OBJECTIVES

After studying this chapter, you should be able to:

◆ Understand the principles of orthographic projection.
◆ Use orthographic projection to develop multiview drawings.
◆ Identify and explain projection planes and how they relate to multiview drawings.
◆ Determine the views necessary to completely describe an object in a multiview drawing.
◆ Identify various types of features existing within objects.
◆ Identify and explain positive and negative mass as it relates to an object.
◆ Explain the difference between primary and secondary views of objects and features.
◆ Center a multiview drawing on the drawing sheet.

DRAFTING VOCABULARY

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Exploring Drafting

When a drawing is made with the aid of instruments, it is called a mechanical drawing. Straight lines are made with a T-square, triangle, or drafting machine straightedge. Circles, arcs, and irregular curves are drawn with a compass, French curve, or the appropriate template for the object needed.

As discussed in Chapter 7, drawings are also generated with computer-aided drafting (CAD) software. While many drafting firms now use CAD for developing drawing projects, knowledge of manual drafting techniques and procedures is still extremely valuable in solving design problems.

Regardless of the technique, whether traditional (manual) or CAD drafting, the principles of drafting remain the same. The drafter must be familiar with the standards and procedures necessary to develop drawings that accurately describe objects.

Many drawings used by industry are created as multiview drawings. A multiview drawing is a drawing that requires more than one two-dimensional view in order to provide an accurate shape and size description of the object being produced. In developing the needed views, the object is normally viewed from six basic directions, as shown in Figure 9-1. These are the six principal views. They include the front, top, right side, left side, rear, and bottom views. See Figure 9-2.

Visualizing the Object and Projecting Views

Before a drafter can generate the necessary views for a multiview drawing, he or she must be able to visualize the object being drawn. In other words, the drafter must be able to see the object in three dimensions in his or her mind’s eye. This is an essential skill in drafting. There are many methods and techniques that aid in the process of visualizing objects. The following approach should help the beginning drafter become successful at visualizing objects.

To obtain the two-dimensional views needed for a multiview drawing, the drafter should first think of the object as being enclosed in a hinged glass box. See Figure 9-3. The six surfaces of the glass box are the standard projection planes to which the individual views are projected. The process used in projecting the views to the projection planes is known as orthographic projection. This process allows three-dimensional objects (objects having width, height, and depth) to be shown on a flat surface having only two dimensions. The flat surface may be a piece of paper or the screen of a computer monitor. Orthographic projection is the key tool used in developing views for engineering working drawings (drawings used to manufacture or construct objects).

There are two ways to project views in orthographic projection, Figure 9-4. Third-angle projection is preferred in the United States. First-angle projection is typically used in most European countries.

The difference between the two types of projection relates to the placement of the imaginary box in one of the quadrants formed by the intersection of the three principal planes. Referring to Figure 9-4, these planes are the frontal plane, horizontal plane, and profile plane. The frontal plane represents the projection for the front view of an object. The horizontal plane represents the projection for the top view of the object. The profile plane represents the projection for the side view of the object. In third-angle projection, the imaginary box containing the object rests in the third quadrant (the lower-right or third-angle quadrant when looking at the profile plane). In this type of projection, the sides of the object are projected to the sides of the box and toward the viewer. In first-angle projection, the imaginary box containing the object rests in the first quadrant (the upper-left or first-angle quadrant when looking at the profile plane). In this type of projection, the sides of the object are projected to the sides of the box and away from the viewer.

A graphic explanation of third-angle projection is shown in Figure 9-5. In this method, the object is viewed from points of view that are perpendicular to the projection planes (the surfaces of the glass box). The drafter looks through the given projection plane and the surfaces, edges, and intersections that make up the object are then projected forward to the projection plane. That is, the views are projected to the six sides of the glass box.
Figure 9-4  Third-angle and first-angle projection. A—The principal planes used in orthographic projection divide the drawing space into four quadrants. B—An imaginary box containing the object is placed in the third quadrant for third-angle projection. C—An imaginary box containing the object is placed in the first quadrant for first-angle projection.
Mechanical Engineer (continued)

Then, the “sides” of the glass box are unfolded toward the drafter. The front is always the featured view with the other views oriented in the order obtained by unfolding the sides of the box. In other words, the right side view is always to the right of the front view, the top view is always above the front view, the bottom view is always below the front view, and so on.

