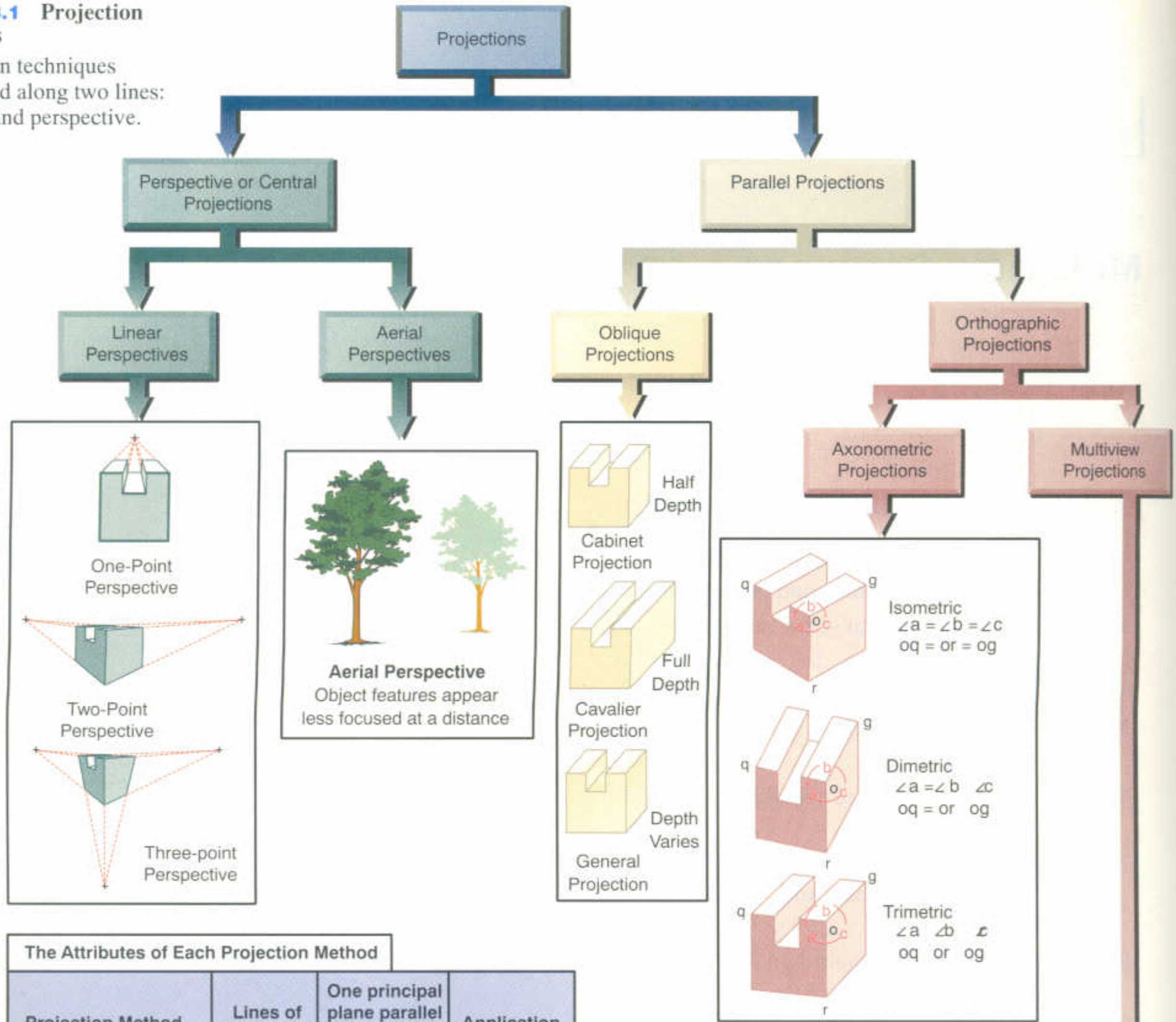
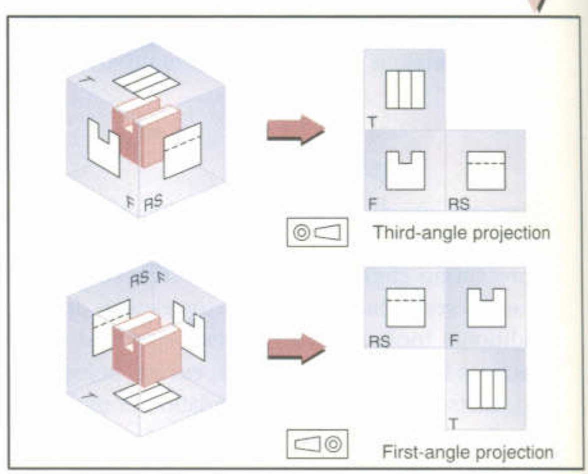
Figure 8.1 Projection Methods

Projection techniques developed along two lines: parallel and perspective.



The Attributes of Each Projection Method

Projection Method	Lines of Sight	One principal plane parallel to plane of projection	Application
Linear Perspective *-One-Point* *-Two-Point* *-Three-Point*	Converging; inclined to plane of projection	Sometimes	Single view pictorial
Oblique Projection *-Cavalier* *-Cabinet* *-General*	Parallel; inclined to plane of projection	Always	Single view pictorial
Orthographic Projection Axonometric *-Isometric* *-Dimetric* *-Trimetric*	Parallel; normal to plane of projection	Never	Single view pictorial
Multiview Projection *-Third Angle (preferrred)* *-First Angle*	Parallel; normal to plane of projection	For all principal views	Multiview drawings



8.1 | PROJECTION THEORY

Engineering and technical graphics are dependent on projection methods. The two projection methods primarily used are perspective and parallel. (Figure 8.1) Both methods are based on projection theory, which has taken many years to evolve the rules used today.

