

# 2

# CHAPTER

## Sketching, Lettering, and Lines

### LEARNING OBJECTIVES

After completing this chapter, you will:

- Sketch lines, circles, arcs, and multiviews.
- Do freehand lettering, and use mechanical lettering equipment.
- Use a CADD system to prepare text.
- Draw ASME standard lines using manual drafting and computer-aided drafting.
- Solve an engineering problem using manual and computer-aided drafting.

### THE ENGINEERING DESIGN APPLICATION

The engineering drafter often works from sketches or written information provided by the engineer. When you receive an engineer's sketch and are asked to prepare a formal drawing, you should follow these steps:

**Step 1.** Whether you are using manual or CADD drafting, prepare your own sketch the way you think it should look on the final drawing, taking into account correct drafting standards.

**Step 2.** Evaluate the size of the object so you can determine the scale and sheet size for your final manual drawing or the screen limits for your final computer-aided drawing.

**Step 3.** Lay out the drawing either very lightly using construction lines or light blue lead. The construction lines may be easily erased if you make a mistake. If you are using a computer, begin the layout on the screen and if you make an error, just erase it and try again. Editing your CADD work is fast and easy.

**Step 4.** Complete the final manual drawing by darkening all construction lines to proper ASME standard line weights and run a copy for checking. After completing the computer drawing, a check plot may be made on the plotter or printer. This gives you a chance to check your work on paper. Sometimes it is easier to check a drawing on paper than it is to check it on screen.

The example in Figure 2.1 shows a comparison between the engineer's rough sketch and the finished drawing.

A CADD drafter can easily work from points established on a Cartesian coordinate system as discussed in Chapter 4. When this is required, you need to first deter-

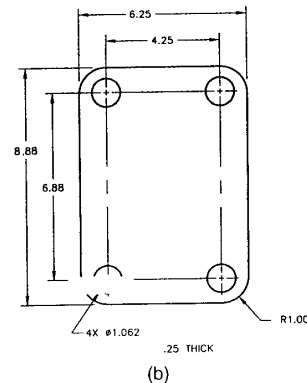
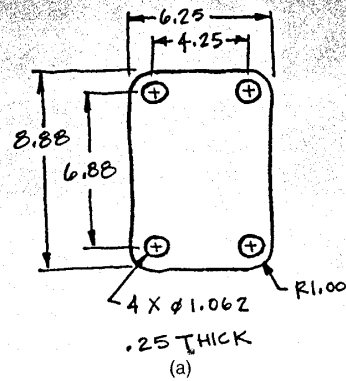


FIGURE 2.1 ■ A comparison between (a) an engineer's rough sketch and (b) the finished drawing.

**APPLICATION (continued)**

mine the type of coordinate system being used: absolute, incremental, or polar. When a situation of this kind occurs, you may be given the X and Y values for each point in a chart similar to Figure 2.2.

Drawing lines between all of the listed points in this demonstration produces the drawing shown in Figure 2.3.

POINT	X	Y
1	2.8	2.3
2	7.7	2.3
3	7.7	5.6
4	5.2	5.6
5	4.1	4.1
6	2.8	4.1
7	2.8	2.3

FIGURE 2.2 ■ Absolute values for X and Y point coordinates.

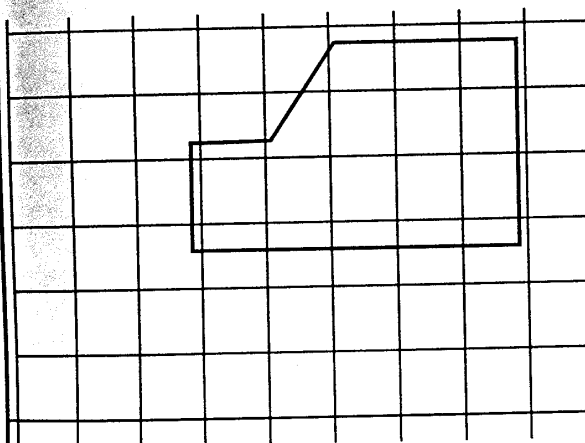


FIGURE 2.3 ■ The solution to a Cartesian coordinate system drawing problem.

**SKETCHING**

Sketching is freehand drawing, that is, drawing without the aid of drafting equipment. Sketching is convenient since all that is needed is paper, pencil, and an eraser. There are a number of advantages and uses for freehand sketching. Sketching is fast visual communication. The ability to make an accurate sketch quickly can often be an asset when communicating with people at work or at home. Especially when technical concepts are the topic of discussion, a sketch may be the best form of communication. Most drafters prepare a preliminary sketch to help organize thoughts and minimize errors on the final drawing. The computer operator usually prepares a sketch on graph paper to help establish the coordinates for drawing components. Some drafters use sketches to help record the stages of progress when designing, until a final design is ready for

implementation into formal drawings. A sketch can be a useful form of illustration in technical reports. Sketching is also used in job shops where one-of-a-kind products are made. In the job shop, the sketch is often used as a formal production drawing. When the drafter's assignment is to prepare working drawings for existing parts or products, the best method to gather shape and size description about the project is to make a sketch. The sketch can be used to quickly lay out dimensions of features for later transfer to a formal drawing.

The quality of a sketch depends on the intended purpose. Normally a sketch does not have to be very good quality as long as it adequately represents what you want to display. *Speed is a big key to sketching.* You normally want to prepare the sketch as fast as possible while making it as easy and clear to read as possible. Sometimes a sketch does need to have the quality of a formal presentation. The degree of quality can vary depending on the intent of the sketch. A sketch can be used as an artistic impression of a product, or as a one-time detail drawing for manufacturing purposes. However, the sketch is normally used in preliminary planning or to relate a design idea to someone very quickly. The quality of your classroom sketches depends on your course objectives. Your instructor may want quality sketches or very quick sketches that help you establish a plan for further formal drafting. You should confirm this in advance. In the professional world, your own judgment determines the nature and desired quality of the sketch.

**TOOLS AND MATERIALS**

Sketching equipment is not very elaborate. As mentioned, all you need is paper, pencil, and an eraser. The pencil should have a soft lead: a common number 2 pencil works fine or an automatic 0.7 or 0.9 mm pencil with F or HB lead is also good. The pencil lead should not be sharp. A dull, slightly rounded pencil point is best. Different thicknesses of line, if needed, can be drawn by changing the amount of pressure you apply to the pencil. The quality of the paper is not critical either. A good sketching paper is newsprint, although almost any kind works. Actually, paper with a surface that is not too smooth is best. Many engineering designs have been created on a napkin around a lunch table. Sketching paper should not be taped down to the table. The best sketches are made when you are able to move the paper to the most comfortable drawing position. Some people make horizontal lines better than vertical lines. If this is your situation, then move the paper so that vertical lines become horizontal. Such movement of the paper may not always be possible, so it does not hurt to keep practicing all forms of lines for best results. Graph paper is also good to use for sketching because it has grid lines that can be used as a guide for your sketch lines.

**SKETCHING STRAIGHT LINES**

Lines should be sketched in short, light, connected segments as shown in Figure 2.4. If you sketch one long stroke in one continuous movement, your arm tends to make the line curved rather than straight, as shown in Figure 2.5. Also, if you make a dark line, you may have to erase if you make an error, whereas if you draw a light line there often is no need to erase.

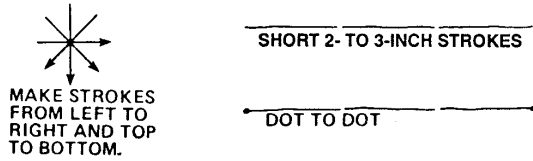


FIGURE 2.4 ■ Sketching short line segments.

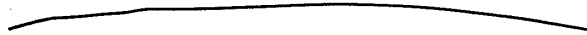


FIGURE 2.5 ■ Long movements tend to cause a line to curve.

Following is the procedure used to sketch a horizontal straight line with the dot-to-dot method:

- Step 1. Mark the starting and ending positions, as in Figure 2.6. The letters A and B are only for instruction. All you need are the points.
- Step 2. Without actually touching the paper with the pencil point, make a few trail motions between the marked points to adjust the eye and hand to the anticipated line.
- Step 3. Sketch very light lines between the points by stroking in short light strokes (2- to 3-in. long). Keep one eye directed toward the end point while keeping the other eye directed on the pencil point. With each stroke, an attempt should be made to correct the most obvious defects of the preceding stroke so the finished light lines are relatively straight. (See Figure 2.7.)
- Step 4. Darken the finished line with a dark, distinct, uniform line directly on top of the light line. Usually the darkness can be obtained by pressing on the pencil. (See Figure 2.8.)

Very long straight lines can often be sketched by using the edge of the paper or the edge of a table as a guide. To do this, position the paper in a comfortable position with your hand placed along the edge as shown in Figure 2.9a. Extend the pencil point out to the location of the line. Next, place one of your fingers or the palm of your hand along the edge of the paper as a guide. Now, move your hand and the pencil continuously along the edge of the paper as shown in Figure 2.9b. A problem with this method is that it works best if the line is fairly close to the edge of the paper. A sketch does not have to be perfect anyway, so a little practice should be good enough.