A graphic explanation of first-angle projection is shown in Figure 9-6. In this method, the views are projected to the six sides of the box and the sides of the glass box are then unfolded away from the viewer. When viewing the object from the front, the surfaces, edges, and intersections of the object seen from that point of view are projected to a plane behind the object. In addition, the object is drawn as if the object were placed on each side of the glass box. When viewing the object from the top, what is seen is projected to a plane below the object. When viewing the object from the bottom, what is seen is projected to a plane above the object.

A very easy way to identify a drawing that has been generated using first-angle projection is to recognize that the views are in the opposite orientation of how they would appear in third-angle projection. That is, the views of the resulting multiview drawing are oriented so that the top view appears where the bottom view should be, the bottom view appears where the top view should be, and so on. Compare the orientation of the views in Figure 9-5 to the orientation of the views in Figure 9-6. Notice that regardless of the method of projection, all views are centered about and originate from the front view.

Different symbols are used in industry to identify third-angle and first-angle projection drawings. See Figure 9-7. The appropriate symbol typically appears next to the title block on the drawing sheet.

Identifying Object Features

An object feature may be defined as a physical characteristic of an object. It may be a hole that has been drilled, a notch that has been cut, or an angular cut. It is important for the drafter to be able to identify the features that exist in an object. This is because the size and location of each feature must be known for the object to be manufactured to the designer’s specifications.

Features are physically represented as the negative mass of an object. Let us say that all objects begin as a solid mass of material. The solid block has what can be termed positive mass. Certain manufacturing operations must be performed on the solid mass to create the object’s end product. These operations may include cutting, drilling, boring, and milling, among others. The important thing to remember about these operations is that they all remove material (positive mass) from...
In first-angle projection, the sides of the object are projected to the sides of the imaginary box. The sides of the box are then unfolded away from the viewer. The views are projected to the rear.

The appropriate symbol is placed on engineering drawings to show the method of projection used.

Third-angle projection
First-angle projection

Figure 9-7

For objects with more complex features, identifying the positive and negative mass becomes more difficult. Objects made from thin material, such as sheet metal, require bending. This process does not remove material. However, the process of bending does create a feature in an object. There are other operations used to create features that do not require removing material. Regardless of what operations are required to create an object, a thorough understanding of positive and negative mass helps in identifying object features.

Figure 9-8

The entire solid object in this multiview drawing represents positive mass. The hole, which is the only feature of the object, represents the negative mass of the object.

**Primary and Secondary Views**

When creating multiview drawings, every feature should be represented in every view. If the feature is visible in the given view, it is drawn with object lines. If the feature is invisible in the given view, it is drawn with hidden lines. Sometimes, in special situations, a feature may be partially visible and partially invisible from a particular point of view.
view. In such cases, the feature is drawn partly with object lines and partly with hidden lines. Nevertheless, all features are represented in every view.

The view in which the feature appears in its true shape and size is the primary view of the feature. All other views then become secondary views of the feature, Figure 9-9. The primary view of a feature usually represents the feature with object lines, except in more complex situations. The secondary views usually represent the feature with hidden lines. In dimensioning multiview drawings, you will learn that, with few exceptions, the primary view is the view in which the drafter will both locate and give the size of any given feature. Dimensioning is discussed in Chapter 10.

The primary projection plane is the face of the glass box to which the primary view of a given feature is projected. The other faces then become the secondary projection planes for that feature, Figure 9-10.

**True Faces and Foreshortening**

When an object surface is drawn in its true shape and size within a view, it is said to be a true face. An object surface or feature is drawn true size when it is parallel to the projection plane. Multiview drawings of planar objects are normally made up of views representing true faces.