Projection theory comprises the principles used to represent graphically 3-D objects and structures on 2-D media. An example of one of the methods developed to accomplish this task is shown in Figure 8.2, which is a pictorial drawing with shades and shadows to give the impression of three dimensions.

Figure 8.2 Pictorial Illustration
This is a computer-generated pictorial illustration with shades and shadows. These rendering techniques help enhance the 3-D quality of the image. (Courtesy of SDRC.)

All projection theory is based on two variables: line of sight and plane of projection. These variables are described briefly in the following paragraphs.

8.1.1 Line of Sight (LOS)

Drawing more than one face of an object by rotating the object relative to your *line of sight* helps in understanding the 3-D form. (Figure 8.3) A **line of sight (LOS)** is an imaginary ray of light between an observer's eye and an object. In perspective projection, all lines of sight start at a single point (Figure 8.4); in parallel projection, all lines of sight are parallel (Figure 8.5).

8.1.2 Plane of Projection

A **plane of projection** (i.e., an image or picture plane) is an imaginary flat plane upon which the image created by the lines of sight is projected. The image is produced by connecting the points where the lines of sight pierce the projection plane. (See Figure 8.5.) In effect, the 3-D object is transformed into a 2-D representation (also called a projection). The paper or computer screen on which a sketch or drawing is created is a plane of projection.

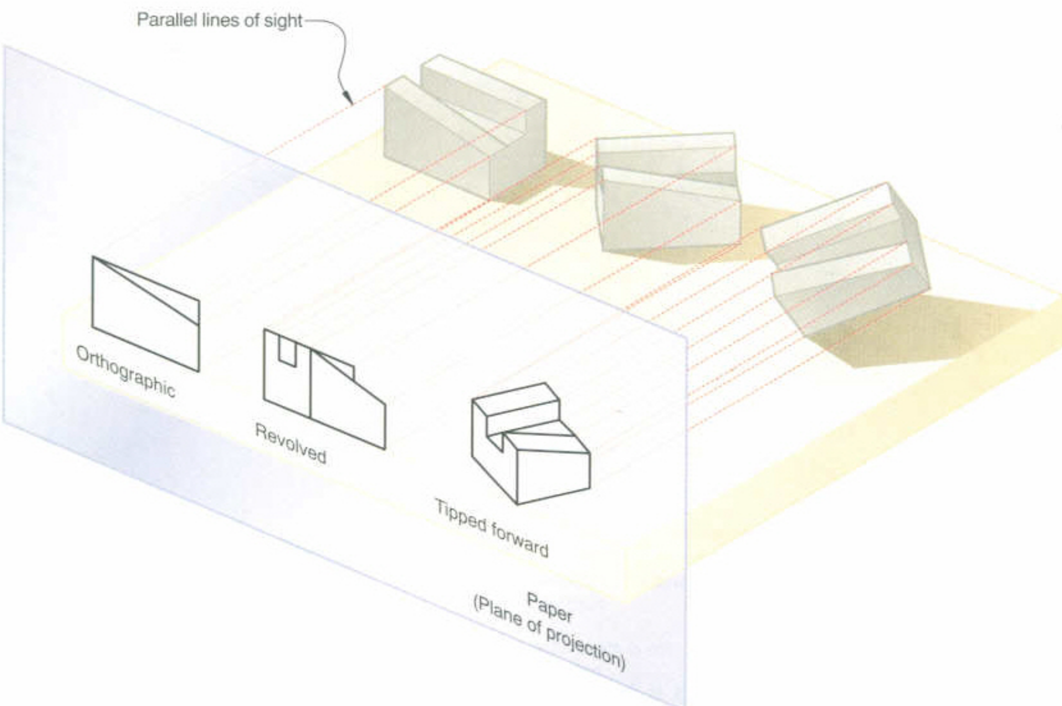


Figure 8.3 Changing Viewpoint
Changing the position of the object relative to the line of sight creates different views of the same object.

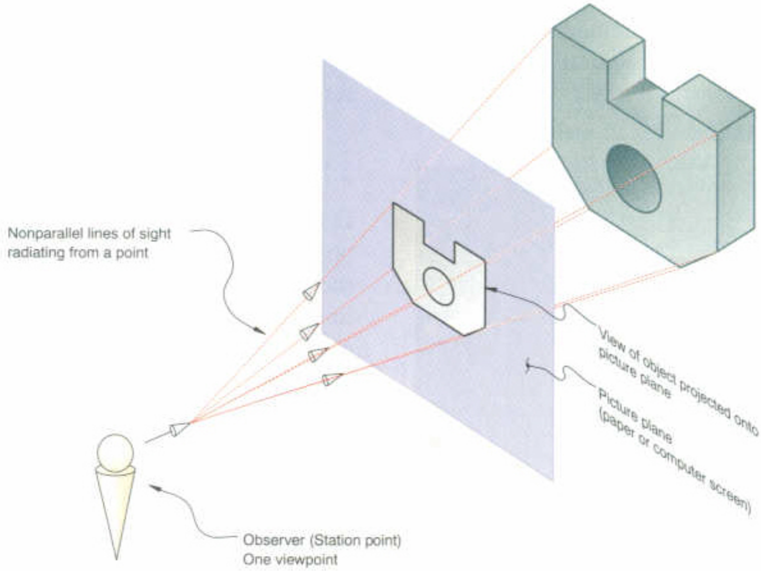


Figure 8.4 **Perspective Projection**
Radiating lines of sight produce a perspective projection.

