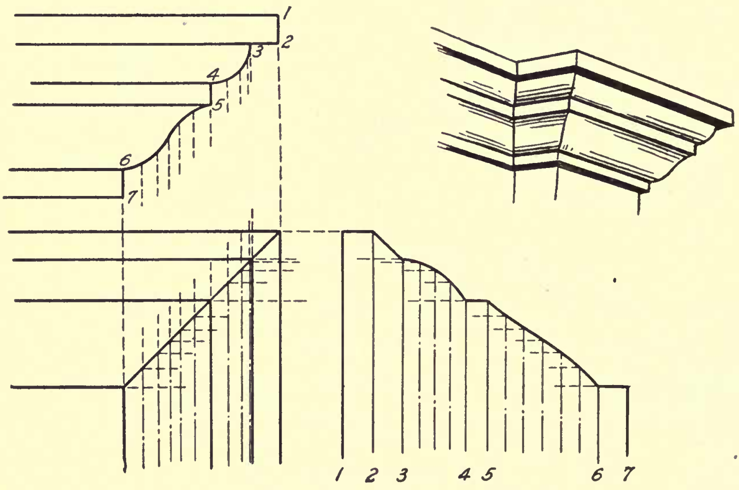


FIG. 237.—Pattern for square return miter.

129. **Development of Pyramids and Cones.**—In the case of prisms and cylinders the stretchout was a straight line with the measuring lines perpendicular to it and parallel to each other. And as their edges were all parallel to the front plane their true lengths were always shown in the front view. Pyramids and cones or any objects larger at one end than at the other will not roll straight, hence their stretchouts are not straight lines. Also since they have sloping sides their edges will not always show in their true lengths.

130. **To find the true length of a line,** revolve the line until it is parallel to one of the planes of projection. Its projection on that plane will then be the true length of the line. The pyramid of Fig. 238, I, is shown by top and front views at II.

The edge OA does not show in its true length in either view. However, if we draw the pyramid in the position shown at III the true length of OA is shown in the front view. In Fig. III the pyramid has been revolved from the position of II about a

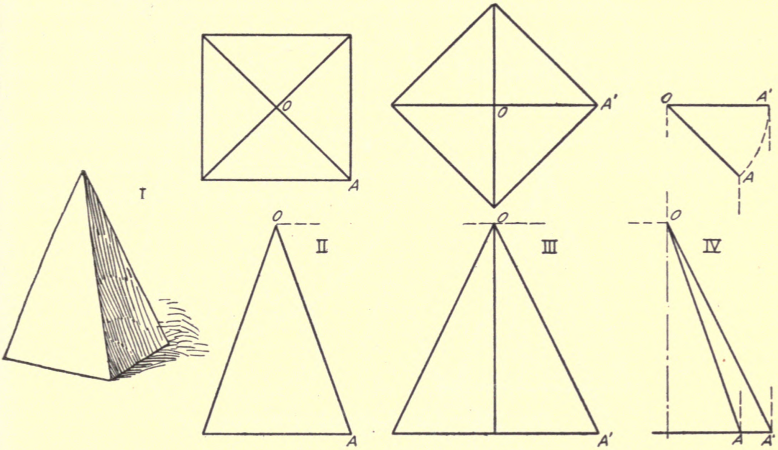


FIG. 238.—True length of line.

vertical axis until the line OA is parallel to the vertical plane. At IV the line OA is shown before and after revolving. Thus

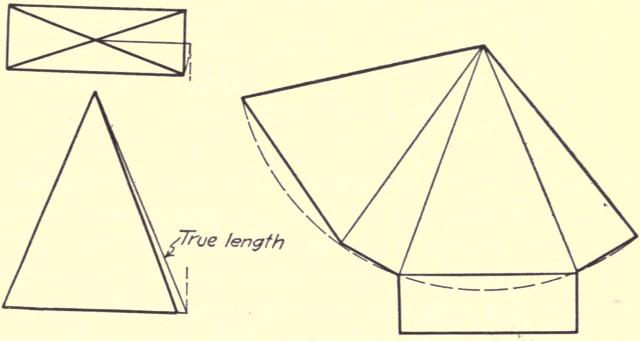


FIG. 239.—Development of a pyramid.

the construction for finding the true length of a line is as follows: In the top view with radius OA and center O revolve the top view of OA until it is horizontal, project the end of the line down to meet a horizontal line through the front view of A. Join this point of intersection with the front view of O.

131. To draw the pattern for a rectangular pyramid, Fig. 239.

Find the true length of one of the edges by swinging it around as shown. With this true length as a radius draw an arc of indefinite length for a stretchout line. On this mark off as chords

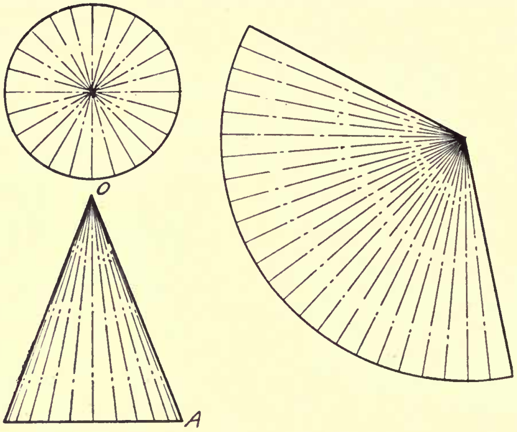


FIG. 240.—Development of a cone.

the four edges of the base 1–2, 2–3, 3–4, 4–1. Connect these points with each other in turn, and draw the crease lines by joining each point with the center.

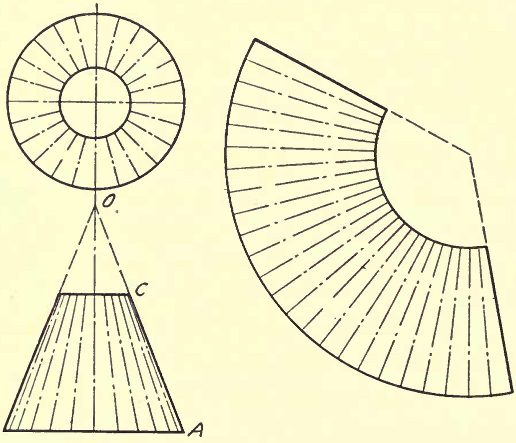


FIG. 241.—Frustum of a cone.

132. To draw the pattern for a cone, Fig. 240. Consider a cone as being a many-sided pyramid and assume the positions of any convenient number of imaginary edges, using equal spac-

ing for convenience. With the front view OA as radius draw an arc of indefinite length as a stretchout. On this step off as many points as were assumed in the top view, and at the same distance apart. Connect beginning and ending points by lines to the center. The resulting sector is the developed surface.

If the cone is cut off as in Fig. 241 develop as before, then with OC as radius draw another arc between the limiting sides.

If the cone is cut off at an angle it will be necessary to find the true length of every imaginary edge and lay it off on the pattern, as shown in Fig. 242, by revolving it around the axis until it is parallel to the front plane.

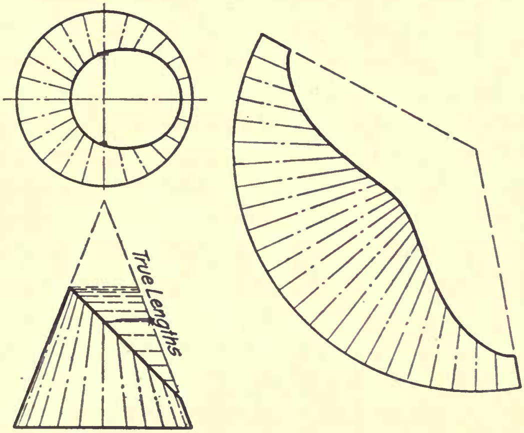


FIG. 242.—Truncated cone.

133. **Development of a Transition Piece.**—A transition piece is used to connect a pipe of one shape with another of a different shape. Transition pieces are made up of parts of different kinds of surfaces and are developed by triangulation. The example shown in Fig. 243 connects a round pipe with a rectangular one. From the picture it is seen that this piece is formed of four triangles, between which are four conical parts, with apexes at the corners of the rectangular opening and bases each one-quarter of the round opening.

Starting with the cone whose apex is at A divide its base 1–5 into a number of equal parts as 2, 3, 4, and draw the lines A–2, A–3, A–4, giving triangles approximating the cone. Find the true length of each of these lines. This is done in practical

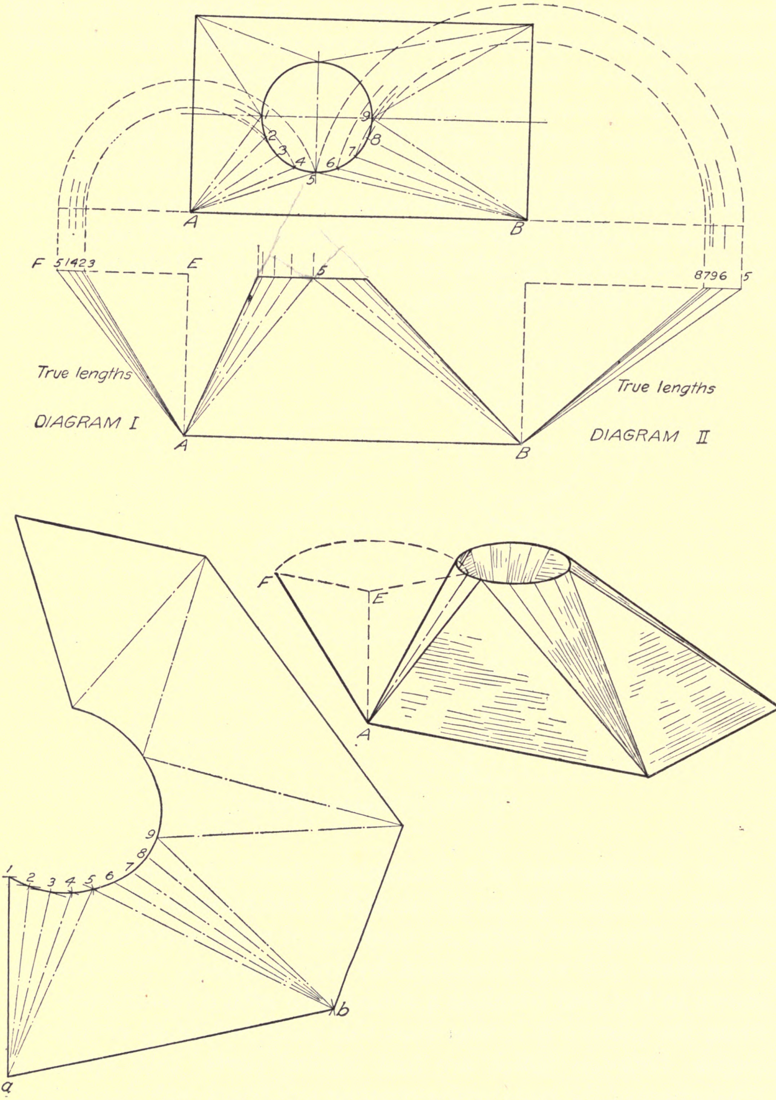


FIG. 243.—Development of transition piece.

work by constructing a separate diagram, as at I, knowing that the true length of each line is the hypotenuse of an imaginary triangle whose altitude is the altitude of the cone and whose base is the length of the top view of the line.

On the front view draw the vertical line *AE* as the altitude of the cone. On the base *EF* lay off the distances *A*–1, *A*–2, etc. This is done in the figure by swinging each distance about the point *A* in the top view, and dropping perpendiculars to *EF*. Connect the points thus found with the point *A* in diagram I, thus obtaining the desired true lengths. Diagram II, constructed in the same way gives the true lengths of lines *B*–5, *B*–6, etc., of the cone whose apex is at *B*. After the true length diagrams are constructed start the development, with the seam at *A*–1. Draw a line *a*–1 equal to the true length of *A*–1. With 1 as a center and radius 1–2 taken from the top view draw an arc. Intersect this arc with an arc from center *a* and radius equal to the true length of *A*–2, thus locating the point 2 on the development. With 2 as center and radius 2–3 draw an arc and intersect it by an arc with center *a* and radius of the true length of *A*–3. Proceed similarly with points 4 and 5 and draw a smooth curve through the points 1, 2, 3, 4, 5 thus found. Then attach the true size of the triangle *A*–5–*B*, locating point *B* on the development by intersecting arcs from *a* with radius *A*–*B* taken from the top view, and from 5 with radius the true length of *B*–5. Continue until the piece is completed.

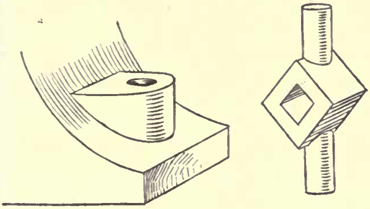


Fig. 244.—Intersections.

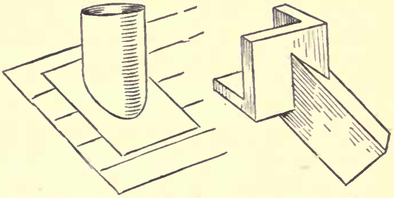


Fig. 245.—Intersections.

134. **Intersections.**—Whenever surfaces come together there is said to be a line of intersection. In Figs. 244 and 245 a number of lines of intersection are shown. It is necessary for both the machine designer and the sheet-metal worker to be able to locate a line of intersection when one occurs.

135. Intersecting Prisms.—Several illustrations of intersecting prisms are illustrated in Fig. 246.

To draw the intersection of two prisms, first start the orthographic views. In Fig. 247 a square prism passes through a hexagonal prism. Through the front edge of the square prism pass a plane parallel to the vertical plane. The top view of this plane

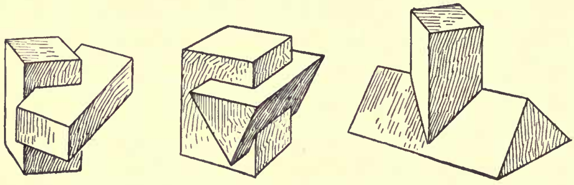


FIG. 246.—Intersecting prisms.

appears as a line *A–A*. The intersection of the plane *A–A* and one of the faces of the vertical prism shows in the front view as

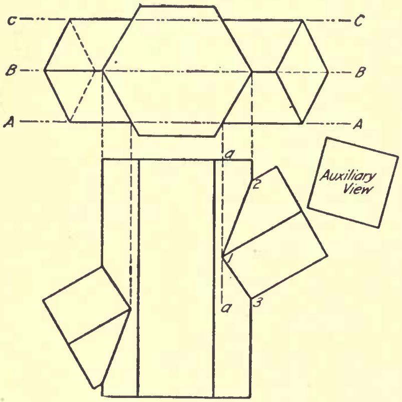


FIG. 247.—Intersection of two prisms.

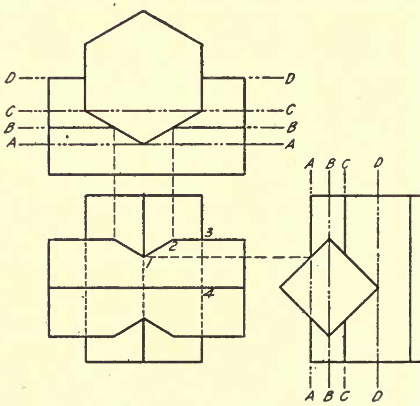


FIG. 248.—Intersection of two prisms.

line *a–a*, and is crossed by the front edge of the square prism, at point 1, which is a point on both prisms and therefore a point in the desired line of intersection. Plane *B–B* is parallel to plane *A–A* and contains an edge of the vertical prism and an edge of the inclined prism which meet at point 2 in the front view. Plane *B–B* also determines point 3.

These planes are called cutting planes and they may be used for the solution of most problems in intersections. For intersecting prisms pass planes through all the edges of both prisms within the limits of the line of intersection. Where the lines cut from both prisms by the same plane cross is a point on the required line of intersection. In Fig. 248 four cutting planes are required. The limiting planes are *A–A* and *D–D* as a plane in front of *A–A* or back of *D–D* would cut only one of the prisms.

136. **Intersecting Cylinders.**—To draw the line of intersection of two cylinders, Fig. 249. Since there are no edges on the cylinders it will be necessary to assume positions for the cutting

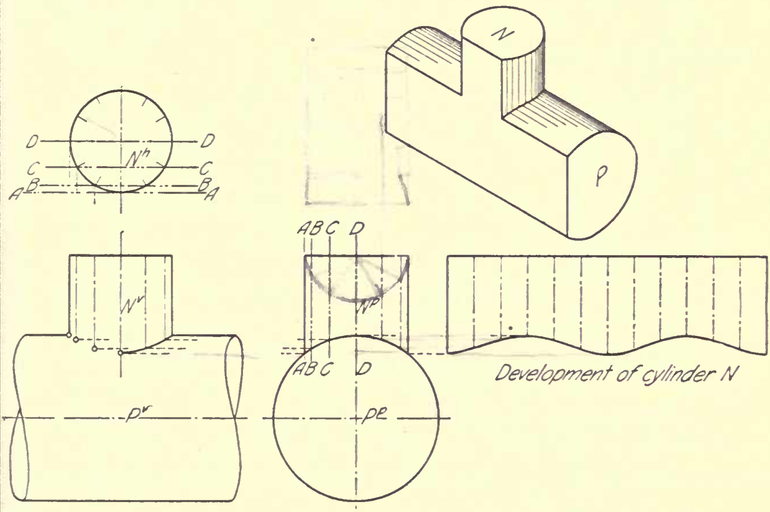


FIG. 249.—Intersection of two cylinders.

planes. Plane *A–A* contains the front line of the vertical cylinder and cuts a line from the horizontal cylinder. Where these two lines intersect in the front view is a point on the required curve. Each plane cuts lines from both cylinders, which intersect at points common to both cylinders. The development of the vertical cylinder, obtained by the method of Art. 125 is shown in the figure.

The solution for an inclined cylinder is given in Fig. 250 where the positions of the cutting planes are located by an auxiliary view. To develop the inclined cylinder the auxiliary view is used to get the length of the stretchout. If the cutting planes have been chosen so that the circumference of the auxiliary view is divided into equal parts, the measuring lines will be equally spaced along the stretchout.

To develop the portion of the vertical cylinder having the hole for the inclined cylinder, lay out a portion of the stretchout and project from the front view to the measuring lines as shown.

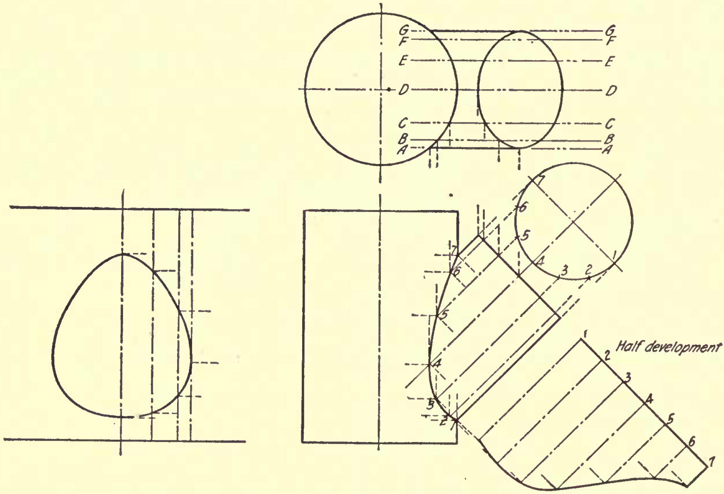


FIG. 250.—Intersection and development of two cylinders.

137. **Intersecting Cylinders and Prisms.**—The intersection of a cylinder and a prism is found by the use of cutting planes as already described. In Fig. 251 a triangular prism intersects a

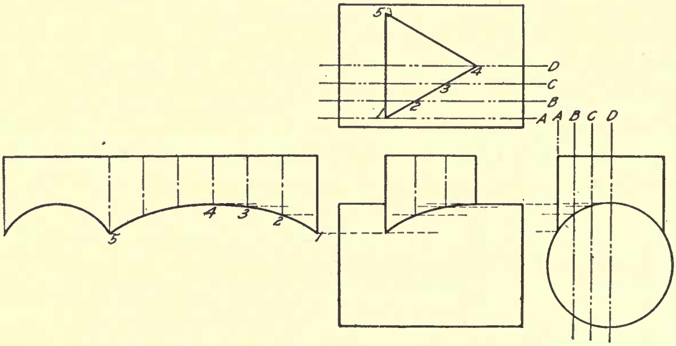


FIG. 251.—Intersection and development of cylinder and prism.

cylinder. The planes *ABCD* cut lines from the prism and lines from the cylinder which cross in the front view and determine the curve of intersection as shown. The development of the triangular prism is found by taking the length of the stretchout line from the top view and the lengths of the measuring lines from the front view. Since one plane of the triangular prism is perpendicular to the axis of the cylinder, the curve of intersection on that face is the radius of the cylinder.

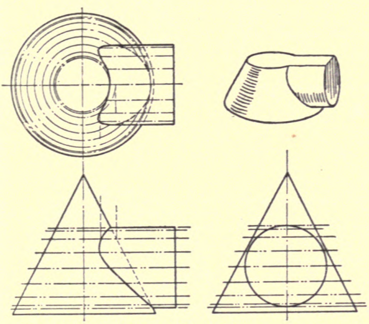


FIG. 252.—Cylinder and cone.

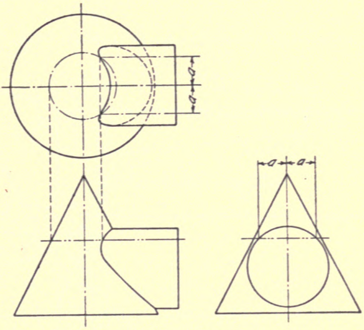


FIG. 253.—A cutting plane.

138. **Intersection of Cylinders and Cones.**—The intersection of a cylinder and a cone may be found by passing planes parallel to the horizontal plane as shown in Fig. 252. Each plane will cut a circle from the cone and straight lines from the cylinder.

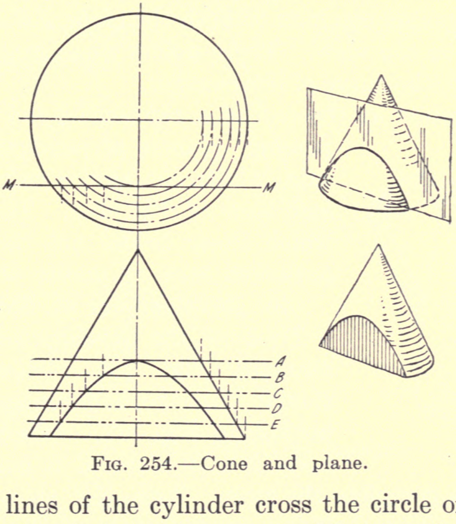


FIG. 254.—Cone and plane.

The straight lines of the cylinder cross the circle of the cone in the top view at points on the curve of intersection, which are then projected to the front view as in Fig. 253, where the construction is shown for a single plane. Use as many planes as are necessary to obtain a smooth curve.

139. Intersections of Planes and Curved Surfaces.—The line of intersection of a cone cut by a plane *EE* as in Fig. 254, may be found by horizontal cutting planes *A,B,C,D.* Each plane cuts a circle from the cone, and a straight line from the plane *EE,*

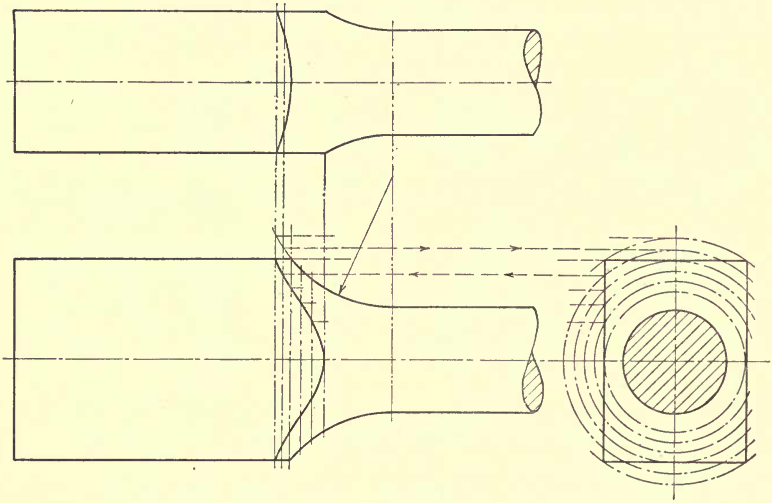


FIG. 255.—Intersection of plane and turned surface.

thus locating points common to both the plane *EE* and the cone as shown in the top view. These points when projected to the front view give the curve of intersection.

The intersection at the end of a connecting rod is found by passing planes perpendicular to the axis, which cut circles as shown in the end view of Fig. 255. The points at which these circles cut the "flat" are projected back as points on the curve.

FIG. 256.

140. Development of Pint Measure.—To draw the development of a pint measure, Fig. 256. Draw the view shown with the half circles at top and bottom in Fig. 257. Observe that the body is a frustum of a cone. Extend the outline to complete the cone. With *MN* as a radius draw an arc. Step off one-half the circumference of the base on this arc and draw the radial lines *MK* and *ML.* With *M* as a center and *MD* as a radius draw arc *PQ,* completing the development of the body. Add the necessary allowance for lap.

To develop the handle divide it into a number of spaces and step them off on the stretch out *RS*. At *R* lay off one-half the width of the upper end of the handle on each side and at *S* one-half the width of the lower end of the handle on

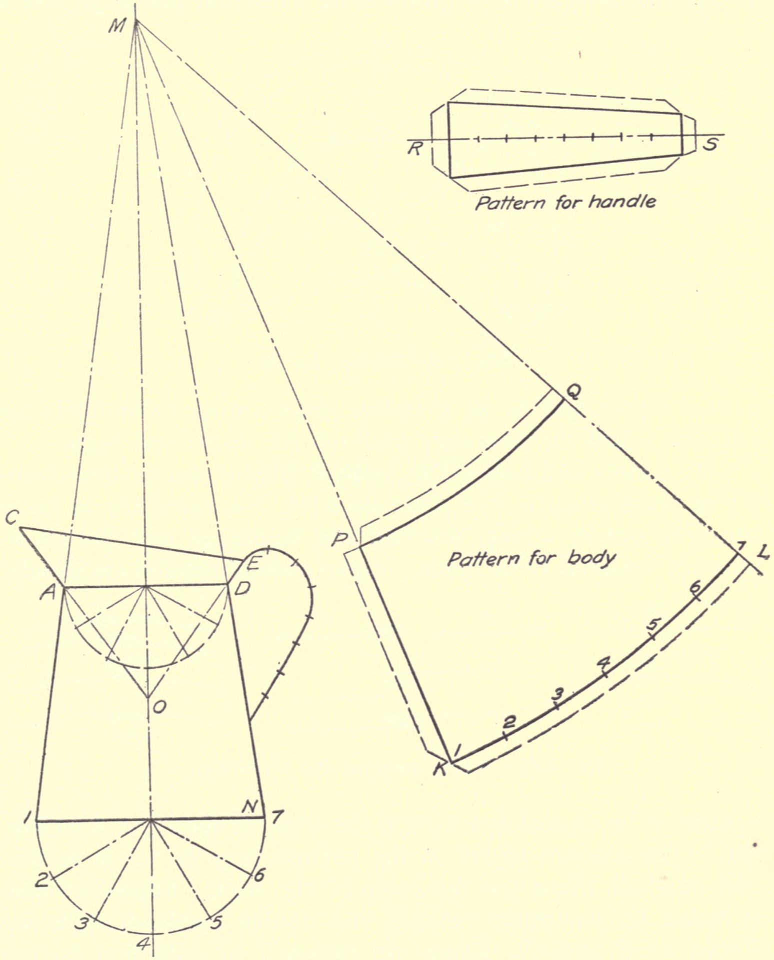


FIG. 257.—Pattern for measure.

each side of the stretchout. Add allowance for laps and hems. The true development of the lip would require the drawing of lines through each point and finding the length of each line as described for the truncated cone, Fig. 242. The usual practical method is as follows, Fig. 258. On a center line *oa* draw an arc with OA as a radius and space off one-half the circumference of the top of the body on each side as shown by *dad*. Draw the radii *od*. Increase OA by $ac = AC$ and increase *od* by $de = DE$ as obtained from the elevation. Draw *ce* and the perpendicular bisector of *ce* intersecting the center line at *g*. With

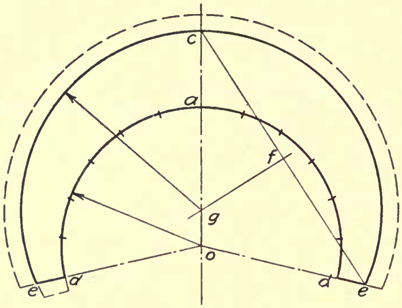


FIG. 258.—Pattern for lip.

g as a center and *gc* as a radius draw arc *ece* to complete the pattern. Add the necessary material for seams and hems.

141. **Seams and Lap.**—The basis of sheet-metal pattern drafting is development. For practical work it is necessary to know the processes of wiring, seaming and hemming, and the allowances of material to be made. Open ends of articles are usually

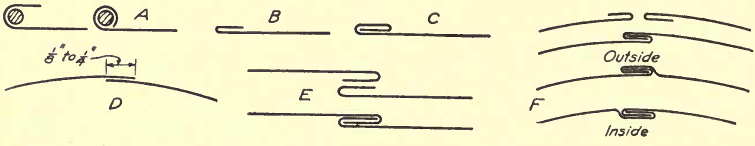


FIG. 259.—Wiring, seaming and hemming.

reinforced by enclosing a wire in the edge, as shown at *A* in Fig. 259. The amount added to the pattern may be taken as two and one-half times the diameter of the wire. Edges are also stiffened by hemming. Single and double hemmed edges are shown at *B* and *C*. Edges are fastened by soldering on lap seams, *D*, folded seams, *E*, or, the commonest way, by grooved seams, shown in three stages, both inside and outside, at *F*. An important consideration in allowing lap on patterns is the shape of the space left at the corners to prevent thick places in the seam. This is called notching, and is illlustrated on Figs. 257 and 258.

PROBLEMS

CHAPTER VIII

PROBLEMS

142. The important part of any course in mechanical drawing consists of the working of a large number of properly selected and graded problems. The problems which follow are arranged somewhat in the order of difficulty in each of the divisions of the subject. The methods of presentation vary with the requirements of the problems. Graphic layouts are given wherever practicable as they are definite and save time for both teacher and pupil. It is not necessary nor intended that all the problems be worked, but that a selection be made by the teacher to suit his own particular needs. A large number of references to text matter bearing upon the methods of solution or principles involved are given in connection with the problems.

Any or all of the drawings may be inked but the best results are generally obtained by delaying this until the pupil has acquired the ability to make a good pencil drawing.

One some of the sheets it may be found desirable to include a freehand pictorial sketch in the style of Figs. 308 and 310, to indicate that the pupil has visualized the object clearly.

The problems are designed for use on the size of sheet and layout given in Fig. 260, but it is of course easily possible to use other sizes.

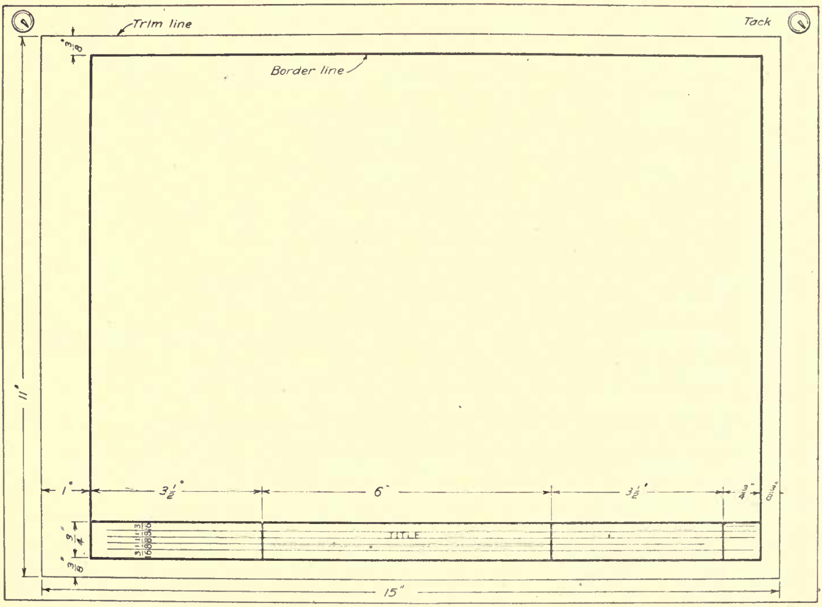


Fig. 260.—Layout of sheet.

143. Layout of the Sheet.—Tack the paper to the board as described in Art. 5. The outside dimensions of the finished sheet are 11″ × 15″ with margin lines and record strip as shown in Fig. 260. The guide lines for lettering the record strip must be drawn *very lightly*. They should not be drawn until ready to be used. On the layouts the title for the sheet in given. Where problems are stated in words the general title of the sheet is printed in black face type. When the following method is understood the layout of the sheet should not take more than two minutes.

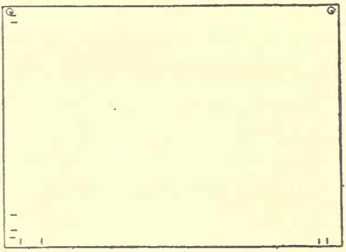


Fig. 261.

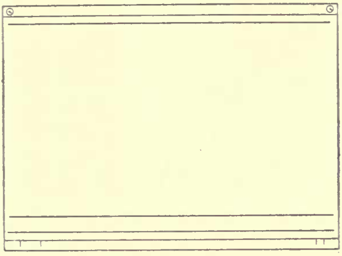


Fig. 262.

The two minute method. Make two short vertical marks near the bottom of sheet, 15″ apart. Measure and mark ⅜″ in from the right hand end and 1″ in from left hand end, Fig 261. Place scale vertically near left edge of paper and make short horizontal marks 11″ apart. Measure down ⅜″ from top and mark. Measure up ⅜″ from bottom and mark. From last mark measure ¾″ up and mark, Fig. 261. Now with T-square draw horizontal lines through horizontal marks as shown in Fig. 262. Next draw vertical lines through vertical marks as in Fig. 263. Then brighten up the trim and border lines and the sheet will appear as in Fig. 264, ready to begin a drawing.