Orthographic drawings use different views to show the width, height, and depth of objects. These are the three most basic dimensions of any object. Width is defined as the horizontal distance measured across an object from side to side. Height is the vertical distance measured from the bottom to the top of an object. Depth is the horizontal distance measured from the front to the back of an object.

When a surface is drawn as a true face in a given view, the surface is seen as true height and true width (in the front or back view), true height and true depth (in the right or left view), or true width and true depth (in the top or bottom view). See Figure 9-11. True faces do not have to be measured actual size. They may be drawn to scale. In other words, they may be drawn to a larger scale for easier viewing, or to a smaller scale to fit on the drawing media.

An object surface that is not parallel to the projection plane is not drawn as a true face in the resulting view. This type of surface is drawn smaller than true size and shape. This is known as foreshortening and is common for objects with inclined surfaces. See Figure 9-12. Objects with inclined surfaces have at least one view where a face is at an angle to the projection plane. For this reason, the surface does not appear in its true shape when drawn on a two-dimensional surface. For example, hole features on angled surfaces are not drawn in their true shape as circles when projected. They are drawn as ellipses because they are not perpendicular to the line of sight. The resulting features are said to be foreshortened.

**Edges, Intersections, and Limiting Edges**

When creating multiview drawings, the visualization of objects can be simplified by identifying what the lines in the different views should represent. In orthographic projection, all lines on multiview drawings represent one of three features of the object. Each line represents the edge view of a surface, an intersection between two surfaces, or the limiting edge of a round or elliptical feature. See Figure 9-13. Notice that most of the object features are described in the primary view. The secondary views use straight lines to show intersections.
and edges. Thinking in these terms can help in the visualization process as well as the problem-solving process.

**Selecting Views to Be Drawn**

As previously discussed, there are six standard views of any object in orthographic projection. This does not mean that all six of the views must be used, or that they are needed to completely describe an object. Only the number of views needed to give a complete shape description of the object should be drawn. Any view that repeats the same shape description in another view (an identical view) can be eliminated, Figure 9-14.

In most instances, two or three views are sufficient to show the shape of an object. Objects that are basically cylindrical in shape can usually be drawn with just two views. Basic and complex prism-shaped objects generally require at least three views. In general, the front view should be the view that shows the most features (visible features) and the fewest hidden features of the object. The number of views needed is then decided in relation to the contents of the front view.

In general, the drafter should draw the views that show the fewest features as hidden lines. These are the views that should be used to create the multiview drawing. Views of objects showing a large number of hidden lines are normally used only when absolutely necessary for the complete understanding of the shape and size of the object. The use of too many hidden lines on a drawing tends to make the drawing confusing to the person reading the drawing or fabricating the part. Use another view without as many hidden lines, Figure 9-15. Sometimes it may be necessary to draw the left side or bottom of an object if the features are visible from one of those points of view instead of the standard right side or top. Regardless of the views shown, they should still be placed in proper orthographic order.

As shown in Figure 9-14B, the top view is placed above the front view, and the right view is placed to the right.

When drawing hidden lines in multiview drawings, it is also important to draw them correctly in relation to other types of lines. Hidden lines should always start and end with a dash in contact with the object line, Figure 9-16. This illustration shows examples of how hidden lines are used and how they properly intersect or do not intersect other lines, depending on the situation.

It is important to remember with any drawing that the viewer wants to see as many visible features as possible, not invisible (hidden) features. The goal is to communicate the size and shape of the object as clearly and precisely as possible to the person making the part. Keep this in mind when laying out views for multiview drawings.

![Figure 9-12](Image)

Objects with inclined surfaces have at least one view where the surface is not parallel to the projection plane. The inclined surface of this object does not appear in its true shape and size when projected to the top and side views. It instead appears foreshortened. The front view shows the inclined surface in its true length but does not show the surface’s true shape. To see the true shape and size of an inclined surface, you must draw an auxiliary view. Auxiliary views are discussed in Chapter 12.

![Figure 9-13](Image)

Lines in a multiview drawing represent edges of surfaces, intersections between surfaces, or limiting edges of round objects.