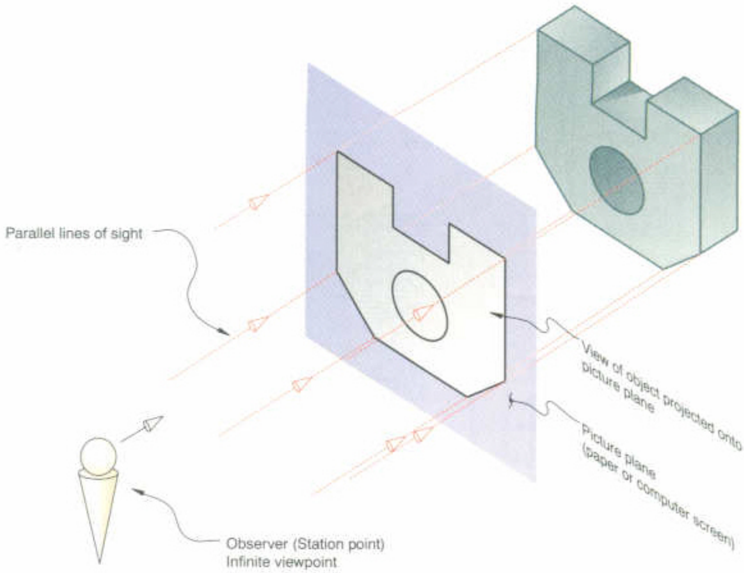


Figure 8.5 **Parallel Projection**
Parallel lines of sight produce a parallel projection.

8.1.3 Parallel versus Perspective Projection

If the distance from the observer to the object is infinite (or essentially so), then the *projectors* (i.e., projection lines) are parallel and the drawing is classified as a parallel projection. (See Figure 8.5.) **Parallel projection** requires that the object be positioned at infinity and viewed from multiple points on an imaginary line parallel to the object. If the distance from the observer to the object is finite, then the projectors are not parallel and the drawing is classified as a perspective projection. (See

Figure 8.4.) **Perspective projection** requires that the object be positioned at a finite distance and viewed from a single point (station point).

Perspective projections mimic what the human eye sees; however, perspective drawings are difficult to create. Parallel projections are less realistic, but they are easier to draw. This chapter will focus on parallel projection. Perspective drawings are covered in Chapter 10.

Orthographic projection is a parallel projection technique in which the plane of projection is positioned between the observer and the object and is perpendicular to the parallel lines of sight. The orthographic projection technique can produce either pictorial drawings that show all three dimensions of an object in one view or multiviews that show only two dimensions of an object in a single view. (Figure 8.6)

Figure 8.6 Parallel Projection
Parallel projection techniques can be used to create multiview or pictorial drawings.

8.2 | MULTIVIEW PROJECTION PLANES

Multiview projection is an orthographic projection for which the object is behind the plane of projection, and the object is oriented such that only two of its dimensions are shown. (Figure 8.7) As the parallel lines of sight pierce the projection plane, the features of the part are outlined.

Multiview drawings employ multiview projection techniques. In multiview drawings, generally three views of an object are drawn, and the features and dimensions in each view accurately represent those of the object. Each view is a 2-D flat image, as shown in Figure 8.8. The views are defined according to the positions of the planes of projection with respect to the object.

8.2.1 Frontal Plane of Projection

The *front view* of an object shows the *width* and *height* dimensions. The views in Figures 8.7 and 8.8 are front views. The **frontal plane of projection** is the plane onto which the front view of a multiview drawing is projected.

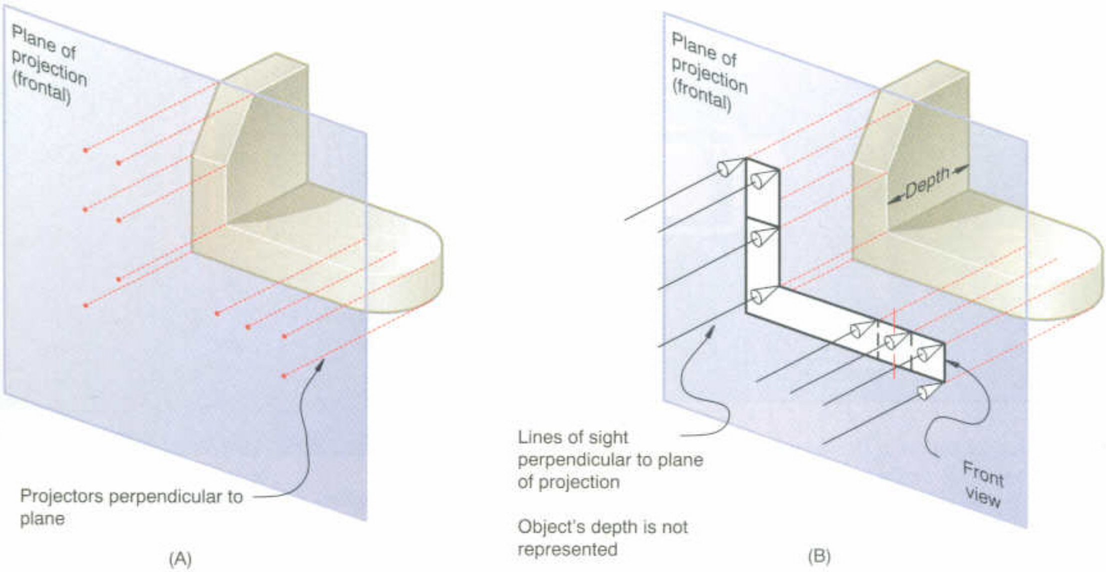


Figure 8.7 Orthographic Projection
Orthographic projection is used to create this front multiview drawing by projecting details onto a projection plane that is parallel to the view of the object selected as the front.