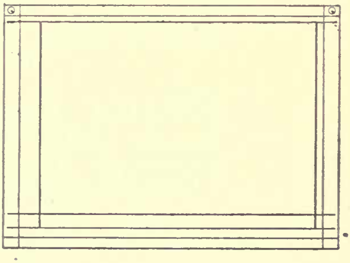


Fig. 263.

On the following problems the figures enclosed in circles are for locating the starting lines and are always measured full size regardless of the scale of the views of the drawing. When such dimensions are given the lines which they locate should be drawn first. Upon these lines the drawing is built. Use light full pencil lines and work very accurately as errors in starting often are not evident until the drawing is nearly completed.

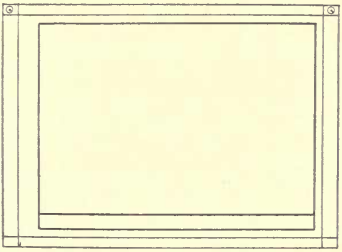


Fig. 264.

Prob. 1. The first sheet, Fig. 265, is a one-view drawing of a **templet.** The complete specification would require that the thickness of material and kind of material be given.

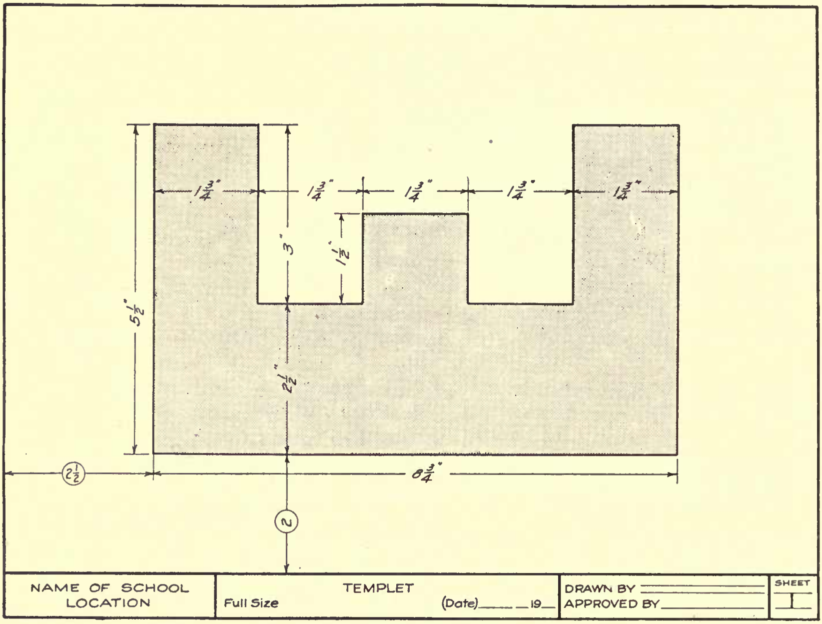


FIG. 265.—Prob. 1.

In this and the following three one-view problems the order of making the drawing in progressive stages. These stages should be followed carefully as they represent the draftsman's practice as to procedure in making drawings.

It is very necessary for the beginner to learn to draw in *good form*, and the most important feature in this regard is the order of working. Do not simply follow the explanations as being directions for the particular problem, but try to understand the system and the reasons for it. This system, thoroughly mastered at the start will apply to all drawings regardless of the number or complexity of views and will develop the two requirements in execution, accuracy and speed.

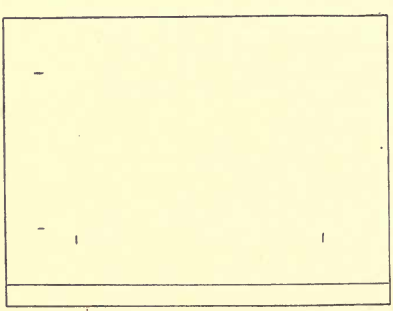


FIG. 266.

(1) Lay out the sheet as described in Art. 143.

(2) Measure 2½″ from left border line and from this mark measure 8¾″ toward the right.

(3) Lay the scale on the paper vertically near the left edge, make a mark 2″ up and from this measure 5½″ more. The sheet will appear as in Fig. 266.

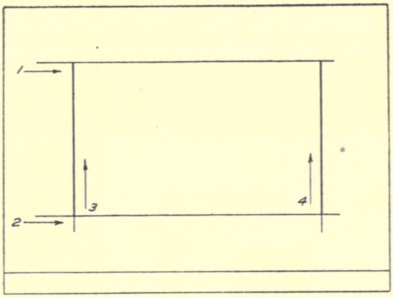


FIG. 267.

(4) Draw horizontal lines *1* and *2* with the T-square, and vertical lines *3* and *4* with T-square and triangle, Fig. 267. These four lines "block in" the figure.

(5) Between the two vertical lines make marks 1¾″ apart, and from lowest line of the figure measure two distances vertically, 2½″ and 1½″. The sheet will appear as in Fig. 268.

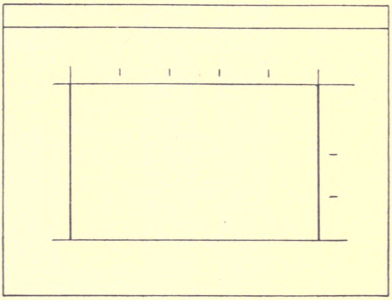


FIG. 268.

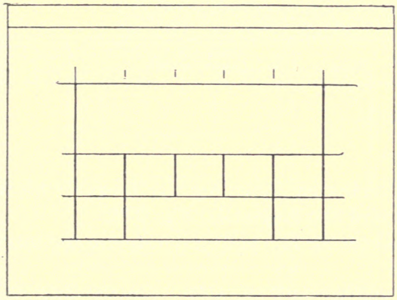


FIG. 269.

(6) Draw the two horizontal lines across the sheet.

(7) Draw the vertical lines, stopping them on the proper horizontal lines, Fig. 269.

(8) Brighten some of the lines and erase others to obtain the finished drawing, Fig. 270.

Write your name, sheet number and date lightly in the record strip. The record strip is to be lettered in after the lettering problems have been mastered. Trim the sheet to finished size.

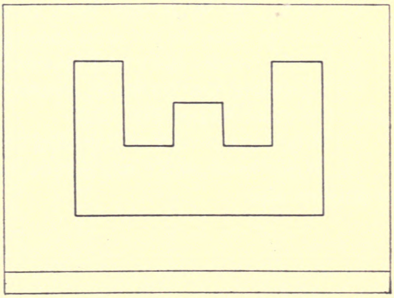


FIG. 270.

Prob. 2. To make a drawing of the **stencil**, Fig. 271. This drawing gives practice in accurate measuring with the scale, and making careful corners with short lines.

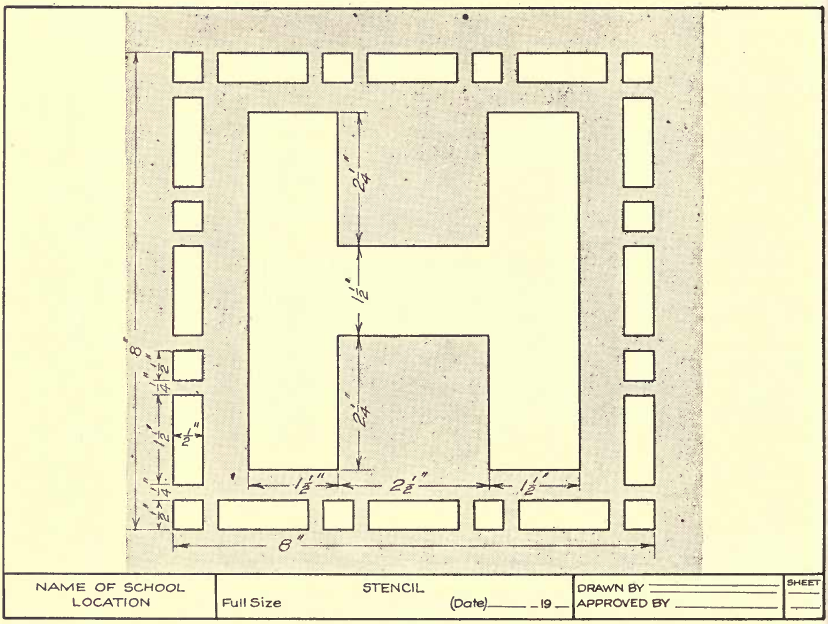


Fig. 271.

(1) Find the center of the sheet inside the border by laying the T-square blade across the corners and drawing a short piece of the diagonals, Fig. 272.

(2) Through the center draw a horizontal center line and on it measure and mark off points for the four vertical lines, Fig. 273.

Draw the vertical lines lightly with T-square and triangle. On the first one measure and mark off points for all horizontal lines, Fig. 274.

(4) Draw the horizontal lines as finished lines, and measure points for the stencil border lines on left side and bottom as shown in Fig. 275.

(5) Draw border lines and measure on them the points for ties, Fig. 276.

(6) Complete the border by drawing the cross lines as finished lines and brightening the other edges, Fig. 277.

(7) Brighten the vertical lines and finish as in Fig. 278.

(8) Write name, sheet number and date in the record strip, and trim the sheet to finished size.

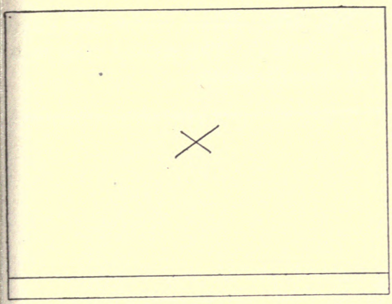


FIG. 272.

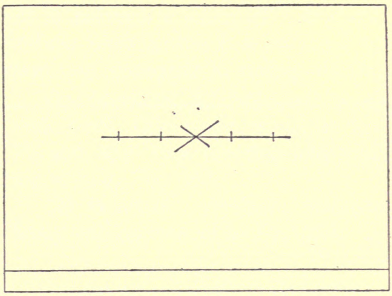


FIG. 273.

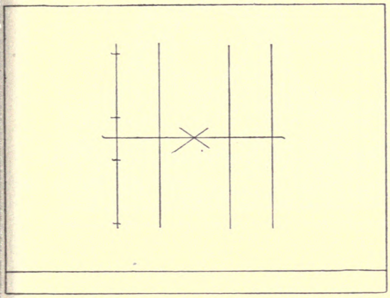


FIG. 274.

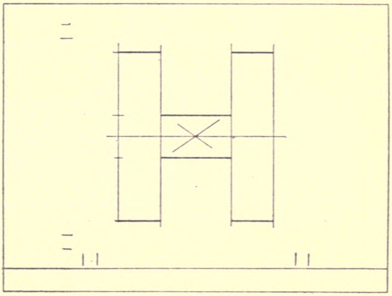


FIG. 275.

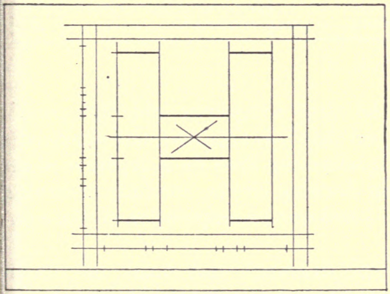


FIG. 276.

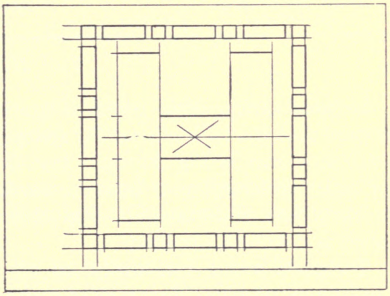


FIG. 277.

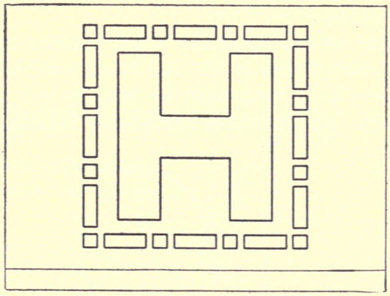


FIG. 278.

Prob. 3. To make a drawing of the **shim,** Fig. 279. When circles and circle arcs occur on a drawing, their centers are first located. The second step is to locate the points of tangency, and make sure of smooth joints.

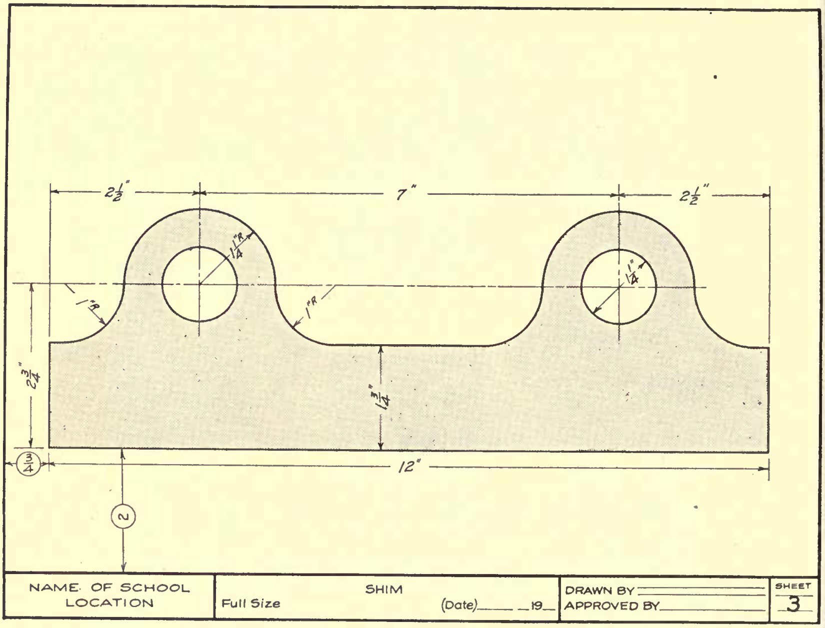


FIG. 279.—Prob. 3.

Before starting this problem examine the large compasses and bow pencil. Be sure that the lead is carefully sharpened and that it is adjusted with the needle point as shown in Fig. 11, Art. 10. Draw intersecting lines on a separate sheet and practice handling of both instruments in drawing circles, carefully observing the operations illustrated in Fig. 12 and 13. Awkward manipulation of the compasses is a severe handicap.

Tangents occur constantly on all machine drawings and must be drawn quickly and neatly. Accuracy in setting the compasses to a required radius should be practiced as any error is doubled when the diameter is measured. This test should be applied frequently.

The needle point may be placed at the exact crossing of the two centerlines by guiding it with the little finger of the left hand, resting the other fingers on the paper. Art. 111 should be read and the tangent arc and tangent line constructions practiced until the student is thoroughly familiar with them.

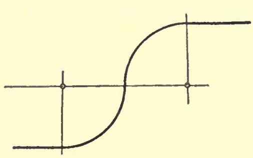


FIG. 280.

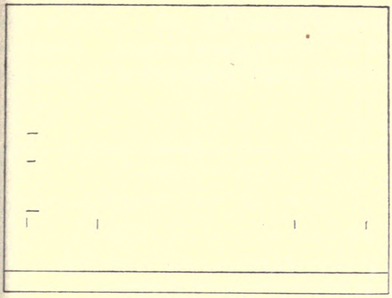


Fig. 281.

(1) Measure $\frac{3}{4}''$ from left border and from this mark measure $2\frac{1}{2}''$, $7''$, and $2\frac{1}{2}''$ thus locating four starting points, Fig. 281.

(2) Measure vertical distances. Sheet will appear as in Fig. 281.

(3) Draw horizontal and vertical lines as in Fig. 282.

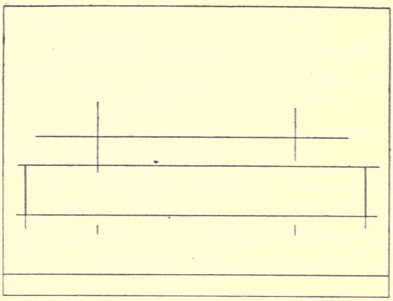


Fig. 282.

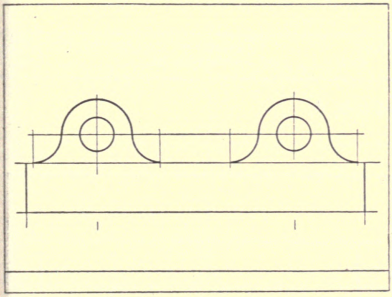


Fig. 283.

(4) Draw circle arcs with bow pencil (Art. 10). Be sure to stop at tangent points, which are located by lines through the centers, Fig. 280. The sheet will appear as Fig. 283.

(5) Brighten the horizontal lines and finish as in Fig. 284.

(6) Write name, sheet number and date lightly in the record strip, and trim the sheet.

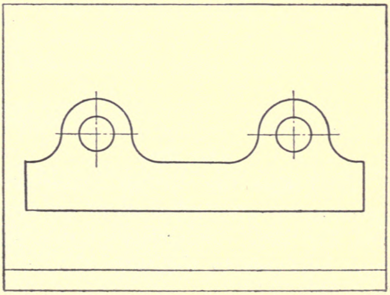


Fig. 284.

Prob. 4. To make a drawing of the **shearing blank,** Fig. 285. When a view has inclined lines it should first be "blocked in" with square corners. Angles of 30°, 45° and 60° are drawn with the triangles after locating one end of the inclined line.

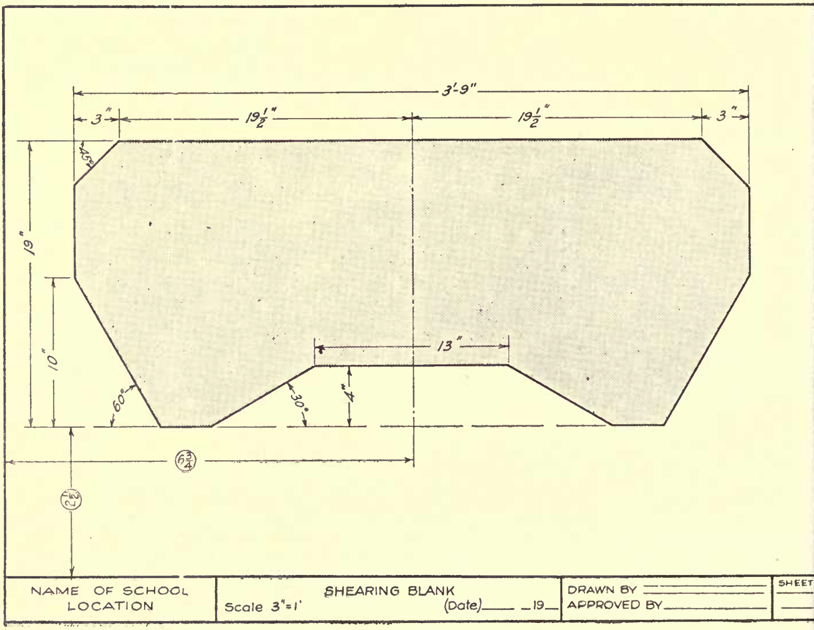


FIG. 285.—Prob. 4.

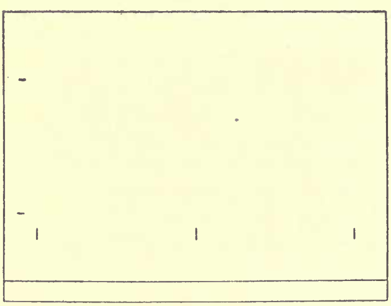


FIG. 286.

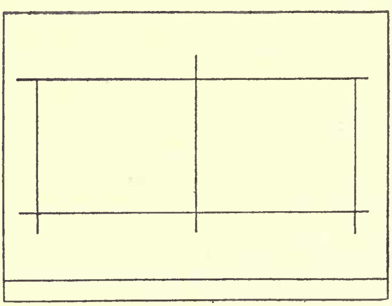


FIG. 287.

(1) Locate the vertical center line and measure one-half of 3′–9″ on each side, Fig. 286. Note that this drawing must be made to the scale of 3″ = 1′ (Art. 13).

(2) Locate vertical distances for top and bottom lines.

(3) Draw main blocking-in lines as in Fig. 287.

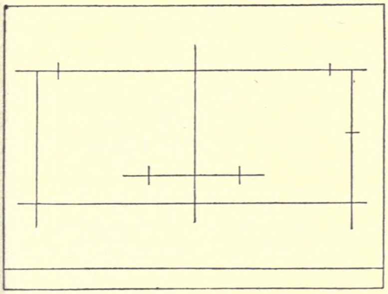


FIG. 288.

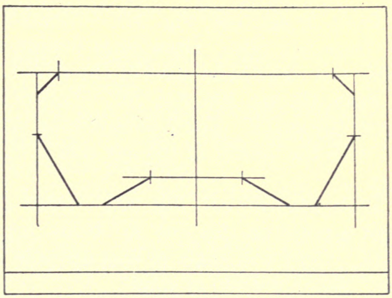


FIG. 289.

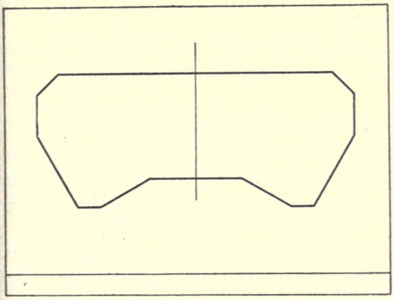


FIG. 290.

(4) Make measurements for inclined lines. The drawing will appear as in Fig. 288.

(5) Draw inclined lines with 45° and 30°–60° triangles, Fig. 289.

(6) Brighten lines and finish as in Fig. 290.

(7) Write name, sheet number and date in the record strip, and trim to size.

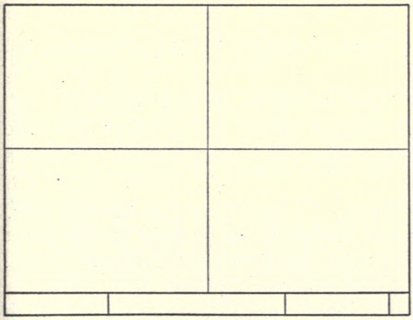


FIG. 291.

144. Geometrical Constructions.—The working of a limited number of geometrical exercises is valuable for the practice in the use of instruments and to give familiarity with the constructions which occur most frequently. Such problems must be worked very accurately, with a very sharp pencil and comparatively light lines. A point should be located by two intersecting lines, and the length of a line by two short dashes crossing the given line.

The following problems are for use in one-quarter of the working space. Lay out the sheet as in Fig. 260 and draw horizontal and vertical lines to divide the space into four equal parts, Fig. 291.

Prob. 5, Art. 102, Fig. 194.—Near the center of the space draw a horizontal line 3$\frac{9}{16}$″ long and bisect it.

Prob. 6, Art. 102, Fig. 194.—Near the center of the space draw a vertical line 3$\frac{7}{16}$″ long and bisect it.

Prob. 7, Art. 103, Fig. 195.—Above the center of the space draw a horizontal line 4$\frac{3}{16}$″ long. Divide it into five equal parts geometrically.

Prob. 8, Art. 103, Fig. 195.—To the left of the center draw a vertical line 2$\frac{7}{8}$″ long and divide it into three equal parts geometrically.

Prob. 9, Art. 106, Fig. 201.—Locate a point ½″ above lower line of space and ½″ from left side. Draw lines joining this point with the middle points of the upper and right hand sides of the space. Bisect the angle between these lines.

Prob. 10, Art. 106, Fig. 201.—Locate a point ½″ below the middle of the upper line of the space. Draw lines joining this point with the lower right hand corner and with the middle of the left side of the space. Bisect the angle between these lines.

Prob. 11, Art. 107, Fig. 202.—Draw a vertical line ½″ from left edge of space. From a point on this line ½″ below top of space draw another line making any angle. Copy this angle so that one side is ½″ from right side of space and vertex is ½″ above bottom of space.

Prob. 12, Art. 107, Fig. 202.—From the middle point of the left side of space draw lines to upper and lower right hand corners. Copy this angle so that one side is horizontal and ½″ above bottom of space.

Prob. 13, Art. 108, Fig. 203.—Draw a horizontal line 4⅝″ long and ½″ above bottom of space. On this line as a base construct a triangle having sides of 3⅞″ and 2¾″.

Prob. 14, Art. 108, Fig. 203.—Draw a vertical line 2⅝″ long and ¾″ from left side of space. On it construct a triangle having sides of 4¾″ and 4¼″.

Prob. 15, Art. 108, Fig. 206.—Draw a horizontal line 4″ long and ¾″ above bottom of space. Using this as the longer of the two sides, construct a right triangle by the "6–8–10" method.

Prob. 16, Art. 108, Fig. 206.—Draw a horizontal line 3¾″ long and 1½″ above bottom of space. Using this as the hypotenuse, construct a right triangle by the "6–8–10" method.

Prob. 17, Art. 109, Fig. 207.—Draw a regular hexagon having a distance across corners of 3¼″.

Prob. 18, Art. 110, Fig. 209.—Draw a regular octagon having a distance between parallel sides of 3″.

Prob. 19, Art. 111, Fig. 210.—Locate three points as follows: Point *A* 3¼″ from left edge of space and 3¾″ above bottom of space; *B* 4¾″ from left edge and 2″ from bottom; *C* 1½″ from left edge and 1¼″ from bottom. Draw a circle through *A*, *B*, and *C*.

Prob. 20, Art. 113, Fig. 212.—Locate a point ½″ from bottom of space and ½″ from left edge. Draw lines from this point to middle of top of space and to lower right hand corner. Draw an arc tangent to these two lines with a radius of 1½″.

Prob. 21, Art. 116, Fig. 216.—Draw an arc having a radius of 3″, with its center ½″ from top of space and ½″ from left edge. Find the length of an arc of 60°.

Prob. 22, Art. 117, Fig. 217.—From the left edge of the space draw a horizontal line 1½″ long and 1¼″ below top of space. From right edge draw a horizontal line 1½″ long and 1¼″ above bottom of space. Join these two lines by an "ogee" curve. Point *E* to be one-third the distance from *B* to *C*.

Prob. 23, Art. 120, Fig. 221.—Draw an ellipse having a major axis of 5″ and minor axis of 2½″. Use concentric circle method.

Prob. 24, Art. 120, Fig. 221.—Draw an ellipse having a major axis of 6″ and a minor axis of 1″. Use concentric circle method.

Prob. 25, Art. 121, Fig. 222.—Draw an approximate ellipse having a major axis of 4½″ and a minor axis of 3¼″.

Lettering.—These exercises are for use in one-quarter of the working space of a regular sheet (see Fig. 291).

For pencil letters use a long conical point. Rotate the pencil in the fingers after each few strokes to keep the point symmetrical.

For ink letters use a penholder with a cork grip and set the pen well into the holder. Always use drawing ink for lettering. To get clean cut letters it is necessary to wipe the pen frequently with a cloth penwiper.

Problems are given for both vertical and inclined letters but only one kind should be taught beginners.

Prob. 26, Fig. 292.—Single stroke vertical caps. Lay out a sheet as in Fig. 291. Starting with the top border line rule guide lines $3/8''$ apart. With a pencil make the letter I on the first line. Make each of the other letters six times. Make a careful study of the letters with the order and direction of strokes as given in Fig. 24.

Prob. 27, Fig. 293.—Make $3/8''$ pencil letters. Complete each line (Fig. 24).

Prob. 28, Fig. 294.—Make $3/8''$ pencil letters. Complete each line (Fig. 24).

Prob. 29, Fig. 295. Vertical Figures.—Make $3/8''$ pencil figures. Complete each line.

Prob. 30, Fig. 296.—Rule guide lines $3/16''$ apart. Make the first two lines in pencil. Make the next two lines very lightly in pencil and go over them with pen and ink. Use 404 Gillott pen. Make the fifth and sixth lines in ink without first penciling.

Prob. 31, Fig. 297.—Single stroke vertical lower-case. Starting one inch from left edge and one inch up, rule guide lines as shown. The bodies of the letters are $1/8''$ high. The first space is $1/8''$ up, the next $1/16''$, and the next $3/16''$. Repeat until there are guide lines for eight lines of letters. Make pencil letters shown and complete each line (Fig. 25).

Prob. 32, Fig. 298.—Same as Prob. 31, except directly in ink.

Prob. 33, Fig. 299.—Rule as for Prob. 31. Copy the sentences, first in pencil and then in ink as shown.

Prob. 34, Fig. 300.—Single stroke inclined caps. Lay out a sheet as in Fig. 291. Starting with the top border line rule guide lines $3/8''$ apart. With a pencil make the letter I on the first line. Make each of the other letters six times. Make a careful study of the letters with the order and direction of strokes as given in Fig. 30.

Prob. 35, Fig. 301.—Make $3/8''$ pencil letters. Complete each line (Fig. 30).

Prob. 36, Fig. 302.—Make $3/8''$ pencil letters. Complete each line (Fig. 30).

Prob. 37, Fig. 303.—Inclined figures. Rule guide lines $3/8''$ apart. Make each figure six times in pencil. On the last line make the fractions (Fig. 30).

Prob. 38, Fig. 304.—Rule guide lines $3/16''$ apart. Make the first two lines in pencil. Make the next two lines very lightly in pencil and go over them with pen and ink. Use 404 Gillott pen. Make the fifth and sixth lines in ink without first penciling.

Prob. 39, Fig. 305.—Single stroke inclined lower case. Starting one inch from left edge and one inch up, rule guide lines as shown. The bodies of the letters are $1/8''$ high. The first space is $1/8''$ up, the next $1/16''$, and the next $3/16''$. Repeat until there are guide lines for eight lines of letters. Make pencil letters shown and complete each line (Fig. 33).

Prob. 40, Fig. 306.—Same as Prob. 39, except directly in ink.

Prob. 40, Fig. 307.—Rule as for Prob. 39. Copy the sentences first in pencil and then in ink as shown.

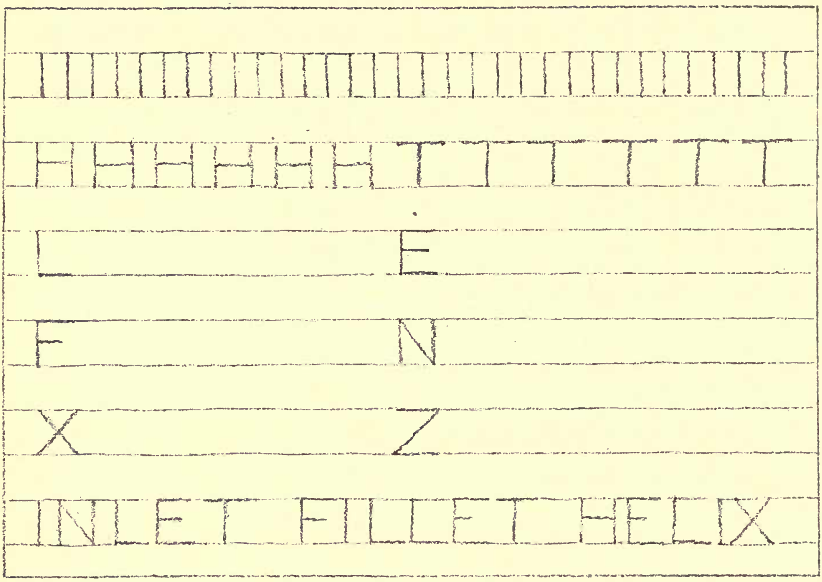


FIG. 292.—Prob. 26.

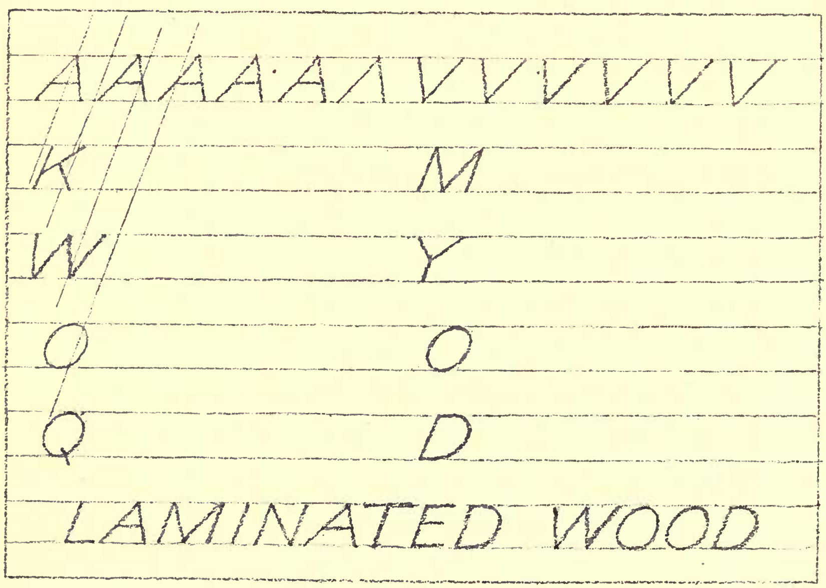


FIG. 293.—Prob. 27.

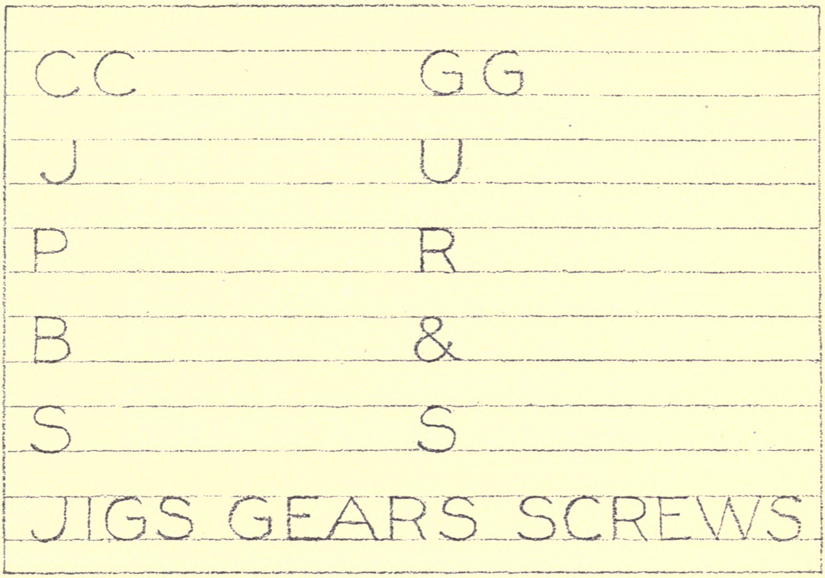


FIG. 294.—Prob. 28.

