FUNDAMENTALS OF ENGINEERING GRAPHICS

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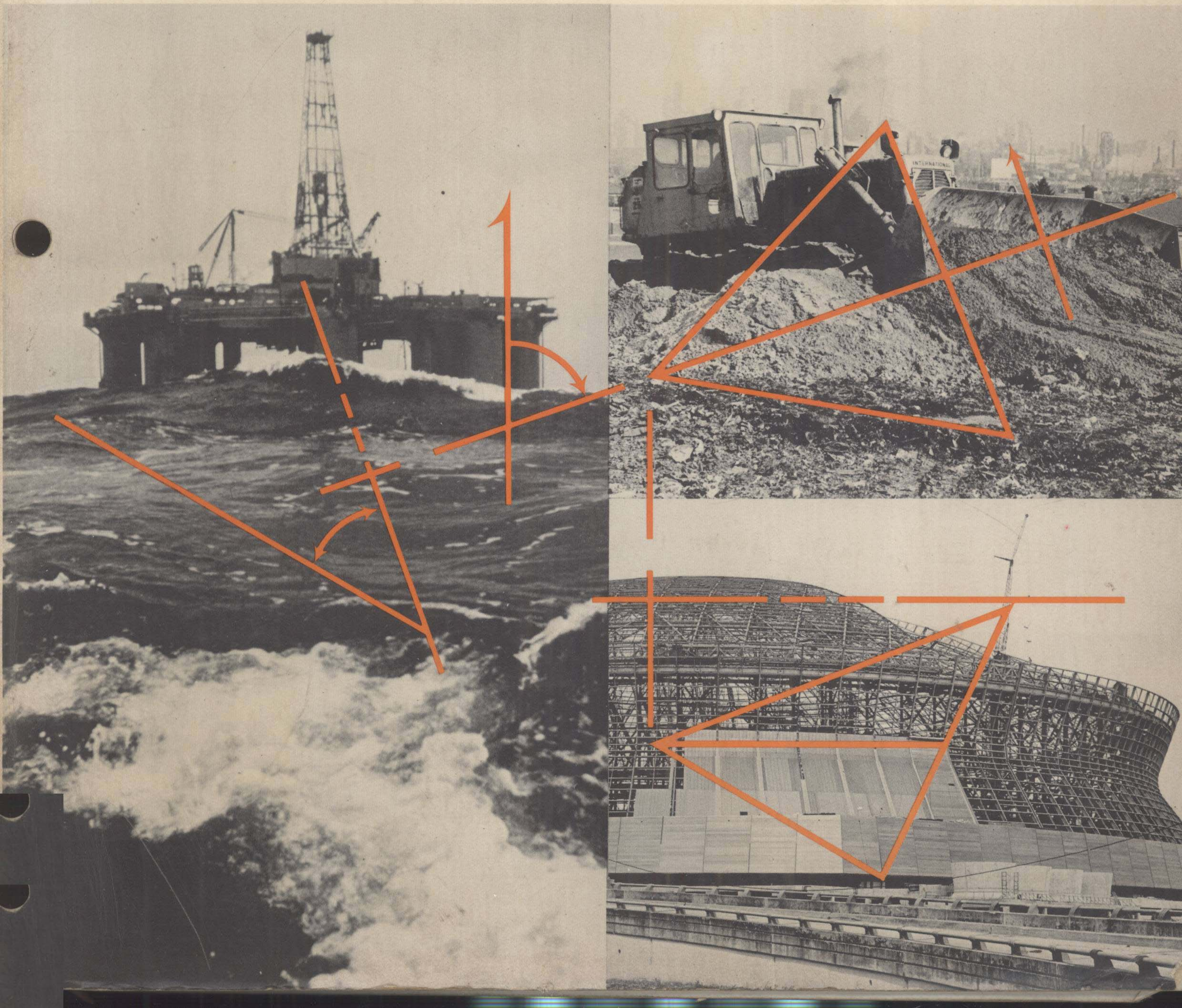

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PREFACE

This engineering graphics text-workbook has been developed to meet the needs of the introductory engineering graphics program. The text is comprehensive in scope, as all topics normally studied by freshman engineering students are presented. It has been the authors' goal to discuss concisely the fundamental concepts involved—without going into lengthy, verbose discussions—in order to save both the student and instructor valuable classroom time. We have found that many complex concepts can be reduced, clarified, and stated in common, straightforward language that the engineering student can easily understand and assimilate.

The text and problems cover the subjects of engineering drawing, descriptive geometry, and graphical mathematics as one integrated course. Emphasis has been placed on the fundamentals of each area of instruction, with the anticipation that each topic will be further amplified and illustrated by the instructor. The authors believe that this approach will be useful and appealing to the beginning student.

Practical application of principles is emphasized in the 109 printed problems following the text. Problem sheets are arranged in sequence with the text material to permit variety in scheduling laboratory and homework assignments. A complete solutions manual is available from the publisher.

The authors express their appreciation to Mrs. Clarice Williams and Mrs. Doris Foster for their assistance in the preparation of this book.

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1 LETTERING AND SKETCHING ORTHOGRAPHIC AND PICTORIAL VIEWS

Engineering graphics is a prime means of communication and a medium for the development of design ideas. The ability to letter and sketch is the hallmark of the competent engineer. This first chapter is devoted to a description of techniques necessary to develop the ability to work freehand with pencil and paper; to letter; and to illustrate by using orthographic and pictorial projection methods.