FIGURE 2.6 ■ Step 1, use dots to identify both ends of a line.



FIGURE 2.7 ■ Step 3, use short light strokes.

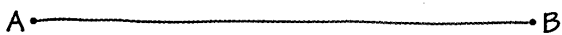
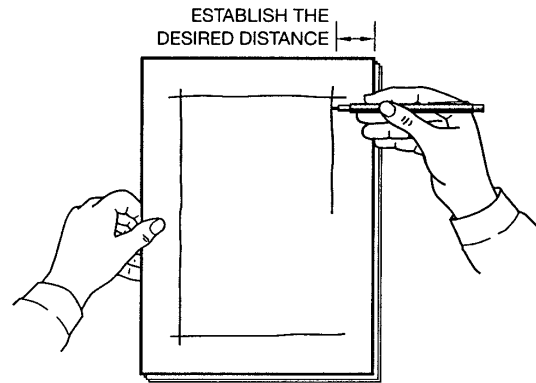
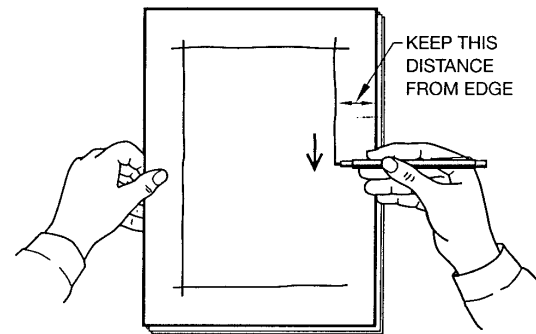


FIGURE 2.8 ■ Step 4, darken to finish the line.



(a)



KEEP YOUR FINGER RIGID—SLIDE ALONG EDGE

(b)

FIGURE 2.9 ■ Sketching very long straight lines using the edge of the sheet as a guide. (a) Place your hand along the edge as a guide. (b) Move your hand and the pencil along the edge of the paper using your finger or palm as a guide to keep the pencil a constant distance from the edge.

## SKETCHING CIRCULAR LINES

Figure 2.10 shows the parts of a circle. There are several sketching techniques to use when making a circle; this text explains the quick freehand method for small circles, the box method, the centerline method, the hand-compass method, and the trammel method for very large circles.

### Sketching Quick Small Circles

Small circles are easy to sketch if you treat them just like drawing the letter o. You should be able to do this in two strokes by sketching a half circle on each side as shown in Figure 2.11.

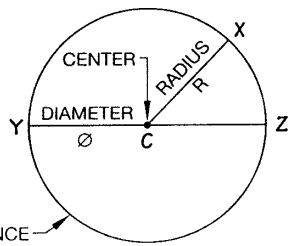


FIGURE 2.10 ■ The parts of a circle.

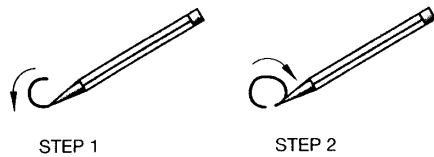


FIGURE 2.11 ■ Sketching a small circle just like drawing the letter o.

### Using the Box Method

It is always faster to sketch a circle without first creating other construction guides, but it can be difficult to do so. The box method can help you by providing a square that contains the desired circle. Start this method by very lightly sketching a square box that is equal in size to the diameter of the proposed circle as shown in Figure 2.12. The very light lines are called *construction lines*. Next, sketch diagonals across the square. This establishes the center and allows you to mark the radius of the circle on the diagonals as shown in Figure 2.13. Use the sides of the square and the marks on the diagonals as a guide to sketch the circle. Create the circle by drawing arcs that are tangent to the sides of the square and go through the marks on the diagonals as shown in Figure 2.14. If you have trouble sketching the circle as dark and thick as desired, sketch it very lightly first and then go back over it to make it dark. You can easily correct very lightly sketched lines, but it is difficult to correct very dark lines. Your construction lines do not have to be erased if they are sketched very lightly.

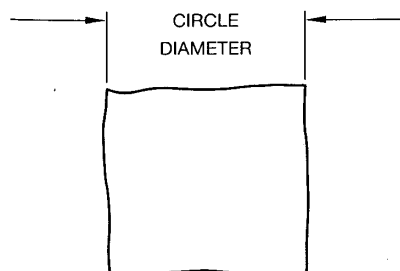


FIGURE 2.12 ■ Very lightly sketch a square box that is equal in size to the diameter of the proposed circle.

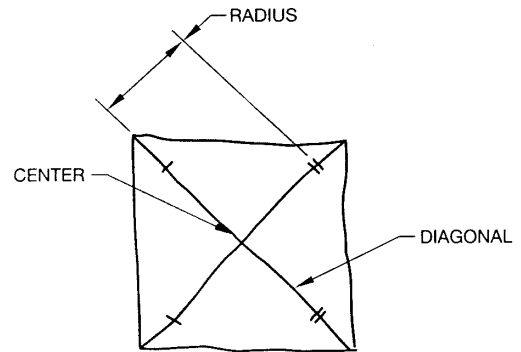


FIGURE 2.13 ■ Sketch light diagonal lines across the square, and mark the radius on the diagonals.

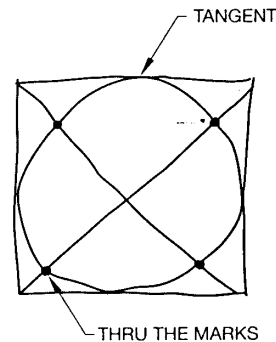


FIGURE 2.14 ■ Create the circle by sketching arcs that are tangent to the sides of the square and go through the marks on the diagonals.

### Using the Centerline Method

The centerline method is similar to the box method, but without a box. This method uses very lightly sketched horizontal, vertical, and two 45° diagonal centerlines as shown in Figure 2.15. Next, mark the approximate radius of the circle on the centerlines as shown in Figure 2.16. Create the circle by drawing arcs that go through the marks on the centerlines as shown in Figure 2.17.

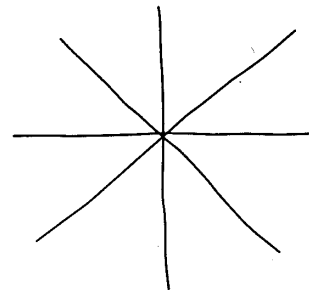


FIGURE 2.15 ■ Sketch very light horizontal, vertical, and 45° lines that meet at the center of the proposed circle.

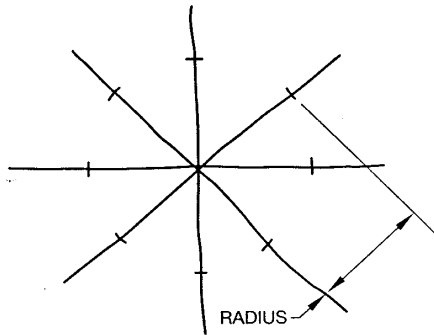


FIGURE 2.16 ■ Mark the approximate radius of the circle on the centerlines created in Figure 2.15.

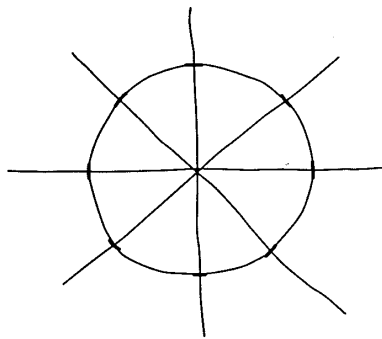


FIGURE 2.17 ■ Create the circle by sketching arcs that go through the marks on the centerlines.

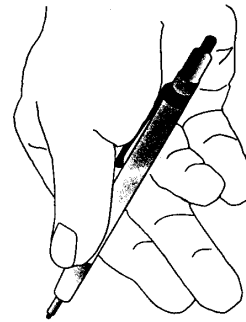


FIGURE 2.18 ■ Step 2, holding the pencil in the hand compass.

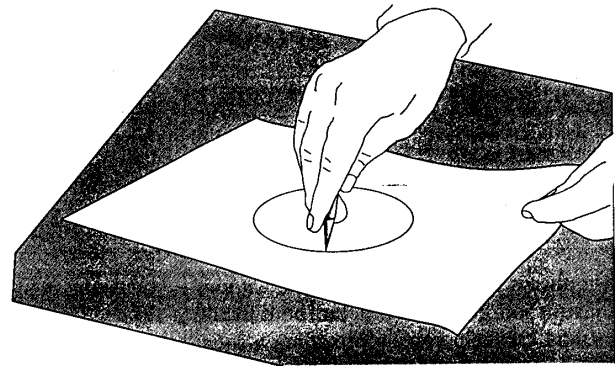


FIGURE 2.19 ■ Step 4, rotate the paper under your finger center point.

### Using the Hand-compass Method

The hand-compass method is a quick and fairly accurate method of sketching circles, although it is a method that takes some practice.