[Figure 9-14A](Image) Not all views are needed in a multiview drawing. Eliminate any view that repeats the same shape description shown in another view. A—The six views of the object. B—Three views are sufficient for a complete description.
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Projecting Points and Edges

It is essential that the beginning drafter learn to properly use orthographic projection to project points and create views in multiview drawings. Each view will show a minimum of two dimensions. The front view will show the overall width and overall height, the side view will show the height and depth, and so on. Also, any two views of an object will have at least one dimension in common. For example, the front and side views will both have the overall height of the object in common.

The process of using orthographic projection in creating the views of a multiview drawing is known as blocking in the drawing. This process can save much time and eliminate many measurement errors. A good rule to follow when blocking in a drawing is to measure each distance one time, double-check the measurement for accuracy, and project the distance to the adjacent view. Do not “double-measure” distances. In other words, if a particular feature has a height of 1", do not measure that inch distance in the front view and then remeasure the same distance in the side view. Measure once and project. This rule should be followed for each measurement. If an object has seven different measurements associated with it, the seven distances are each measured one time and then projected between the views.

When projecting points, width measurements are projected between the front and top views. Height measurements are projected between the front and side views. See Figure 9-17. Depth distances are projected between the top and side views with a 45° projection angle or a compass, Figure 9-18. Of the two, the projection angle method is probably more accurate than the compass method for most beginning drafters. However, if careful and precise compass placement and adjustment is followed and the compass is kept properly sharpened, both methods work very effectively.

All projection lines are drawn as construction lines. If these lines are drawn correctly, they are very easily erased with a quality eraser and erasing shield. Projection lines are generally erased after all lines are darkened to the proper line weights. Occasionally a drafting instructor may require the student to leave projection lines on a drawing to check for proper usage.

Centering a Multiview Drawing

In previous chapters of this text, you have learned that the keys to high-quality, efficient work are accuracy, neatness, and speed. A drawing looks neater and more professional if the views are evenly spaced and centered on the drawing sheet. Centering the views on a sheet is not difficult if one of two basic methods is used. These methods are discussed in the following sections.

Centering the Drawing with Construction Lines

1. Examine the object to be drawn. Observe its width, depth, and height dimensions, Figure 9-19. Determine the orientation in which the object will be drawn.

2. Measure the working area of the sheet after drawing the border and title block. It
should measure 7” × 10” if you are using 1/2” borders on a 8-1/2” × 11” drawing sheet and the title block measures 1/2.” Refer to Chapter 5 on how to prepare a drawing sheet.

3. Allow 1” spacing between views.

4. To locate the front view, add the width of the front view, 1” spacing between views, and the depth of the right view. Subtract this total from the horizontal width of the working surface (10”). Divide this total by 2. This will be the starting point for laying out the sheet horizontally.

Using the object shown in Figure 9-20, for example, the calculations are as follows:

- Width of front view = 5”
- Spacing between views = 1”
- Depth of right view = 1-1/2”
- Total = 7-1/2”
- Width of working area = 10”
- Total width of views = 2-1/2”

Divide 2-1/2” by 2 = 1-1/4”

- This is the distance measured from the left border to locate the starting point for drawing.

5. Measure in 1-1/4” from the left border line. Draw a vertical construction line through this point.

6. From this line, measure over a distance equal to the width of the front view. Draw another vertical construction line. See Figure 9-21.

7. The same procedure is followed to center the views vertically. The height of the front view and the depth of the top view are used. A 1” space will separate the views. Add these distances together. Subtract the sum from the vertical working space (7”).

- Height of front view = 2-1/2”
- Space between views = 1”
- Depth of top view = 1-1/2”
- Total = 5”
- Height of working area = 7”
- Total height of views = -5”

Divide 2” by 2 = 1”

- This is the distance measured up from the lower border line to locate the starting point for drawing.

8. Measure up 1” from the lower border line. Draw a horizontal construction line through this point.

9. From this line, measure up the height of the front view and mark a point. Mark a point for the 1” spacing that separates the views. Mark one more point for the depth of the top view. Draw construction lines through these points. See Figure 9-22.