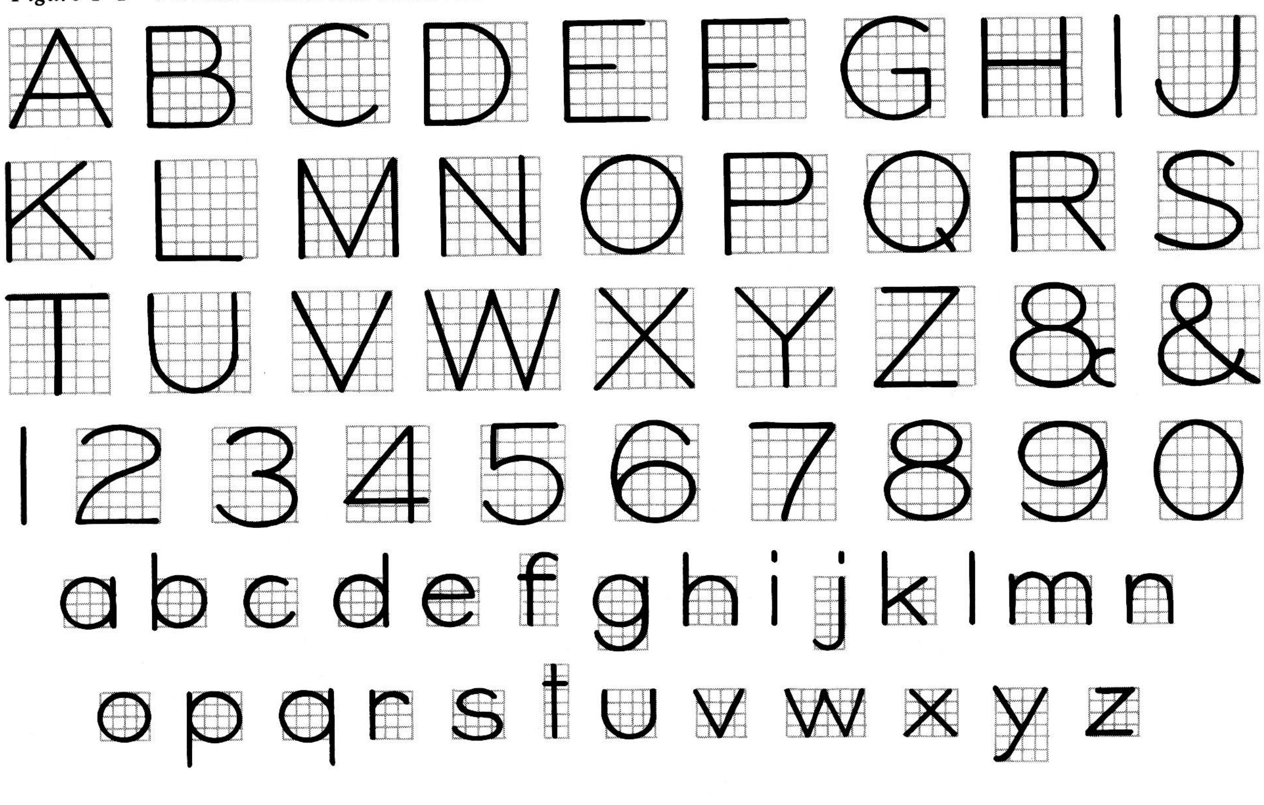
1.1 LETTERING

Illegible or poorly executed notes and dimensions tend to defeat the purpose of a drawing. The ability to letter neatly and rapidly can be acquired by anyone with the will to practice, but practice in making incorrectly shaped letters is of no value. The student should learn the shapes and proportions of the single stroke commercial Gothic alphabet and numerals as illustrated for the vertical style in Figure 1-1.

1.2 LETTERING TECHNIQUE

The experienced engineer will modify the letter shapes and develop a personal style, but the beginner should strive for the correct shape and proportion of each letter.

Figure 1-1 Vertical Letters and Numerals



In lettering the vertical "caps" it is important to remember that the middle horizontal stroke of the letters E, F, and H is placed a little above center and that the letters B, E, K, S, X, and Z are not quite as wide on top as on the bottom; otherwise these letters would appear top-heavy. The letters I, J, and M are often formed incorrectly by the beginner.

Bold black letters are achieved by using the F grade of lead. The point should be conical in shape and at least ¼ inch in length. The single strokes forming the letters are made with a finger and wrist motion. The sequence of strokes, in general, should be from top to bottom and from left to right. The pencil must be kept sharp and should be rotated frequently in the fingers to keep the width of lines uniform. The forearm should always rest on the drawing surface. Letters larger than ¼ inch in height may first be sketched with light overlapping strokes, cleaned up with an eraser, and then darkened with firm single strokes.

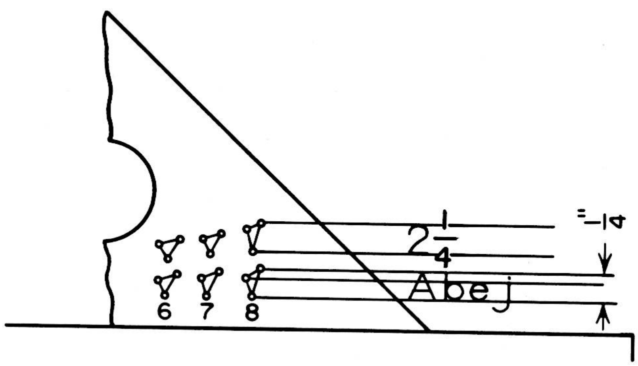
In combining letters to form words, the letters are *not* spaced equal distances apart—the spaces are proportioned to give equal clear areas between letters. Words should be spaced the width of the letter "O" apart.

Lettering may also be done mechanically by using special tools such as the Leroy or Wrico lettering sets, alphabet templates, lettering typewriters, or transfer letters.

1.3 GUIDELINES

Guidelines should be used for lettered notes and titles on drawings. Special devices are useful for drawing guidelines. For example, a lettering triangle is illustrated in Figure 1-2.

Figure 1-2 Lettering Triangle



Horizontal guidelines are drawn by placing the sharp point of a hard lead pencil in the holes and moving the triangle back and forth along the edge of the T-square blade. The lower hole of each group of three locates the base line, the middle hole locates the waist line for lowercase letters, and the top hole locates the cap line. The identifying numerals 3, 4, 5, etc. denote the letter height in thirty-seconds of an inch. The beginner should also draw randomly spaced vertical guidelines to avoid sloping the letters to the right or left. Guidelines for common fractions are not usually drawn. The total height of the fraction is estimated to be double the height of the whole number.

1.4 TITLES

Title blocks are designed and drawn or printed in block form on the drawing sheet with blank spaces for detailed information. Map titles are designed for symmetrical layout about a center line with letter heights of the different lines dependent upon the relative importance of each line.