- Step 1. Be sure that your paper is free to rotate completely around 360°. Remove anything from the table that might stop such a rotation.
- Step 2. To use your hand and a pencil as a compass, place the pencil in your hand between your thumb and the upper part of your index finger so your index finger becomes the *compass point* and the pencil becomes the *compass lead*. The other end of the pencil rests in your palm as shown in Figure 2.18.
- Step 3. Determine the circle radius by adjusting the distance between your index finger and the pencil point. Now, with the desired approximate radius established, place your index finger on the paper at the proposed center of the circle.
- Step 4. With the desired radius established, keep your hand and pencil point in one place while rotating the paper with your other hand. Try to keep the radius steady as you rotate the paper. (See Figure 2.19.)
- Step 5. You can perform step 4 very lightly and then go back and darken the circle or, if you have had a lot of practice, you may be able to draw a dark circle as you go.

### Trammel Method

The trammel method should be avoided if you are creating a quick sketch, because it takes extra time and materials to set up this technique. Also, the trammel method is intended for large to very large circles that are difficult to draw when using the other methods. The following examples demonstrate the trammel method to create a small circle. This is done to save space. Use the same principles to draw a large circle.

- Step 1. Make a trammel to sketch a 6-in. diameter circle. Cut or tear a strip of paper approximately 1 in. wide and longer than the radius, 3 in. On the strip of paper, mark an approximate 3-in. radius with tick marks such as A and B in Figure 2.20.
- Step 2. Sketch a straight line representing the circle radius at the place where the circle is to be located. On the sketched line, locate with a dot the center of the circle to be sketched. Use the marks on the trammel to mark the other end of the radius line as shown in Figure 2.21. With the trammel next to the sketched line, be sure point B on the trammel is aligned with the center of the circle you are about to sketch.
- Step 3. Pivot the trammel at point B, making tick marks at point A as you go, as shown in Figure 2.22, until the circle is complete.

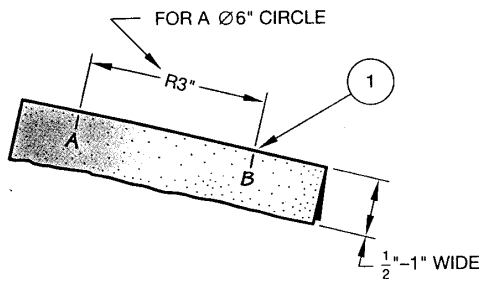


FIGURE 2.20 ■ Step 1, make a trammel.

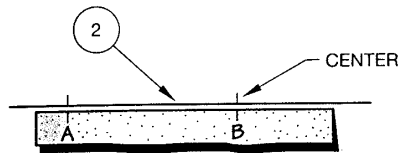


FIGURE 2.21 ■ Step 2, locate the center of the circle.

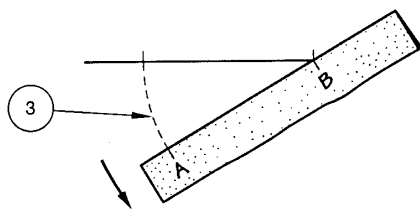


FIGURE 2.22 ■ Step 3, begin the circle construction.

Step 4. Lightly sketch the circumference over the tick marks to complete the circle, then darken it (step 5) as shown in Figure 2.23.

Another similar trammel method, generally used to sketch very large circles, is to tie a string between a pencil and a pin. The distance between the pencil and pin is the radius of the circle. Use this method when a large circle is to be sketched, since the other methods may not work as well. Workers at a construction site some-

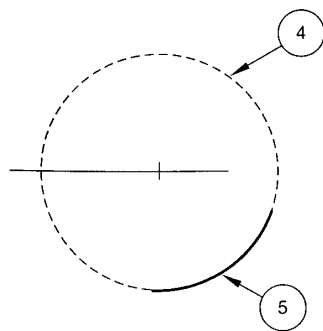


FIGURE 2.23 ■ Steps 4 and 5, darken the circle.

times use this method by tying the string to a nail and driving the nail at the center location.

## SKETCHING ARCS

Sketching arcs is similar to sketching circles. An arc is part of a circle as you can see in Figure 2.24. An arc is commonly used as a rounded corner or at the end of a slot. When an arc is a rounded corner, the ends of the arc are typically tangent to adjacent lines. In short, *tangent* means that the arc touches the line at only one point and does not cross over the line as shown in Figure 2.24. An arc is generally drawn with a radius. The most comfortable way to sketch an arc is to move the paper so your hand faces the inside of the arc. Having the paper free to move helps with this practice.

One way to sketch an arc is to create a box at the corner. The box establishes the arc center and radius as shown in Figure 2.25. You can also sketch a 45° construction line from the center to the outside corner of the box, and mark the radius on the 45° line. (See Figure 2.25.) Now, sketch the arc by using the tangent points and the mark as a guide as shown in Figure 2.26. You should generally connect the straight lines to the arc after the arc is created, because it is usually easier to sketch straight lines than it is to sketch arcs.

The same technique can be used to sketch any arc. For example, a full radius arc is sketched in Figure 2.27. This arc is half of a circle, so using half of the box method or centerline method works well.

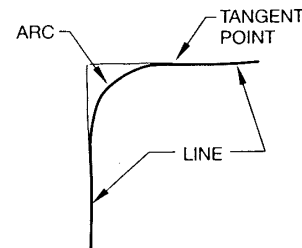


FIGURE 2.24 ■ An arc is part of a circle. This arc is used to create a rounded corner. Notice that the arc creates a smooth connection at the point of tangency with the straight lines.

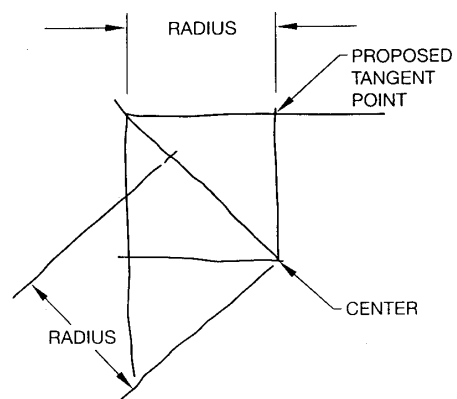


FIGURE 2.25 ■ The box establishes the center and radius of the arc. The 45° diagonal helps establish the radius.

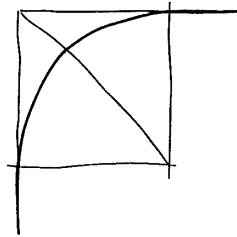
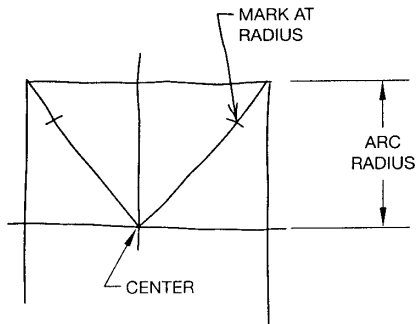
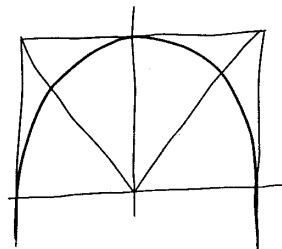


FIGURE 2.26 ■ Sketch the arc using the tangent points and mark on the diagonal as a guide for the radius.

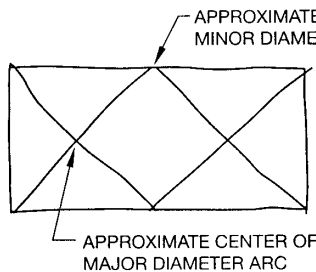


STEP 1



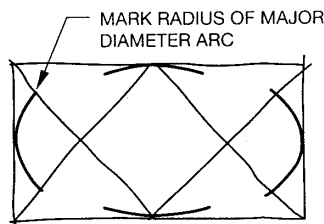
STEP 2

FIGURE 2.27 ■ Sketching a full radius arc uses the same method as sketching any arc or circle.



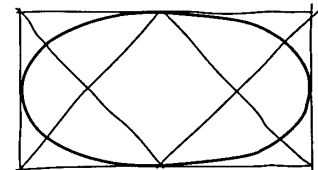
SET UP THE ELLIPSE CONSTRUCTION

(a)



SKETCH THE MAJOR AND MINOR DIAMETER ARCS

(b)



THE COMPLETE ELLIPSE

(c)

FIGURE 2.29 ■ Sketching an ellipse. (a) Sketch a light rectangle equal in length and width to the major and minor diameters of the desired ellipse. Sketch crossing lines from the corners of the minor diameter to the midpoint of the major diameter sides. (b) Use the point where the lines cross as the center to sketch the major diameter arcs. Use the midpoint of the minor diameter sides as the center to sketch the minor diameter arcs. (c) Blend in connecting arcs to fill the gaps.

## SKETCHING ELLIPSES

If you look directly at a coin, it represents a circle. As you rotate the coin, it takes the shape of an ellipse. Figure 2.28 shows the relationship between a circle and an ellipse, and shows the parts of an ellipse.

If you can fairly accurately sketch an ellipse without a construction line, then do it. If you need help, an ellipse can also be sketched using a box method. To start this technique, sketch a light rectangle equal in length and width to the major and minor diameters of the desired ellipse as shown in Figure 2.29a. Next, sketch crossing lines from the corners of the minor diameter to the midpoint of the major diameter sides as in Figure 2.29a. Now, using the point where the lines cross as the center, sketch the major diameter arcs. (See Figure 2.29b.) Use the midpoint of the minor diameter sides as the center to sketch the minor diameter arcs as shown in Figure 2.29b. Finally, blend in connecting arcs to fill the gaps as shown in Figure 2.29c.