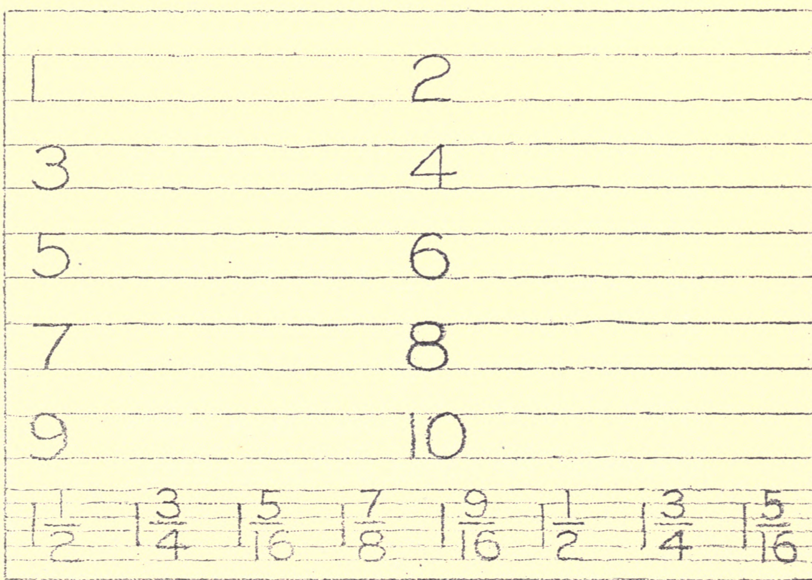


FIG. 295.—Prob. 29.

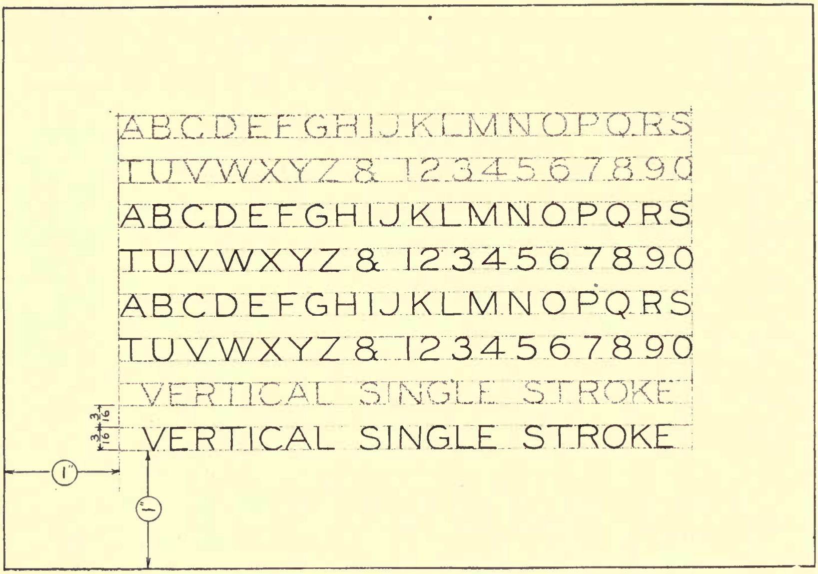


Fig. 296.—Prob. 30.

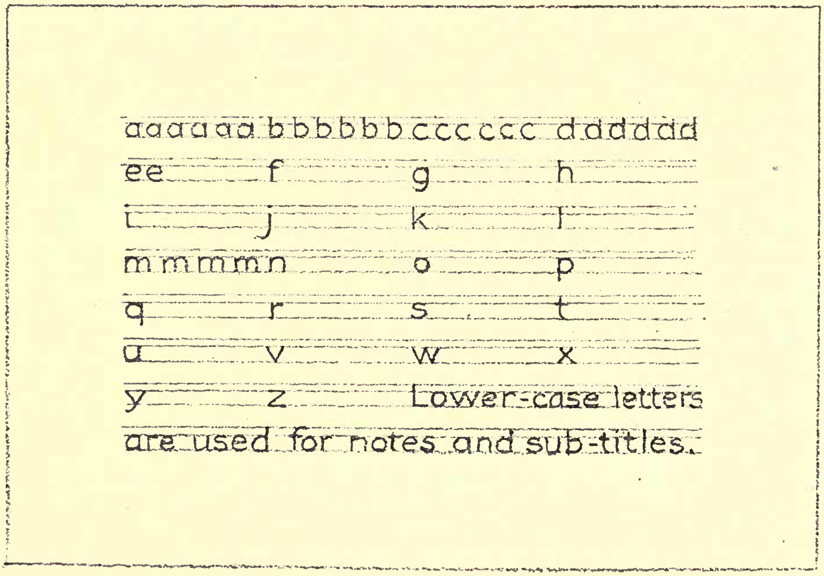


Fig. 297.—Prob. 31.

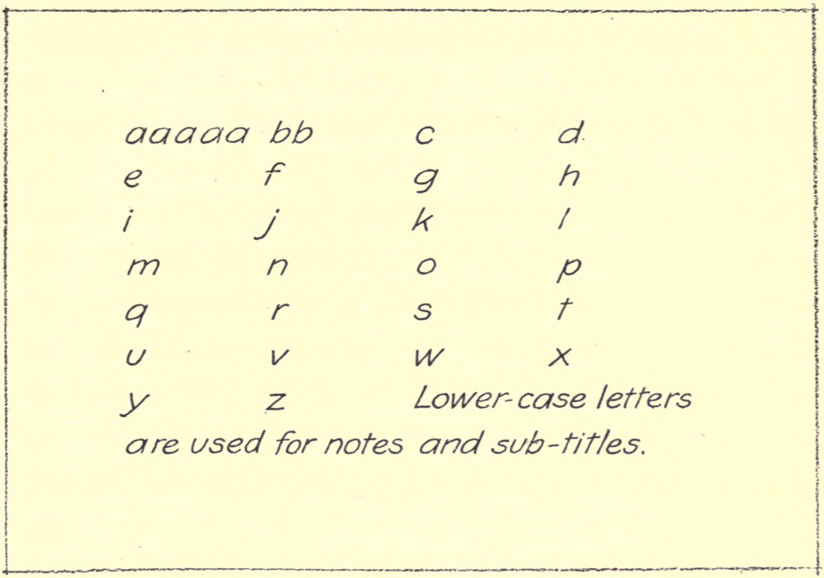


FIG. 298.—Prob. 32.

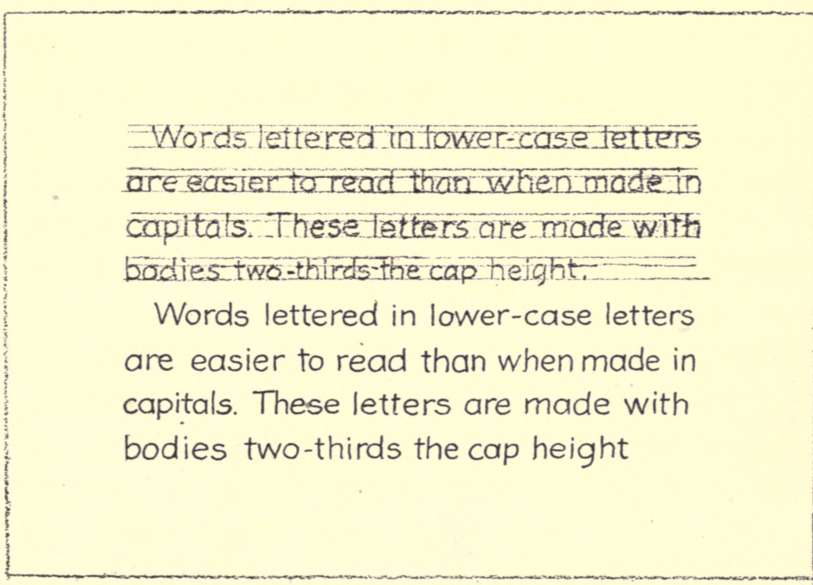


FIG. 299.—Prob. 33.

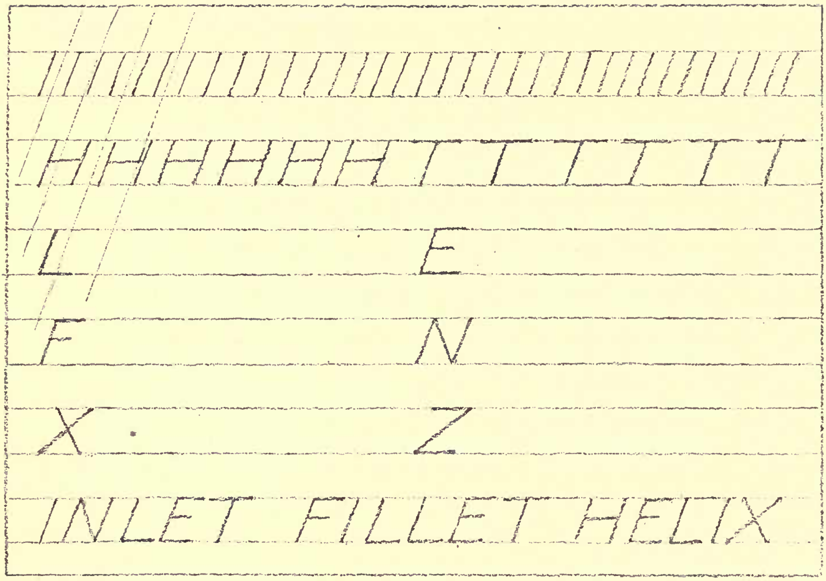


Fig. 300.—Prob. 34.

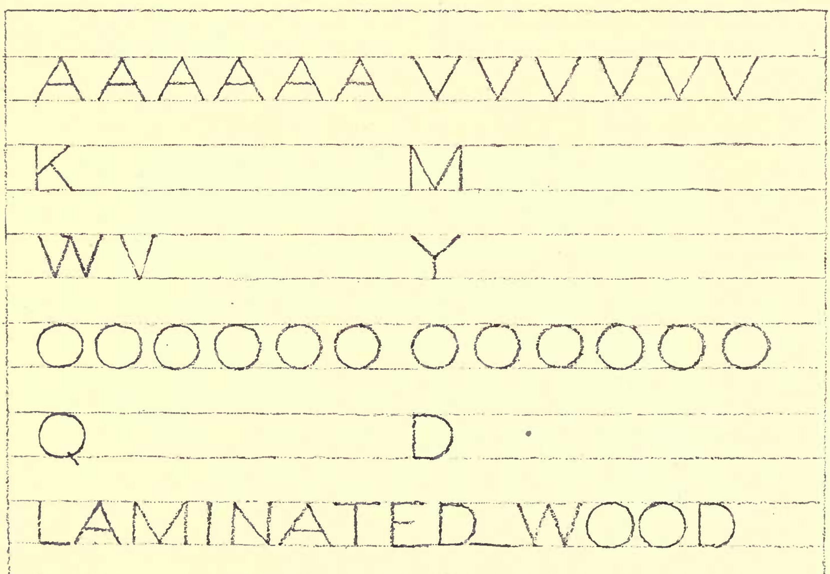


Fig. 301.—Prob. 35.

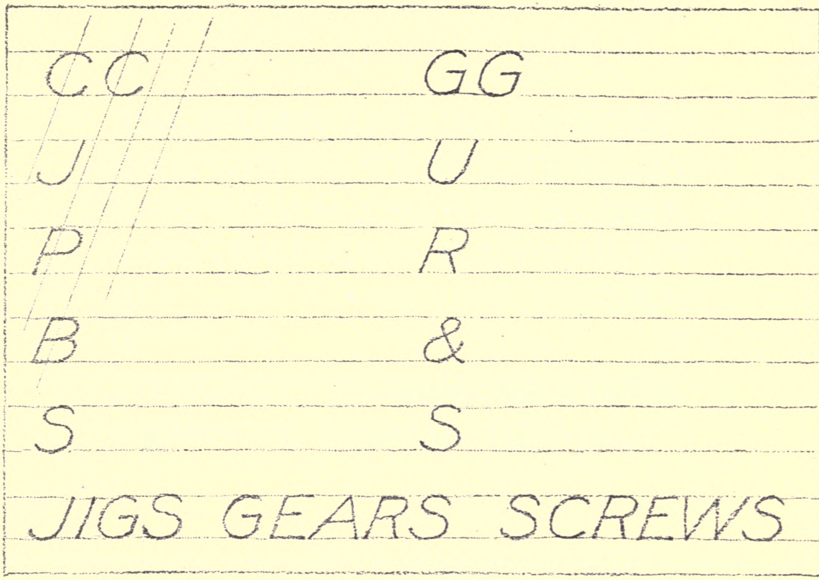


FIG 302.—Prob. 36.

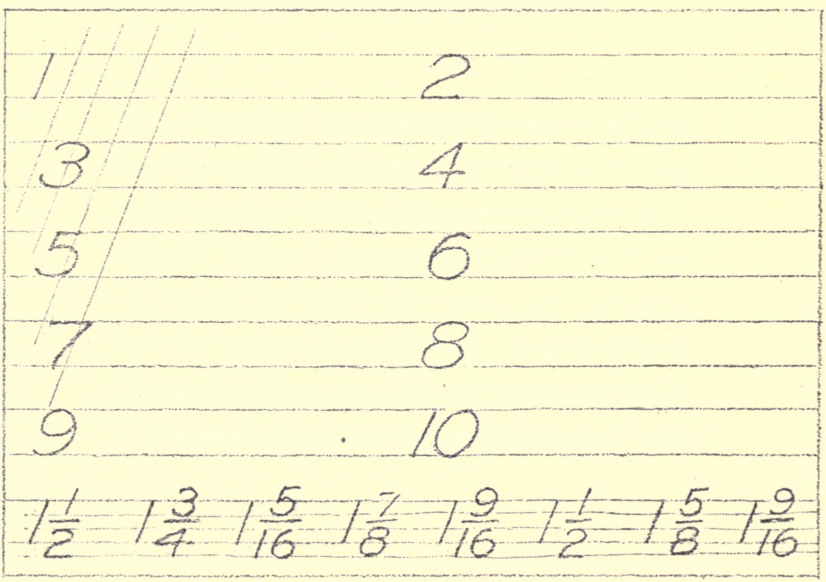


FIG. 303.—Prob. 37.

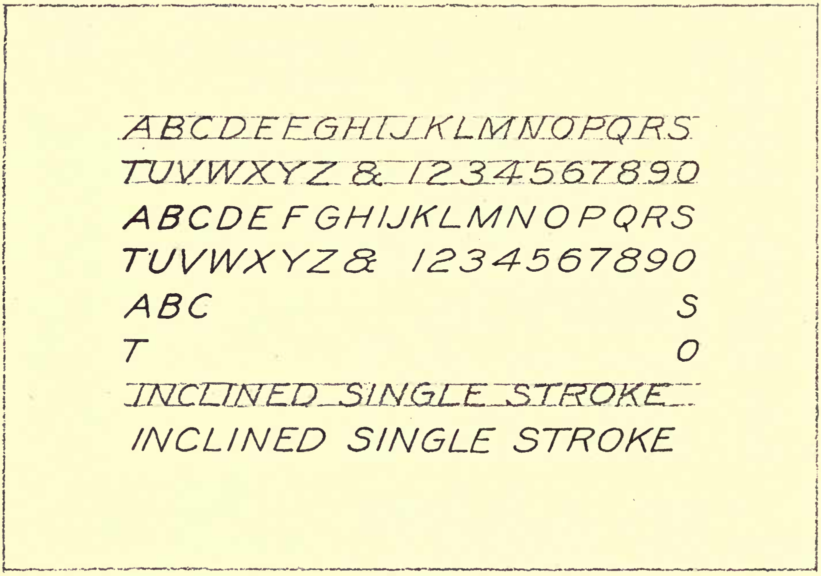


FIG. 304.—Prob. 38.

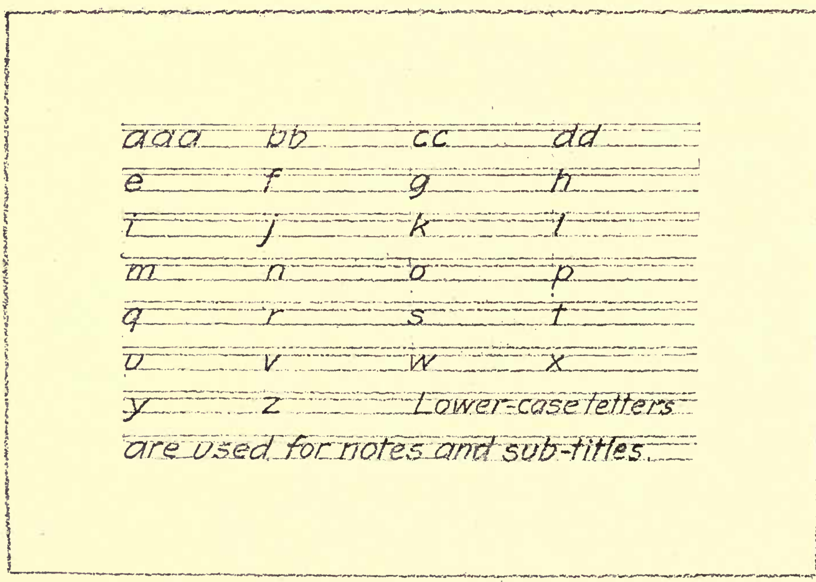


FIG. 305.—Prob. 39.

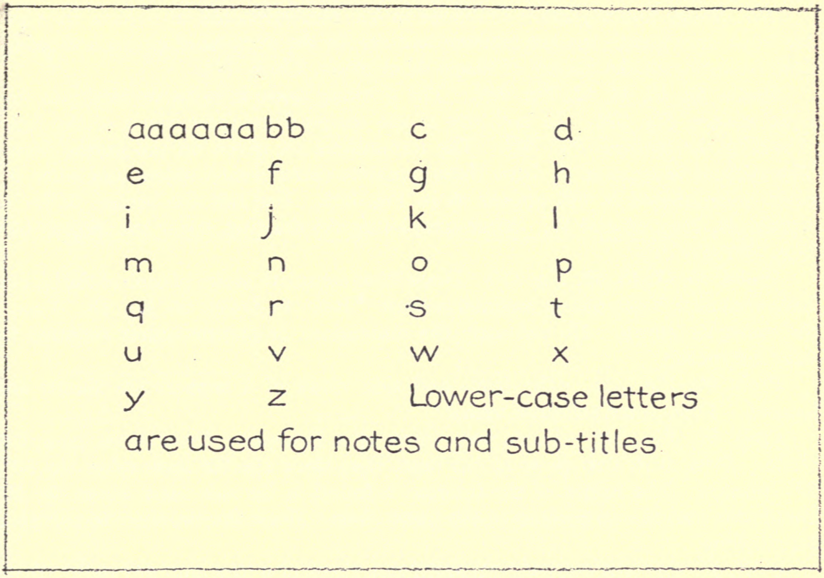


FIG. 306.—Prob. 40.

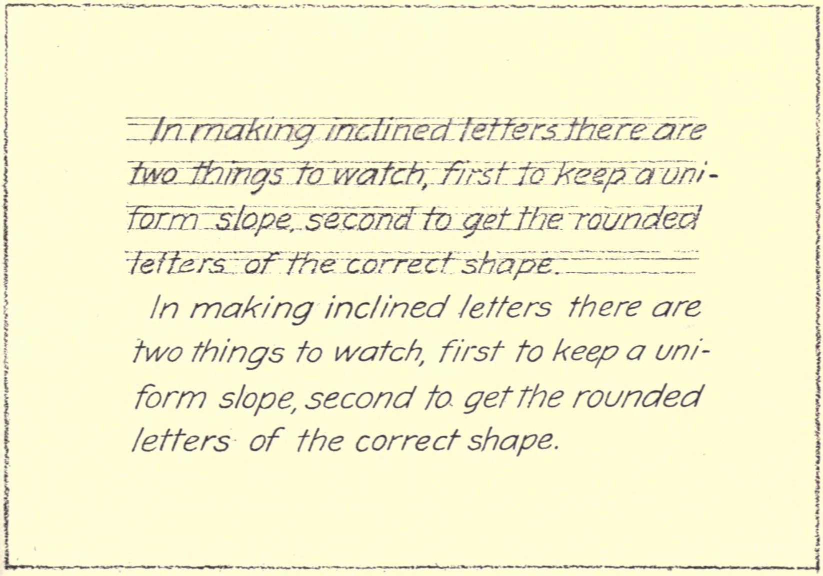


FIG. 307.—Prob. 41.

145. Shape Description.—Problems in the representation of objects by views are to be drawn with the instruments and are for the purpose of giving a thorough understanding of the theory of shape description, Chap. III.

Probs. 42, 43, 44, 45, Fig. 308. The working space is to be divided into four equal spaces, Fig. 291. In each one of the spaces draw three views of the block shown in the picture, Fig. 308. The dimensions are given on the partial views. The student is required to draw three complete views of each object and when his plate is completed it will appear as in Fig. 309. Use full size scale. Refer to Article 26, Figs. 46 and 47. After completing the drawing, letter the record strip, Figs. 260 and 310.

Probs. 46, 47, 48, 49, Fig. 310. Draw three complete views of each of the blocks. Note that each block has an inclined surface. Refer to Article 26, Fig. 48. Locate the views as shown. Do not copy the dimensions or picture unless required by your instructor.

Prob. 50, Fig. 311.—The front and side views of a **support** are shown and located. Draw three complete views.

Prob. 51, Fig. 312.—Given two views of a **fulcrum.** Draw three complete views. First draw two views of the base, then draw the 60° lines using the 30°–60° triangle. The height of the fulcrum is found in the side view where the 60° lines cross, and then projected to the front view. Draw the top view to complete the drawing.

Prob. 52, Fig. 313.—Given top and front views of a **cast iron dovetail.** Draw three complete views. In the top view note the center line and lay off one-half of 1¾″ on each side of it. Draw 60° lines to intersect the ¾″ depth line.

Prob. 53, Fig. 314.—Draw three views of the **dovetail joint** with the two pieces together. Note the 60° lines in the top view.

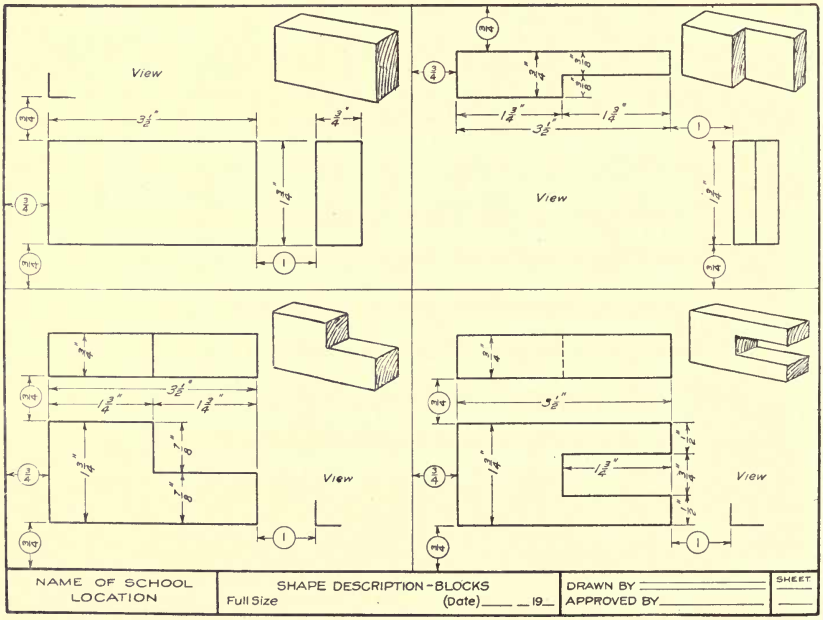


FIG. 308.—Probs. 42, 43, 44, 45.

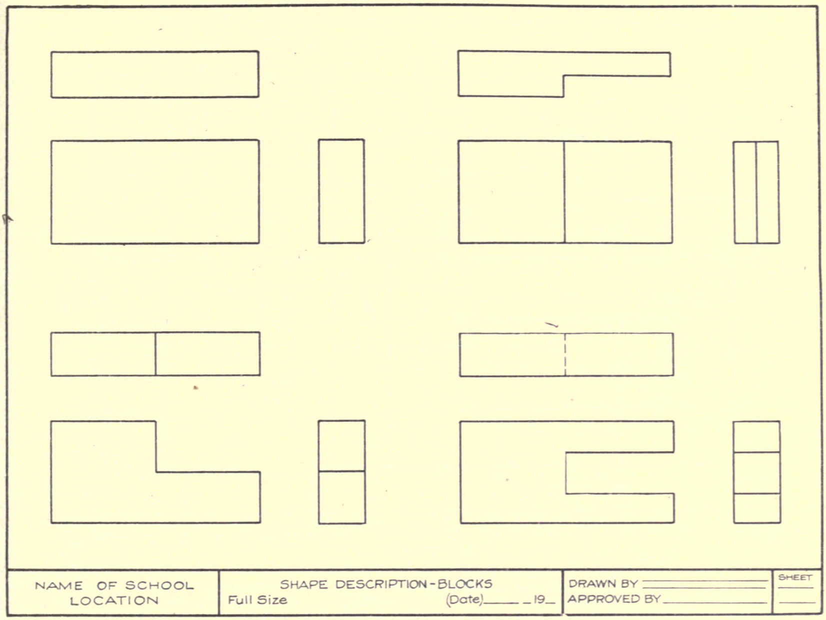


Fig. 309.

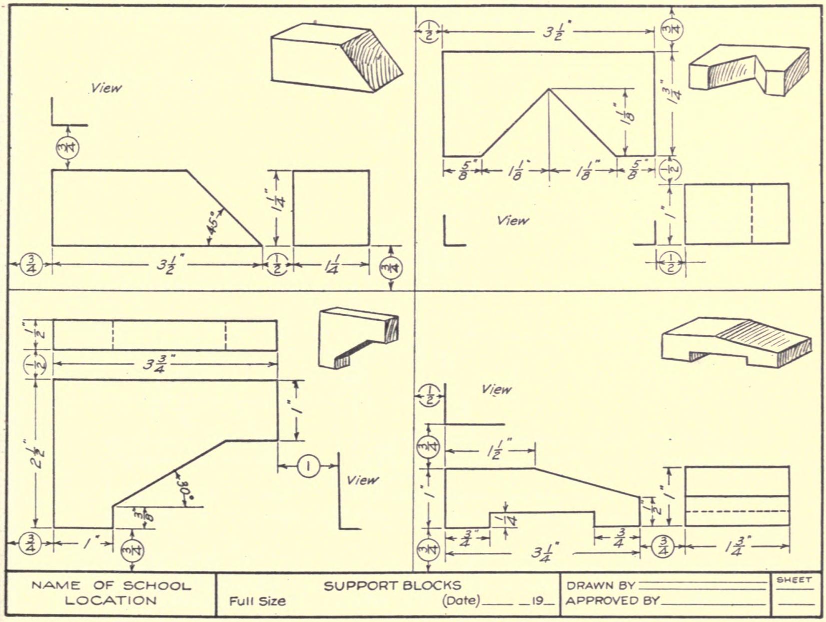


Fig. 310.—Probs. 46, 47, 48, 49.

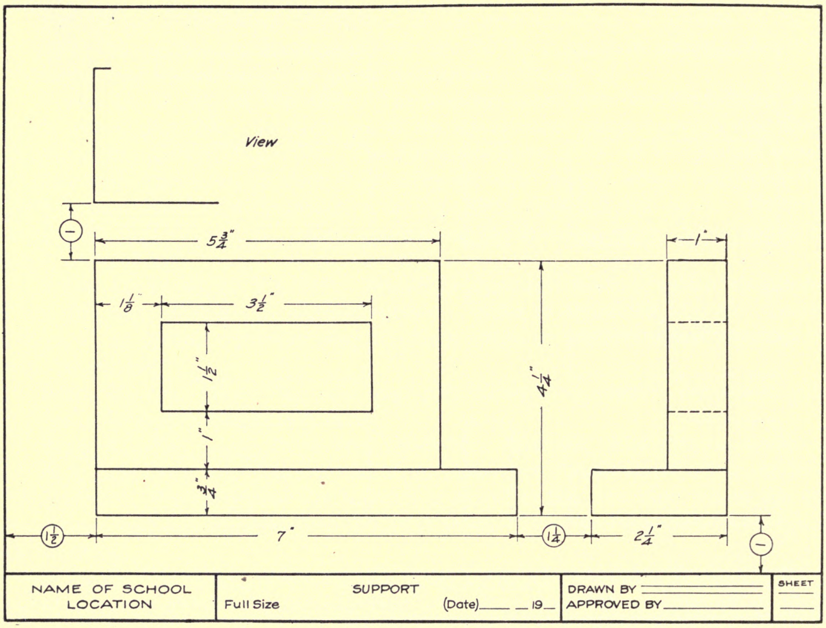


FIG. 311.—Prob. 50.

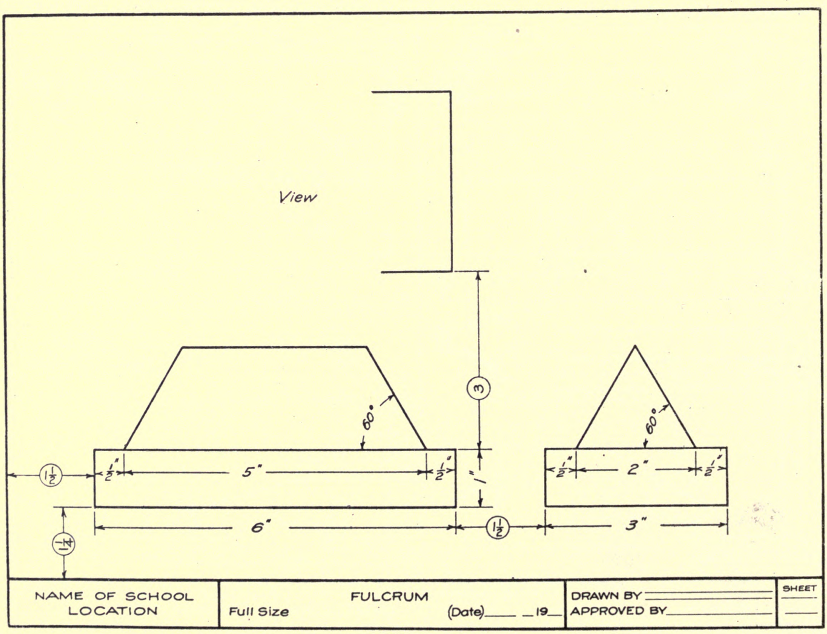


FIG. 312.—Prob. 51.

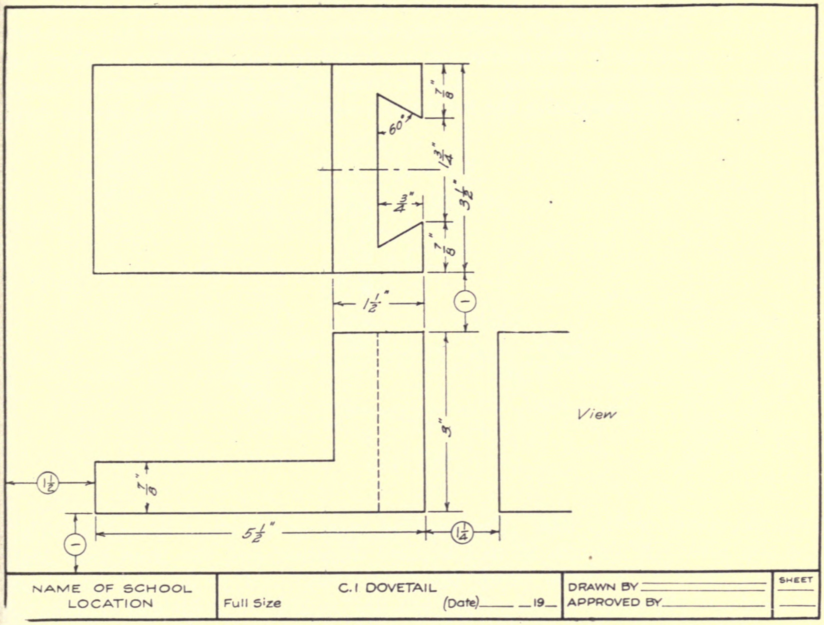


FIG. 313.—Prob. 52.

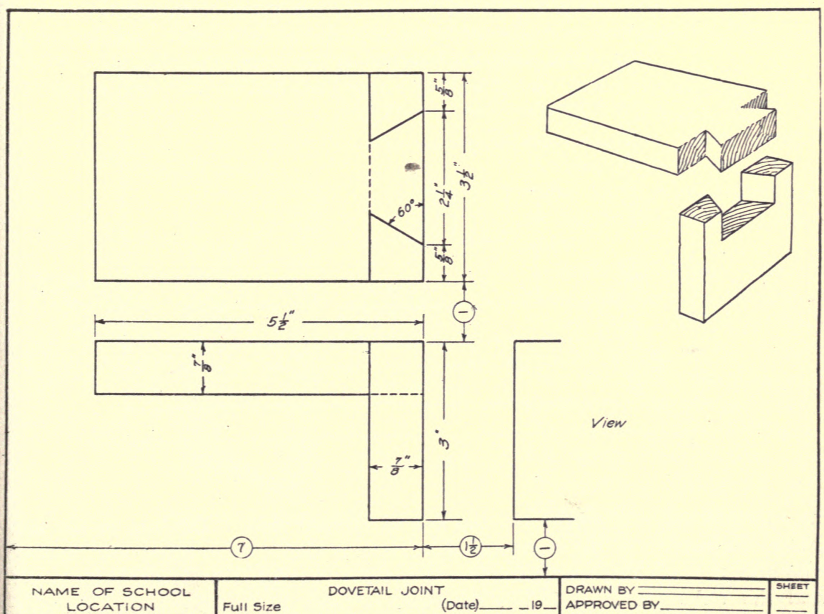


FIG. 314.—Prob. 53.

146. Placing Views.—The location of the views for the preceding problems has been given. When making drawings from objects or for things which have not been made, it is necessary for the draftsman to be able to place the views so that they will go in the space to advantage. This is done by considering the space necessary for each view and comparing the total room required with the size of the sheet.