10. Use either the 45° angle method or the radius method to transfer the depth of the top view to the right side of the object, Figure 9-23.

11. Draw in the right view. Use construction lines.

12. Complete the drawing by going over the construction lines, Figure 9-24. Use the correct weight for the type of line drawn. Use the erasing shield when erasing the remaining construction lines.

This centering method and the next method discussed are intended for multi-view drawings with three views. The calculations should be adjusted accordingly for drawings with one view, two views, or more than three views. Always leave at least 1” of space between any two given views for dimensioning purposes. The spacing may vary depending on the space available on the drawing sheet. However, regardless of the spacing used, it should be the same between all views.

**Centering the Drawing with a Centering Rectangle**

1. First, determine the maximum overall size of the object being drawn. See Figure 9-25. You must know the maximum overall...
Exploring Drafting

width, height, and depth of the object. Determine the orientation in which the object will be drawn.

2. Using the format of your choice, draw the border and title block on the sheet. This example uses an 8-1/2” × 11” drawing sheet.

3. Draw construction lines from corner to corner across the drawing area. See Figure 9-26. This locates the center of a rectangle representing the drawing area.

4. Lay out two construction lines, one horizontal and one vertical, intersecting the center point of the drawing area.

5. Add the width of the object (5”) to the depth (1-1/2”) plus 1” for the distance between views to determine the horizontal space needed for the layout. Then add the height (2-1/2”) to the depth (1-1/2”) plus 1” to determine the vertical space of the layout. These dimensions are used to establish the width and height of a centering rectangle within the drawing area. For this example, the rectangle measures 7-1/2” × 5”. The three views of the object will fit inside this rectangle. After completing the drawing, the views will be centered horizontally and vertically on the drawing sheet.

6. To draw the centering rectangle, divide the width (7-1/2”) by 2. Mark points for this measurement (3-3/4”) from the center point on each side along the horizontal construction line. Draw two vertical construction lines through the two measured points to create the sides of the centering rectangle.

7. In similar fashion, divide the height of the centering rectangle (5”) by 2. Mark points for this measurement (2-1/2”) from the center point on each side along the vertical construction line. Draw two horizontal construction lines through the two measured points to create the top and bottom of the centering rectangle.

8. Erase the diagonal construction lines used for locating the center of the drawing area. Also, erase the horizontal and vertical construction lines intersecting the center. These lines are no longer needed and could be misidentified as part of the object drawing. After erasing these lines, the centering rectangle can be used to block in the views.

9. To complete the drawing, measure horizontally from the lower-left corner of the centering rectangle. Lay out the overall width, the 1” spacing between views, and the depth of the object. See Figure 9-27. Draw two vertical construction lines through the two measured points and extending the full height of the centering rectangle. These are Lines A and B in Figure 9-27E.

Figure 9-26 The object used as an example for centering views.

Figure 9-26 Laying out the centering rectangle for the drawing.

Figure 9-27 Completing the multiview drawing. After blocking in the views, the object lines are darkened.
10. From the lower-left corner, measure vertically along the left edge of the centering rectangle and lay out the overall height of the object. Draw a horizontal construction line through the measured point extending the entire width of the centering rectangle. This is Line C in Figure 9-27E.

11. Where Line A and Line C intersect, draw a 45° projection angle extending to the upper-right corner of the centering rectangle. If the angle does not intersect these points, check for incorrect measurements and adjust the layout as needed.

12. Draw a construction line through the intersection of the projection angle and Line B. This line should also extend the entire distance across the centering rectangle.

13. Measure and lay out the features of the object. When projecting points, measure each distance only once and project the distance to the adjacent view. Do not double-measure features.

14. Complete the drawing by darkening lines. Use the correct weight for the type of line drawn. Recommended methods for darkening lines are discussed in Chapter 5.