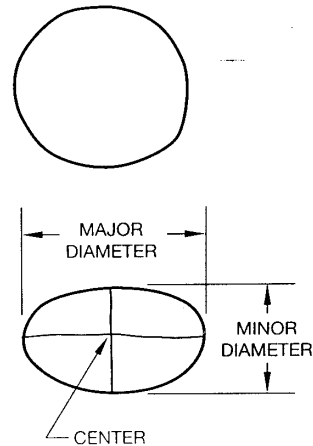


FIGURE 2.28 ■ The relationship between an ellipse and a circle.

## MEASUREMENT LINES AND PROPORTIONS

When sketching objects, all the lines that make up the object are related to each other by size and direction. In order for a sketch to communicate accurately and completely, it must be drawn in the same proportion as the object. The actual size of the sketch depends on the paper size and how large you want the sketch to be. The sketch should be large enough to be clear, but the proportions of the features are more important than the size of the sketch.

Look at the lines in Figure 2.30. How long is line 1? How long is line 2? Answer these questions without measuring either line, but instead relate each line to the other. For example, line 1 could be stated as being half as long as line 2, or line 2 called twice as long as line 1. Now you know how long each line is in relationship to the other (proportion), but we do not know how long either line is in relationship to a measured scale. No scale is used for sketching, so this is not a concern. Whatever line you decide to sketch first determines the scale of the drawing. This first line sketched is called the *measurement line*. Relate all the other lines in the sketch to that first line. This is one of the secrets of making a sketch look like the object being sketched.

The second thing you must know about the relationship of the two lines in the above example is their direction and position relative to each other. For example, do they touch each other, are they parallel, perpendicular, or at some angle to each other? When you look at a line, ask yourself the following questions (for this example use the two lines given in Figure 2.31):

1. How long is the second line?
  - a. same length as the first line?
  - b. shorter than the first line? How much shorter?
  - c. longer than the first line? How much longer?
2. In what direction and position is the second line related to the first line?

Typical answers to these questions for the lines in Figure 2.31 would be as follows:

1. The second line is about three times as long as the first line.
2. Line two touches the lower end of the first line with about a 90° angle between them.

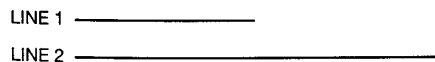


FIGURE 2.30 ■ Measurement lines.

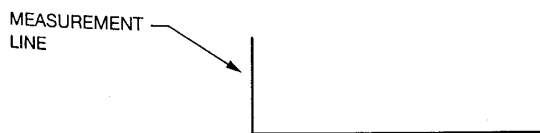


FIGURE 2.31 ■ Measurement line.

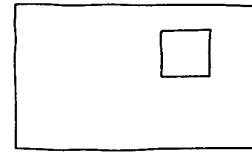


FIGURE 2.32 ■ Space proportions.

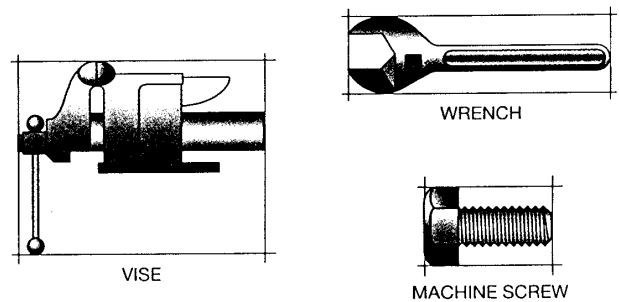


FIGURE 2.33 ■ Block technique.

Carrying this concept a step further, a third line can relate to the first line or the second line and so forth. Again, the first line drawn (measurement line) sets the scale for the whole sketch.

This idea of relationship can also apply to spaces. In Figure 2.32, the location of the square can be determined by space proportions. A typical verbal location for the square in this block might be as follows: the square is located about one-half square width from the top of the object or about two square widths from the bottom, and about one square width from the right side or about three square widths from the left side of the object. All the parts must be related to the whole object.

### Introduction to the Block Technique

Any illustration of an object can be surrounded with some sort of an overall rectangle, as shown in Figure 2.33. Before starting a sketch, visualize the object to be sketched inside a rectangle in your mind. Then use the measurement-line technique with the rectangle, or block, to help you determine the shape and proportion of your sketch.

## PROCEDURES IN SKETCHING

- Step 1. When starting to sketch an object, visualize the object surrounded with an overall rectangle. Sketch this rectangle first with very light lines. Sketch the proper proportion with the measurement-line technique, as shown in Figure 2.34.
- Step 2. Cut sections out or away using proper proportions as measured by eye, using light lines, as in Figure 2.35.
- Step 3. Finish the sketch by darkening in the desired outlines for the finished sketch. (See Figure 2.36.)

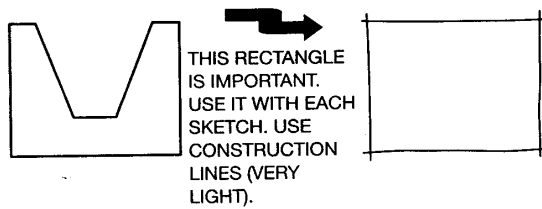


FIGURE 2.34 ■ Step 1, outline the drawing area with a block.

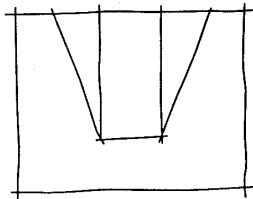


FIGURE 2.35 ■ Step 2, draw features to proper proportions.

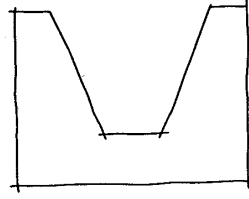


FIGURE 2.36 ■ Step 3, darken the object lines.

### Sketching Irregular Shapes

By using a frame of reference or an extension of the block method, irregular shapes can be sketched easily to their correct proportions. Follow these steps to sketch the cam shown in Figure 2.37.

- Step 1. Place the object in a lightly constructed box. (See Figure 2.38.)
- Step 2. Draw several equally spaced horizontal and vertical lines as shown in Figure 2.39. If you are sketching an object already drawn, just draw your reference lines on top of the object's lines to establish a frame of reference. If you are sketching an object directly, you have to visualize these reference lines on the object you sketch.
- Step 3. On your sketch, correctly locate a proportioned box similar to the one established on the original drawing or object, as shown in Figure 2.40.
- Step 4. Using the drawn box as a frame of reference, include the grid lines in correct proportion, as seen in Figure 2.41.
- Step 5. Then, using the grid, sketch the small irregular arcs and lines that match the lines of the original, as in Figure 2.42.
- Step 6. Darken the outline for a complete proportioned sketch, as shown in Figure 2.43.

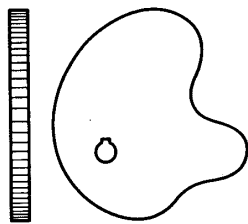


FIGURE 2.37 ■ Cam.

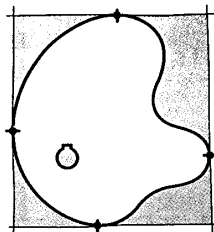


FIGURE 2.38 ■ Step 1, box the object.

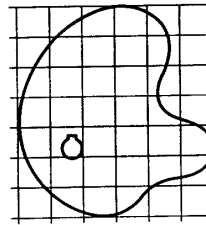


FIGURE 2.39 ■ Step 2, evenly spaced grid.

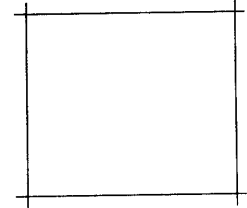


FIGURE 2.40 ■ Step 3, proportioned box.

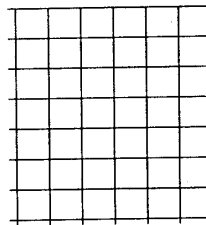


FIGURE 2.41 ■ Step 4, regular grid.

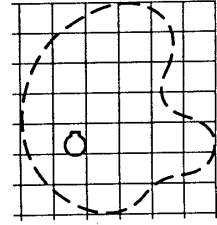


FIGURE 2.42 ■ Step 5, sketched shape using the regular grid.

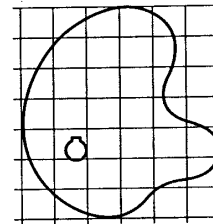


FIGURE 2.43 ■ Step 6, completely darken the outline of the object.

## CREATING MULTIVIEW SKETCHES

Multiview projection is also known as orthographic projection. Multiviews are two-dimensional views of an object that are established by a line of sight that is perpendicular ( $90^\circ$ ) to the surface of the object. When making multiview sketches, a systematic order should be followed. Most drawings are in the multiview form. Learning to sketch multiview drawings will save you time when making a formal drawing. The pictorial view shows the object in a 3-D (three-dimensional) picture, while the multiview shows the object in a 2-D representation. Figure 2.44 shows an object in 3D and 2D.