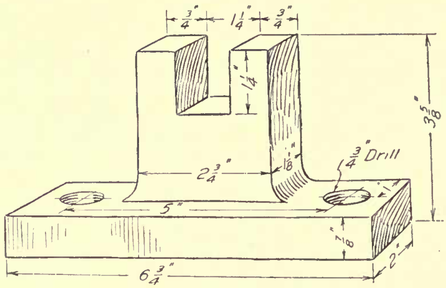


FIG. 315.

Note the object of Fig. 315. The working space in our sheet is 9½″ × 13⅝″. The top view will require 2″ in a vertical direction and the front view 3⅝″. Allowing (say) 1″ between views, the total is 6⅝″. If we subtract 6⅝″ from the height of the space, we have 9½″ less 6⅝″ = 2⅞″ to be divided between top and bottom. In Fig. 316 the lowest line of the front view has been placed 1½″

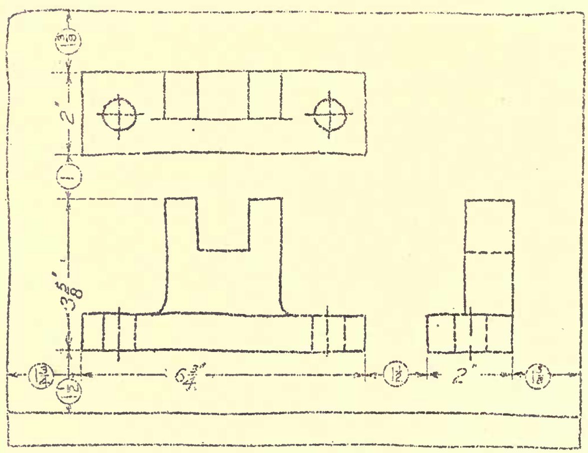


FIG. 316.

up which leaves 1⅜″ above the top line of the top view. The sum of the horizontal dimensions of the front and side views is 8¾″. If we allow 1½″ between views there is left 3⅜″ for the two side spaces. In Fig. 316 the left space is 1¾″ and the right 1⅝″. It is not necessary to have the spaces exactly alike either between views or around them.

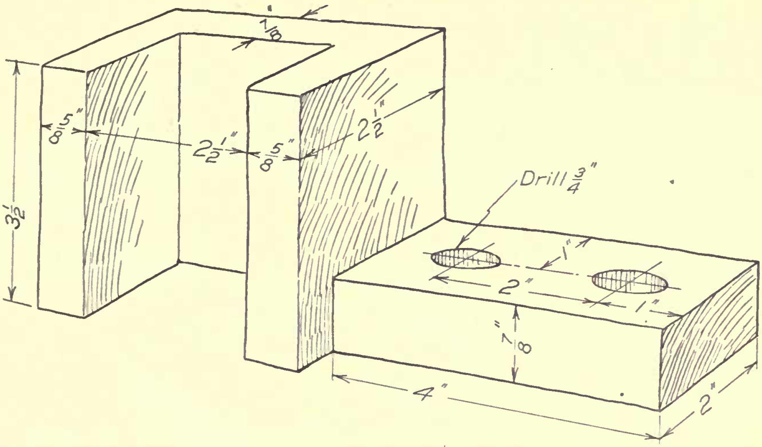


FIG. 317.—Prob. 54.

Prob. 54, Fig. 317.—From the picture of the **vertical holding piece,** draw three complete views. First work out the placing of the views as described for Figs. 315 and 316. Do not dimension unless required by your instructor.

Prob. 55, Fig. 318.—From the picture and part view of the **post cap** draw two views. Work out the placing of the views before starting the drawing. Three views are not needed as two of the three would be just alike.

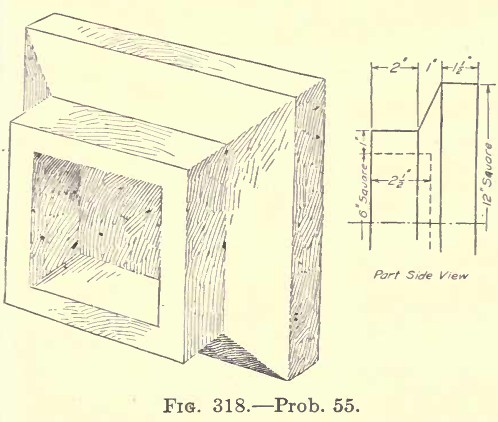


FIG. 318.—Prob. 55.

Prob. 56, Fig. 319.—Draw three complete views of the **bench hook.** Work out the placing of the views. Note that the end view is to be drawn by projecting from the top view instead of from the front view. This arrangement is sometimes desirable, as in this case.

Prob. 57, Fig. 320. Draw three complete views of the **book rack.** Work out the placing of the views. Show both ends in position on the base as the book rack would appear when put together. Scale 6″ = 1′. Add dimensions if required by your instructor.

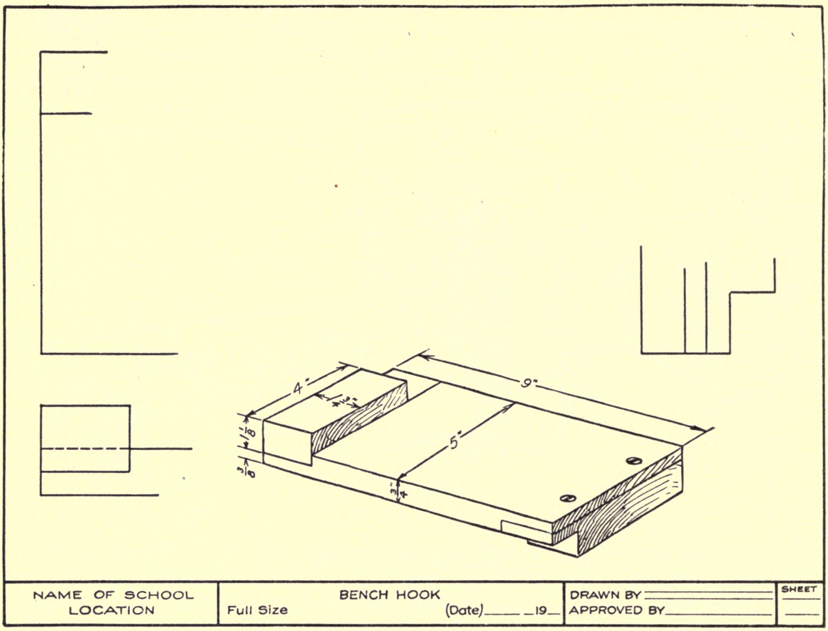


FIG. 319.—Prob. 56.

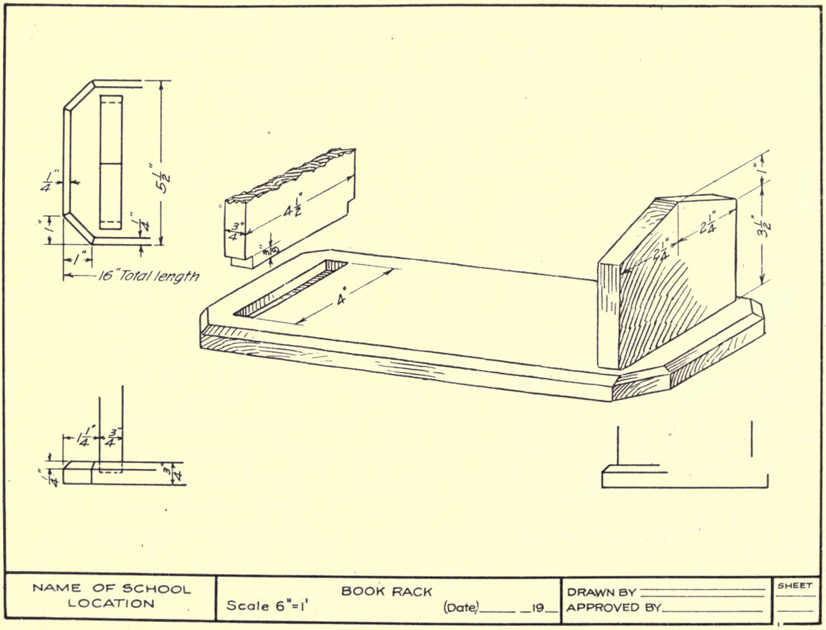


FIG. 320.—Prob. 57.

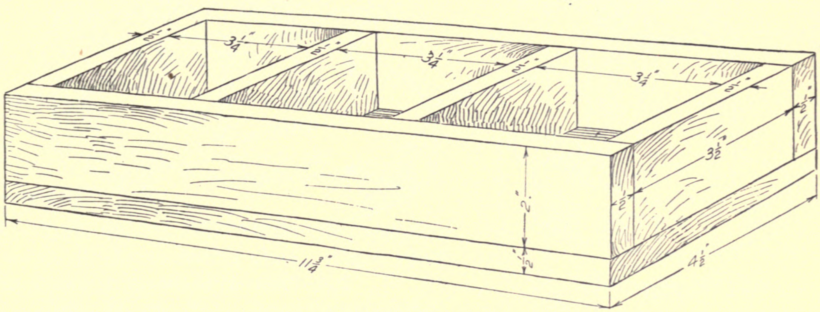


FIG. 321.—Prob. 58.

Prob. 58, Fig. 321.—Draw top and front views of the **nail box.** Place views carefully. Draw full size.

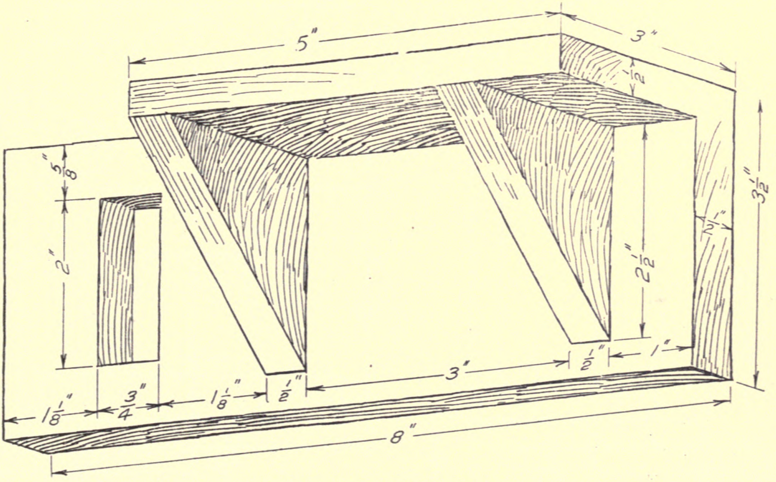


FIG. 322.—Prob. 59.

Prob. 59, Fig. 322.—Draw three complete views of the step bracket. Place views carefully. Draw full size.

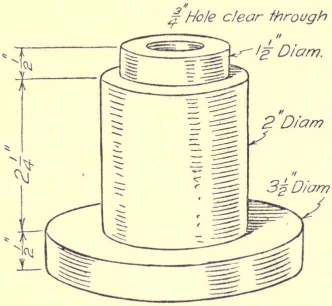


FIG. 323.—Prob. 60.

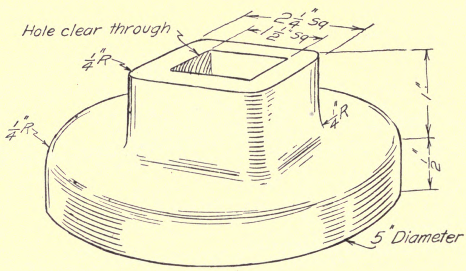


FIG. 324.—Prob. 61.

Prob. 60, Fig. 323.—Draw two complete views of the cast iron collar. Place views as shown in the layout, Fig. 325.

Prob. 61, Fig. 324.—Draw two complete views of the socket. Place views as shown in the layout, Fig. 325.

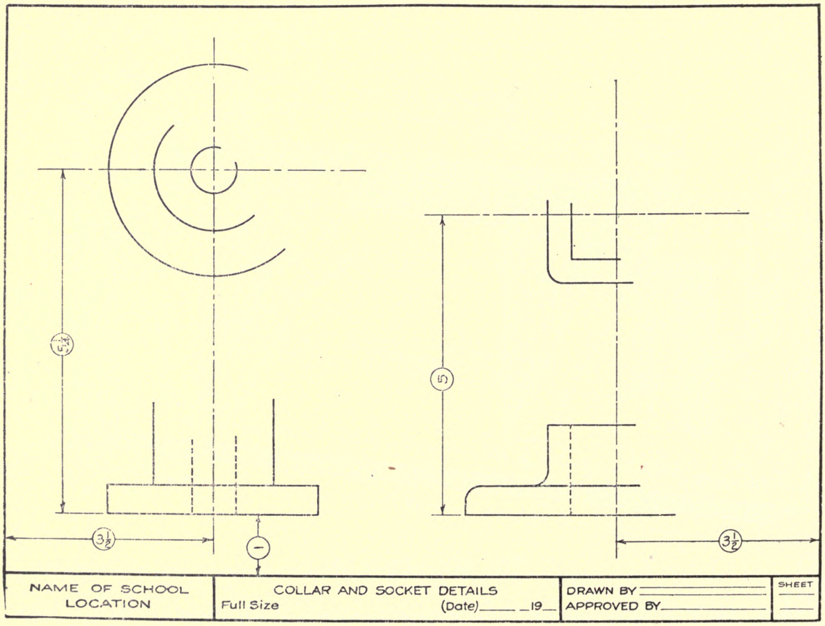


FIG. 325.—Layout for Probs. 60 and 61.

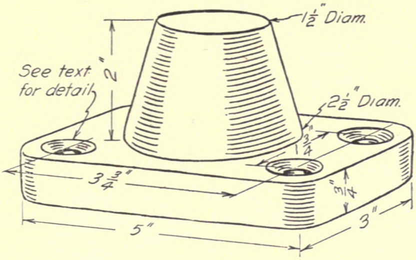


FIG. 326.—Prob. 62.

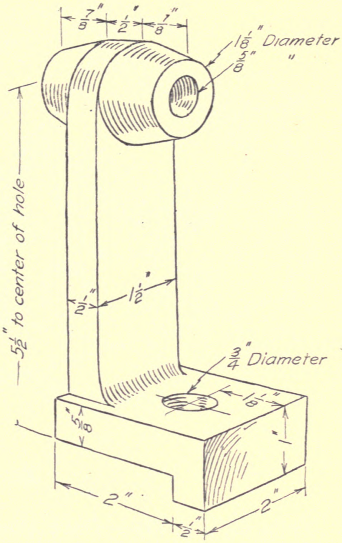


FIG. 327.—Prob. 63.

Prob. 62, Fig. 326.—Draw two complete views of the **centering plate.** Place views as shown in layout, Fig. 328.

Prob. 63, Fig. 327.—Draw two complete views of **bearing.** Place views as shown in layout, Fig. 328.

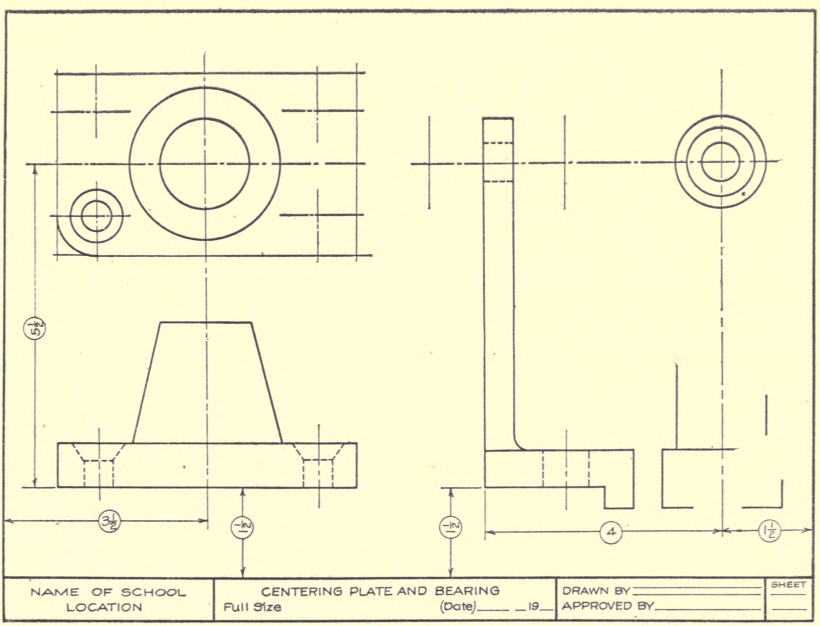


FIG. 328.—Layout for Probs. 62 and 63.

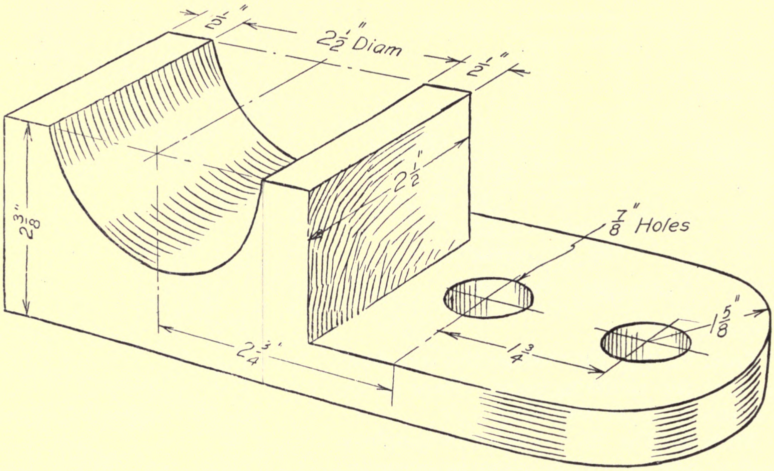


Fig. 329.—Prob. 64.

Prob. 64, Fig. 329.—Draw three complete views of the horizontal guide. Locate views as shown in layout, Fig. 330. Add dimensions if required by instructor.

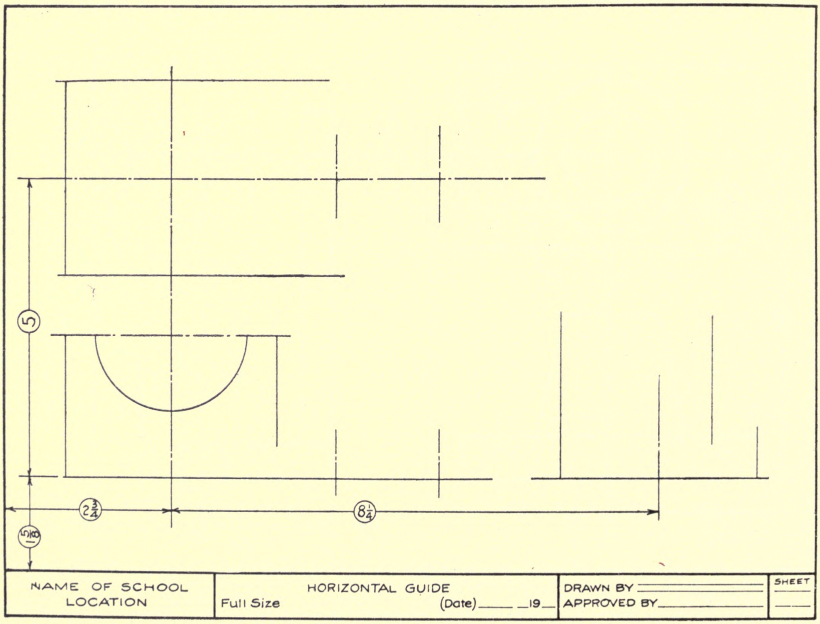


Fig. 330.—Layout for Prob. 64.

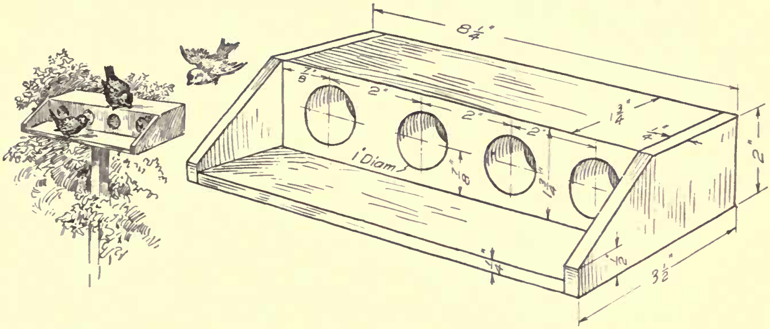


Fig. 331.—Prob. 65.

Prob. 65, Fig. 331.—Draw three complete views of the **bird feeding stick.** Work out the placing of the views as for Figs. 315 and 316. Draw full size. After blocking in the three views, measure the depth of the holes on the top and side views. Then draw the holes in the front view and project to the top and side views. Show center lines for the holes.

147. Sections.—As explained in Article 30, a sectional view shows an object as if it had been cut and a part removed. The cut surface is indicated by section lining with a fine line, generally at 45°, spaced uniformly. The spacing is done entirely by eye. In the following figures use the spacing of the first rectangle of Fig. 159.

Prob. 66, Fig. 332.—The layout for problem 66 is shown as a freehand sketch. The student is required to make a mechanical drawing of the **cylindrical spacer.** The right-hand view is to be drawn as a section, Art. 30.

Prob. 67, Fig. 333.—The sketch layout for a **clamping disc** is shown in the figure. Make a mechanical drawing. The right view is to be in section.

Prob. 68, Fig. 334.—The sketch layout for a **cast iron piston body** is shown in the figure. Make a mechanical drawing showing the left view in section.

Prob. 69, Fig. 335.—The sketch layout of a **protected bearing** is shown in the figure. Make a mechanical drawing showing the right view as a half section, Art. 30, Fig. 73.

Prob. 70, Fig. 336.—Draw three views of the **yoke,** the front view to be a section. Note that there are two pieces, the yoke and the bushing. Read Article 30 in regard to section lines when two pieces are drawn together, Fig. 74.

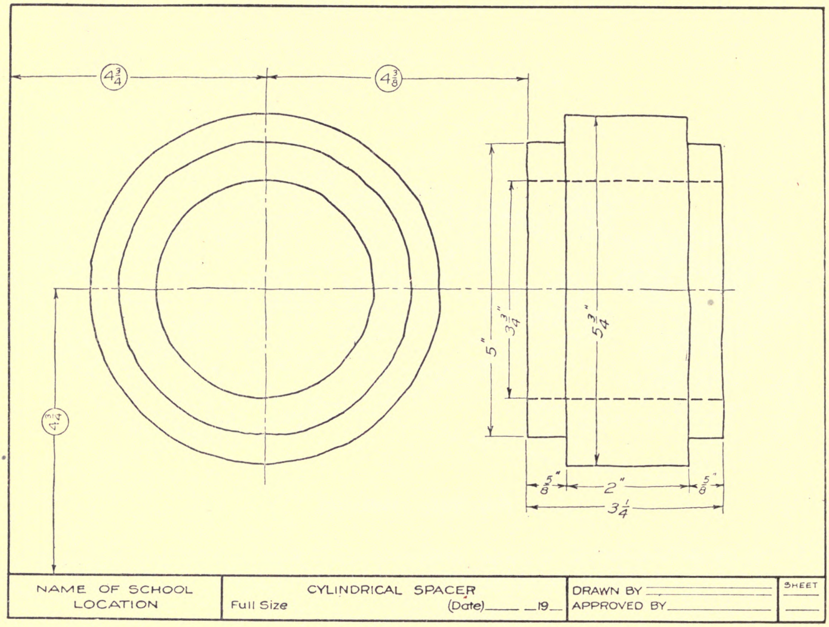


FIG. 332.—Prob. 66.

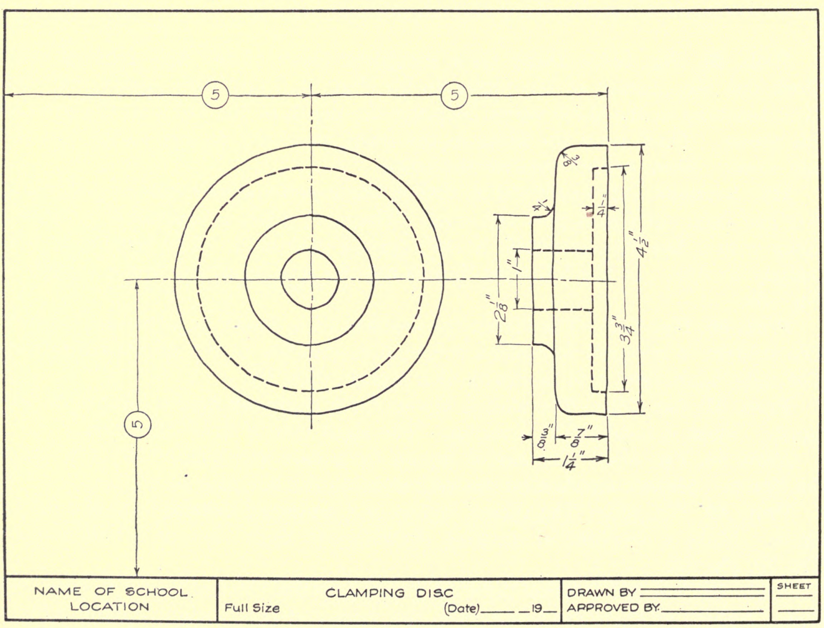


FIG. 333.—Prob. 67.

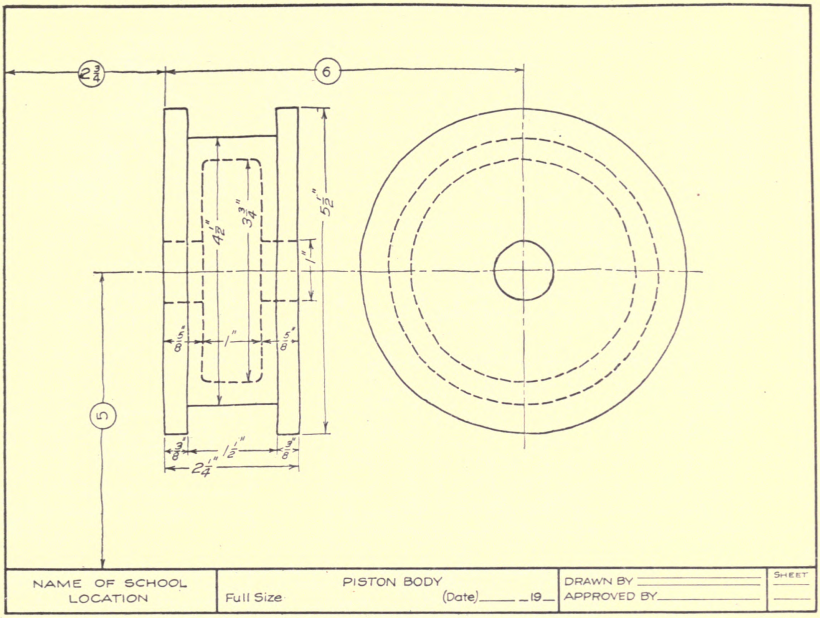


FIG. 334.—Prob. 68.

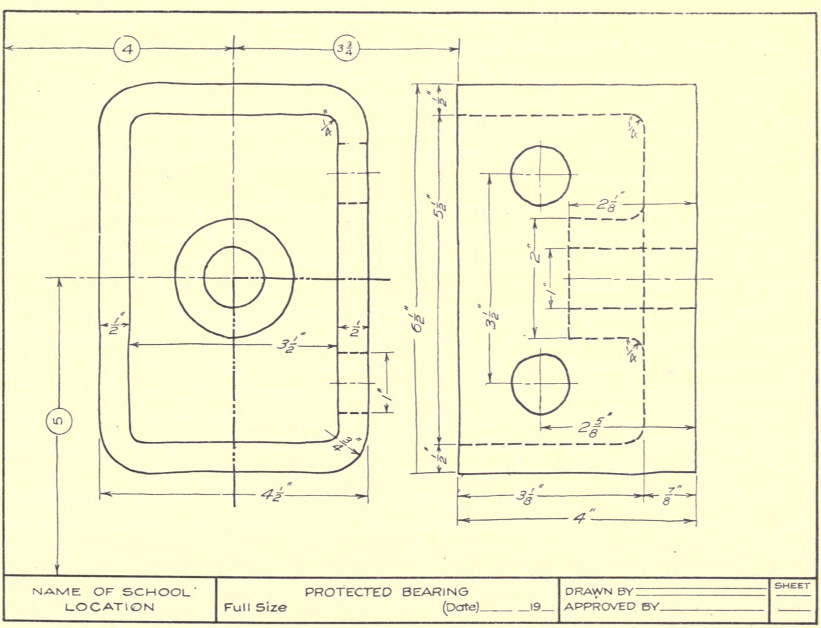


FIG. 335.—Prob. 69.

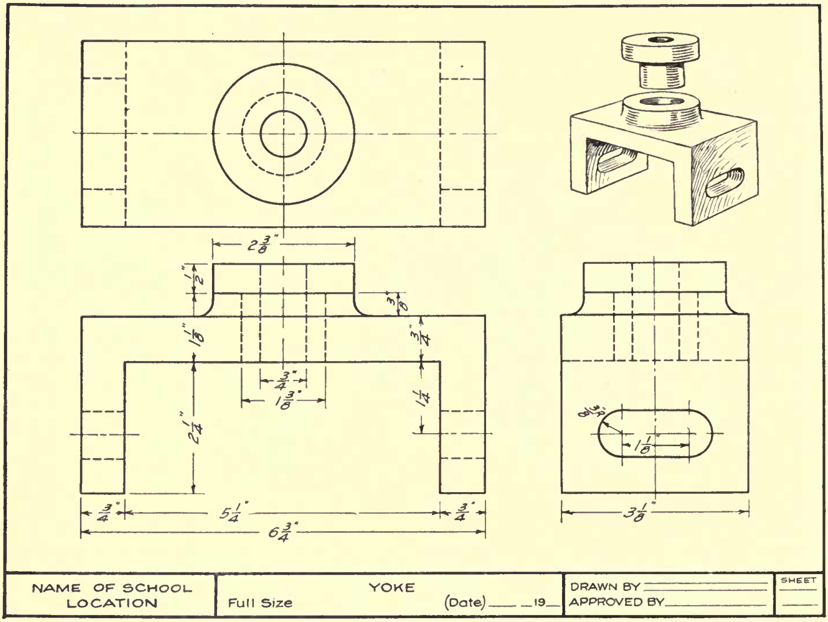


FIG. 336.—Prob. 70.

148. Auxiliary Views.—Center or other reference lines are used in working problems in auxiliary projection. See Arts. 31 and 32.

Prob. 71, Fig. 337.—The figure gives the layout for two problems. Draw the top, front and the complete auxiliary view of the rectangular prism as shown.

Prob. 72, Fig. 337. Draw the two views given and the complete auxiliary view of the square prism.

Prob. 73, Fig. 338.—The figure gives the layout for two problems. Draw the views given and the complete auxiliary view for the **dovetail moulding.**

Prob. 74, Fig. 338.—Draw the two views given and the complete auxiliary view of the "**half round.**"

Prob. 75, Fig. 339.—A picture and layout for an **angle stop** are shown in the figure. Draw the two views given and a part auxiliary view. The picture need not be copied. Dimension if required by instructor. This is the form in which auxiliary projection most frequently occurs in practical work, Art. 31, Fig. 80.

Probs. 76, 77, 78, 79, 80, 81, Figs. 340 to 345.—Choice of any two of these problems will require the same space as problems 71 and 72. Draw the two views given and the complete auxiliary view on the center line indicated.

Prob. 82, Fig. 346.—The figure gives the layout and picture of a **hollow moulding.** Draw the two views given, and from these draw the complete auxiliary view.

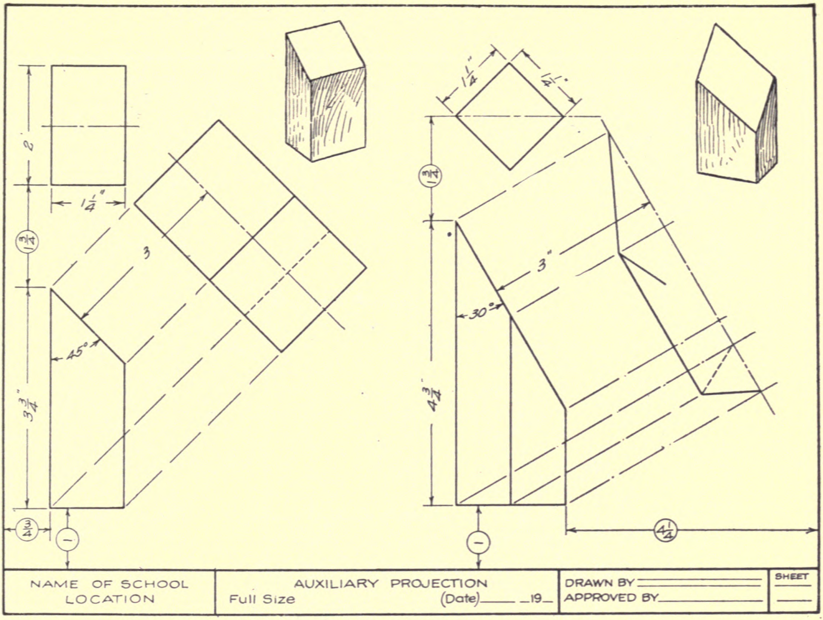


Fig. 337.—Probs. 71 and 72.

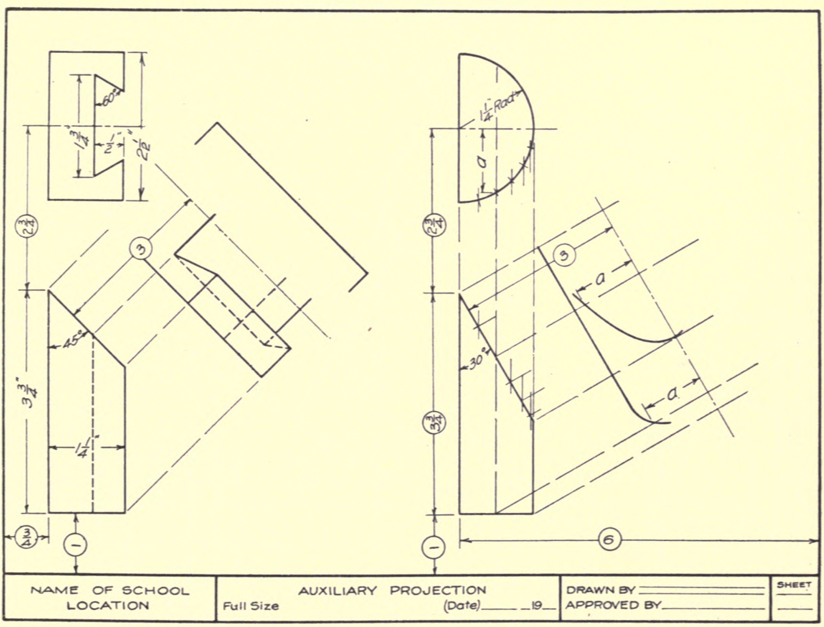


Fig. 338.—Probs. 73 and 74.