1.5 SKETCHING

In engineering design, the first drawings are in the form of sketches. Many sketches are drawn and redrawn before a new or improved design reaches the drawing board. Sketches may be made entirely freehand or instrument-aided by templates and straight edges.

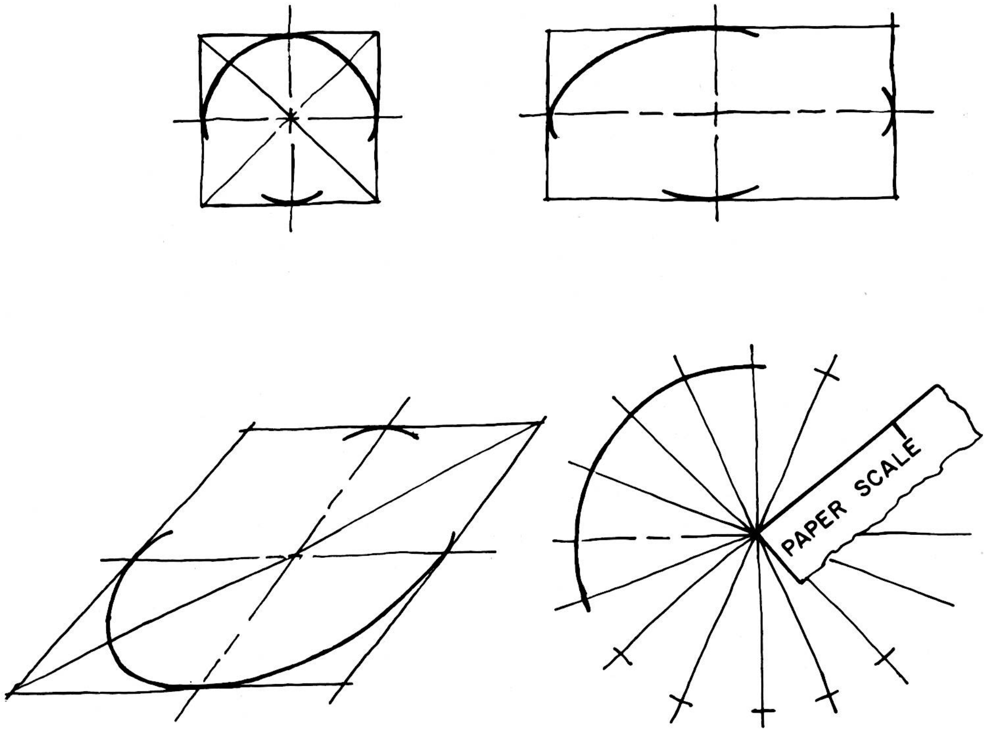
This unit on sketching is confined to freehand work where the only materials used are pencils, a sharpener or lead pointer, an eraser, and paper. HB or F grade lead is used, and the point is sharpened to give the width of line desired.

1.6 SKETCHING TECHNIQUE

Sketching on grid paper is not difficult because the horizontal and vertical directions are fixed and the grid squares may be counted for correct dimensions and proportion. Horizontal lines are sketched from left to right and vertical lines from top to bottom. The forearm should rest on the table top and the lines are drawn in lengths to correspond to the natural swing of the fingers, hand, and wrist. Very short gaps may be left between strokes or the strokes may join for a continuous line. The paper should be turned to the most convenient angle for ease in sketching, even 90° if necessary for long vertical lines.

Sketching on plain paper requires special care in obtaining true directions and proportional size relationships. To sketch a straight line, mark the beginning and end points and aim for the end point with the eye. First, sketch with light overlapping strokes as though brushing in a line with a watercolor brush, then correct and clean up the line with the eraser and finally go over the line with firm, black strokes. Distances are usually estimated for correct proportions.

Figure 1-3 Sketching Circles and Ellipses



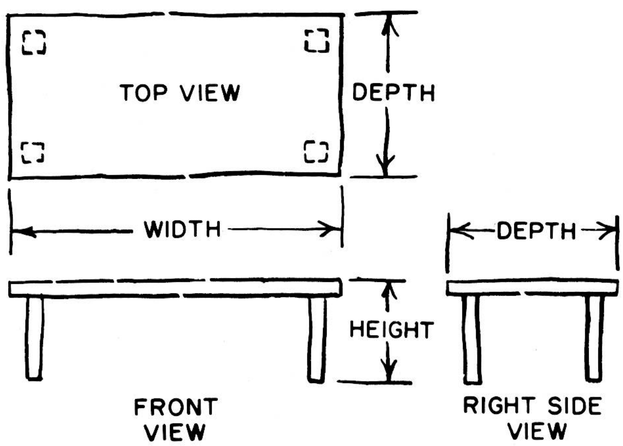
Circles and ellipses are sketched by drawing center lines and "box" lines which establish the lines of symmetry and overall dimensions of the required figure. See Figure 1-3. Four short arcs are drawn tangent to the sides of the box at the midpoint and then the missing segments filled in. The sheet should be turned for ease in sketching each of the four arc segments.

Large circles are sketched through points set off on diameter lines drawn through the center points.

1.7 ORTHOGRAPHIC VIEWS

Three-dimensional objects may be represented on a sheet of paper by sketching one or more orthographic views. Orthographic views are obtained by looking squarely at one or more faces, as required, to describe the shape and proportions of the object. The true shape of a gasket or template can be shown by one view with a note to give the thickness of the material. A minimum of two views is normally required to describe the shape and show the width, height, and depth dimensions of an object. Theoretically, each view is projected onto a plane of projection by projecting each point of the object to the plane with projecting lines or projectors constructed perpendicular to the plane. Since the views are projections of the same fixed object on mutually perpendicular planes, the front, top, and right-side views share exact relationships in shape, size, and position. This relationship must be retained when the views are sketched, and it is of the *utmost* importance that the top view be placed directly above the front view and the right-side view placed to the right and aligned with the front view. See Figure 1-4.