### Multiview Alignment

To keep your drawing in a common form, sketch the front view in the lower left portion of the paper, the top view directly above the front view, and the right-side view to the right side of the front view. (See Figure 2.44.) The views needed may differ depending on the object. Your ability to visualize between 3-D objects and 2-D views is very important in understanding how to lay out a multiview sketch. Multiview arrangement is explained in detail in Chapter 5.

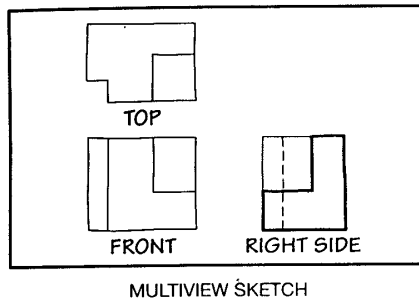
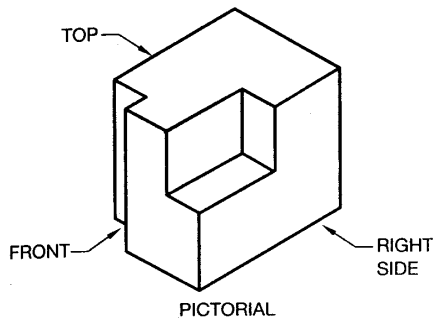


FIGURE 2.44 ■ Views of objects shown in pictorial view and multiview.

### Multiview Sketching Technique

Steps in sketching:

- Step 1. Sketch and align the proportional rectangles for the front, top, and right side views of the object given in Figure 2.44. Sketch a 45° line to help transfer width dimensions. The 45° line is established by projecting the width from the top view across and the width from the right-side view up until the lines intersect as shown in Figure 2.45.
- Step 2. Complete the shapes by cutting out the rectangles, as shown in Figure 2.46.
- Step 3. Darken the lines of the object as in Figure 2.47. Remember, keep the views aligned for ease of sketching and understanding.
- Step 4. In the views where some of the features are hidden, show those features with hidden lines, which are dashed lines

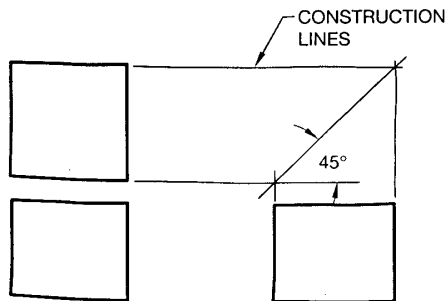


FIGURE 2.45 ■ Step 1, block out views.

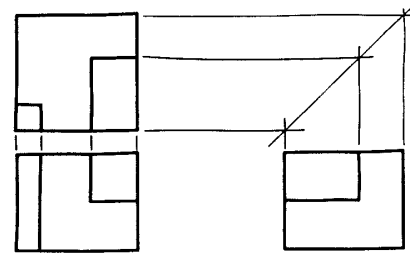


FIGURE 2.46 ■ Step 2, block out shapes.

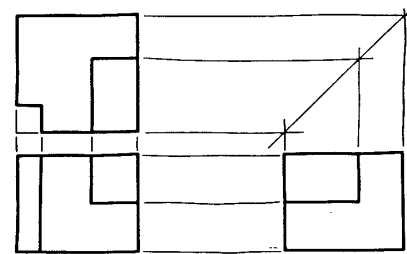


FIGURE 2.47 ■ Step 3, darken all object lines.

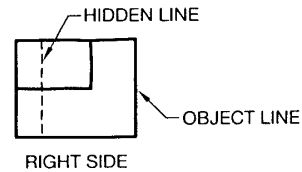


FIGURE 2.48 ■ Step 4, draw hidden features.

as shown in Figure 2.48. Start the practice of sketching object lines thick and hidden lines thin.

### Creating Isometric Sketches

Isometric sketches provide a three-dimensional pictorial representation of an object. Isometric sketches are easy to create and make a very realistic exhibit of the object. The surface features or the axes of the objects are drawn at equal angles from horizontal. Isometric sketches tend to represent the objects as they appear to the eye. Isometric sketches help in the visualization of an object, because three sides of the object are sketched in a single three-dimensional view. Chapter 19 covers isometric drawings in detail.

### Establishing Isometric Axes

In setting up an isometric axis, you need four beginning lines: a horizontal reference line, two 30° angular lines, and one vertical line. Draw them as very light construction lines. (See Figure 2.49.)

- Step 1. Sketch a horizontal reference line (consider this the ground-level line.)
- Step 2. Sketch a vertical line perpendicular to the ground line and somewhere near its center. The vertical line is used to measure height.

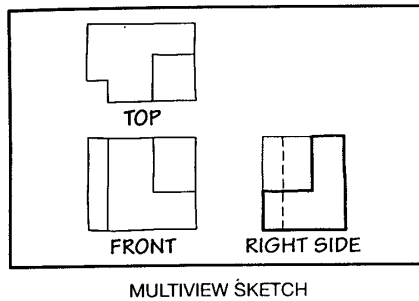
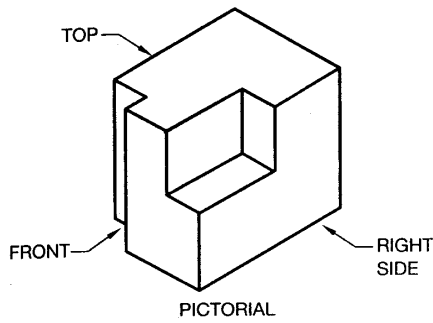


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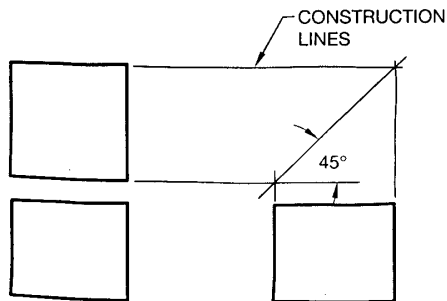


FIGURE 2.45 ■ Step 1, block out views.

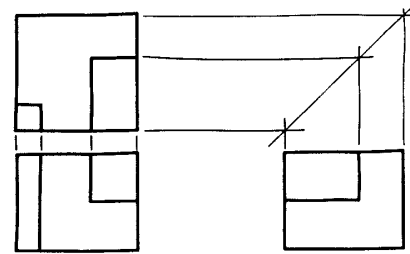


FIGURE 2.46 ■ Step 2, block out shapes.

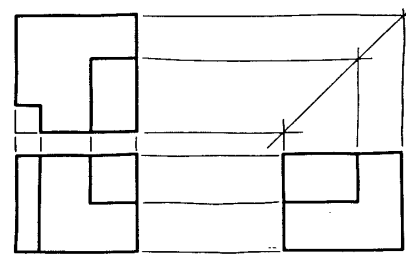


FIGURE 2.47 ■ Step 3, darken all object lines.

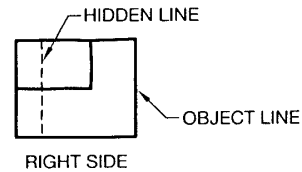


FIGURE 2.48 ■ Step 4, draw hidden features.

as shown in Figure 2.48. Start the practice of sketching object lines thick and hidden lines thin.

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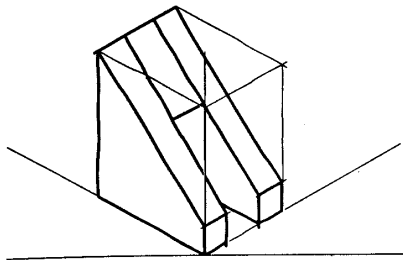


FIGURE 2.56 ■ Step 6, darken the outline.

Step 6. To finish the sketch, darken all the object lines (outlines), as in Figure 2.56. For clarity, do not show any hidden lines.

### Nonisometric Lines

*Isometric lines* are lines that are on or parallel to the three original isometric axes lines. All other lines are *nonisometric lines*. Isometric lines can be measured in true length. *Nonisometric lines* appear either longer or shorter than they actually are. (See Figure 2.57.) You can measure and draw nonisometric lines by connecting their end points. You can find the end points of the nonisometric lines by measuring along isometric lines. To locate where nonisometric lines should be placed, you have to relate to an isometric line. Follow through these steps, using the object in Figure 2.58 as an example.

Step 1. Develop a proportional box, as in Figure 2.59.

Step 2. Sketch in all isometric lines, as shown in Figure 2.60.

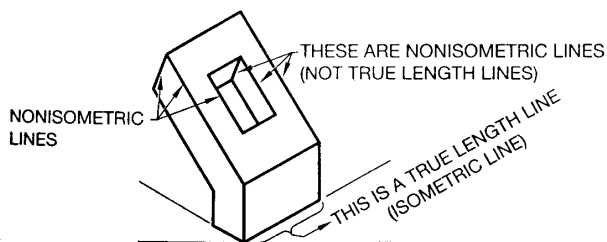


FIGURE 2.57 ■ Nonisometric lines.