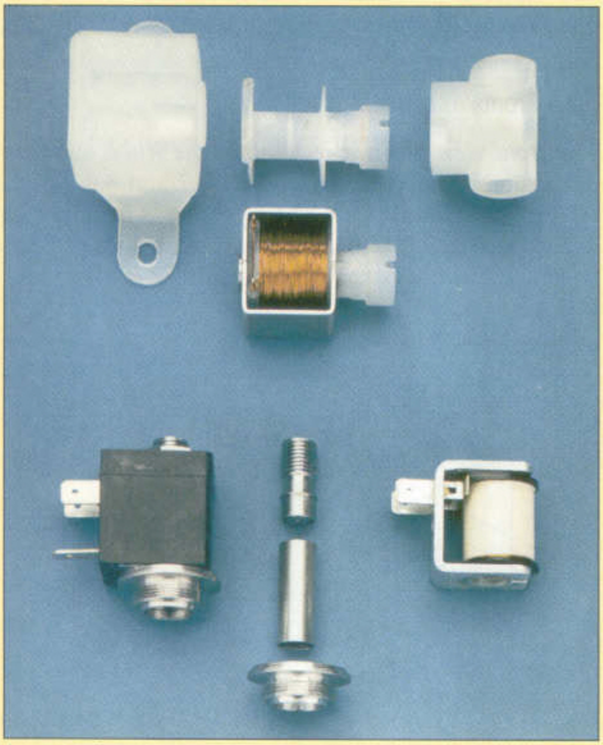
CAD and Stereolithography Speed Solenoid Design

When Peter Paul Electronics faced the need to quickly redesign a humidifier solenoid valve, Senior Design Engineer Thomas J. Pellegatto naturally turned his CAD-KEY-based system loose on the physical parameters of the new valve. But that wasn't enough. The design required lower-cost manufacturing technology as well as dimensional and mechanical design changes.

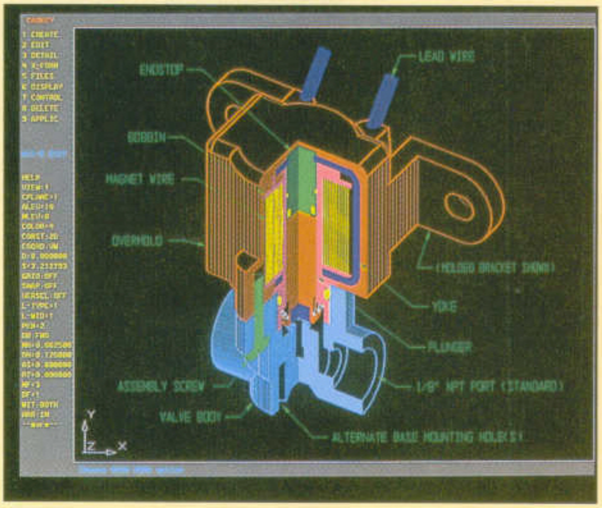
Existing valves from the company feature an all-steel sleeve, consisting of a flange nut, tube, and end stop, all of which are staked together for welding. A weld bead secures the end stop to the tube at the top edge and joins the tube and threaded portion of the flange nut at the bottom. Alignment of these components becomes critical because the sleeve sits inside the coil, which is the heart of the solenoid valve. In addition, a plunger that causes air or fluid to flow in the valve rises inside the sleeve.

According to Pellegatto, the simplest method for reducing cost and complexity of the critical sleeve assembly was to use the coil's bobbin to replace the sleeve and house the plunger. Working directly with engineers at DuPont, designers selected a thermoplastic named Rynite to eliminate misalignment and the need for welding the new assembly. The CAD system fed Peter Paul's internal model shop with the data to develop bobbin prototypes from the thermoplastic. In addition, designers decided to mold the formerly metallic mounting bracket as part of the plastic housing.

Once designs were finalized, Pellegatto sent the CAD file to a local stereolithography shop, which built demonstration models using a 3D Systems unit. Two copies each of three molded components—the bobbin, valve body, and overmolded housing—were produced for about $3,000. Finally, after sample parts were approved by the customer, hard tooling was developed using revised CAD files. This venture into "desktop manufacturing" saved enormous amounts of design cycle time, according to Pellegatto. ■



Redesign and simplification of the solenoid valve coil and sleeve assembly (left) is easily compared with the coil-on-bobbin assembly. The extended and molded one-piece bobbin eliminates the use of two machined parts, two welds, and one quality operation while providing an improved magnetic circuit, reduced weight, and lower cost.



The three components created in plastic include the overmolded valve housing with integral bracket (red), the bobbin on which the coil is wound, and the valve body with which the solenoid valve is connected (blue).

Source: "CAD and Stereolithography Speed Solenoid Design," *Machine Design*, August 13, 1993, p. 80. Photos courtesy of Thomas J. Pellegatto, Senior Design Engineer, Peter Paul Electronics Co. Inc., New Britain, CT 06050–1180.

8.2.2 Horizontal Plane of Projection

The *top view* of an object shows the *width* and *depth* dimensions. (Figure 8.9) The top view is projected onto the **horizontal plane of projection,** which is a plane suspended above and parallel to the top of the object.