Figure 1-4 Three Orthographic Views of a Table



In order to learn to "read" engineering drawings, the student must develop the ability to visualize three-dimensional spatial relationships. Therefore, it is very important to always think of the related views and dimensions as seen from different positions in space and not as independent drawings on a single plane.

1.8 SKETCHING VIEWS

The correct procedure for sketching the three principal views, front, top, and right side, is to lay out the overall width, height, and depth dimensions of the object to form three rectangles to enclose the three views as shown in Figure 1-5. The front view will show width and height, the top view width and depth, and the side view height and depth. After "blocking in" the views, the detail representation of the geometric shapes are sketched in light lines. Details are projected back and forth from view to view. Thus all views are completed together, not one at a time. Finally, after checking for errors and omissions the lines are made sharp and black. All views should show all features complete with correct line symbols. See Figure 1-6.

Figure 1-7 illustrates four basic geometric shapes pictorially and by orthographic views with the correct line symbols for visible, hidden, and center lines. A sphere appears as a circle in all views. All designs include composites of the basic geometric shapes.

Figure 1-5 Blocking in Views

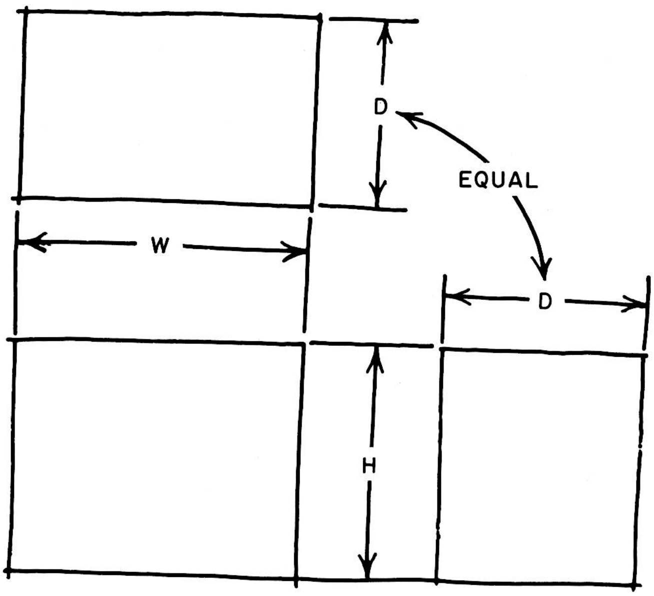


Figure 1-6 Line Symbols

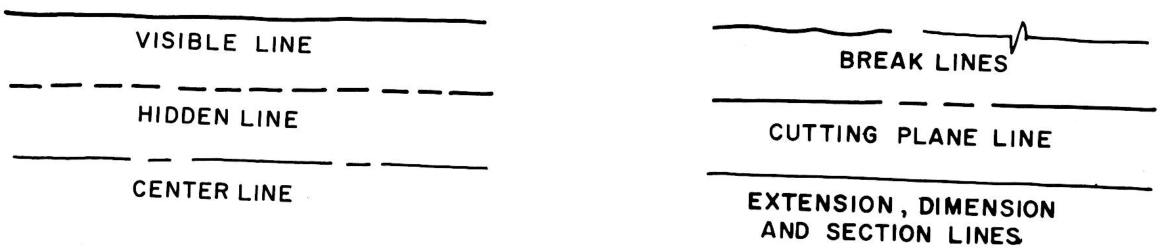
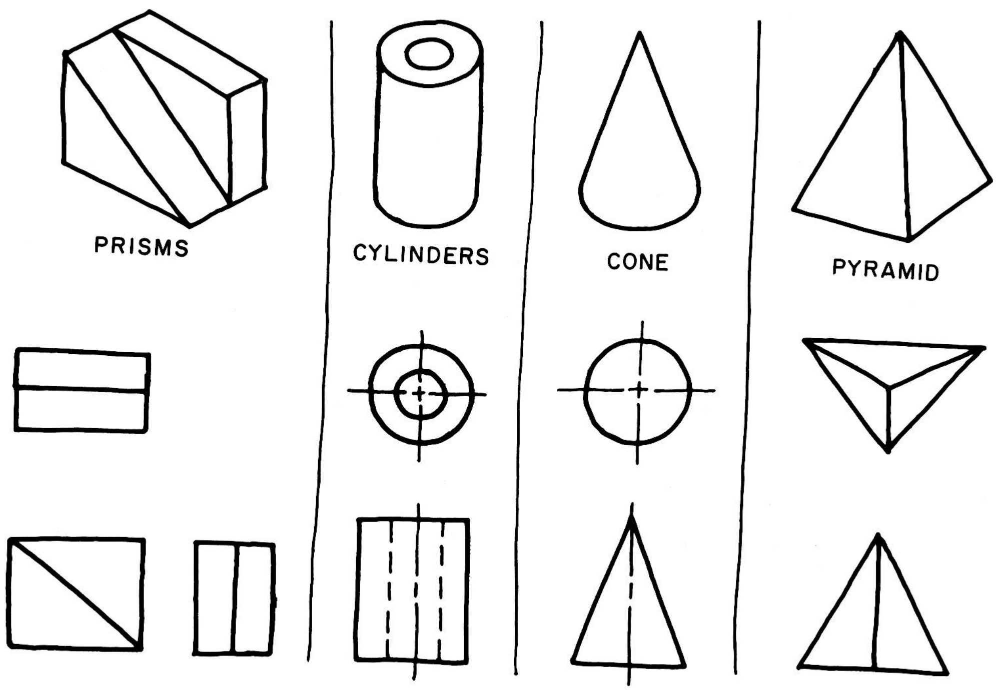