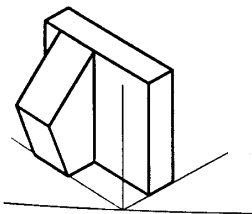


FIGURE 2.58 ■ Guide.

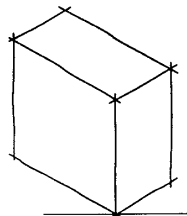


FIGURE 2.59 ■ Step 1, sketch the box.

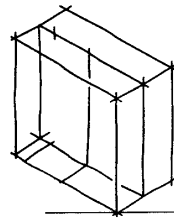


FIGURE 2.60 ■ Step 2, sketch isometric lines.

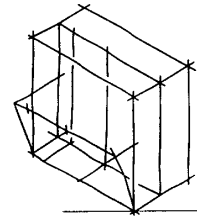


FIGURE 2.61 ■ Step 3, locate nonisometric line end points.

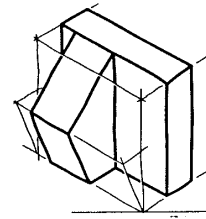


FIGURE 2.62 ■ Step 4, complete the sketch and darken all outlines.

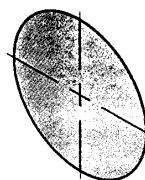
Step 3. Locate the starting and end points for the nonisometric lines. (See Figure 2.61.)

Step 4. Sketch the nonisometric lines, as shown in Figure 2.62, by connecting the points established in step 3. Also darken all outlines.

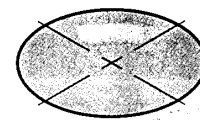
### Sketching Isometric Circles

Circles and arcs appear as ellipses in isometric views. To sketch isometric circles and arcs correctly, you need to know the relationship between circles and the faces, or planes, of an isometric cube. Depending on which face the circle is to appear, isometric circles look like one of the ellipses shown in Figure 2.63. The angle the ellipse (isometric circle) slants is determined by the surface on which the circle is to be sketched.

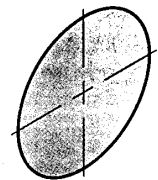
To practice sketching isometric circles, you need isometric surfaces to put them on. The surfaces can be found by first sketching a cube in isometric. A *cube* is a box with six equal sides. Notice, as shown in Figure 2.64, that only three of the sides can be seen in an isometric drawing.



LEFT PLANE



HORIZONTAL PLANE



RIGHT PLANE

FIGURE 2.63 ■ Isometric circles.

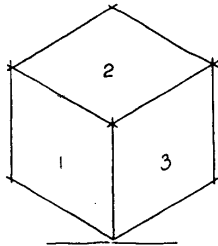


FIGURE 2.64 ■ Step 1, draw an isometric cube.

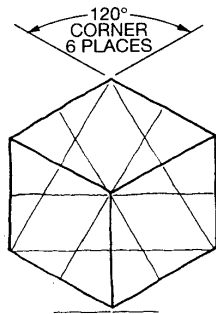


FIGURE 2.65 ■ Step 2, four-center isometric ellipse construction.

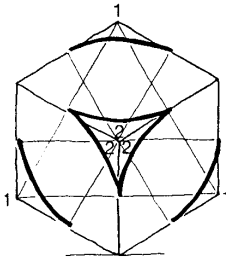


FIGURE 2.66 ■ Step 3, sketch arcs from points 1 and 2 as centers.

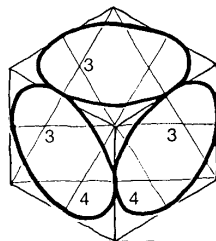


FIGURE 2.67 ■ Step 4, sketch arcs from points 3 and 4 as centers.

#### Four-center Method

The four-center method of sketching an isometric ellipse is easier to perform, but care must be taken to form the ellipse arcs properly so the ellipse does not look distorted.

- Step 1. Draw an isometric cube similar to Figure 2.64.
- Step 2. On each surface of the cube, draw line segments that connect the 120° corners to the centers of the opposite sides. (See Figure 2.65.)
- Step 3. With points 1 and 2 as the centers, sketch arcs that begin and end at the centers of the opposite sides on each isometric surface. (See Figure 2.66.)
- Step 4. On each isometric surface, with points 3 and 4 as the centers, complete the isometric ellipses by sketching arcs that meet the arcs sketched in step 3. (See Figure 2.67.)

#### Sketching Isometric Arcs

Sketching isometric arcs is similar to sketching isometric circles. First, block out the overall configuration of the object, then establish the centers of the arcs. Finally, sketch the arc shapes as shown in Figure 2.68. Remember that isometric arcs, just like isometric circles, must lie in the proper plane and have the correct shape.

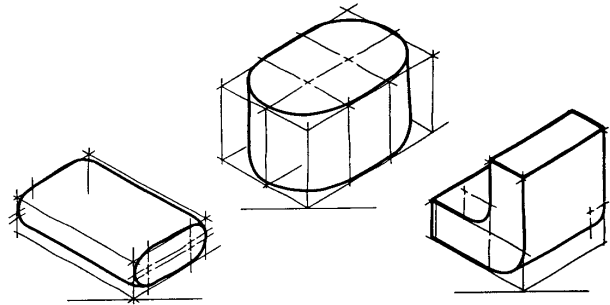


FIGURE 2.68 ■ Sketching isometric arcs.

## LETTERING

Information on drawings that cannot be represented graphically by lines may be presented by lettered dimensions, notes, and titles. It is extremely important that these lettered items be exact, reliable, and entirely legible in order for the reader to have confidence in them and never have any doubt as to their meaning. This is especially important when using reproduction techniques that require a drawing to be reduced in size such as with photocopy or microfilm. Poor lettering ruins an otherwise good drawing.

### SINGLE-STROKE GOTHIC LETTERING

ASME The standard for lettering was established in 1935 by the American National Standards Institute (ANSI). This standard is now conveyed by the American Society of Mechanical Engineers document ASME Y14.2M, *Line Conventions and Lettering*.

The standardized lettering format was developed as a modified form of the Gothic letter font. The term *font* refers to a complete assortment of any one size and style of letters. The simplification of the Gothic letters resulted in elements for each letter that became known as single-stroke Gothic lettering. The name sounds complex but it is not. The term *single stroke* comes from the fact that each letter is made up of a single straight or curved line element that makes it easy to draw and clear to read. There are upper- and lowercase, vertical, and inclined Gothic letters, but industry has become accustomed to using vertical uppercase letters as the standard. (See Figure 2.69.)

ABCDEFGHIJKLMNOPQRSTUVWXYZ  
 QRSTUVWXYZ &  
 1234567890

FIGURE 2.69 ■ Vertical uppercase single-stroke Gothic letters and numbers.

## OTHER LETTERING STYLES

### Inclined Lettering

Some companies prefer inclined lettering. The general slant of inclined letters is 68°. One edge of the Ames Lettering Guide has a 68° slant, which may be used to help maintain the proper angle. Structural drafting is one field where slanted lettering is commonly found. Figure 2.70 shows slanted uppercase letters.

### Lowercase Lettering

Occasionally, lowercase letters are used; however, they are very uncommon in mechanical drafting. Civil or map drafters use lowercase lettering for some practices. Figure 2.71 shows lowercase lettering styles.

### Architectural Styles

Architectural lettering is much more varied in style than mechanical lettering; however, neatness and readability are essential. (See Figure 2.72.)

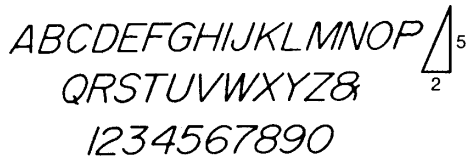


FIGURE 2.70 ■ Uppercase inclined letters and numbers.

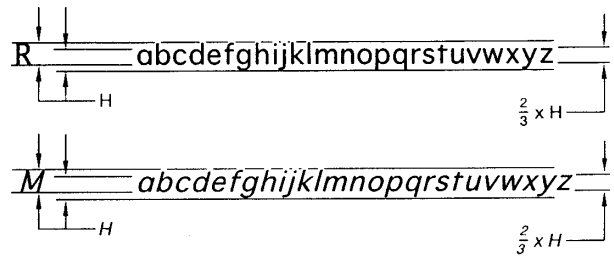


FIGURE 2.71 ■ Lowercase lettering.

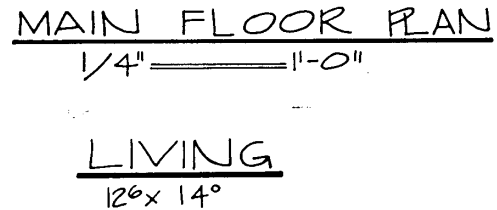


FIGURE 2.72 ■ Architectural lettering.

## LETTERING

Lettering with a CADD system is one of the easiest tasks associated with computer-aided drafting. It is just a matter of deciding on the style or font of lettering to use, locating the text where it is needed, and typing the desired text. Lettering is called *text* when using CADD.