8.2.3 Profile Plane of Projection

The *side view* of an object shows the *depth* and *height* dimensions. In multiview drawings, the right side view is the standard side view used. The right side view is projected onto the right **profile plane of projection,** which is a plane that is parallel to the right side of the object. (Figure 8.10)

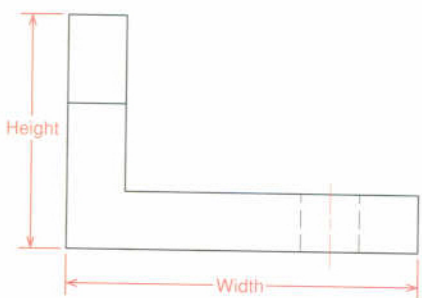


Figure 8.8 **Single View**

A single view, in this case the front view, drawn on paper or computer screen makes the 3-D object appear 2-D; one dimension, in this case the depth dimension, cannot be represented since it is perpendicular to the paper.

8.2.4 Orientation of Views from Projection Planes

The views projected onto the three planes are shown together in Figure 8.11. The top view is always positioned above and aligned with the front view, and the right side view is always positioned to the right of and aligned with the front view, as shown in the figure.

8.3 | ADVANTAGES OF MULTIVIEW DRAWINGS

In order to produce a new product, it is necessary to know its true dimensions, and true dimensions are not adequately represented in most pictorial drawings. To illustrate, the photograph in Figure 8.12 is a pictorial perspective image. The image distorts true distances, which are essential in manufacturing and construction. Figure 8.13 demonstrates how a perspective projection distorts measurements. Note that the two width dimensions in the front view of the block appear different in length; equal distances do not appear equal on a perspective drawing.

In the pictorial drawings in Figure 8.14, angles are also distorted. In the isometric view, right angles are not shown as 90 degrees. In the oblique view, only the front surfaces and surfaces parallel to the front surface show true right angles. In isometric drawings, circular holes appear as ellipses; in oblique drawings, circles also appear as ellipses, except on the front plane and surfaces parallel to the front surface. Changing the position of the object will minimize the distortion of some surfaces, but not all.

Since engineering and technology depend on exact size and shape descriptions for designs, the best approach

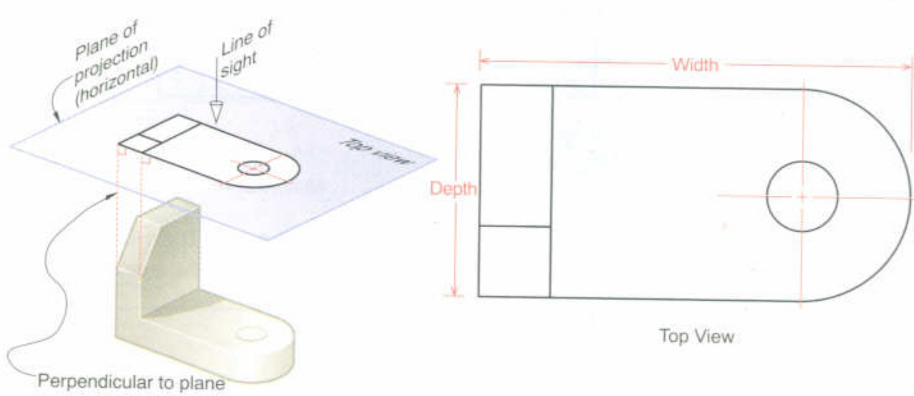
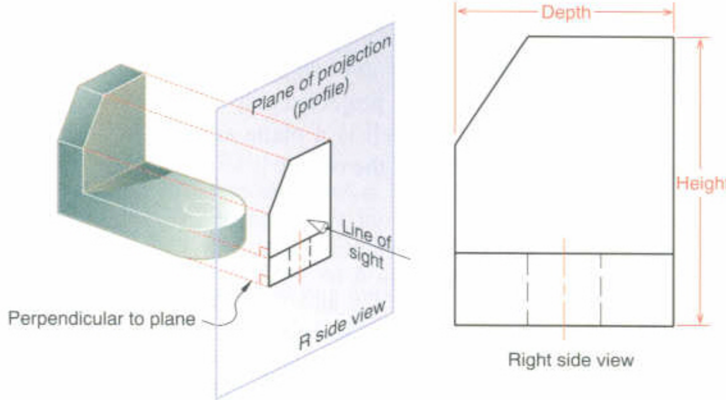


Figure 8.9 **Top View**

A top view of the object is created by projecting onto the horizontal plane of projection.

8.10 Profile View
right side view of the object is created by projecting onto the profile plane of projection.



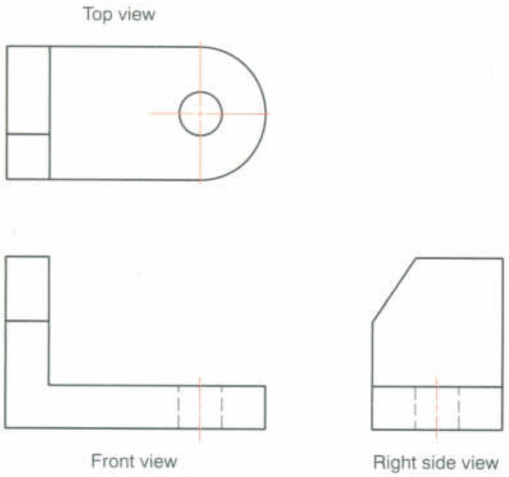


Figure 8.11 Multiview Drawing of an Object
For this object three views are created: front, top, and right side. The views are aligned so that common dimensions are shared between views.

Figure 8.12 Perspective Image
The photograph shows the road in perspective, which is how cameras capture images. Notice how the telephone poles appear shorter and closer together off in the distance. (Photo courtesy of Anna Anderson.)