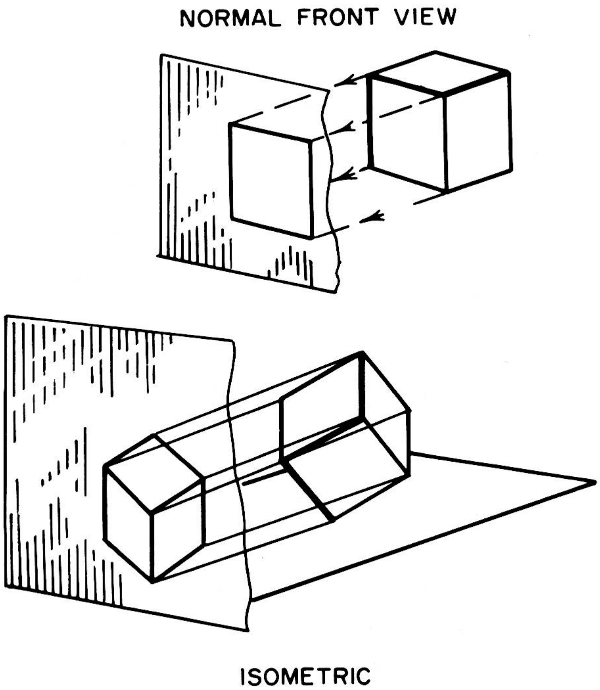
Figure 1-7 Four Basic Geometric Shapes



1.9 ISOMETRIC PROJECTION

An orthographic view will be a three-dimensional pictorial if the principal faces of the object are inclined to the plane of projection. Single-view pictorials within the orthographic system are classified as isometric, dimetric, and trimetric under the general heading of axonometric projection. Isometric is the easiest of the three to draw and is therefore most often used. A comparison of a normal front view of a cube with an isometric is shown pictorially in Figure 1-8.

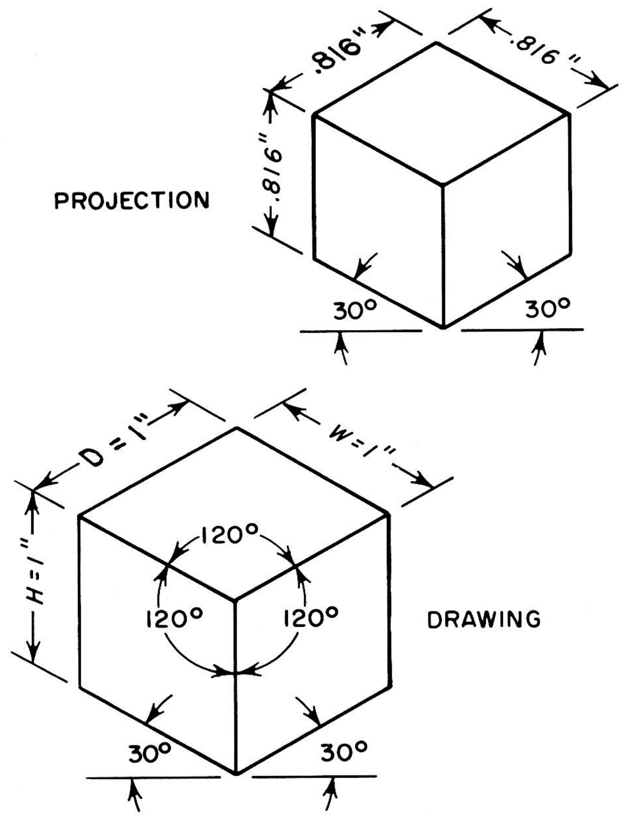
Figure 1-8 Orthographic Projection of a Cube



In *isometric projection* the three principal axes of the object make equal angles (35°16′) with the plane of projection. A cube in this position would have a rear corner directly behind the front corner and the body diagonal from front to rear would be parallel to the line of sight and therefore perpendicular to the projection plane. The projections of the axes or edges of the cube will form angles of 120° with each other and the image of the cube on the plane will be smaller than the actual cube in the ratio of .816 to 1. To avoid using a special isometric scale, the reduction is usually ignored, and the drawing made in a ratio of 1:1. This is called an *isometric drawing* as distinguished from the true isometric projection of an object. See Figure 1-9.

The projections of the principal axes on the drawing are called the isometric axes, and the projections of all lines parallel to the principal axes are called isometric lines.

Figure 1-9 Isometric Projection and Isometric Drawing of a 1″ Cube



1.10 ISOMETRIC SKETCHING

Isometric sketches are made by sketching the isometric axes at angles of 120° with each other. The height axis is usually drawn vertical and the other two up to the right and left at 30° to the horizontal as shown in Figure 1-9. Overall width, height, and depth distances are measured on the isometric axes, and the "box" which will enclose the view is constructed by drawing parallel edge lines. The view is completed by drawing all visible lines. Hidden lines are not shown unless essential for clarity. *Measurements can only be made on isometric lines.*

1.11 COORDINATE CONSTRUCTION

Nonisometric lines are drawn by locating points on the line by coordinates. The 30° and 45° angle lines in Figure 1-10 are located by transferring the coordinate distances *a, b,* and *c* from the axes on the true-size view to the isometric axes. Irregularly shaped objects are drawn by offset or coordinate construction. Points are located as illustrated in Figure 1-11 for point 1 on the circular arc and point *1′* on the elliptical curve in the nonisometric plane.

Figure 1-10 Angles by Coordinates

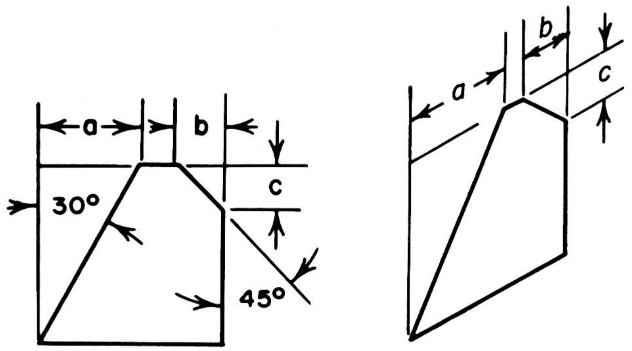
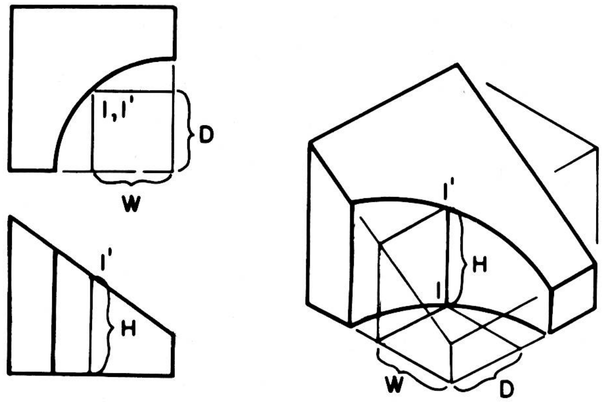


Figure 1-11 Coordinate Construction



1.12 CIRCLES IN ISOMETRIC

A circle will project as an ellipse when the plane of the circle is inclined to the plane of projection. An ellipse in an isometric plane is sketched by first sketching the rhombus, which is the projection of the square that circumscribes the circle. See Figures 1-3 and 1-12. The construction for drawing an approximate ellipse with the compass is illustrated in Figure 2-11.