Multiview drawings showing 2D views are developed in CAD programs using drawing commands and layout methods similar to those involved in manual drafting. CAD commands are introduced in Chapter 7. When using a CAD program to generate views, points are projected using construction lines, coordinate entry, and drawing aids such as orthogonal mode and snap. Object features in each view are drawn with basic drawing commands. Hidden features are drawn in the same manner using the hidden linetype.

Some CAD programs provide the ability to create multiview drawings from 3D models. For example, it is common to orient several 2D orthographic views of a 3D drawing along with a pictorial view, such as an isometric view. CAD-based pictorial drawing and modeling functions are discussed in more detail in Chapter 13.

Test Your Knowledge

Please do not write in this book. Place your answers on another sheet of paper.

1. Name the six viewing directions that define the principal views in a multiview drawing.

2. In orthographic projection, the _____ plane represents the projection for the top view of the object.

3. In the _____ method of orthographic projection, an imaginary glass box containing the object rests in the lower-right quadrant when looking at the profile view.

4. The view in which an object feature appears in its true shape and size is the _____ view of the feature.

5. Define true face.

6. Objects that are drawn smaller than true size and shape in a view because they are not parallel to the projection plane are said to be _____.

7. When selecting object views to be drawn, why is it recommended to use the views showing the fewest features as hidden lines?

8. A drawing that has views in the proper orthographic order shows the top view above the _____ view.

9. The process of using orthographic projection in creating the views of a multiview drawing is called _____ the drawing.

10. Identify two methods used to project depth distances between the top and side views in a multiview drawing.

Outside Activities

1. Collect objects for the class to create multiview drawings using manual instruments. One object should require only two views; another object should require a three-view drawing. Find other objects that require more than three views to give a complete shape description.

2. Build a hinged box out of clear plastic that can be used to demonstrate the “unfolding” of the sides to show the front, top, bottom, and side views of an object. Place an object inside the box, trace the profiles of the object on the sides of the plastic with chalk or a marker, and then unfold the box to show the multiview projections.

3. Make a large poster for your drafting room showing the step-by-step procedure for centering a drawing on a sheet using one of the two methods explained in this chapter.

STEM Activities

1. Obtain a common workshop tool, such as a wrench or C-clamp. Using digital calipers, practice making internal and external measurements of the tool. Make measurements in both inch and metric units. Once you are comfortable making measurements with the calipers, record the various measurements and make a multiview drawing of the tool. Use an appropriate drawing scale. Select the most appropriate view for the front view and project other views as needed.

2. Select several objects in your drafting room. Select one that would require two views to fully describe it, another that would require three views, and yet another that would require more than three views. Measure each object with the appropriate measuring tools necessary to make measurements accurately. Select an appropriate drawing scale for each object and create a multiview drawing of the object.

Drawing Problems

Draw the problems shown on the problem sheets on the following pages. Use the dimensions provided. Dimensions are in inches unless otherwise indicated. Follow the directions on each problem sheet.
Problem Sheet 9-1: Draw each problem on a separate sheet and complete as indicated.

Problem Sheet 9-2: Draw each problem on a separate sheet and complete as indicated.
Draw each problem on a separate sheet and complete as indicated.

Problem Sheet 9-3

Draw each problem on a separate sheet. Draw as many views as necessary to fully describe each problem.

Problem Sheet 9-4
Problem Sheet 9-5
Draw each problem on a separate sheet. Draw as many views as necessary to fully describe each problem.
Problem 9-55: Draw as many views as necessary to fully describe the object.

Problem 9-56: Draw as many views as necessary to fully describe the object.

Problem 9-57: Draw as many views as necessary to fully describe the object.

Problem 9-58: Draw as many views as necessary to fully describe the object.
Design Problems

Design and prepare drawings for the following.
A. Contemporary bookcase
B. Bookends (any material)
C. Stool
D. Model drag racer
E. Model boat (speed, sail, etc.)
F. Workbench
G. Table lamp
H. Lawn or patio furniture

Problem 9-59
Draw as many views as necessary to fully describe the object.

Problem 9-60
Complete each design problem. Draw as many views as necessary to fully describe the object.