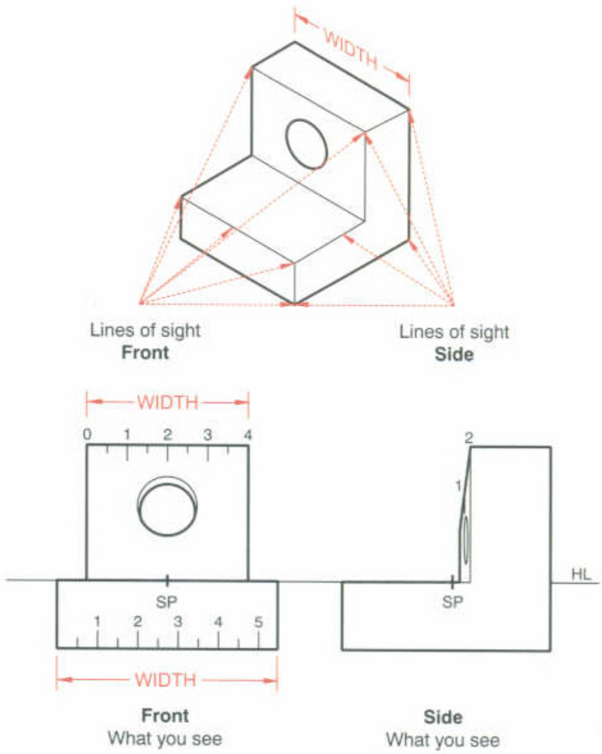


Figure 8.13 Distorted Dimensions
Perspective drawings distort true dimensions.

is to use the parallel projection technique called orthographic projection to create views that show only two of the three dimensions (width, height, depth). If the object is correctly positioned relative to the projection planes, the dimensions of features will be represented in true size in one or more of the views. (Figure 8.15) Multiview drawings provide the most accurate description of three-dimensional objects and structures for engineering, manufacturing, and construction requirements.

In the computer world, 3-D models replace the multiview drawing. These models are interpreted directly from the database, without the use of dimensioned drawings. (Figure 8.16) See Chapter 7.

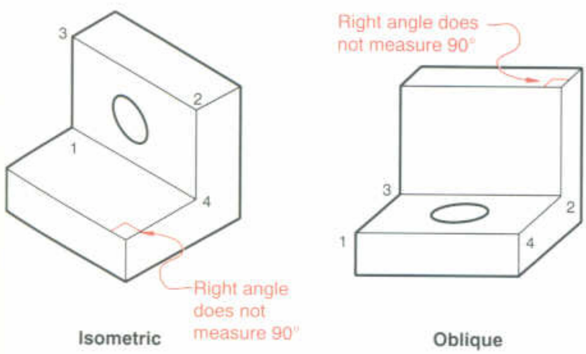


Figure 8.14 Distorted Angles
Angular dimensions are distorted on pictorial drawings.

8.4 | THE SIX PRINCIPAL VIEWS

The plane of projection can be oriented to produce an infinite number of views of an object. However, some views are more important than others. These **principal views** are the six mutually perpendicular views that are produced by six mutually perpendicular planes of projection. If you imagine suspending an object in a glass box with major surfaces of the object positioned so that they are parallel to the sides of the box, the six sides of the

Figure 8.16 CAD Data Used Directly by Machine Tool
This computer-numeric-control (CNC) machine tool can interpret and process 3-D CAD data for use in manufacturing, to create dimensionally accurate parts. (Courtesy of Intergraph Corporation.)

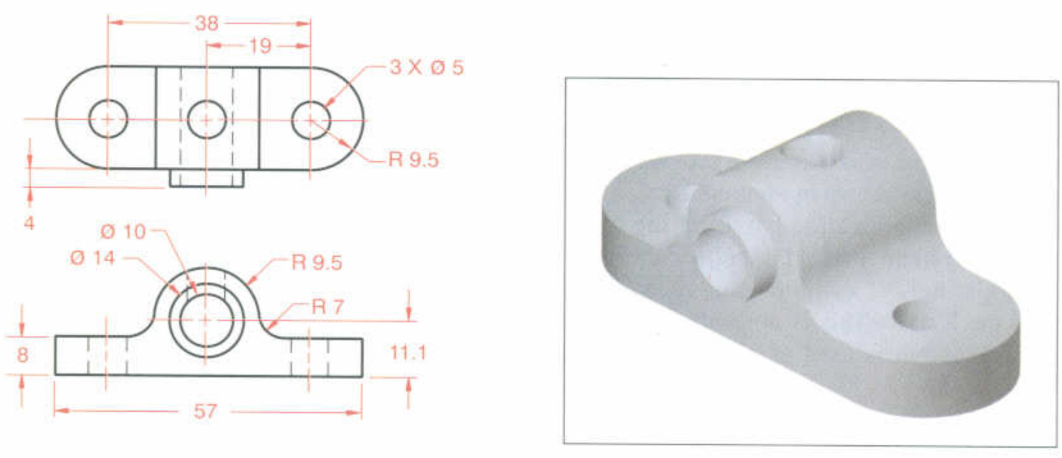


Figure 8.15 Multiview Drawing
Multiview drawings produce true-size features, which can be used for dimensionally accurate representations.