A cylinder is sketched by constructing the two elliptical bases and then drawing object lines parallel to the cylinder axis and tangent to the base curves at the points of intersection with the long rhombus diagonals. The long diagonals will always be perpendicular to the axis of the cylinder.

Figure 1-12 Sketching Ellipses in Isometric

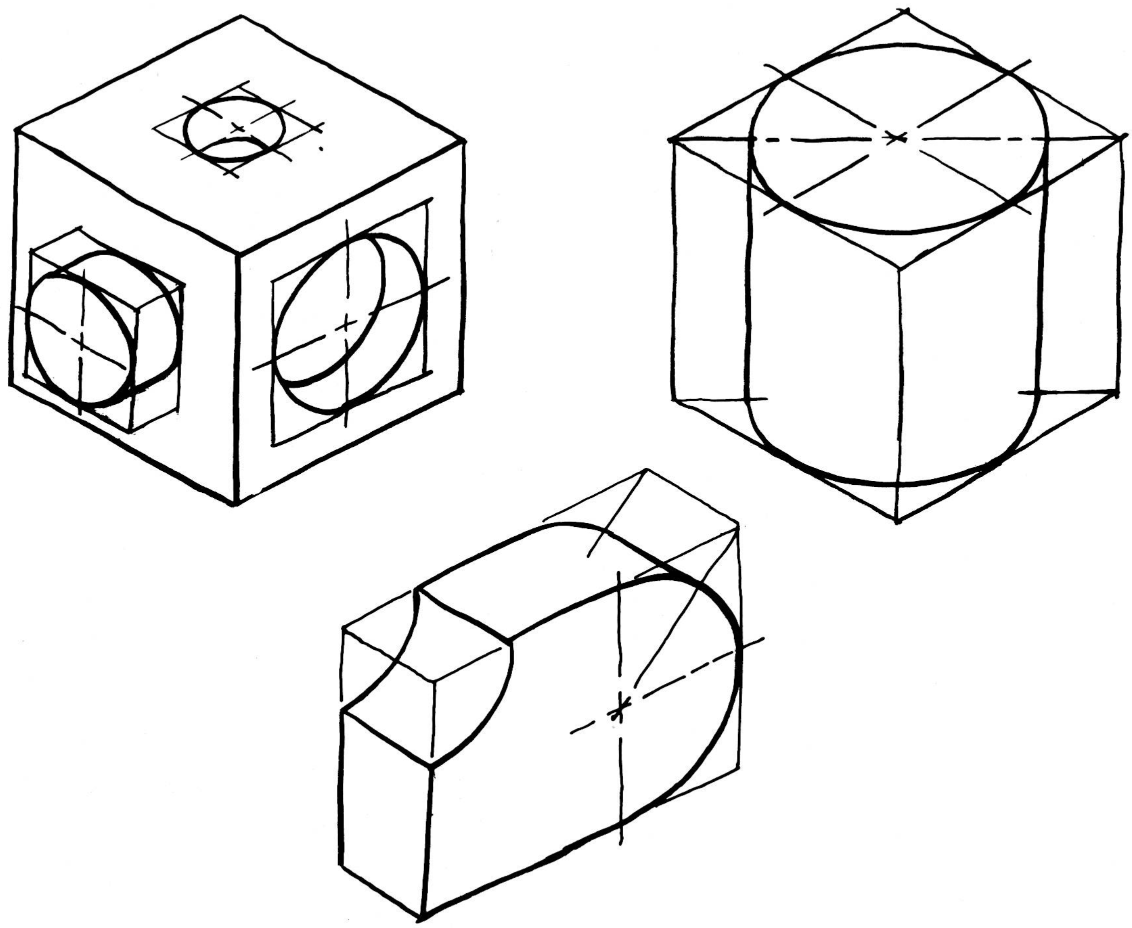
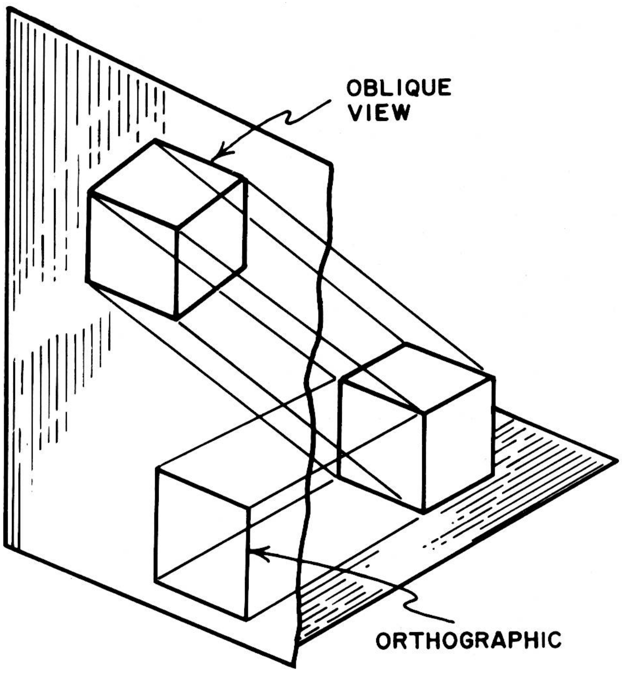


Figure 1-13 Orthographic and Oblique Projection



1.13 OBLIQUE PROJECTION

Cavalier, cabinet, and general oblique drawings are single-view pictorial projections in which the projecting lines are parallel to each other and oblique (not perpendicular) to the plane of projection. See Figure 1-13.