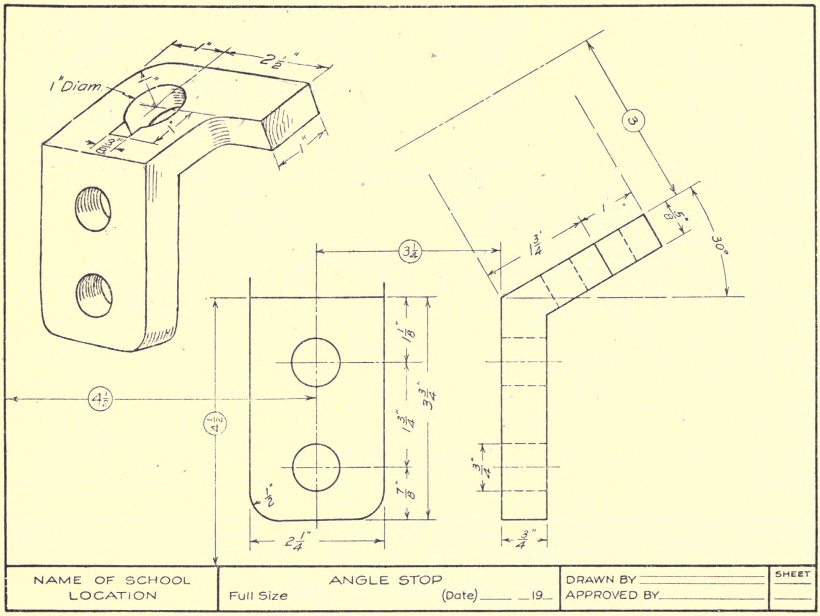


FIG. 339.—Prob. 75.

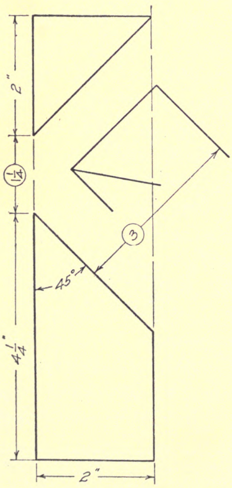


FIG. 340.— Prob. 76.

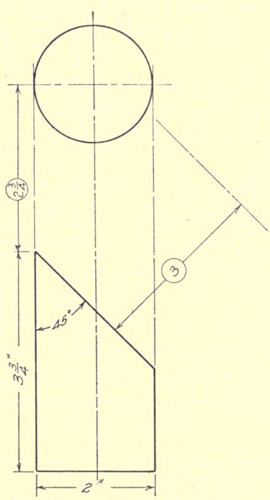


FIG. 341.—Prob. 77.

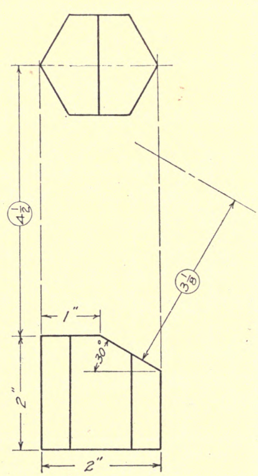


FIG. 342.—Prob. 78.

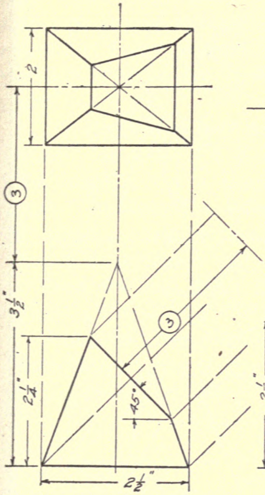


Fig. 343.—Prob. 79.

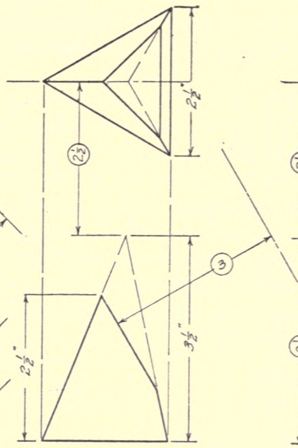


Fig. 344.—Prob. 80.

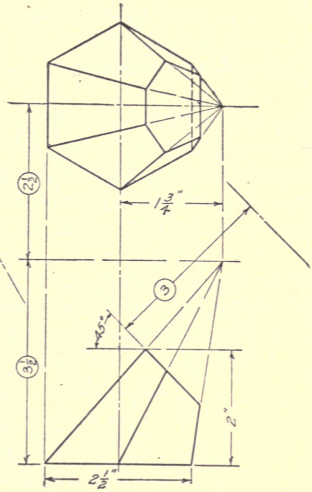


Fig. 345.—Prob. 81.

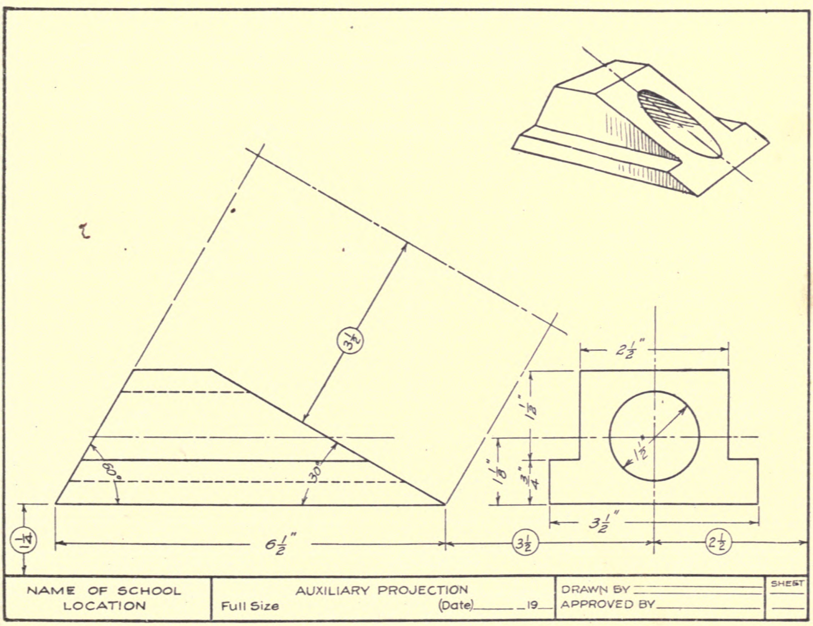


Fig. 346.—Prob. 82.

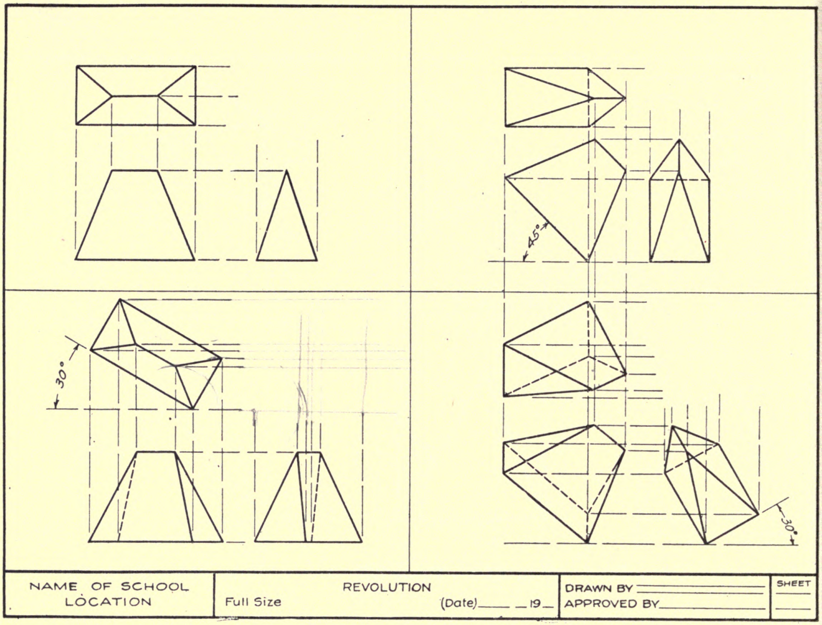


FIG. 347.—Prob. 83.

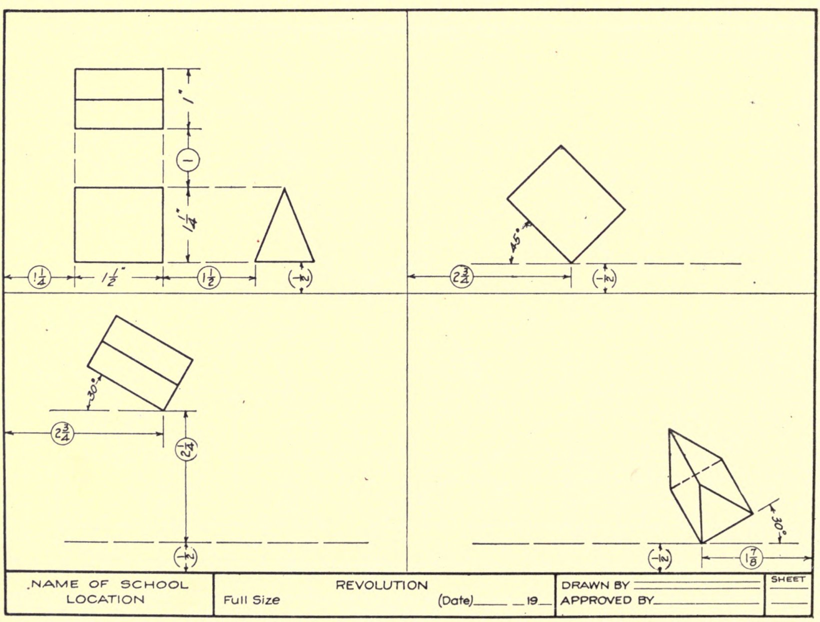


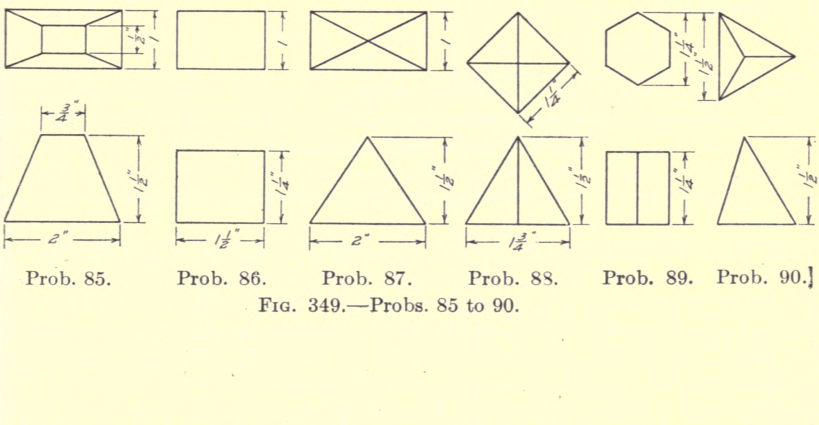
FIG. 348.—Prob. 84.

148. Revolutions.—Prob. 83, Fig. 347.—The figure shows the completed problem. This should not be copied but is given for comparison. The sheet is divided into four spaces as shown. The first space is for three views of the object. In space No. 2 (upper right hand) the object is shown after being revolved from the position of space No. 1, through 45°, about an axis perpendicular to the vertical plane.

The front view was drawn first and the top and side views obtained by projection. In space No. 3 (lower left hand) the object is shown after being revolved from position No. 1 through 30° about an axis perpendicular to the horizontal plane. In space No. 4 the object has been revolved from position No. 2 through 30° about an axis perpendicular to the side plane (Art. 33). Problem 84 is to be worked in the same way, using the dimensions given.

Prob. 84, Fig. 348.—From the given views draw three complete views of the object in the position indicated in each space. Read explanation of Problem 83.

Probs. 85 to **90,** Fig. 349.—These figures are given as alternates for problem 84. Draw three views of the one selected, and revolve using the same positions and placing as in Fig. 348.



Prob. 85. Prob. 86. Prob. 87. Prob. 88. Prob. 89. Prob. 90.]

Fig. 349.—Probs. 85 to 90.

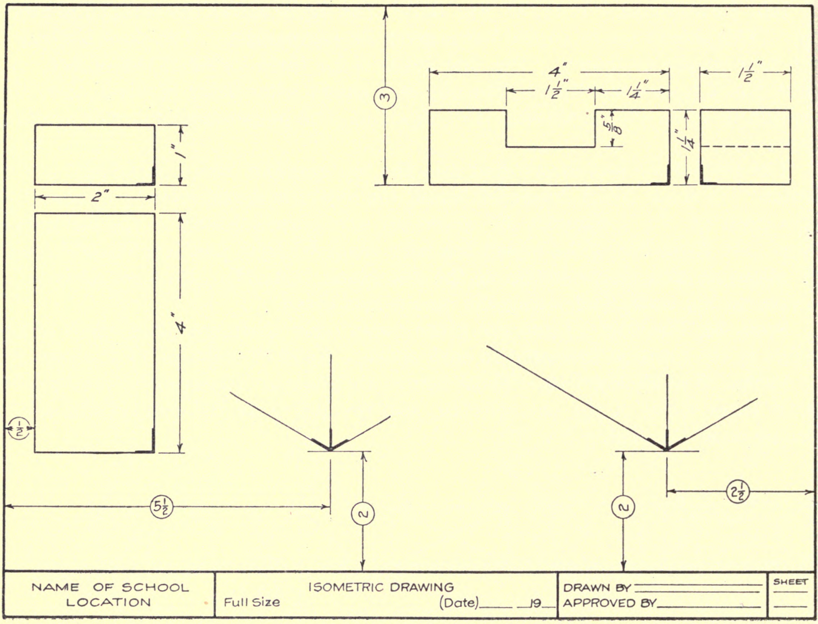


FIG. 351.—Probs 91 and 92.

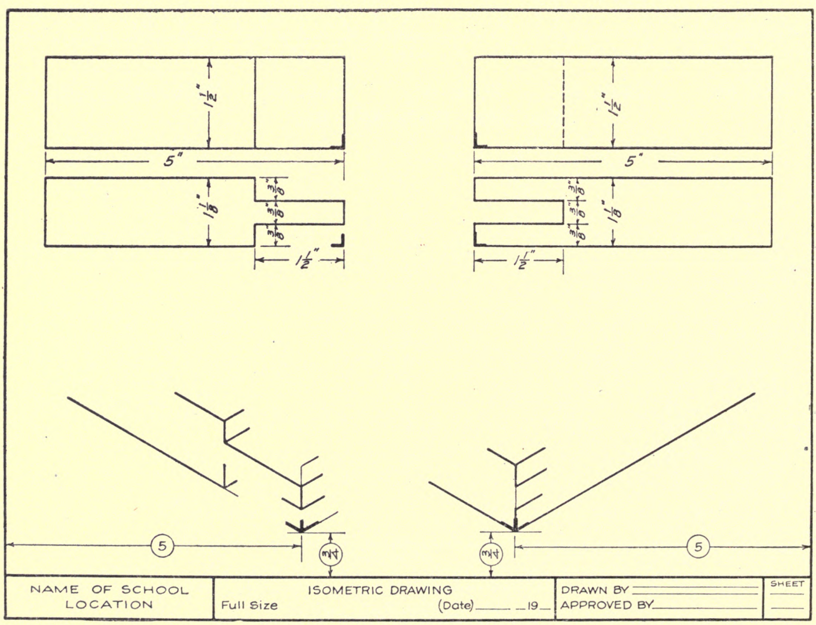


FIG. 352.—Probs. 93 and 94.

149. Pictorial Drawing.—When making isometric drawings it is necessary to decide upon the point which will be taken for the center of the three axes. The isometric cube with the two starting positions for the axes is shown in Fig. 350. The position to use is given on the layout for each of the following problems. Remember that all measurements must be taken parallel to the axes (Arts. 34 to 40).

Prob. 91, Fig. 351.—Draw the orthographic views as given for the block. Construct the isometric drawing using the axes in the second position as started on the layout. The heavy lines indicate the corner of the object from which the axes start (Art. 35).

Prob. 92, Fig. 351.—Draw the given views and an isometric drawing of the half lap joint (Art. 35).

Prob. 93, Fig. 352.—Draw the views given and an isometric drawing of the tenon.

Prob. 94, Fig. 352.—Draw views given and an isometric drawing of the mortise.

Prob. 95, Fig. 353.—Make an isometric drawing of the notched block. Locate as on Fig. 355. Start with the corner indicated by heavy lines.

Prob. 96, Fig. 354.—Make an isometric drawing of the plate. Locate as on Fig. 355.

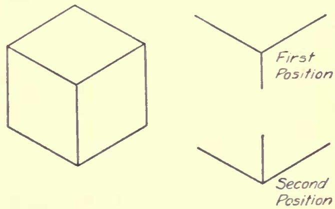


FIG. 350.

Prob. 97, Fig. 356.—Make an isometric drawing of the stirrup. The drawing is started on the layout of Fig. 358. Note the heavy lines at the starting corner. The slant lines of Fig. 356 are non-isometric lines (Art. 36).

Prob. 98, Fig. 357.—Make an isometric drawing of the brace. The drawing is started in Fig. 358. Note the 60° angle and read Art. 37 before making the drawing.

Prob. 99, Fig. 359.—Make an isometric drawing of a cube each edge of which measures 3″. On each face construct an isometric circle by method of Art. 38.

Prob. 100, Fig. 359.—Make an isometric drawing of a cylinder $2\frac{1}{2}''$ diameter and $3\frac{1}{2}''$ high, resting on a square plate as shown. First draw the square plate. On it construct a square prism having sides of $2\frac{1}{2}''$ and a height of $3\frac{1}{2}''$. On the top and bottom faces of the prism construct isometric circles. Vertical tangent lines will complete the drawing. Note that the distance between these vertical lines is more than the actual diameter of the cylinder. Why?

Prob. 101, Fig. 360.—Draw the three views given of the hung bearing and make an isometric drawing. Most of the construction is indicated on the layout. Make the drawing as though all corners were square and then construct the curves (Art. 38).

Prob. 102, Fig. 361.—Make an isometric drawing in section of the post socket. Locate as on Fig. 363 (Art. 39, Fig. 95).

Prob. 103, Fig. 362.—Make an isometric drawing as a half section of the box. Locate as on Fig. 363 (Art. 39, Fig. 94).

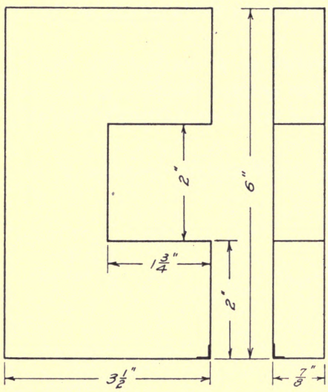


Fig. 353.—Prob. 95.

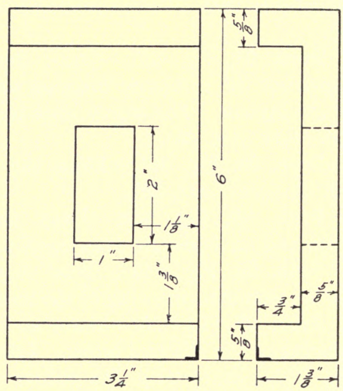


Fig. 354.—Prob. 96.

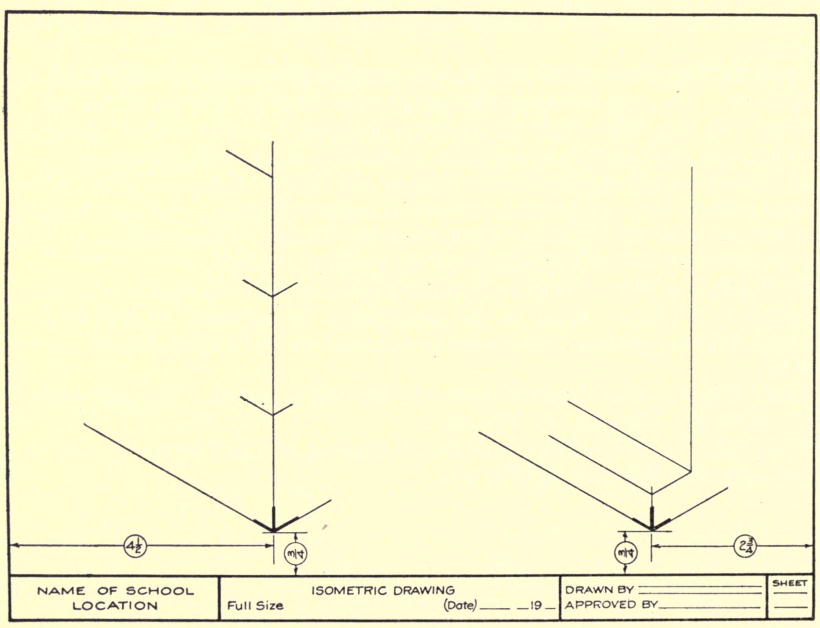


Fig. 355.—Layout for Probs. 95 and 96.

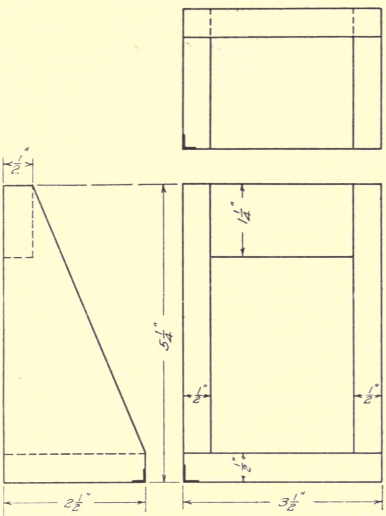


FIG. 356.—Prob. 97.

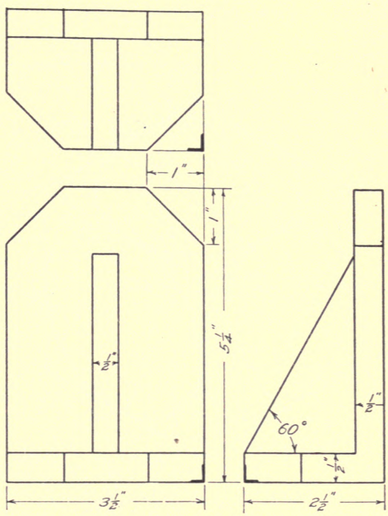


FIG. 357.—Prob. 98.

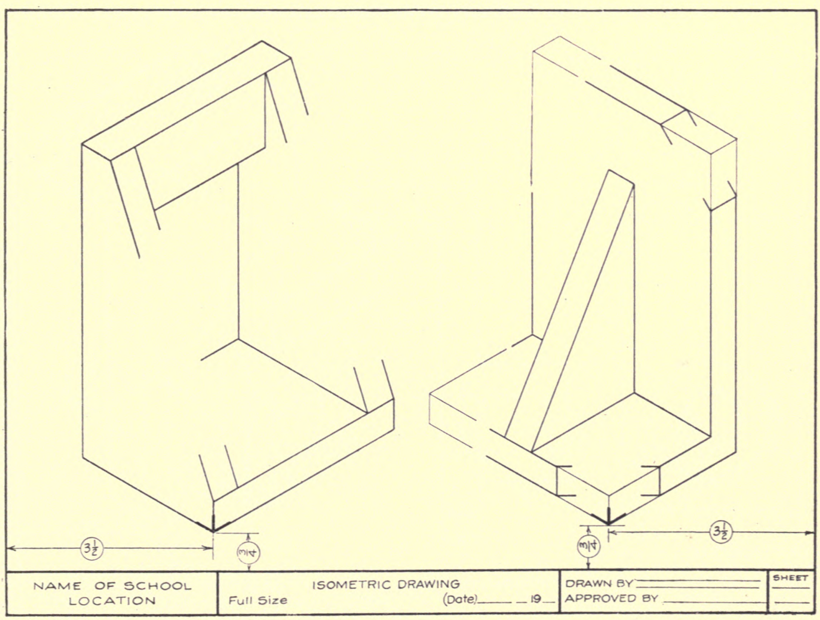


FIG. 358.—Layout for Probs. 97 and 98.

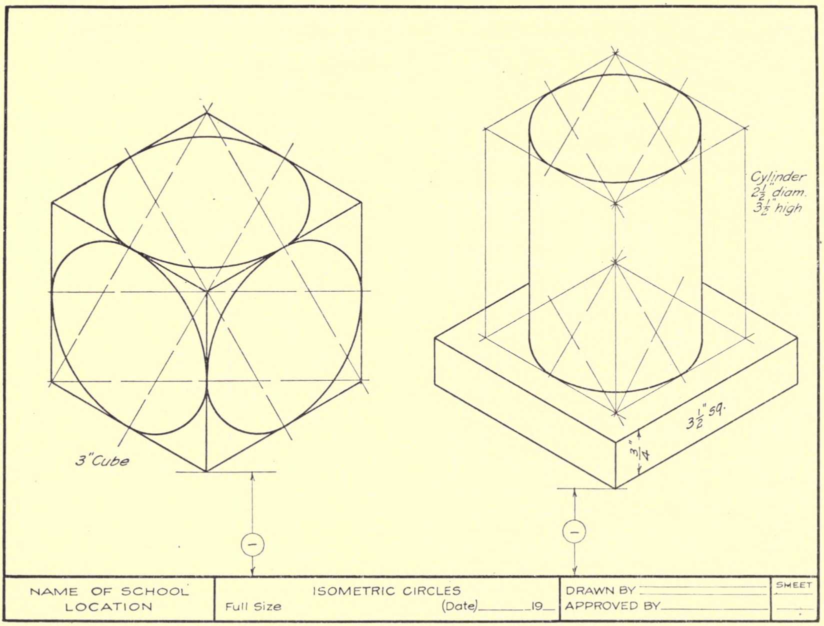


FIG. 359.—Probs. 99 and 100.

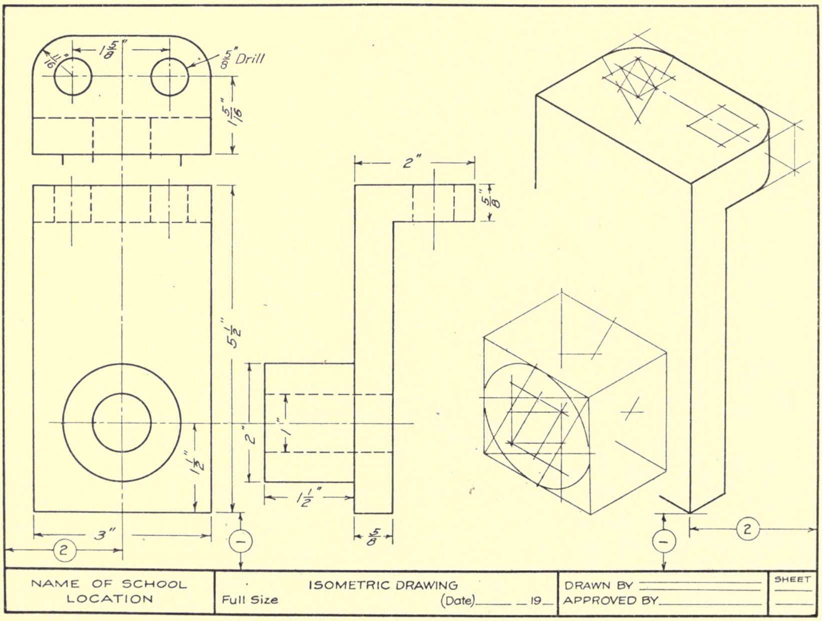


FIG. 360.—Prob. 101.

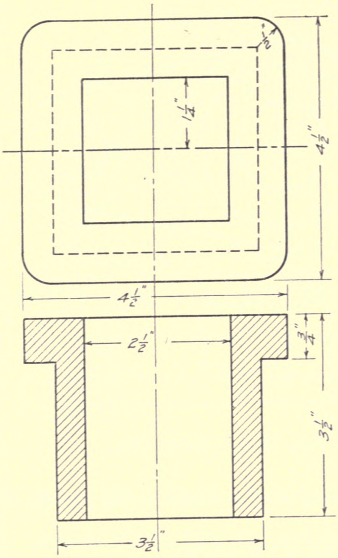


FIG. 361.—Prob. 102.

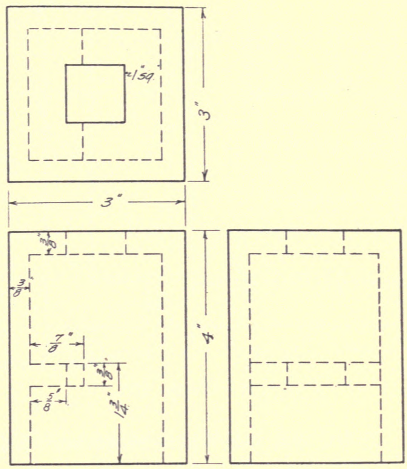


FIG. 362.—Prob. 103.

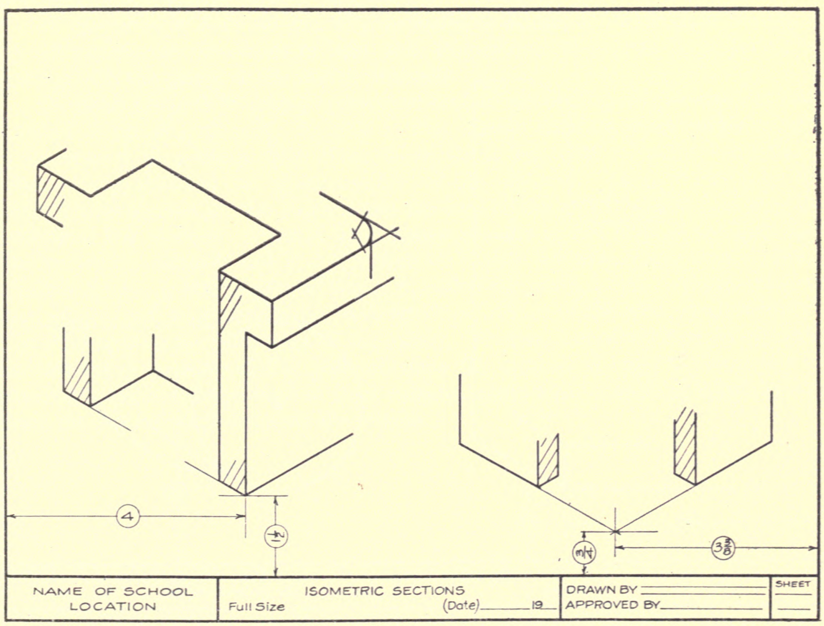


FIG. 363.—Layout for Probs. 102 and 103.

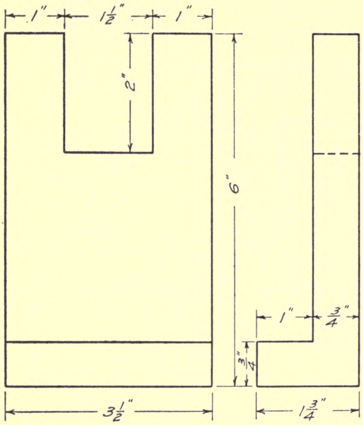


Fig. 364.—Prob. 104.

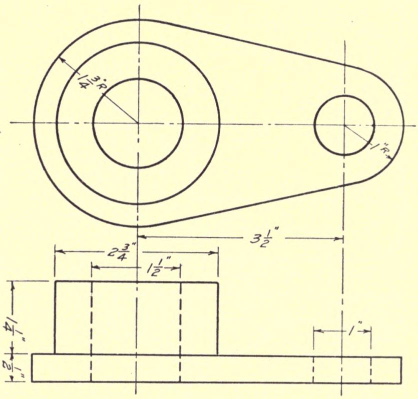


Fig. 365.—Prob. 105.

Prob. 104, Fig. 364.—Make an oblique drawing of the **angle** using layout of Fig. 366 (Arts. 42 to 44).

Prob. 105, Fig. 365.—Make an oblique drawing of the **crank.**

Prob. 106, Fig. 367.—Make an oblique drawing of the **clock case.**

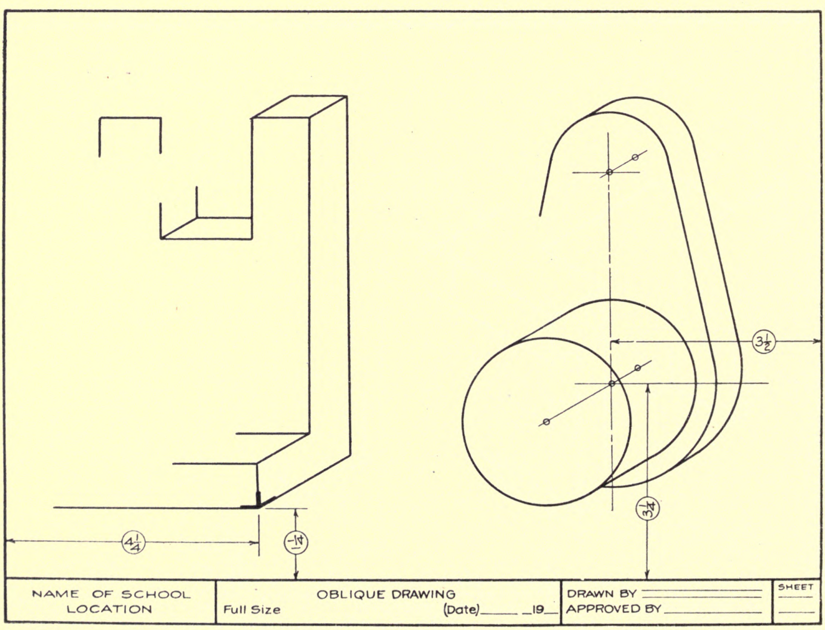


Fig. 366.—Layout for Probs. 104 and 105.