The CADD drafter often rejoices when the time comes to place text and notes on the drawing because no freehand lettering is involved. The computer places text of a consistent shape and size on a drawing in any number of styles, or fonts. The FONT, STYLE, or TEXT command is one of several that can be found in a section of the menu labeled *text* or *text attributes*. The drafter is also able to specify the height, width, and slant angle of characters (letters and numbers). Most systems maintain a certain size of text called the *default* size that is used if the operator does not specify a value. The term *default* refers to any value that is maintained by the computer for a command or function that has variable parameters. The default text height may be 1/8 in., but you can change it if needed.

### Lettering Styles

CADD systems have a variety of lettering styles, or fonts. The drafter can select the style to use simply by picking a menu command, symbol, or by typing a command at the keyboard. Figure 2.73 shows some of the styles and sizes of characters that can be used in CADD. The size and style of characters used is determined by the nature of the drawing.

### Locating Text

The process of locating text has not changed. The drafter still needs to decide where to locate dimensions, notes, and parts lists, but with CADD the process of placing notes is a little more technical. Most CADD systems provide for keyboard entry of location and size coordinates, thus allowing the drafter to accurately locate text. But using the keyboard to

(Continued)

ABCDEFGHIJKLMNOPQRSTUVWXYZ  
 abcdefghijklmnopqrstuvwxyz  
 1234567890  
  
 ABCDEFGHIJKLMNOPQRSTUVWXYZ  
 abcdefghijklmnopqrstuvwxyz  
 1234567890  
  
 ABCDEFGHIJKLMNOPQRSTUVWXYZ  
 abcdefghijklmnopqrstuvwxyz  
 1234567890

FIGURE 2.73 ■ Samples of CADD character font styles.

input text location coordinates takes time. A quicker way to select the text location is to move the screen cursor to the desired location and pick the point with the mouse.

Text is positioned by selecting one of several places on the lettering. Figure 2.74 shows an example of several points on the text that can be used for positioning purposes. Positioning and aligning text is referred to as *justification*. Not all CADD systems use all the points shown, but most systems have a command known as TEXT that is used for placing written information on the drawing. For example, AutoCAD has three commands that can be used to place text for different applications. These are TEXT, DTEXT, and MTEXT. Some systems may allow you to locate text between two

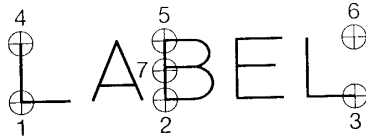


FIGURE 2.74 ■ Text can be placed on a drawing by choosing one of several location points shown here.

points. The computer calculates the size of each letter so the text fits in the desired space.

The first decision regarding text is to determine its height, width, and slant angle. Most CADD systems maintain a default text size that is used by the computer if the operator decides not to change it. The angle of rotation, direction, or text path is also determined by the drafter. The text path is the angle from horizontal that the text will lie on. This is also referred to as rotation angle. An example of text rotation angle is shown in Figure 2.75. Text located on a horizontal line has a direction of 0°, and text that reads from the bottom up vertically has a direction of 90°.

With the size and slant angle decided, you then need to locate it on the drawing and type the text at the keyboard. This process can occur in a couple of ways. You could be asked to first pick the text location using a pointing input device and then type the text. The second method is the reverse of the first. Type the text and it appears on the screen with the crosshairs at the point of location that you previously specified. Then *drag* the text to the proper location, press a button on the mouse, puck, or keyboard, and it is in place. A nice thing about locating notes and labels on a drawing with a CADD system is the ability to move them around instantaneously, as often as you want, without crasing holes in your drawing.

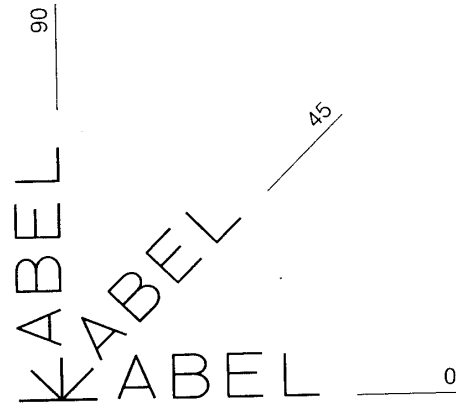


FIGURE 2.75 ■ Examples of text rotation angles.

## LETTERING LEGIBILITY

**ASME** The minimum recommended lettering size on engineering drawings is .125 in. (3 mm). All dimension numerals, notes, and other lettered information should be the same height except for titles, drawing numbers, section and view letters, and other captions which are .25 in. (6 mm) high.

Either vertical or inclined lettering may be used on a drawing depending on company preference. However, only one style of let-

tering should be used on a drawing. Lettering must be dark, crisp, and opaque for the best possible reproducibility.

The composition or spacing of letters in words and between words in sentences should be such that the individual letters are uniformly spaced with approximately equal background areas. This usually requires that letters such as I, N, or S be spaced slightly farther from their adjacent letters than L, A, or W. A minimum recommended space between letters in words is approximately .06 in. (1.5 mm). The space between words in a note or sentence should be about the same as the height of the letters. The space between

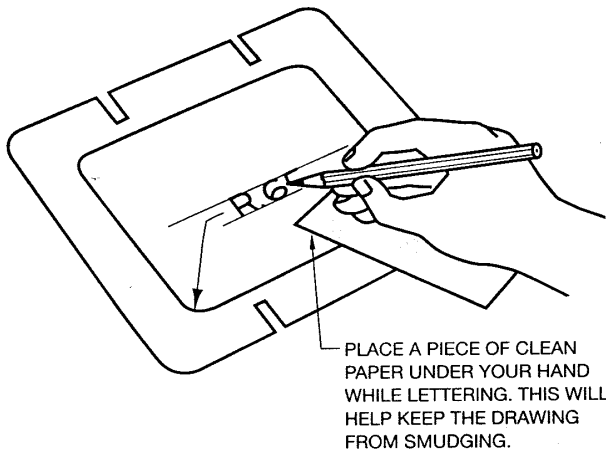


FIGURE 2.78 ■ Place clean paper under your hand when lettering.

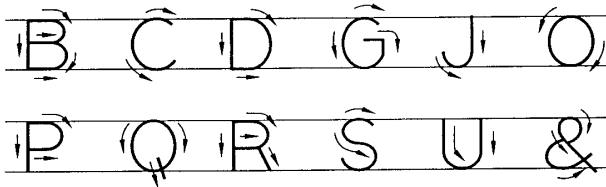


FIGURE 2.79 ■ Recommended strokes for vertical uppercase Gothic letters with curved strokes.

shown provide the best lettering results. Vertical guidelines are often an asset for the best lettering results.

### Vertical Numerals and Fractions

Vertical numerals, as seen in Figure 2.80, are also made up of recommended strokes. Numerals are the same height as capital letters.

#### Fractions

Fractions are not as commonly used on engineering drawings as decimal inches or millimeters, but are common on architectural and structural drawings. When fractions are used on a drawing, the fraction numerals should be the same size as other numerals on the drawing. The fraction bar should be drawn in line with the direction of the dimension. For example, if all dimensions read hori-

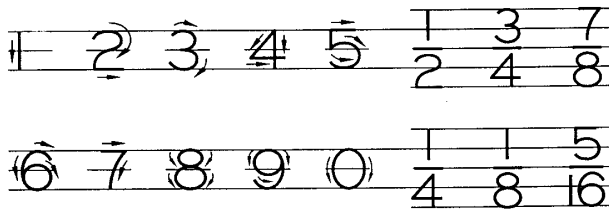
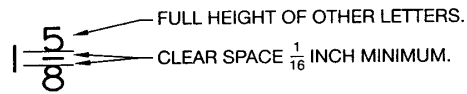


FIGURE 2.80 ■ Vertical numerals and fractions.



ALTERNATE FRACTION STYLE FOR TITLE BLOCKS AND UNIQUE CASES.

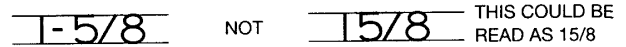


FIGURE 2.81 ■ Fractions.

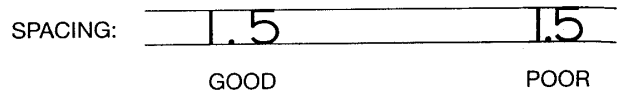


FIGURE 2.82 ■ Spacing of decimal point in numerals.

zontally, all fraction bars are horizontal. The fraction's numerals should not touch the fraction bar. A space of 1.5 mm or .06 in. between the numeral and bar is suggested. The fraction bar may be diagonal in certain situations such as when used in a general note, in a drawing title, or when using CADD. (See Figure 2.81.)

#### Decimal Points

The placement of the decimal point in a decimal dimension is critical. If the decimal point is crowded or drawn too lightly, it may be lost and the result is an unclear dimension. Always make the decimal point dark and bold. Also space the numerals far enough to clearly provide room for the decimal point. Two-thirds the height of letters is recommended. (See Figure 2.82.)

## LETTERING TECHNIQUES

*Always use guidelines.* Straight, even letters of consistent height look better than letters of varying heights. Even when using guidelines be sure to extend each letter directly to the guidelines. Letters that periodically extend beyond or fall short of the guidelines tend to make the words or notes irregular.