The front face and all elements parallel to the frontal plane will project true shape and size. Therefore, the width and height axes are sketched in their normal position. The depth axis, called the *receding axis,* is drawn at any desired angle with the horizontal and is measured in any ratio in comparison with the height and width axes. If the oblique projecting lines in space made 45° with the plane of projection, the ratio will be 1 to 1 and the view is a cavalier projection. If the ratio is 1 to ½ on the receding axis, the view is a cabinet drawing. All other ratios are classified as general oblique. In Figure 1-14, θ may be any desired angle.

1.14 OBLIQUE SKETCHING

In sketching an oblique view, the angle, direction, and scale of the receding axis are selected to give maximum definition and least distortion. The axis is usually drawn at either 30° or 45° upward to the right or left. A cabinet or general oblique will minimize distortion due to a long depth dimension. In general, the long dimension of the object should be selected as width, but not if this position places the most irregular features in a receding plane.

Measurements in the receding planes can only be made parallel to the axes, and particular care must be exercised when two scales are used as in cabinet and general oblique drawings. Angular cuts and curves in inclined planes are located by offset measurements or coordinates the same as in isometric drawings.

Circles will project as ellipses in the receding planes and are sketched as illustrated in Figure 1-15.

Figure 1-15 Sketching Circles and Ellipses in Oblique

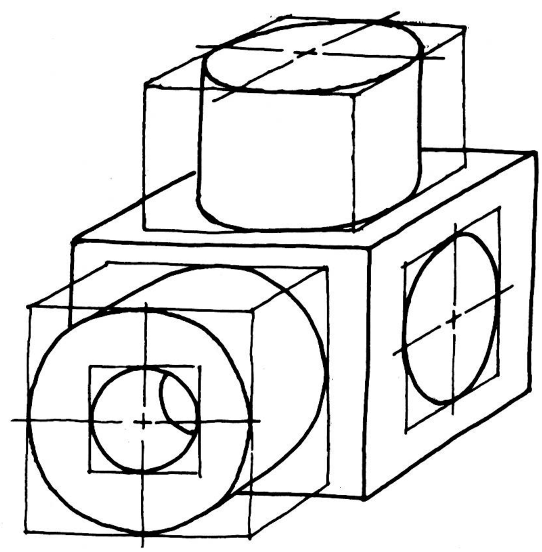


Figure 1-14 Types of Oblique Projection

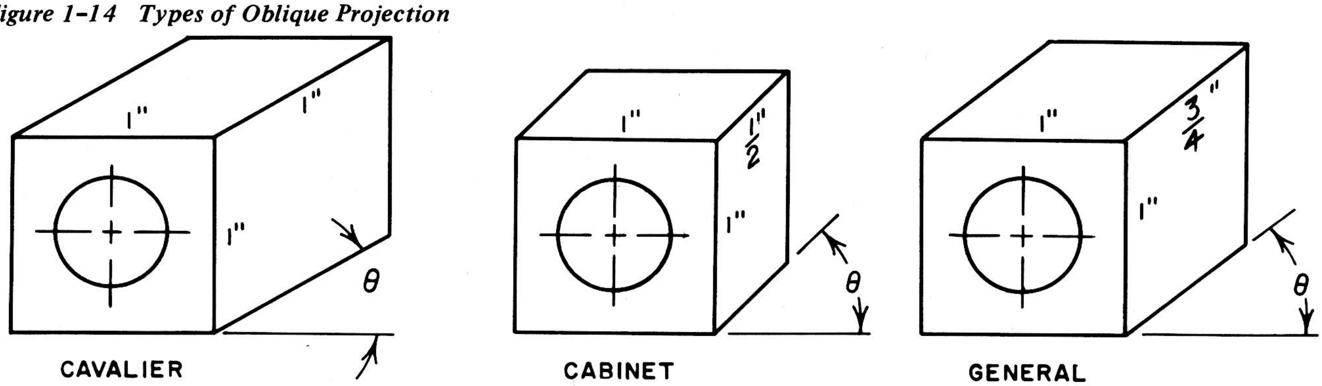
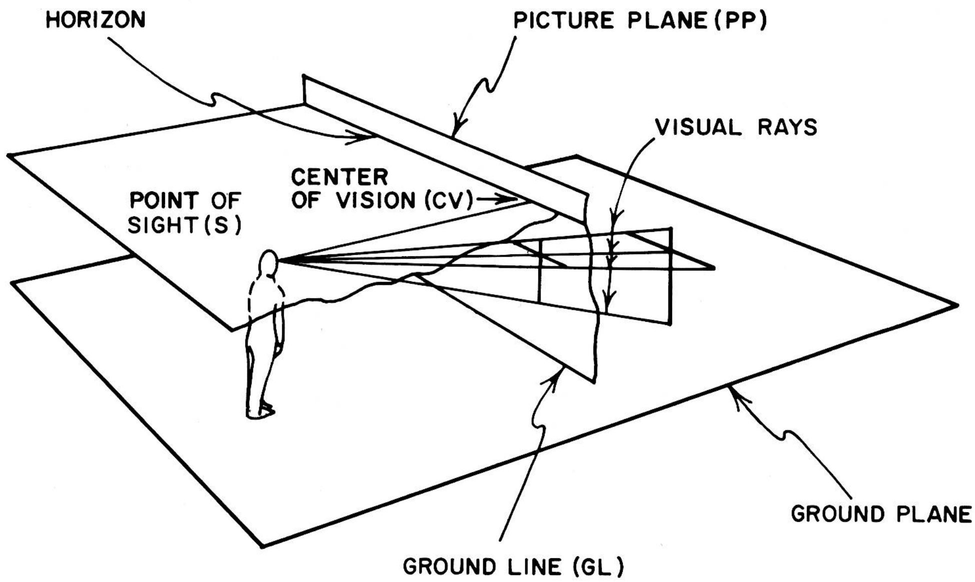


Figure 1–16 The Perspective System



1.15 PERSPECTIVE

Perspective is that form of projection in which the projecting lines or visual rays radiate from a point of sight located a finite distance from the object. It produces the most realistic image of all forms of projection. The nomenclature and space relations of the elements of a perspective system are illustrated in Figure 1–16.