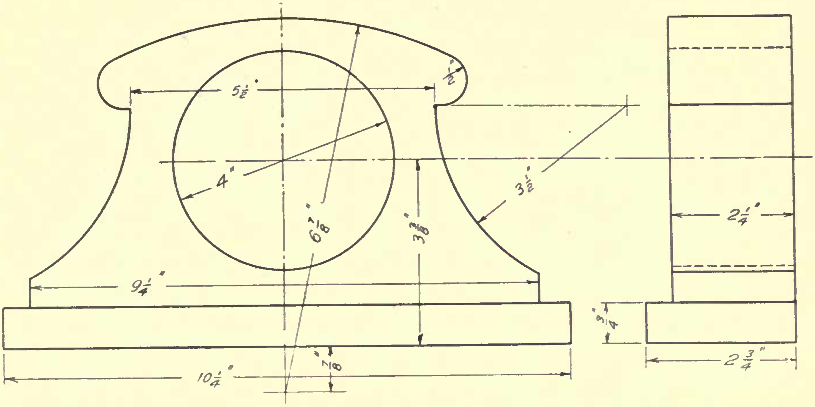


Fig. 367.—Prob. 106.

Prob. 107.—Make a cabinet drawing of the bird feeding stick (Fig. 331).

Probs. 108 to 115, Fig. 370.—Make freehand pictorial sketches of the objects shown, in any of the methods studied. Problem 108 is illustrated in Fig. 368 as it would appear when sketched in isometric and oblique drawing. The same problem is shown in Fig. 369 as a single figure on one sheet sketched in angular perspective. This sheet illustrates in general such assignments as may be made in pictorial sketching from actual parts of machines or other objects.

As described in Arts. 46 and 47 a perspective sketch is drawn from the object by estimating the directions of lines and proportions of lengths by observation, testing with the pencil as the sketch proceeds.

To make a sketch in angular perspective when the orthographic views are given instead of the object itself, the plan is first drawn with its front corner against a line representing the picture plane, as shown in Fig. 369. A point *S* in front of this corner is taken as the "station point" of the observer. Lines drawn from this point to each point on the object cross the line of the picture plane and give the widths of the picture. From *S* lines drawn parallel to the lines of the plan give the vanishing points *V* and *V′*. The line *V–V′* then becomes the horizon. Below the horizon draw the horizontal line *G.L.* called the ground line. At the intersection of *G.L.* and a perpendicular from the front corner of the plan, draw a vertical line representing the front edge of the object. Vertical measurements are all made on this line. A study of Fig. 369 will show the method of making the sketch by vanishing the horizontal lines to their vanishing points and dropping perpendiculars from the picture plane to locate the widths.

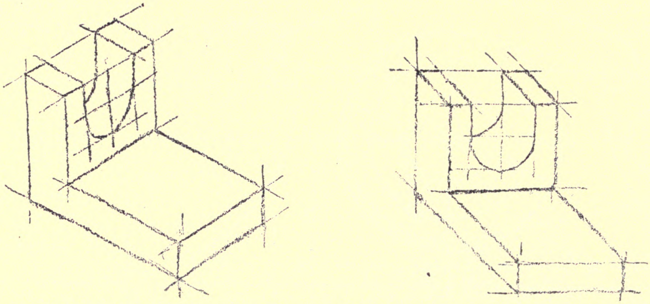


FIG. 368.—Solution of Prob. 108 in isometric and oblique.

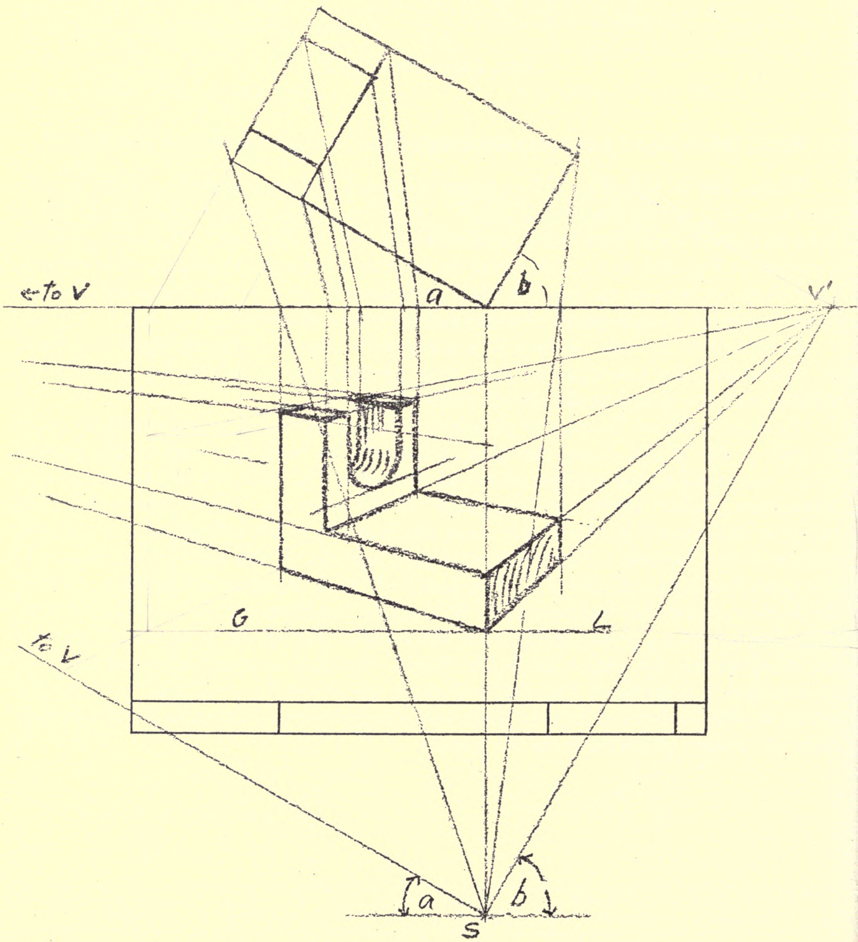


FIG. 369.—Solution of Prob. 108 in Perspective.

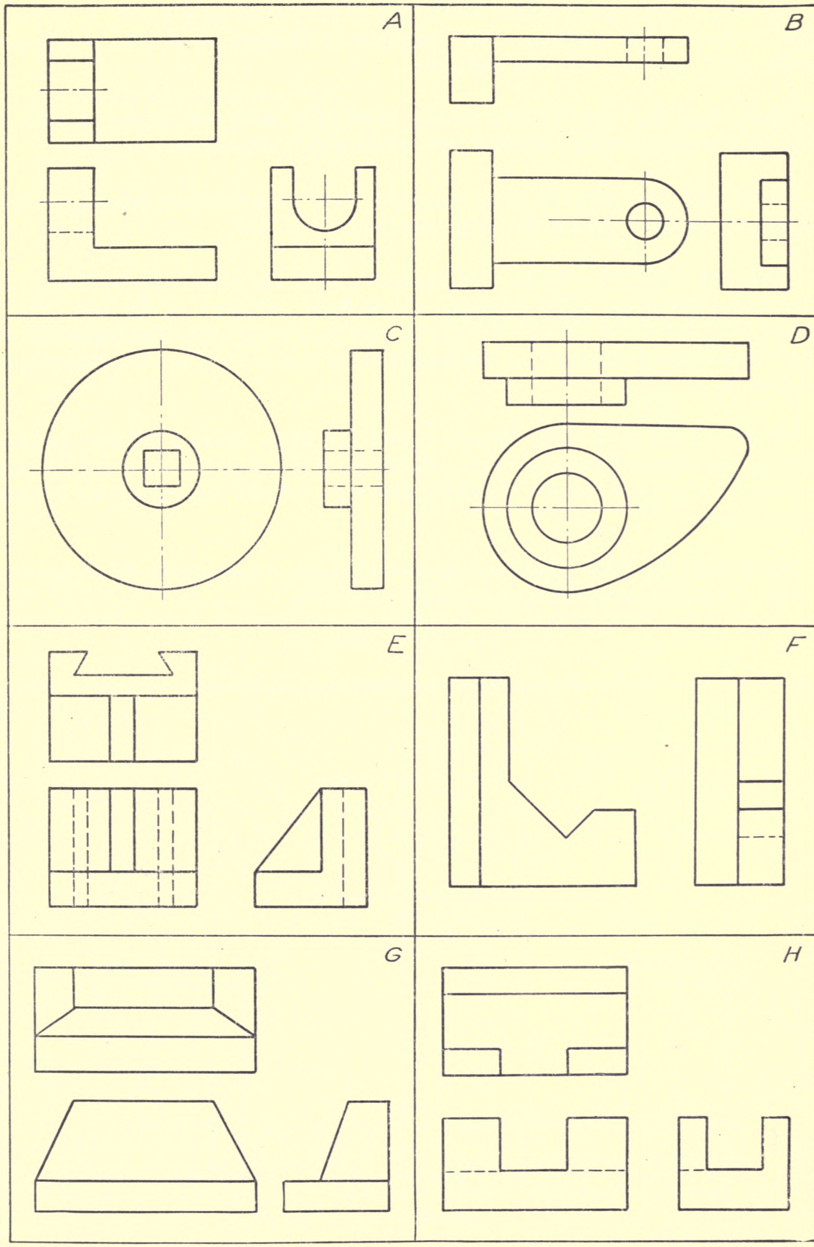


FIG. 370.—Probs. 108 to 115.

150. Size Description.—Size description or dimensioning is a very important part of mechanical drawing. The principles of Chapter IV should be applied to the solutions of the following problems.

Prob. 116, Fig. 371.—Three partial views of a **slide rod carrier** are given. Make a complete working drawing with all necessary dimensions (Art. 49).

Prob. 117, Fig. 372.—Make a complete three view working drawing of the **adjustable center.** Locate the views carefully (Art. 146).

Prob. 118, Fig. 373.—Make working drawings of the gland and bearing with complete dimensions. The diameter of the hole (1″) and of the hub (1¾″) should be added to the gland. For the bearing the distance from the under side of base up to center of hole is 2″. The length of the hole is 1¾″, and the diameter of the hole is ¾″.

Prob. 119, Fig. 374.—The figure is drawn half size. Make a full size working drawing and dimension completely. Either the dividers or the scale can be used to transfer the views to the student's drawing. Obtain dimensions by scaling your drawing.

Prob. 120, Fig. 375.—Copy the views double size. Completely dimension the views. Obtain dimensions by scaling your drawing.

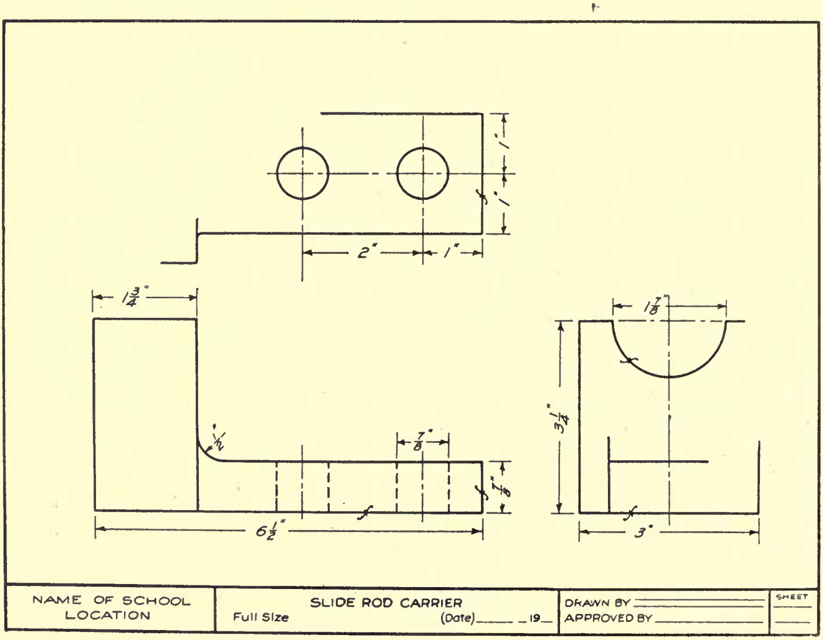


Fig. 371.—Prob. 116.

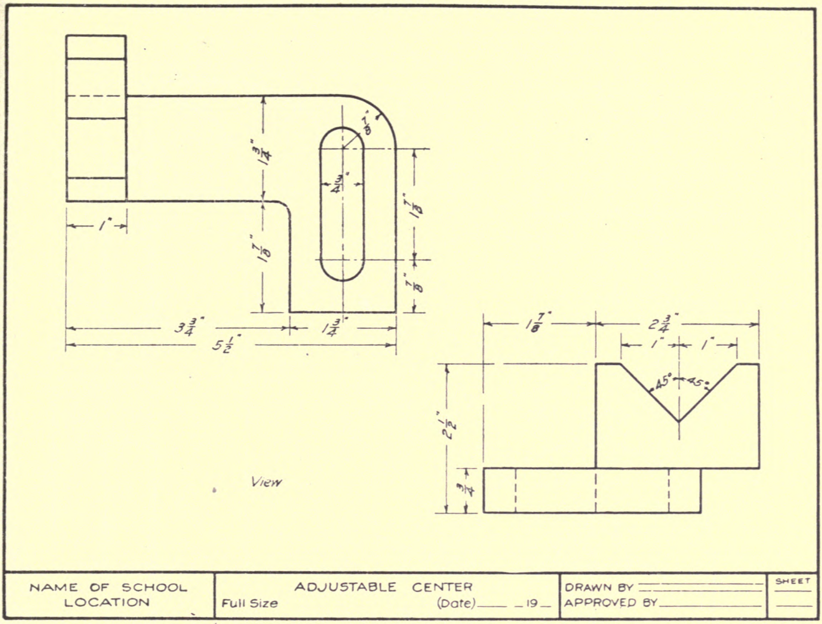


Fig. 372.—Prob. 117.

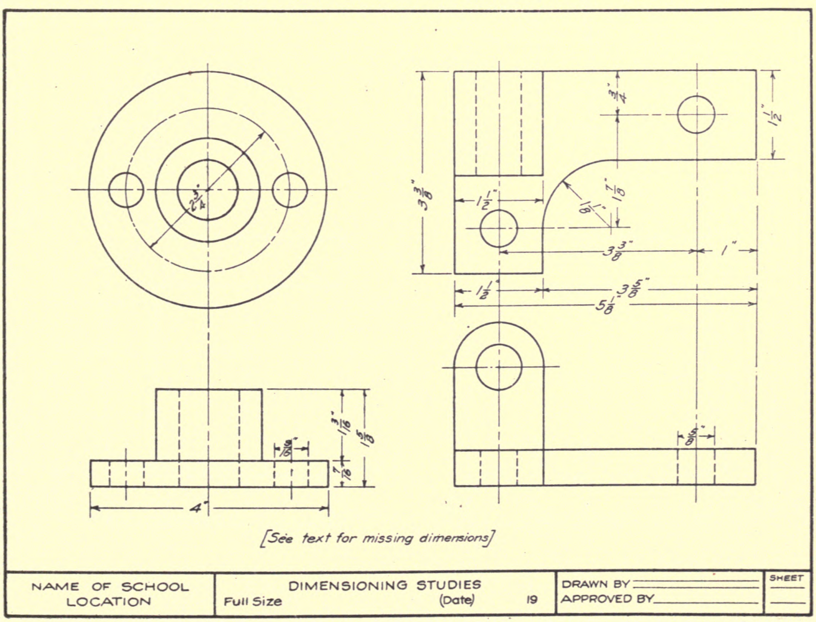


Fig. 373.—Prob. 118.

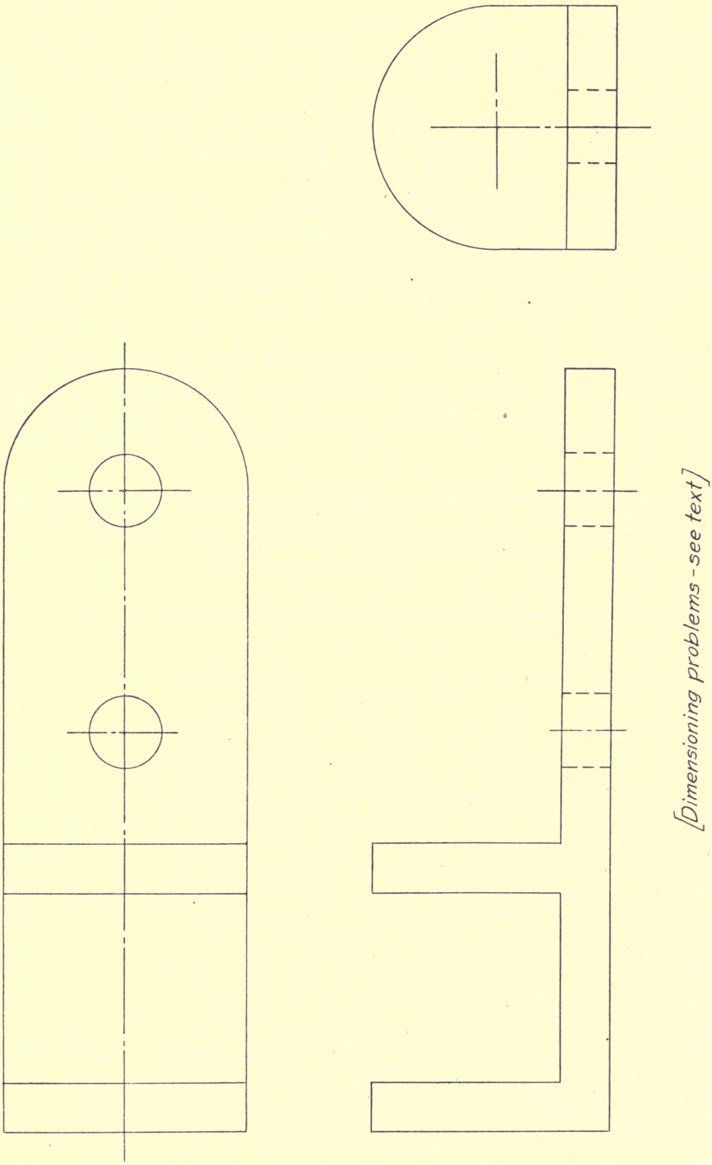


FIG. 374.—Prob. 119.

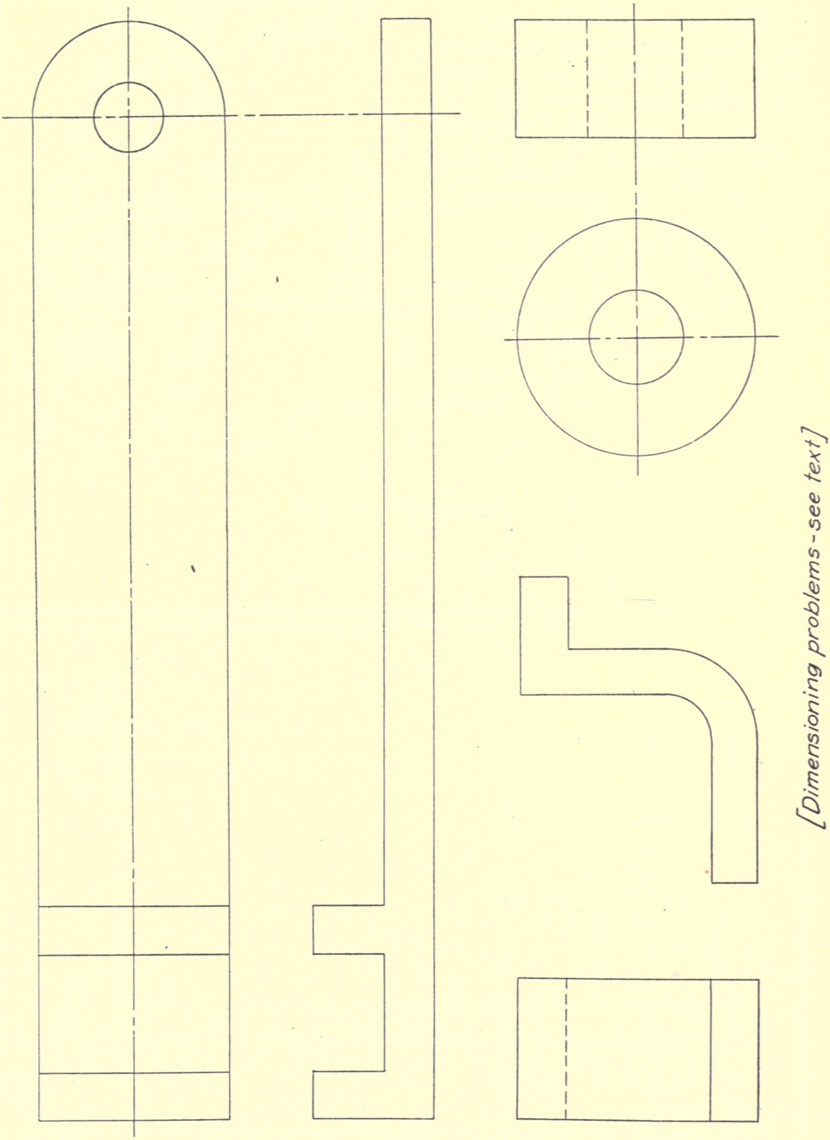


FIG. 375.—Prob. 120.

Prob. 121, Fig. 376.—Make a complete working drawing of the **lever.** Give all dimensions. Do not copy notes nor locations from the picture. The student is required to draw dimension and extension lines. Fig. 377 is the layout for this problem.

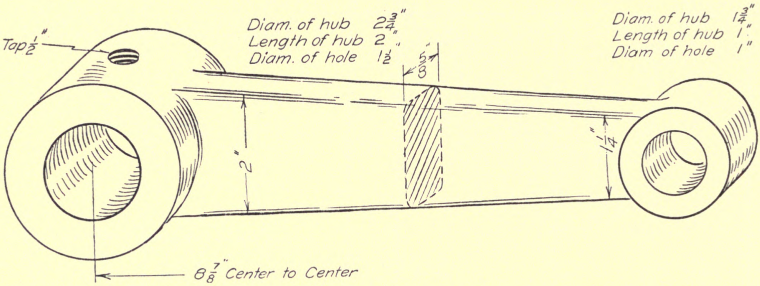


FIG. 376.—Prob. 121.

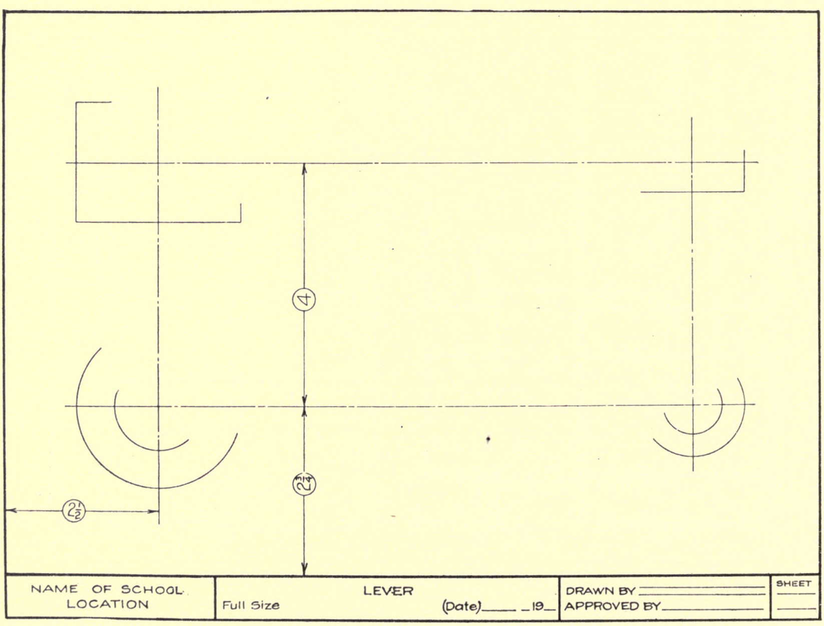


FIG. 377.—Layout for Prob. 121.

Prob. 122, Fig. 378.—Make a complete working drawing of the **bell crank.** Give all dimensions. Do not copy the notes from the picture. Fig. 379 is the layout.

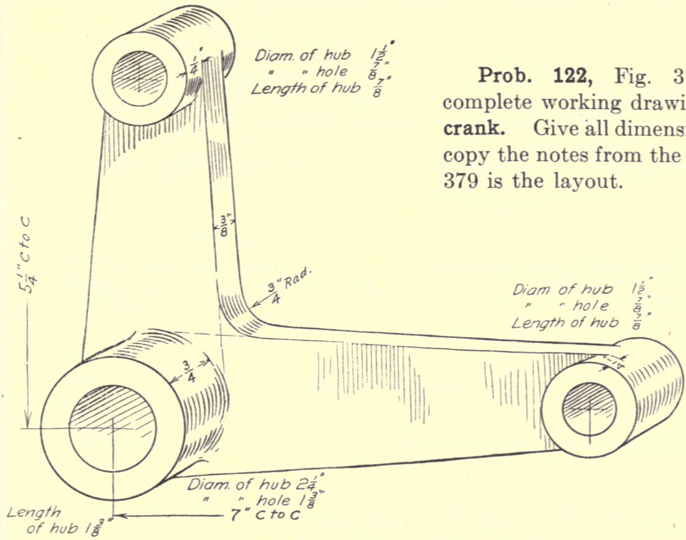


Fig. 378.—Prob. 122.

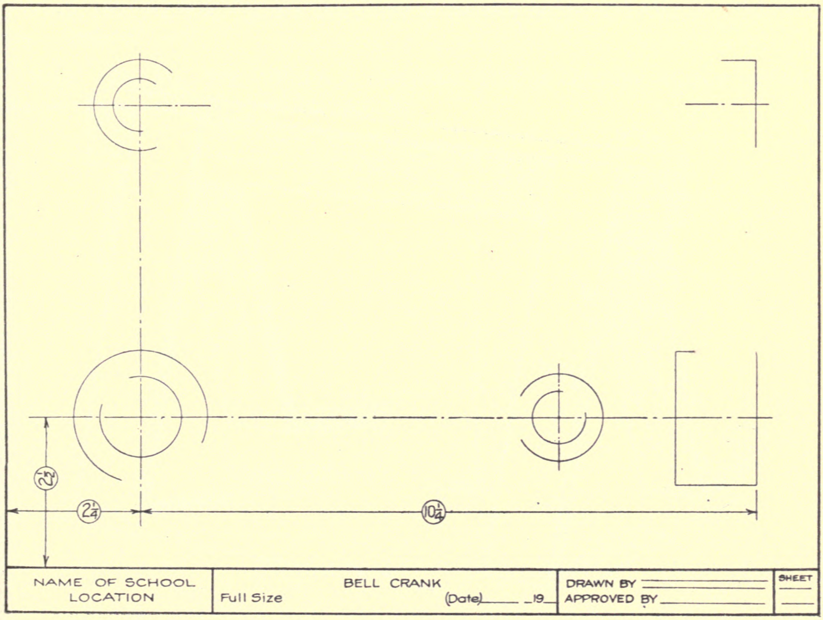


Fig. 379.—Layout for Prob. 122.

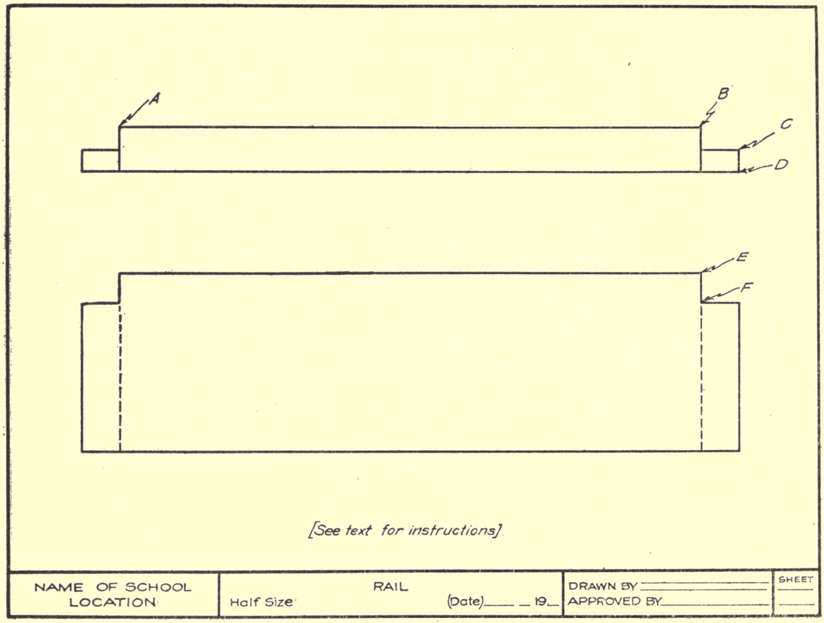


FIG. 380.—Prob. 123.

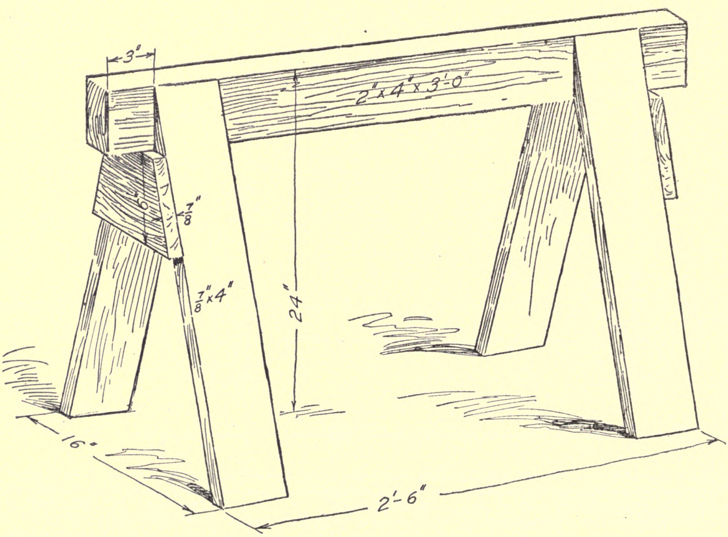


FIG. 381.—Prob. 124.

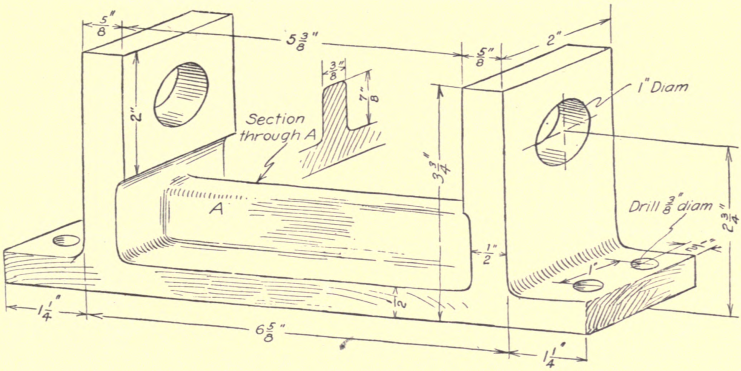


Fig. 382.—Prob. 125.

Prob. 123, Fig. 380.—Draw the two views of the **rail,** and locate dimensions carefully. Scale 6″ = 1′. The distances are as follows:

Stock is 1½″ × 6″ × 22″.

Distance from *A* to *B* is 19½″.

Distance from *C* to *D* is ¾″.

Distance from *E* to *F* is 1″.

Prob. 124, Fig. 381.—Draw two views of the **saw horse,** and completely dimension. Scale 3″ = 1′.

Prob. 125, Fig. 382.—Make a complete working drawing at the **support.** Choose views and locate carefully (Art. 86).

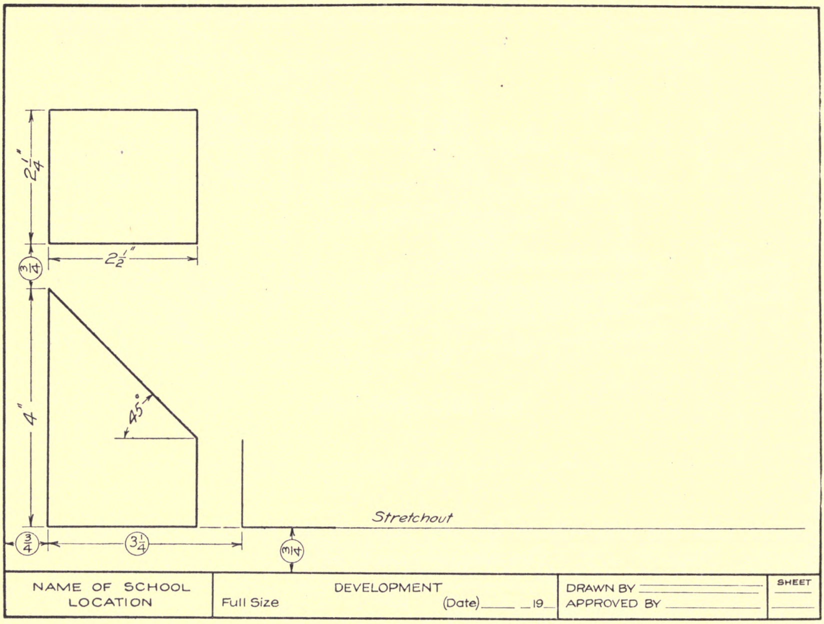
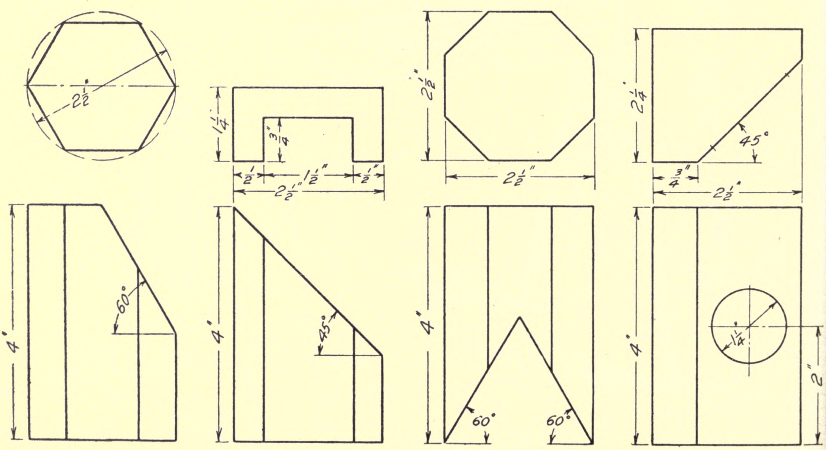


FIG. 383.—Prob. 126.