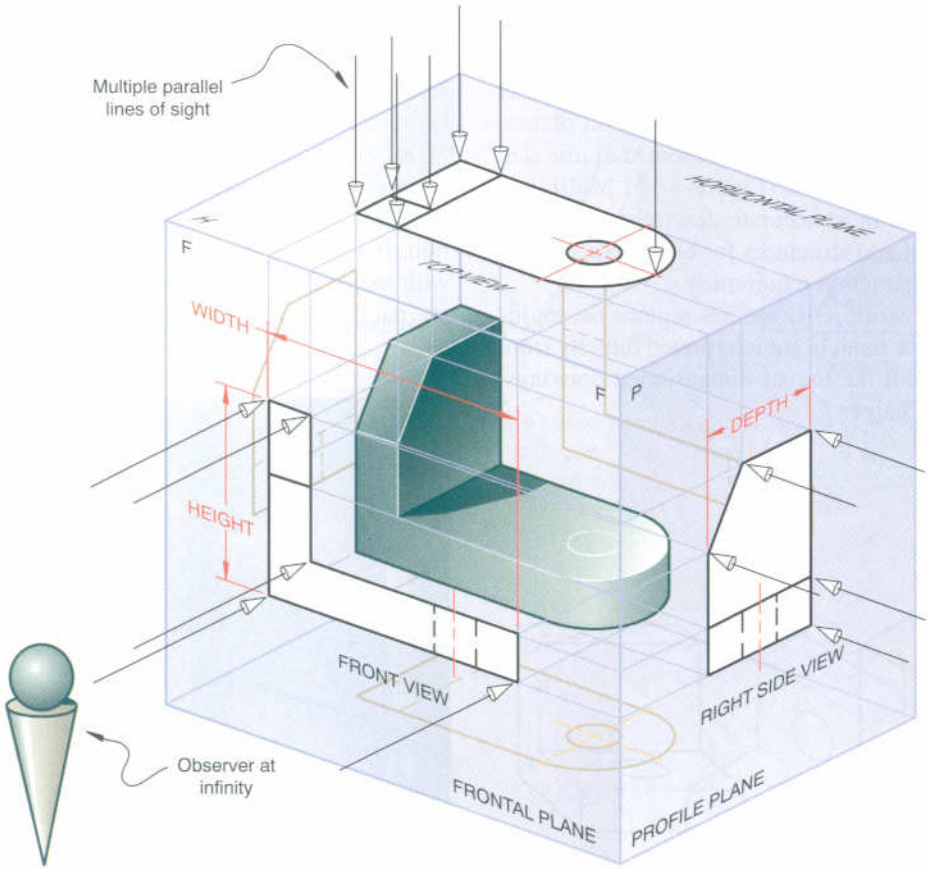


Figure 8.17 **Object Suspended in a Glass Box, Producing the Six Principal Views**
Each view is perpendicular to and aligned with the adjacent views.

box become projection planes showing the six views. (Figure 8.17) The six principal views are front, top, left side, right side, bottom, and rear. To draw these views on 2-D media, that is, a piece of paper or a computer monitor, imagine putting hinges on all sides of the front glass plane and on one edge of the left profile plane. Then cut along all the other corners, and flatten out the box to create a six-view drawing, as shown in Figure 8.18.

The following descriptions are based on the X, Y, and Z coordinate system. In CAD, *width* can be assigned the X axis, *height* assigned the Y axis, and *depth* assigned the Z axis. This is not universally true for all CAD systems but is used as a standard in this text. ◎ CAD Reference 8.1

The **front view** is the one that shows the most features or characteristics. All other views are based on the orientation chosen for the front view. Also, all other views, except the rear view, are formed by rotating the lines of sight 90 degrees in an appropriate direction from the front view. With CAD, the front view is the one created by looking down the Z axis (in the negative Z viewing direction), perpendicular to the X and Y axes.

The **top view** shows what becomes the top of the object once the position of the front view is established. With CAD, the top view is created by looking down the Y axis (in the negative Y viewing direction), perpendicular to the Z and X axes.

The **right side view** shows what becomes the right side of the object once the position of the front view is established. With CAD, the right side view is created by looking down the X axis from the right (in the negative X viewing direction), perpendicular to the Z and Y axes.

The **left side view** shows what becomes the left side of the object once the position of the front view is established. The left side view is a mirror image of the right