Skill in making freehand perspectives requires study and practice but pseudoperspectives are easily made and may be useful to the engineer whenever an isometric or oblique sketch appears too distorted. The view is sketched in a manner similar to isometric or oblique with one major change. The receding parallel horizontal line systems are drawn to converge at vanishing points on a horizon line. The vanishing points are selected to give the desired view and the receding planes are foreshortened visually for optimum effect. See Figure 1–17.

Figure 1–17 Perspective Sketching

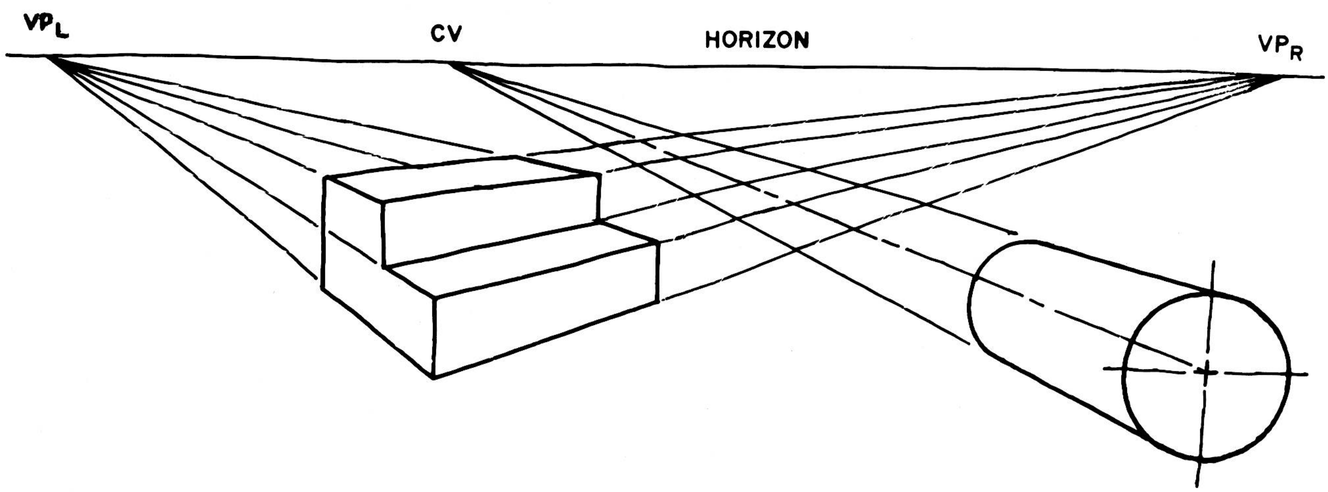
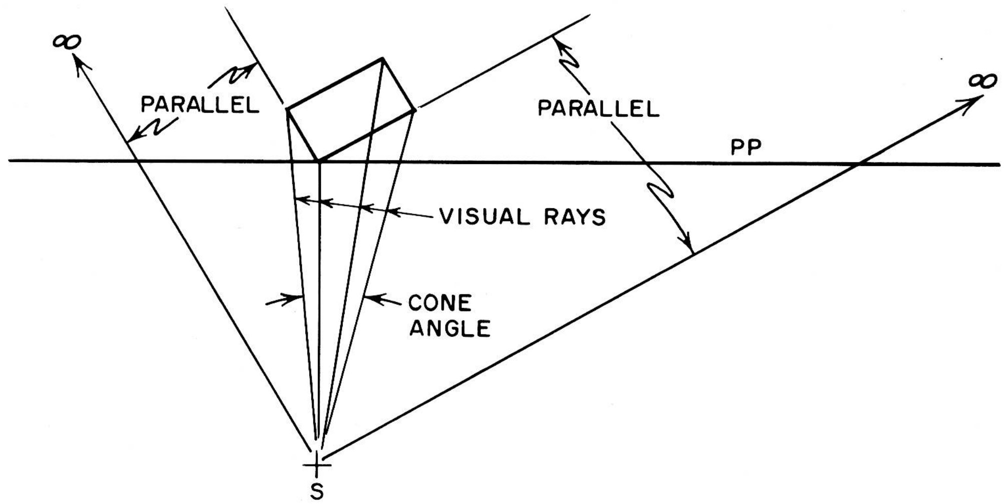


Figure 1-18 Top-View Layout for Angular Perspective



1.16 ANGULAR PERSPECTIVE

Mechanical perspectives are made by drawing orthographic views of the system. The *angular* or *two-point perspective* of a rectangular prism is constructed as shown in Figures 1-18 and 1-19. The object is normally placed with a front corner in the picture plane and with the front face at 30° with the plane. The point of sight is selected to give the desired view with the least distortion. The cone of vision angle should not exceed 30°.

The top view or plan (Figure 1-18) is drawn first to show the relative positions of the object, the picture plane (*PP*), the point of sight (*S*), the visual rays and the construction lines through *S* to infinity (∞).

A front view of the picture plane will show the perspective of the prism as determined by the points in which the visual rays pierce the plane. See Figure 1-19.

The horizon line is drawn at eye height above the ground line at any convenient distance from the top view. A front-elevation view of the prism is drawn for convenience in projecting height dimensions.

The perspective of the front corner *AB* will show true height because it lies in the picture plane. Points *A* and *B* are projected from the top view and the height from the side view. The vertical edge *CD* will not show true height. *Height can only be measured in the picture plane.* Therefore, points *C* and *D* are projected into the picture plane to points *A* and *B* and/or to points *C′* and *D′*. The horizontal edge lines of the prism are then drawn to the correct vanishing points BP_L and VP_R on the horizon, and the vertical edges projected from the top view to complete the perspective.

Figure 1-19 Angular Perspective of a Prism