Prob. 126, Fig. 383.—Develop the lateral surface of the truncated square prism. Use the given stretchout (Art. 124).

Probs. 127 to 130, Figs. 384 to 387.—Develop the lateral surface.



384 385 386 387

FIGS. 384 to 387.—Probs. 127 to 130.

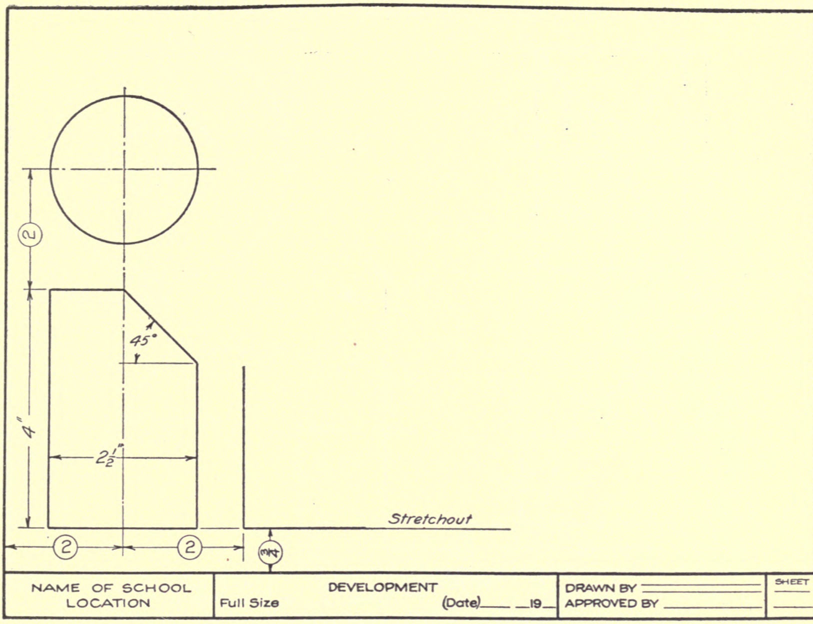
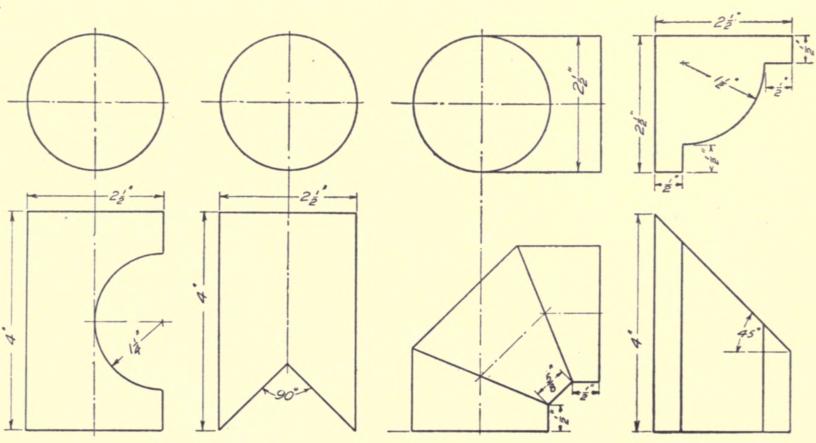


FIG. 388.—Prob. 131.

Prob. 131, Fig. 388.—Develop the lateral surface of the cylinder. Use the given stretchout (Arts. 125 and 126).

Probs. 132 to 135, Figs. 389 to 392.—Develop the surfaces.



389 390 391 392

FIGS. 389 to 392.—Probs. 132 to 135.

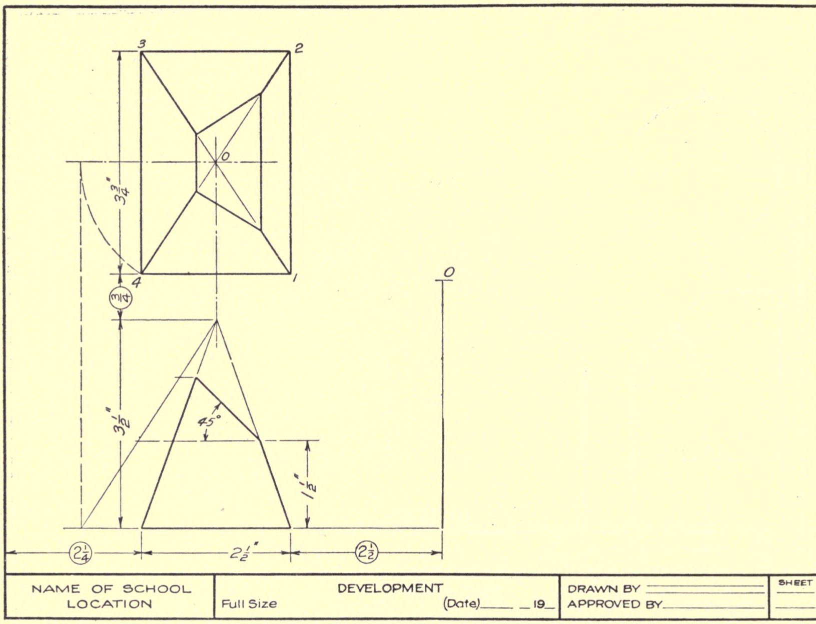


Fig. 393.—Prob. 136.

Prob. 136, Fig. 393.—Develop the truncated rectangular pyramid. First revolve edge 04 until its true length shows in the front view. Start with this edge in the position shown to the right of the views (Arts. 129 and 130).

Probs. 137, 138, 139, Figs. 394, 395, 396.—Develop the slanting surfaces.

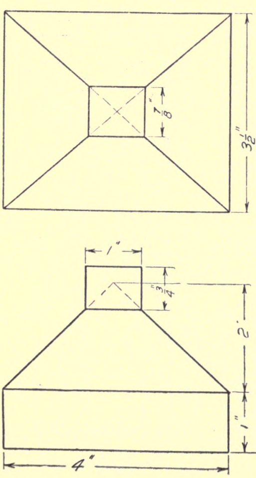


Fig. 394.—Prob. 137.

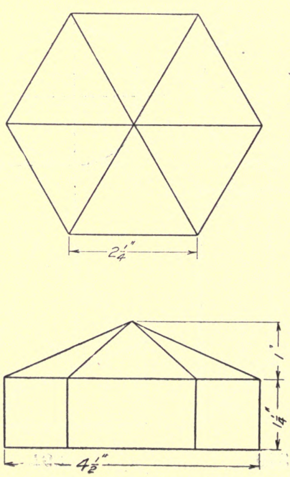


Fig. 395.—Prob. 138

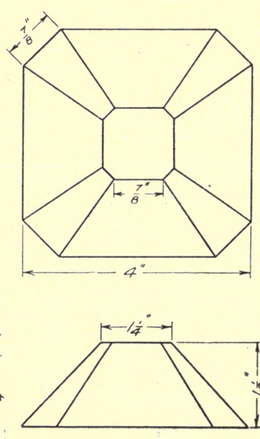


Fig. 396.—Prob. 139.

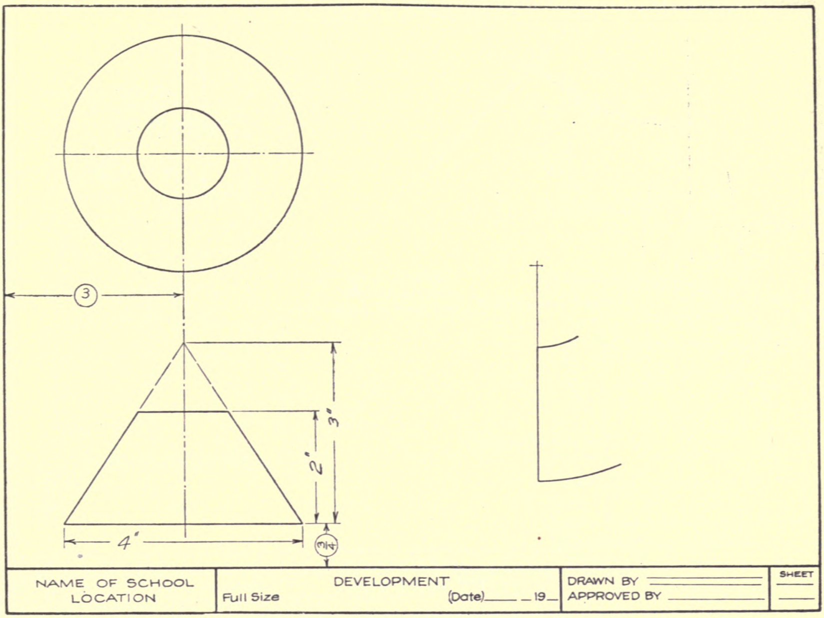


FIG. 397.—Prob. 140.

Prob. 140, Fig. 397.—Develop the lateral surface of the frustum of the cone (Art. 132).

Probs. 141, 142, 143, Figs. 398, 399, 400.—Develop the lateral surfaces of the parts of cones.

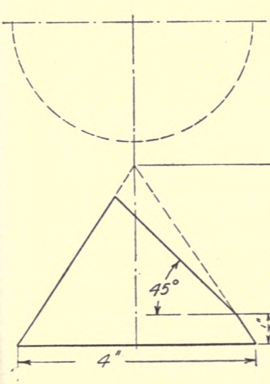


FIG. 398.—Prob. 141.

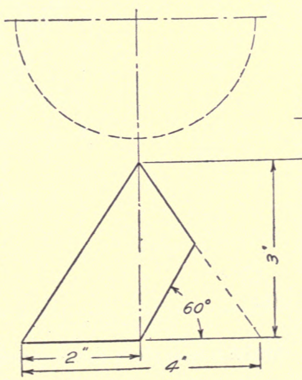


FIG. 399.—Prob. 142.

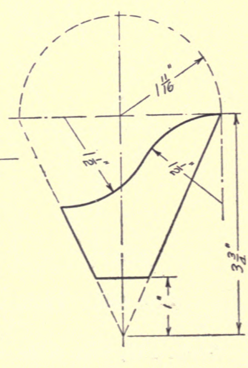


FIG. 400.—Prob. 143.

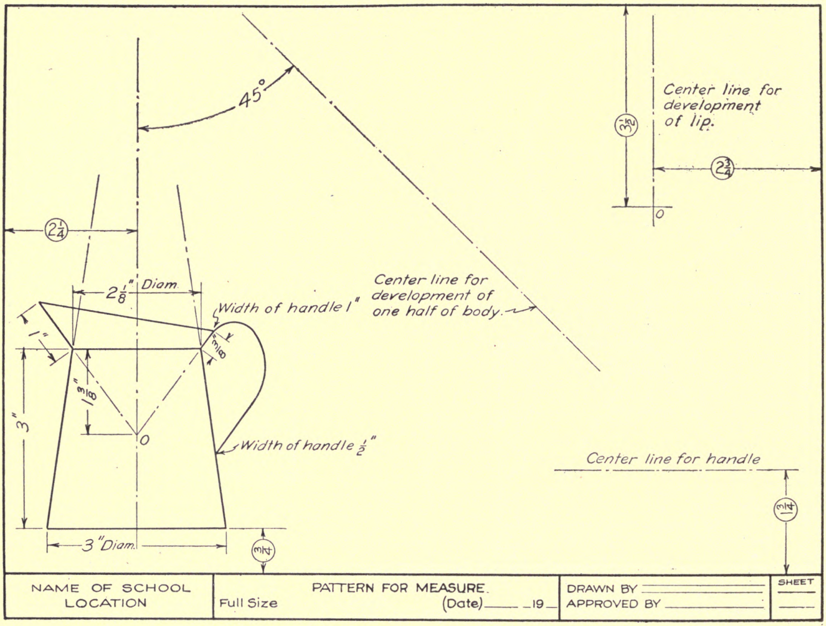


FIG. 401.—Prob. 144.

Prob. 144, Fig. 401.—Make a complete development of the pint measure (Arts. 140 and 141).

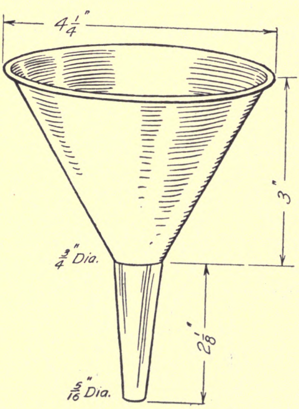


FIG. 402.—Prob. 145.

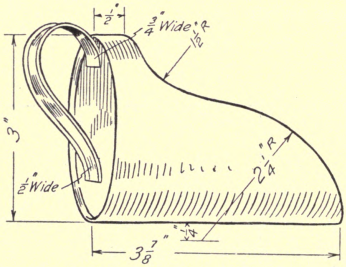


FIG. 403.—Prob. 146.

Prob. 145, Fig. 402.—Make a complete development of the funnel.

Prob. 146, Fig. 403.—Make a complete development of the scoop.

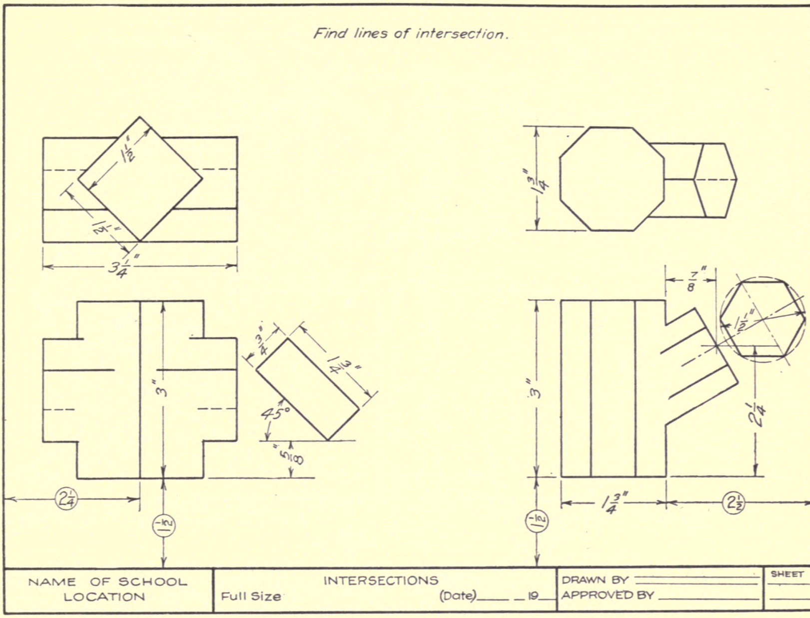


FIG. 404.—Probs. 147 and 148 (Art. 135).

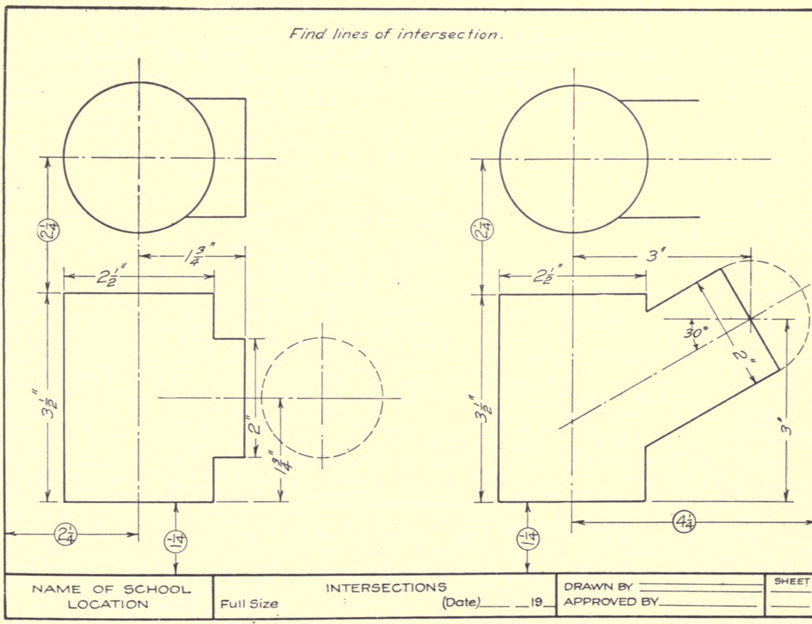


FIG. 405.—Probs. 149 and 150 (Art. 136).

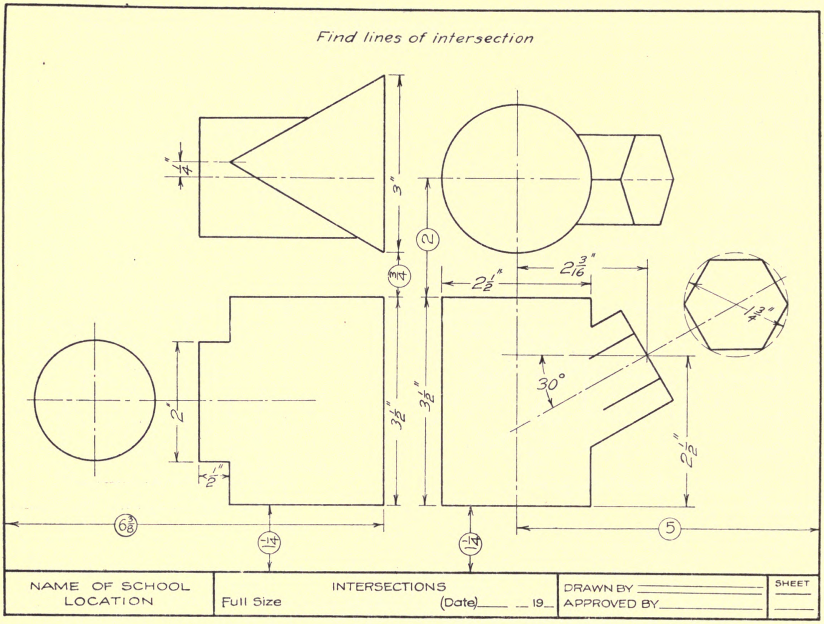


Fig. 406.—Probs. 151 and 152 (Art. 137).

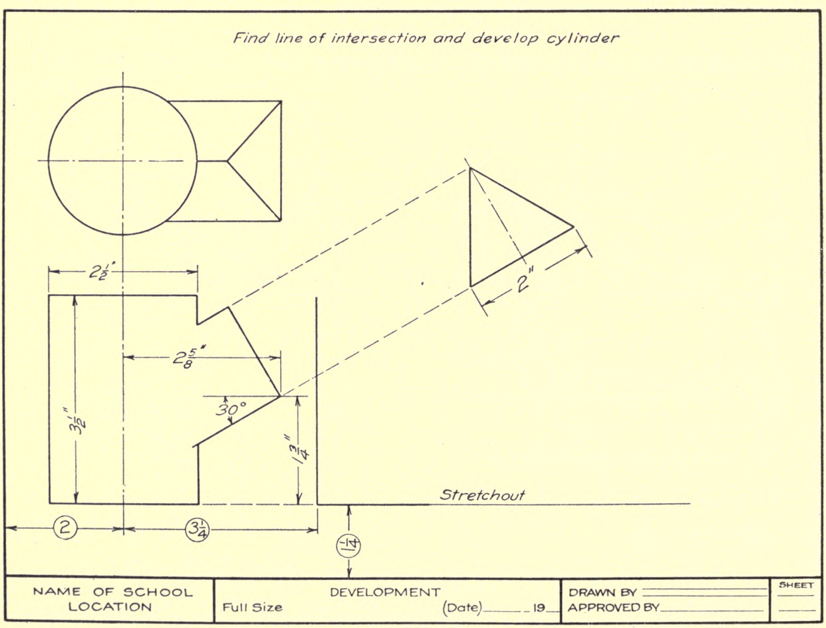


Fig. 407.—Prob. 153.

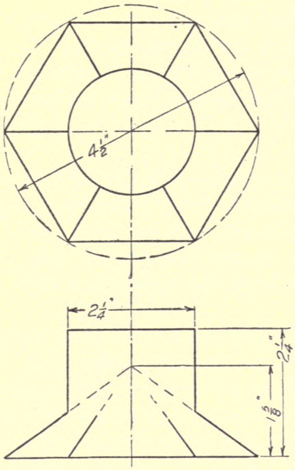


Fig. 408.—Prob. 154.

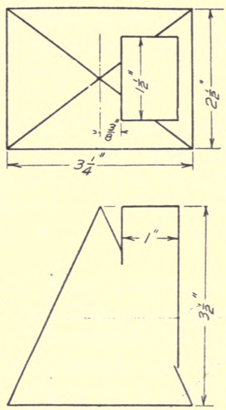


Fig. 409.—Prob. 155.

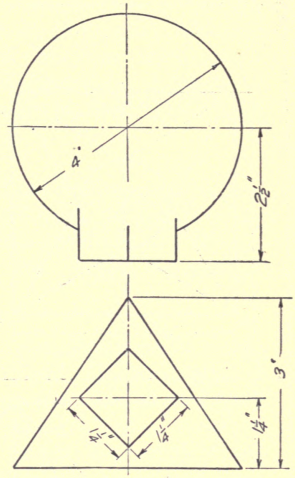


Fig. 410.—Prob. 156.

Prob. 154, Fig. 408.—Find line of intersection and develop lateral surface of the pyramid.

Prob. 155, Fig. 409.—Find line of intersection and develop lateral surface of the pyramid.

Prob. 156, Fig. 410.—Find line of intersection and develop lateral surface of cone.

Any of the intersection problems may be used for development by solving one problem on a sheet.

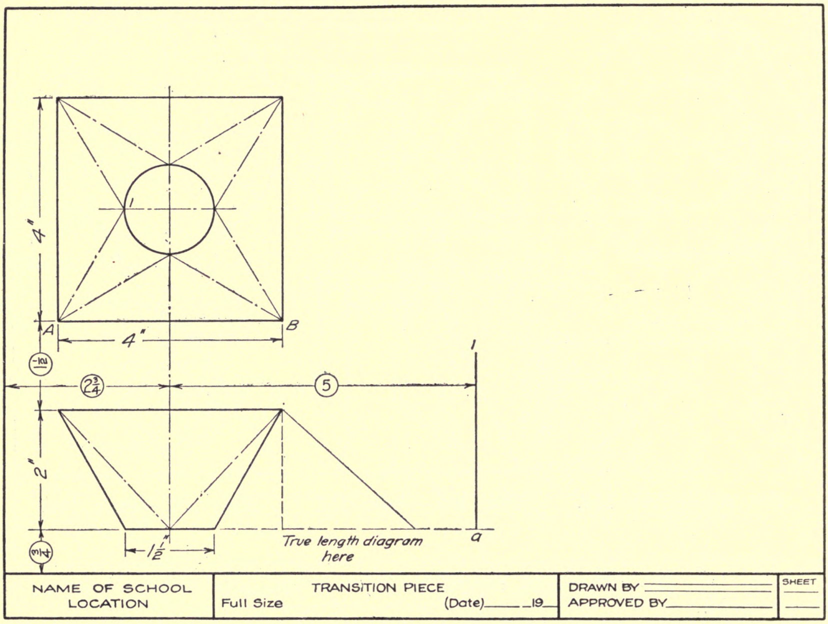


FIG. 411.—Prob. 157.

Prob. 157, Fig. 411.—Develop the surface of the transition piece (Art. 133).

Probs. 158, 159, 160.—Figs. 412, 413, 414. Develop surface of transition pieces.

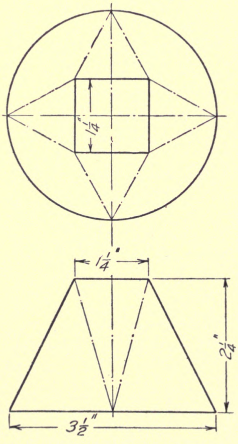


FIG. 412.—Prob. 158.

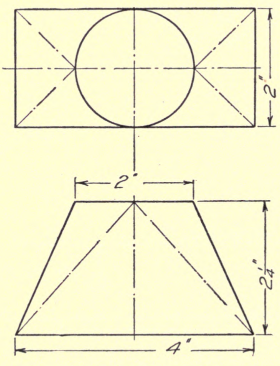


FIG. 413.—Prob. 159.

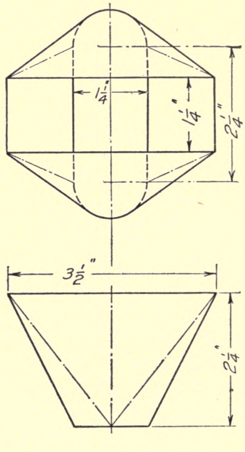


FIG. 414.—Prob. 160.

152. Screw threads and bolts.—It is very necessary for a draftsman to know the forms of screw threads and the conventional methods of drawing bolts and screws. Threads are always understood to be single and right hand unless otherwise specified. A right hand thread enters when turned clockwise. A left hand thread enters when turned counter clockwise, and is always marked "L.H." on a drawing.

Prob. 161, Fig. 415.—In the left half of the sheet construct two complete turns of a right hand helix whose diameter is 4″ and pitch 1½″ (Arts. 70 and 71). In the right half of the sheet draw, as shown in the layout, the forms of the *V* thread, U. S. Std. thread and square thread. Pitch 1″(Art. 70). Letter the name of each form under the drawing of it.

Prob. 162.—In the left half of the sheet construct two complete turns of a right hand helix whose diameter is 3″ and pitch 2″ (Arts. 70 and 71). Sometimes in drawing a helix a templet is made by laying out the curve on a piece of cardboard or thin wood and cutting out with a sharp knife. In the right half of the sheet draw as in the layout Fig. 415, the forms of the U. S. Std. thread, Whitworth thread and knuckle thread, 1″ pitch (Art. 70, Fig. 139). Letter the name of each form under the drawing of it.

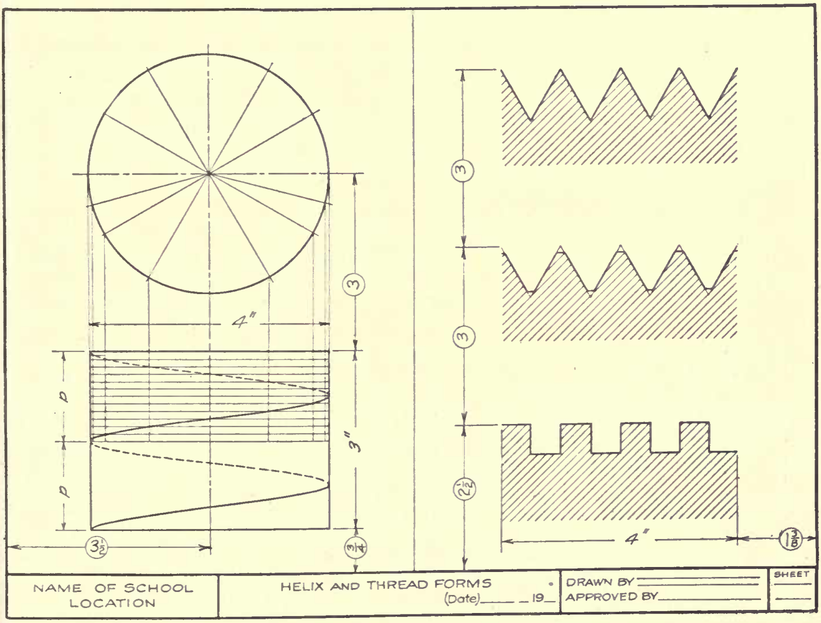


FIG. 415.—Prob. 161.

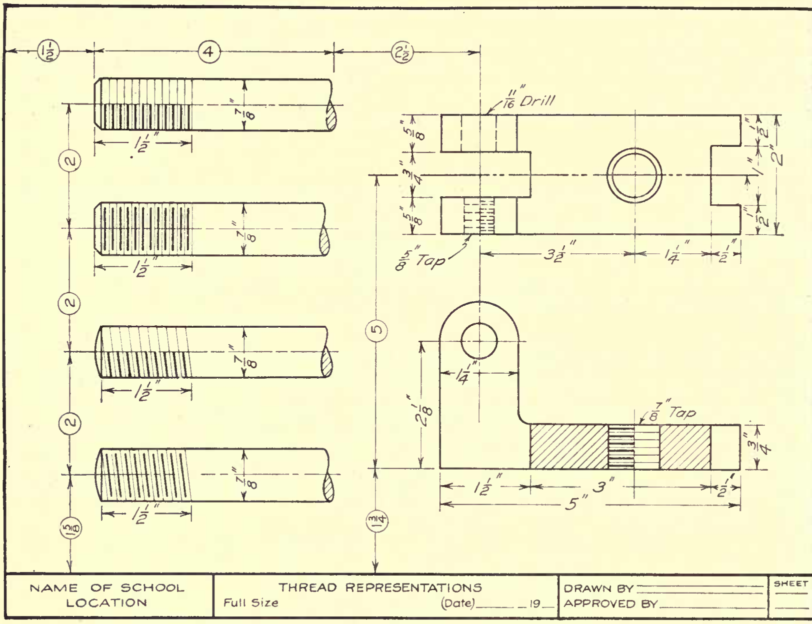


FIG. 416.—Prob. 163.

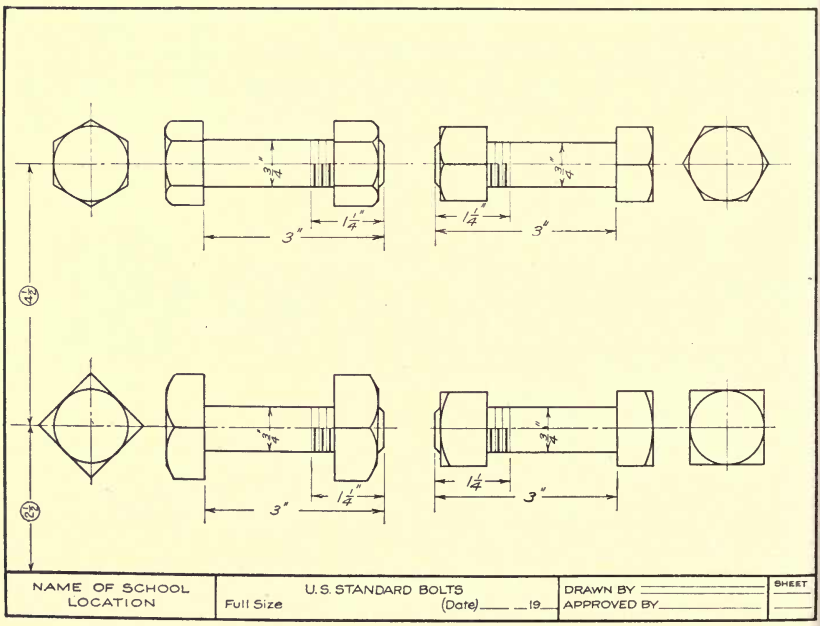


FIG. 417.—Prob. 164.

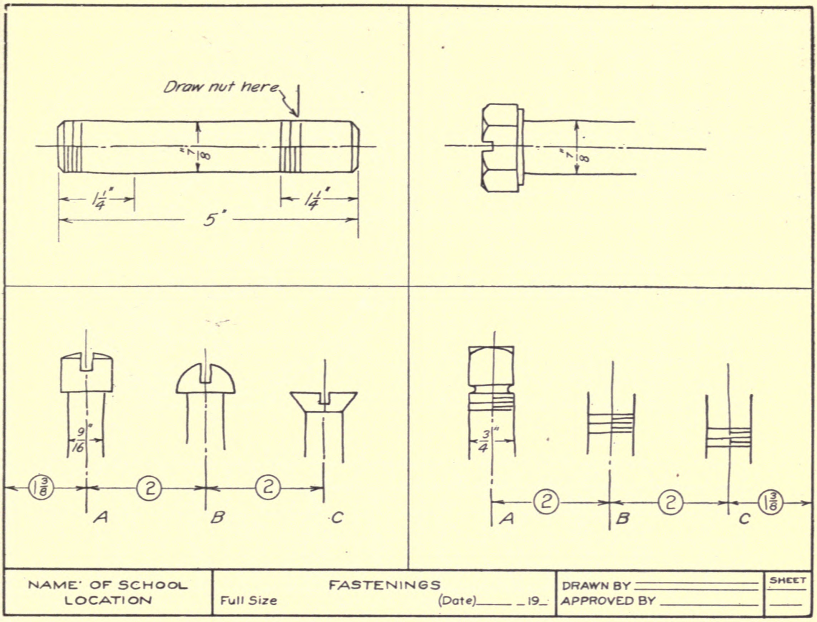


FIG. 418.—Prob. 165.

Prob. 163, Fig. 416.—Locate center lines as shown and draw the conventional thread representations given in the layout (Art. 71). These and several other conventional forms are in use for representing screw threads, and are drawn here for practice. On working drawings one of the forms should be selected and used for all thread representations. The casting drawn on the right half of the sheet has threaded holes represented conventionally under three different conditions (Art. 71).

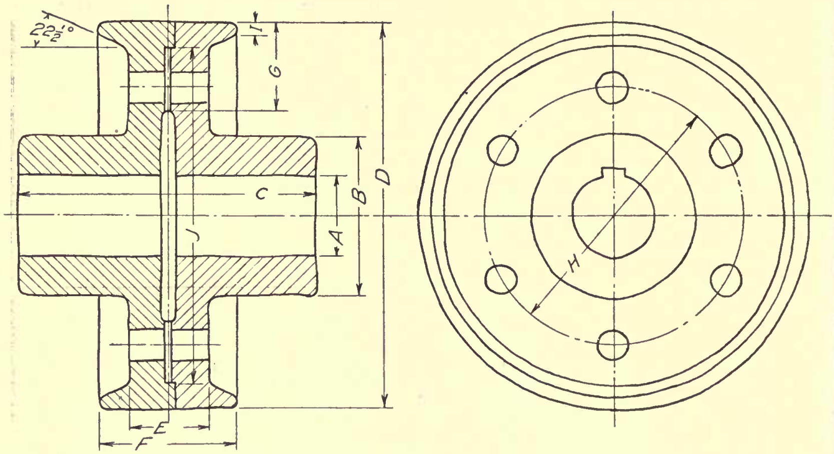
Prob. 164, Fig. 417.—Locate the center lines. On the upper line draw a hex head bolt and nut in the two positions shown, across corners and across flats.

On the lower line draw a square head bolt and nut across corners and across flats (Arts. 73, 74, 75).