Try an H or F pencil for lettering if you have a light touch or try a 2H pencil if your touch is heavy. Use a 0.5 mm automatic pencil. Lines should be black, crisp, and sharp. All vertical lines are made perpendicular, starting at the top for each stroke; all horizontal lines are made from left to right. Balance angles for the letters A, V, W, X, and Y about a vertical guideline. Use a round form for curved letters. Be careful to not allow any space to show between the letter and the guideline.

## COMPOSITION

As a rule of thumb, curved letters can be placed close together, straight letters should be placed further apart. Good lettering composition is evident when all letters in a word look as if they have the same amount of space between them. To achieve this appearance it is often necessary to shorten the horizontal strokes of open letters

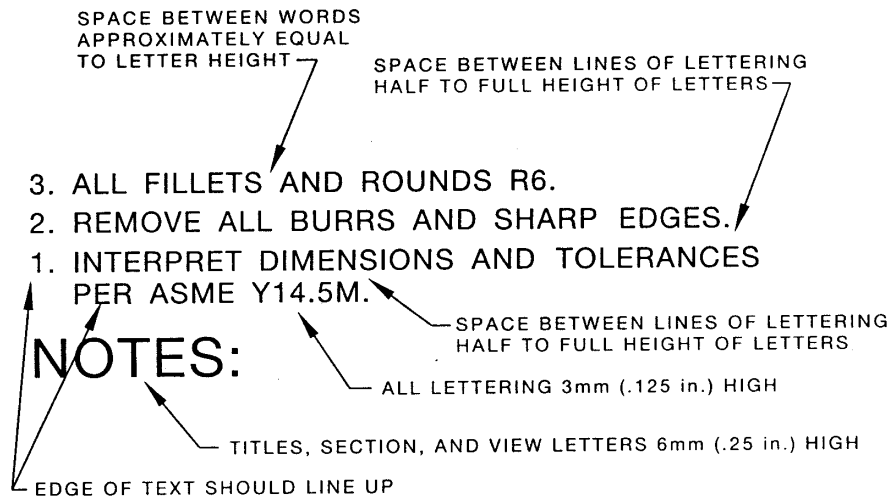


FIGURE 2.76 ■ Spacing of letters, words, and notes.

two numerals with a decimal point between them is a minimum of two-thirds of the letter height.

Notes should be lettered horizontally on the sheet. When lettering notes, sentences, or dimensions requires more than one line, the vertical space between the lines should be a minimum of one-half the height of letters. The maximum recommended space between lines of lettering is equal to the height of the letters. Some companies prefer to use the minimum space to help conserve space while other companies prefer the maximum space for clarity. (See Figure 2.76.)

Additional specific information about notes is provided in Chapter 12, Dimensioning and Tolerancing.

## VERTICAL FREEHAND LETTERING

Vertical freehand lettering is the standard for mechanical drafting. The ability to perform good-quality lettering quickly is important. A common comment among employers hiring entry-level drafters is the ability to do quality lettering and line work. Although standard, not all companies require freehand lettering. Some companies allow drafters the flexibility of freehand lettering or using a template. As many companies are now changing to computer-aided drafting, traditional lettering skills may become obsolete.

Always use lightly drawn horizontal guidelines that are spaced equal to the height of the letters. Some people need vertical guidelines to help keep their letters vertical. The ability to perform quality freehand lettering requires a great deal of practice for most people.

### Vertical Capital Letters

#### Straight Elements

Use a 0.5 mm automatic pencil for lettering. This kind of pencil does not need sharpening and H, F, or HB leads are usually easy to

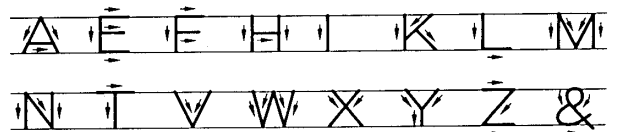


FIGURE 2.77 ■ Recommended strokes for vertical uppercase Gothic letters with straight elements.

control for effective lettering. Remember, you need to experiment with leads to determine which gives you the best results. Letters should be dark and crisp. Fuzzy letters print as fuzzy lines.

Letters composed of straight lines are shown in Figure 2.77. You should become familiar with these letter forms and the strokes needed to make them. The arrows in Figure 2.77 indicate the direction of the stroke used to form the letters. However, if these strokes are uncomfortable, you should develop your own procedure. Try the recommended strokes first. Because these letters are made of single-stroke elements, try not to let the strokes combine as the result may be curves where straight elements should be.

Horizontal guidelines should be used for all lettering at all times. Use vertical guidelines if you have difficulty keeping your letters vertical. Guidelines should be very light 6H or 4H pencil lines. Some drafters prefer to use a light-blue lead rather than a graphite lead for guidelines. Light blue will not reproduce in the diazo or photocopy processes. When lettering, protect your drawing by resting your hand on a clean protective sheet placed over your drawing. This prevents smearing and smudging, as shown in Figure 2.78.

#### Curved Elements

Letters that contain arcs are shown in Figure 2.79. Notice the difference in the sizes of arcs and circles used for different letters. The recommended letter elements, as with straight elements, are made up of a series of suggested strokes. These strokes when used as

sp,  
en  
are  
his  
ar-  
ec-  
in-  
ild  
en

such as L and J. When strokes are parallel and next to each other as the WA in WALL and both Ns and I in PLANNING, they should be placed a little farther apart.

If your letters are wiggly or if you are nervous, try pressing hard to make your lines straighter. If you are pressing too hard, try to relax the pressure. Also try making each letter as rapidly as possible. This tends to eliminate wiggly letters. If your lead is too hard, wiggly letters could result; try a softer lead.

## MAKING GUIDELINES

Guidelines are very lightly drawn lines equal to the height of letters in distance apart. As previously mentioned, some drafters prefer to use a light-blue lead so guidelines will not reproduce.

### Ames Lettering Guide

A commonly used device for making guidelines is the versatile Ames Lettering Guide shown in Figure 2.83. With an Ames Lettering Guide it is possible to draw guidelines and sloped lines for lettering from  $\frac{1}{16}$  to 2 in. in height. Instructions for use are normally found with the lettering guide when purchased. The lettering guide may also be used for parallel lines, needed for such purposes as section lines, including brick, tile, and concrete block, or a music staff.

## OTHER LETTERING AIDS AND GUIDELINE METHODS

Other guideline lettering aids for equidistant spacing of lines have parallel slots ranging in width from  $\frac{1}{16}$  to  $\frac{1}{4}$  in. These lettering guideline aids are not as complex as the Ames Lettering Guide, but they are also not as flexible.

Another method of making guidelines used by a few drafters is to place an  $\frac{1}{8}$ -in. grid paper under the drawing. The lines show through the drawing sheet and guidelines need not be drawn. Be careful with this method, because lines of lettering may not be as straight as with conventional guidelines.

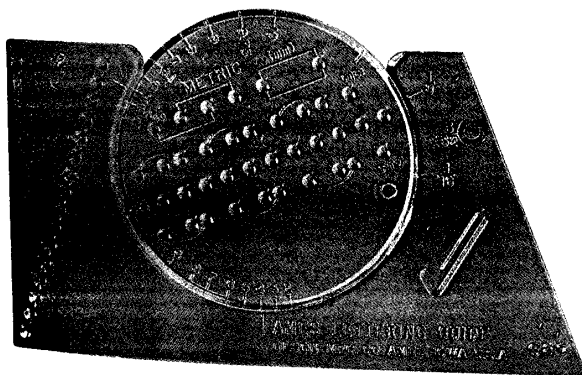


FIGURE 2.83 ■ Ames Lettering Guide. Courtesy Olson Manufacturing Company, Inc.

## BASIC LETTERING CONSIDERATIONS

Always use two guidelines. Three are helpful for beginners. The center guideline is for the letter crossbars.

To adjust eye and hand coordination, first letter lightly, then darken your lettering. Doing so allows you to correct mistakes. This technique should not be necessary after you get some lettering experience.

Make all letters and numbers on the drawing at least  $\frac{1}{8}$  in. (3 mm) high, except for titles which are  $\frac{1}{4}$  in. (6 mm) high. All letters should be the same height. Be consistent.

Make all lettering dark. You may have to press on the pencil to get dark letters.

When practicing lettering, practice no more than 15 minutes per day. Otherwise your hand may cramp and any further practice may be of less value. Practice every day to gain speed and neatness as you letter.

## LETTERING GUIDE TEMPLATES

Some companies prefer that drafters use lettering guides so uniformity is maintained. Standard lettering guide templates are available with vertical Gothic letters and numerals ranging in height from  $\frac{1}{2}$  to  $\frac{3}{8}$  in. (See Figure 2.84.) Lettering guides are also available in many other lettering styles, including slanted Gothic, and Microfont letters in either upper- or lowercase.

## MECHANICAL LETTERING EQUIPMENT

Mechanical lettering equipment has typically been used on government projects and in civil drafting. Mechanical lettering equipment is available in kits with templates for letters and numerals in a wide range of sizes. A complete lettering equipment kit includes a scribe, templates, tracing pins, and lettering pens. Figure 2.85 shows the component parts of a lettering equipment set. Complete instructions are normally found with the lettering equipment when purchased.



FIGURE 2.84 ■ Lettering guide template in use. Courtesy Koh-I-Noor, Inc.