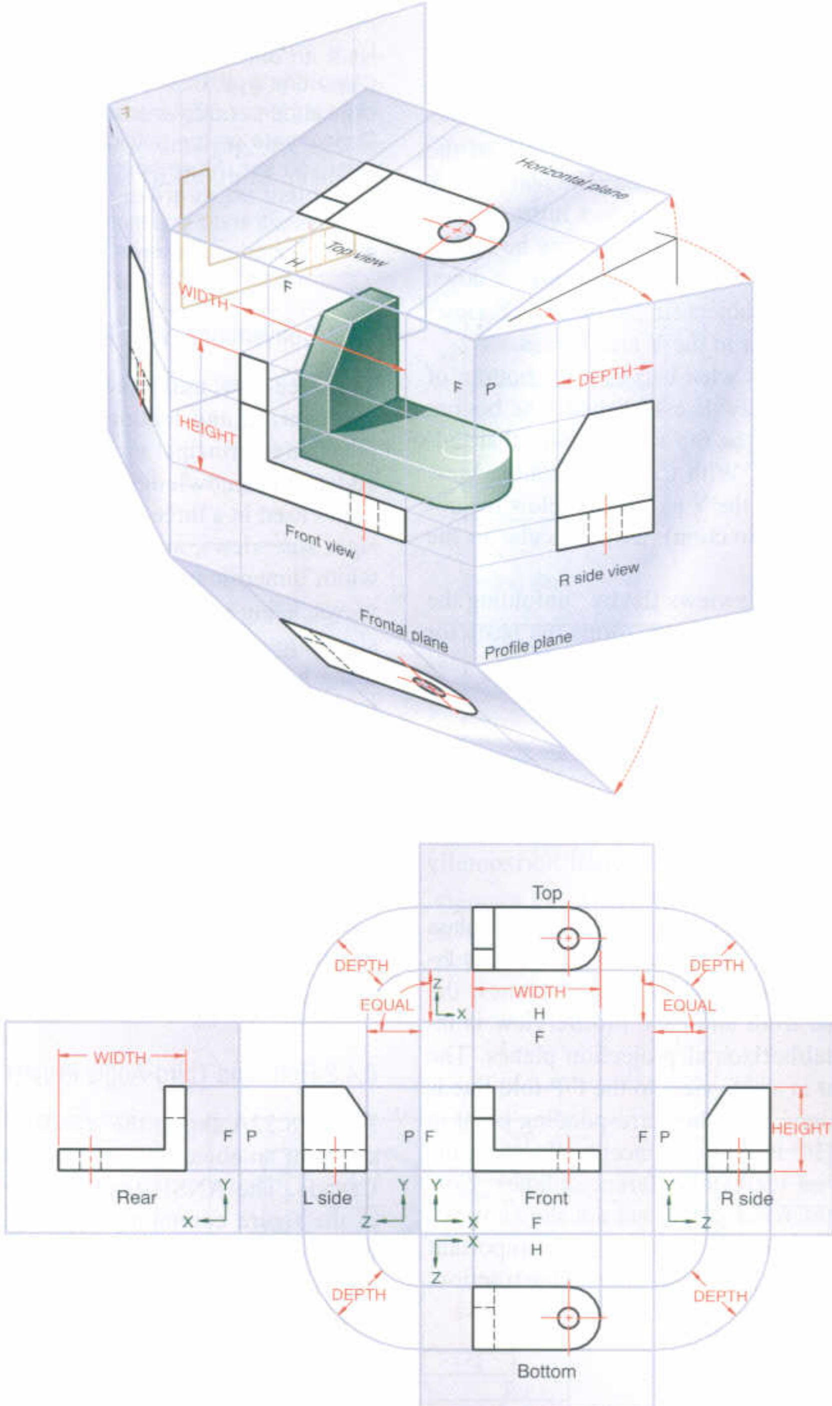


Figure 8.18 Unfolding the Glass Box to Produce a Six-View Drawing

side view, except that hidden lines may be different. With CAD, the left side view is created by looking down the X axis from the left (in the positive X viewing direction), perpendicular to the Z and X axes.

The **rear view** shows what becomes the rear of the object once the front view is established. The rear view is at 90 degrees to the left side view and is a mirror image of the front view, except that hidden lines may be different. With CAD, the rear view is created by looking down the Z axis from behind the object (in the positive Z viewing direction), perpendicular to the Y and X axes.

The **bottom view** shows what becomes the bottom of the object once the front view is established. The bottom view is a mirror image of the top view, except that hidden lines may be different. With CAD, the bottom view is created by looking down the Y axis from below the object (positive Y viewing direction), perpendicular to the Z and X axes.

The concept of laying the views flat by "unfolding the glass box," as shown in Figure 8.18, forms the basis for two important multiview drawing standards:

1. Alignment of views.
2. Fold lines.

The top, front, and bottom views are all aligned vertically and share the same width dimension. The rear, left side, front, and right side views are all aligned horizontally and share the same height dimension.

Fold lines are the imaginary hinged edges of the glass box. The fold line between the top and front views is labeled *H/F,* for horizontal/frontal projection planes; the fold line between the front and each profile view is labeled *F/P,* for frontal/horizontal projection planes. The distance from a point in a side view to the F/P fold line is the same as the distance from the corresponding point in the top view to the H/F fold line. Conceptually, then, the fold lines are edge-on views of reference planes. Normally, fold lines or reference planes are not shown in engineering drawings. However, they are very important for auxiliary views and spatial geometry construction, covered in Chapters 11 and 12. **CAD Reference 8.2**

Practice Exercise 8.1

Hold an object at arm's length or lay it on a flat surface. Close one eye, then view the object such that your line of sight is perpendicular to a major feature, such as a flat side. Concentrate on the outside edges of the object and sketch what you see. Move your line of sight 90 degrees, or rotate the object 90 degrees, and sketch what you see. This process will show you the basic procedure necessary to create the six principal views.

8.4.1 Conventional View Placement

The three-view multiview drawing is the standard used in engineering and technology, because many times the other three principal views are mirror images and do not add to the knowledge about the object. The standard views used in a three-view drawing are the *top, front,* and *right side* views, arranged as shown in Figure 8.19. The width dimensions are aligned between the front and top views, using vertical projection lines. The height dimensions are aligned between the front and profile views, using horizontal projection lines. Because of the relative positioning of the three views, the depth dimension cannot be aligned using projection lines. Instead, the depth dimension is measured in either the top or right side view and transferred to the other view, using either a scale, miter line, compass, or dividers. (Figure 8.20)

The arrangement of the views may only vary as shown in Figure 8.21. The right side view can be placed adjacent to the top view because both views share the depth dimension. Note that the side view is rotated so that the depth dimension in the two views is aligned.

8.4.2 First- and Third-Angle Projection

Figure 8.22A shows the standard arrangement of all six views of an object, as practiced in the United States and Canada. The ANSI standard third-angle symbol shown in the figure commonly appears on technical drawings to denote that the drawing was done following **third-angle projection** conventions. Europe uses the **first-angle projection** and a different symbol, as shown in