Prob. 165, Fig. 418.—Divide the working space into four spaces as shown. In the upper left hand space draw a stud and U. S. Standard nut. Diameter, 7/8″; length 5″; length of thread on each end 1 1/4″. In the upper right hand space draw an S. A. E. St'd. bolt and nut. Diameter 7/8″; length 4″ (Art. 76, Table II).

In the lower left hand space draw three forms of cap screws, at *A*, *B*, and *C*. Diameter 9/16″; length 1 1/2″ (Art. 76, Table III).

In the lower right hand space draw three set screws, regular head, low head, and headless. Diameter 3/4″; length 1 1/2″ (Art. 76, Fig. 155).



A	B	C	D	E	F	G	H	I	J
1¼	2½	4⅝	6	1¼	2⅛	1⅜	4	3/16	5¼
1½	2⅞	5⅛	6¾	1⅜	2¼	1 7/16	4⅝	3/16	5¾
3¾	6½	10	12	2⅜	3¾	2 1/16	8⅞	5/16	10¾
4	7	10⅝	12½	2⅜	4	2¼	9⅛	3/8	11¼

Fig 419.—Prob. 166.

Prob. 166, Fig. 419.—Make a complete working drawing of one of the **plate couplings** in section. Show bolts and key in position. Choose scale. Dimensions given in Table are inches.

For 1¼ shaft use three ½″ bolts and 5⁄16″ square key.
For 1½ shaft use three ½″ bolts and ⅜″ square key.
For 3¾ shaft use six ¾″ bolts and ⅞″ square key.
For 4 shaft use six ⅞″ bolts and 1″ square key.

Missing dimensions are to be supplied by the student.

Prob. 167, Fig. 420.—Make a three view working drawing of the **bracket bearing,** completely dimensioned. Draw full size. Locate the views as described for Figs. 315 and 316.

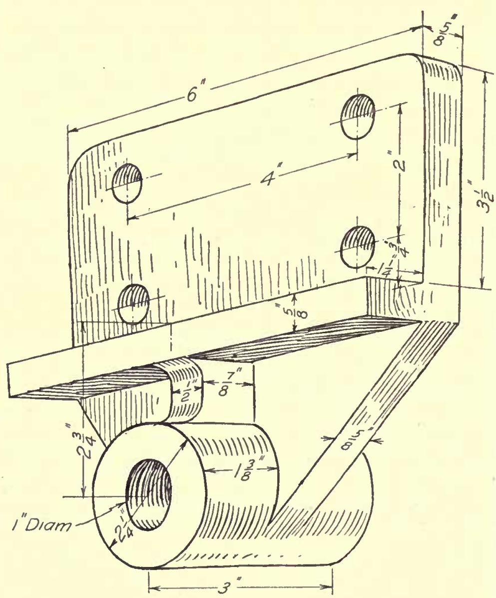


Fig. 420.—Prob. 167.

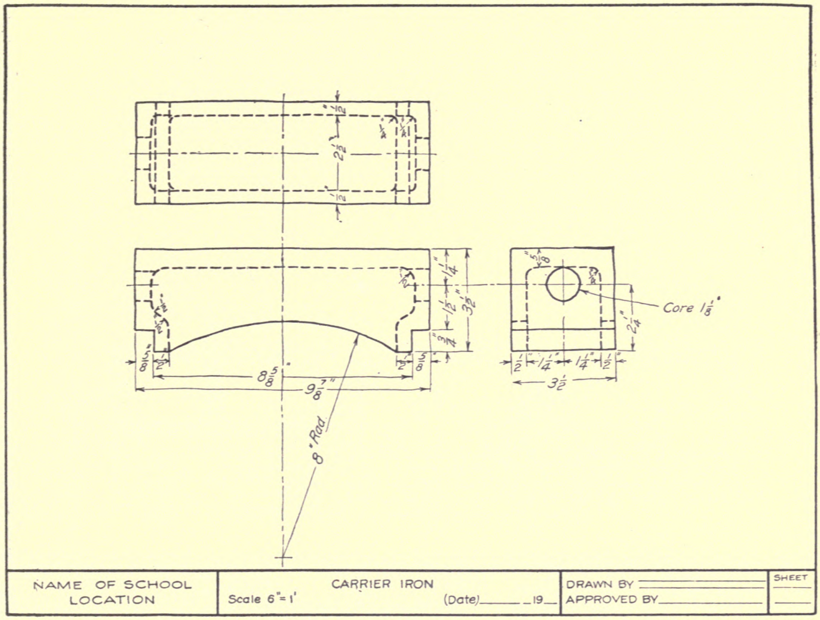


FIG. 421.—Prob. 168.

Prob. 168, Fig. 421.—Make a three view working drawing of the **carrier iron.** Scale 6″ = 1′. Draw the front view as a section. Draw a bottom view instead of the top view.

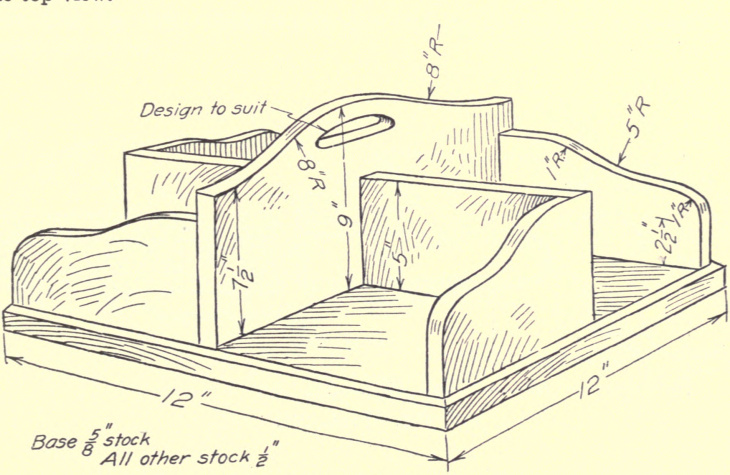


FIG. 422.—Prob. 169.

Prob. 169, Fig. 422.—Make an assembly working drawing with complete dimensions, for the **book rack.** Select views and scale.

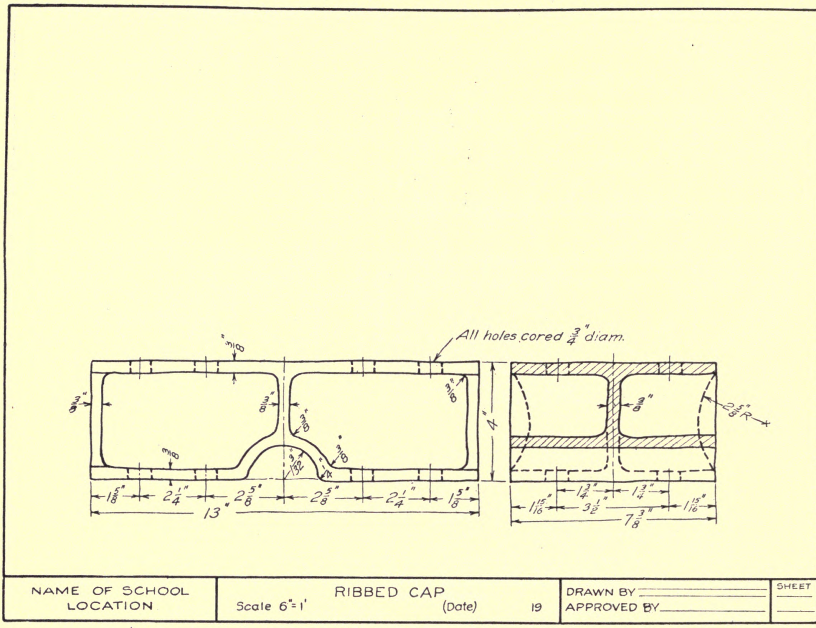


FIG. 423.—Prob. 170.

Prob. 170, Fig. 423.—Make a three view working drawing with complete dimensions for the **ribbed cap.** Show the front and side views as half sections.

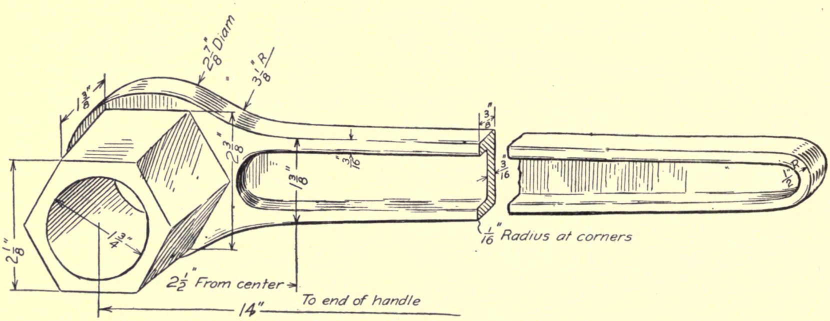


FIG. 424.—Prob. 171.

Prob. 171, Fig. 424.—Make a two view working drawing of the **plug wrench.** Completely dimension.

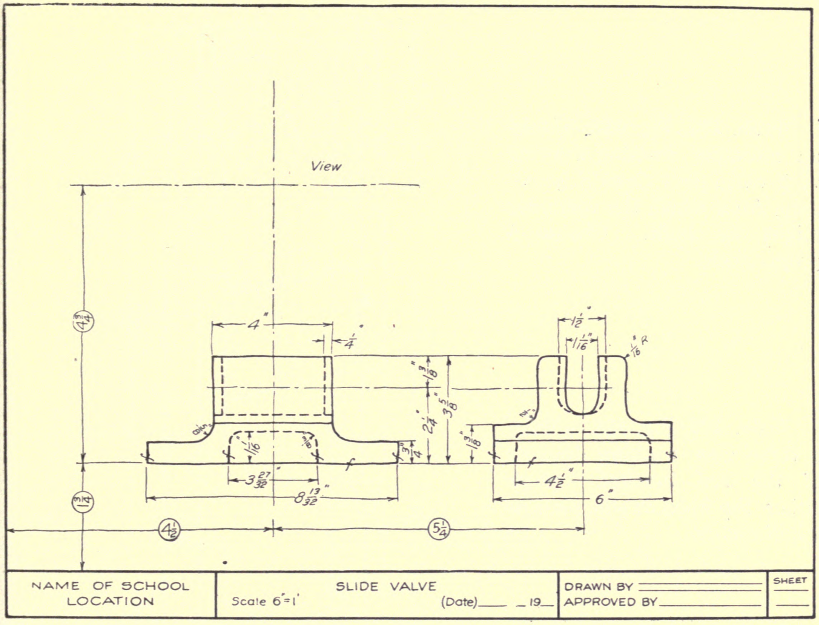


FIG. 425.—Prob. 172.

Prob. 172, Fig. 425.—Make a three view working drawing of the **slide valve.** Show the front view as a section. Completely dimension.

Prob. 173, Fig. 426.—Make a two view working drawing of the **lever** with all necessary dimensions.

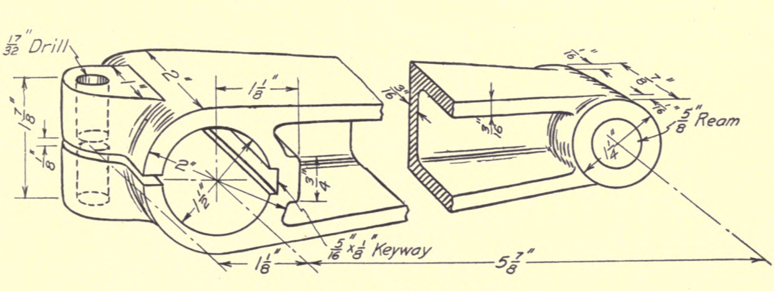


FIG. 426.—Prob. 173.

Prob. 174, Fig. 427.—Make an assembly working drawing with extra part views if necessary, from which the **costumer** might be built. Choose a proper scale.

Prob. 175, Fig. 428.—Make a three view working drawing of the **rod bracket.** Show either the front or side view as a half section.

Prob. 176, Fig. 429.—Make a three view working drawing of the **oil level gauge bracket.** Show the part of the front view to the left of the irregular line *A–A* as a section. A 1¼″ pipe tap has an outside diameter of 1.66″. Ask your teacher about pipe and pipe threads.

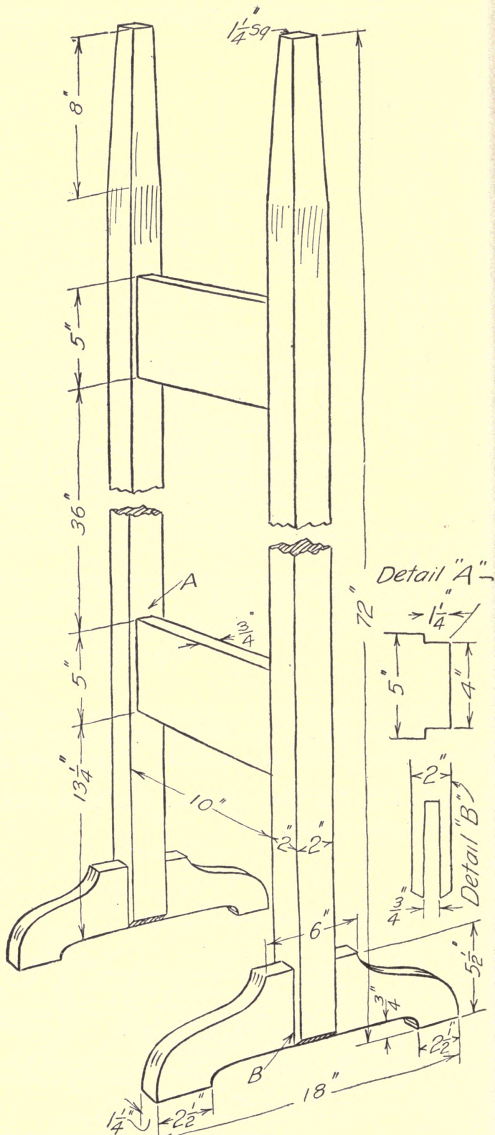


FIG. 427.—Prob. 174.

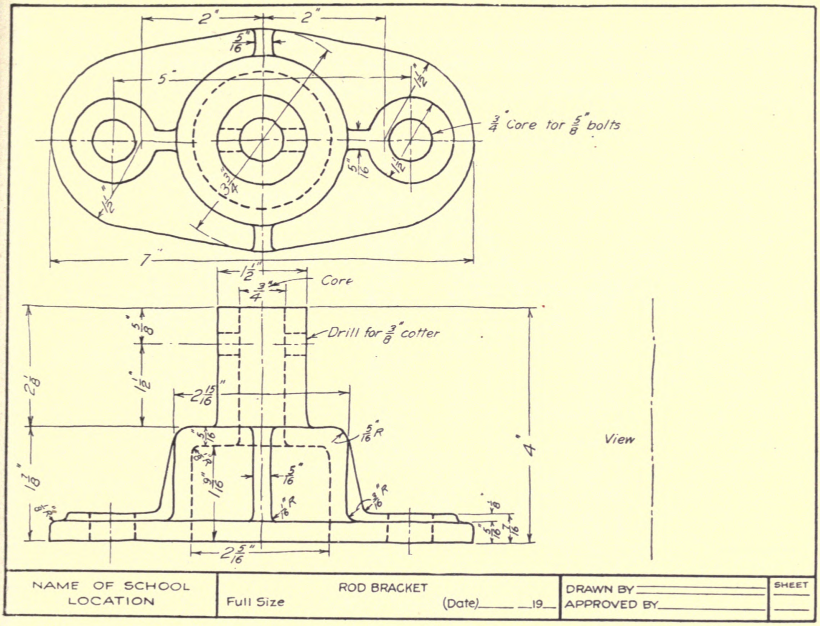


Fig. 428.—Prob. 175.

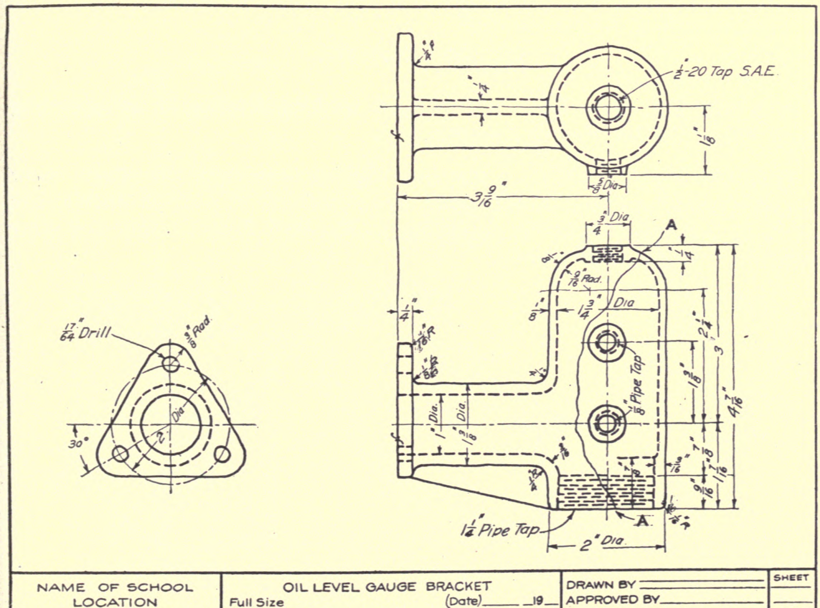


Fig. 429.—Prob. 176.

Prob. 177, Fig. 430.—Make an assembly working drawing with extra part views if necessary, for the **tea table.** Some of the dimensions are not given, and are to be obtained from the students' drawing.

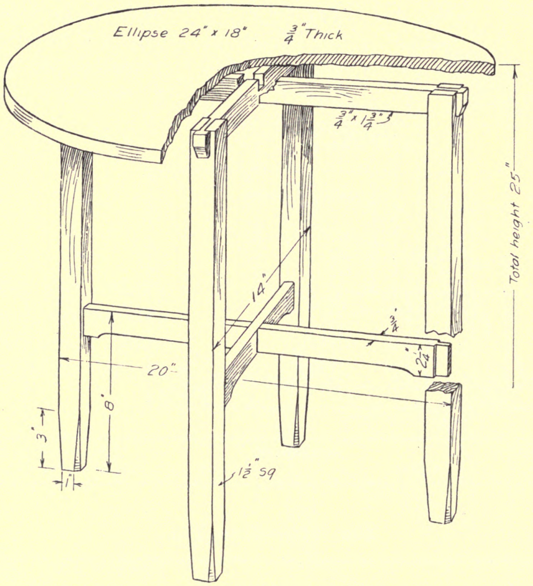


Fig. 430.—Prob. 177.

Prob. 178, Fig. 431.—Make a two view working drawing of the **operating wheel.** Show the left view as a section.

Prob. 179, Fig. 432.—Make a two view working drawing of the **valve.** Show the left view as a section. Locate point *A*, and using it as a center draw an arc with a 9½" radius cutting the center line at *B*. With *B* as a center and same radius draw arc to locate point *C*.

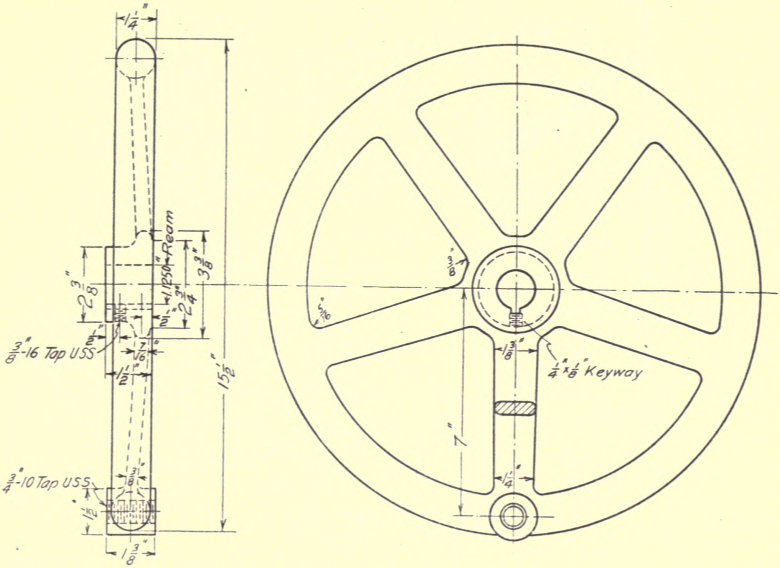


Fig. 431.—Prob. 178.

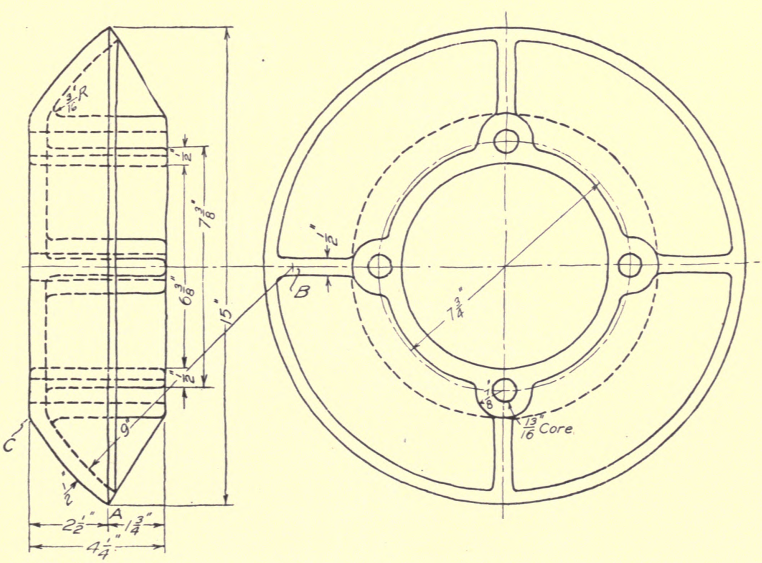


Fig. 432.—Prob. 179.

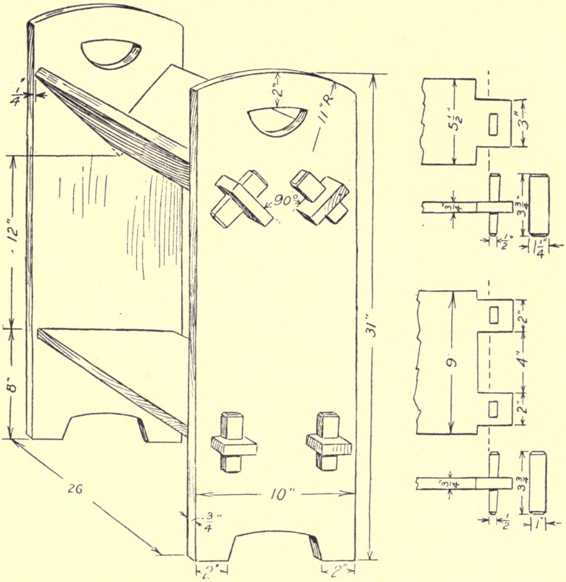


FIG. 433.—Prob. 180.

Prob. 180, Fig. 433.—Make an assembly working drawing with necessary part views for the **book rack.**

Prob. 181, Fig. 434.—Make a complete working drawing of the **fan bracket.** Draw *top*, *front* and *left side* views. Do not draw bottom or right side.

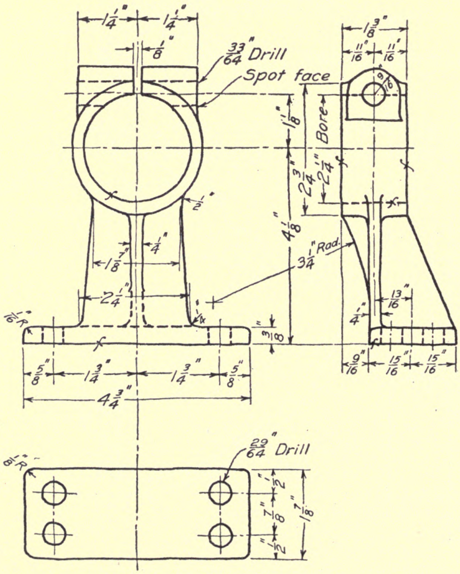


FIG. 434.—Prob. 181.

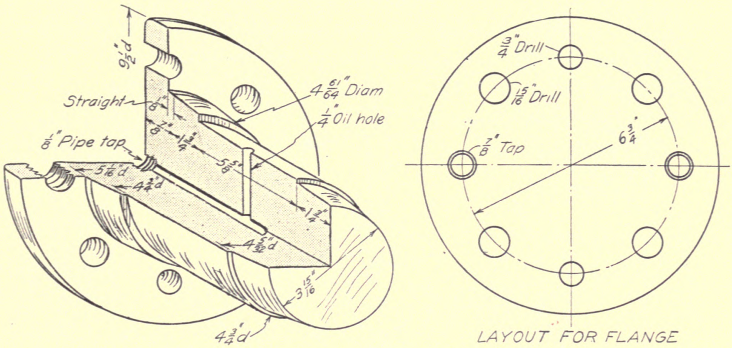


Fig. 435.—Prob. 182.

Prob. 182, Fig. 435.—Make a two view working drawing of the 4¾″ × 5½″ steel **crosshead pin.** Note the size and kind of holes in the flange.

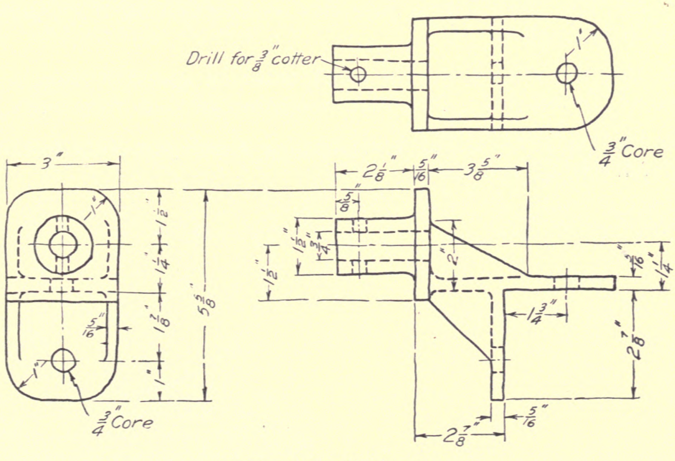


Fig. 436.—Prob. 183.

Prob. 183, Fig. 436.—Given the top, front, and left side views of the **uncoupling rod bracket.** Make a working drawing showing the *top, front,* and *right side* views.

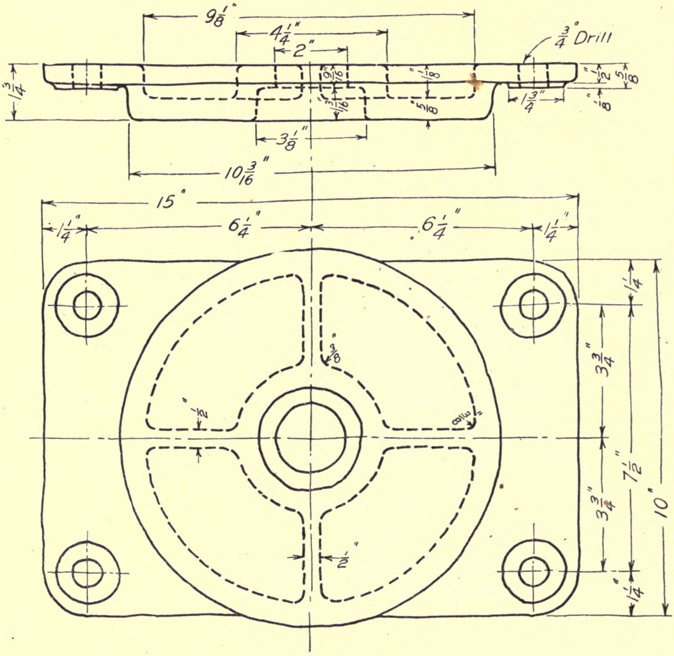


FIG. 437.—Prob. 184.

Prob. 184, Fig. 437.—Make a three view working drawing of the **center plate.** One view to be a section.

Prob. 185, Fig. 438.—From the details make an assembly drawing showing two views of the **tool post.** Dimension as required by your instructor.

Prob. 186, Fig. 163.—Make a detail drawing of each part of the **belt tightener.** If drawn full size, use two sheets.

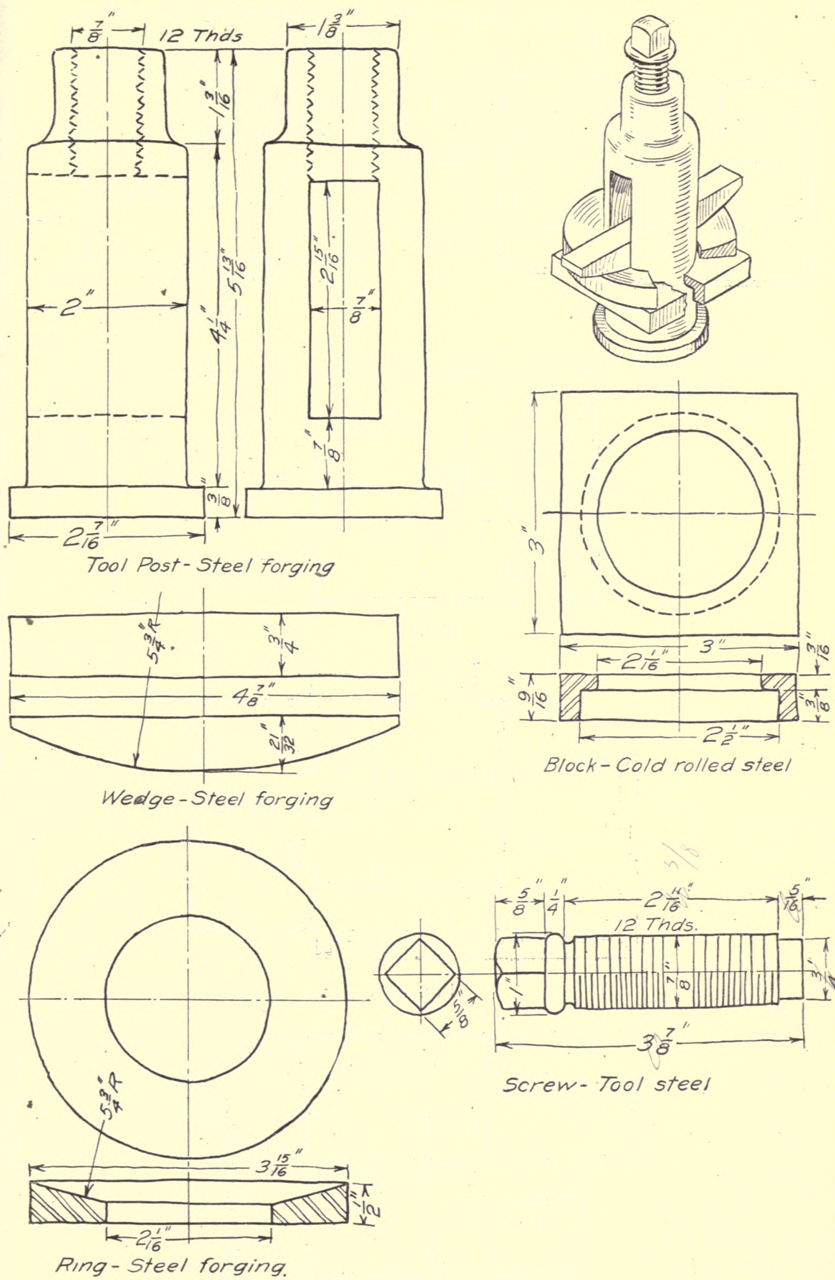


Fig. 438.—Prob. 185.

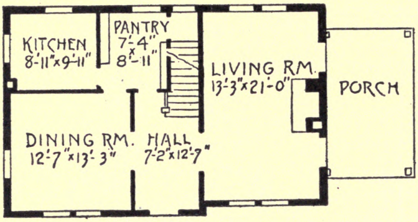


Fig. 439.

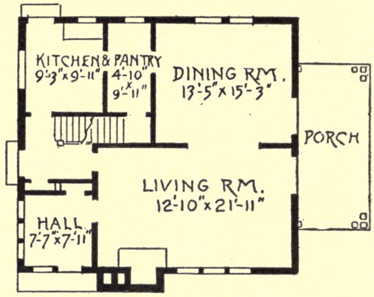


Fig. 440.

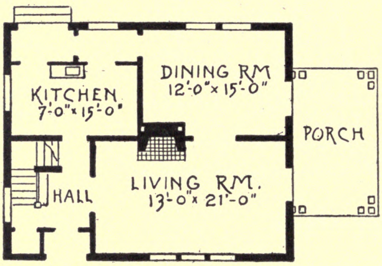


Fig. 441.

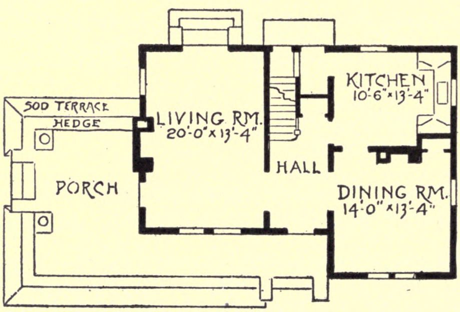


Fig. 442.

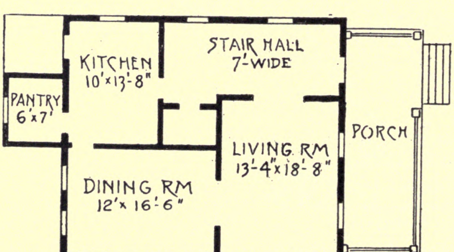


Fig. 443.

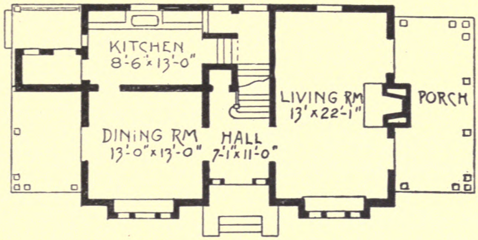


Fig. 444.

Probs. 187 to **192,** Figs. 439 to 444.—Select one of the suggested floor plans and make architectural working drawings as required by your instructor.

1. Basement plan.
2. 1st floor plan.
3. 2nd floor plan.
4. Front elevation.
5. Right side elevation.
6. Left side elevation.
7. Rear elevation.
8. Details.

(Arts. 94 to 100.)

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