

# 3

## Freehand Sketching

### SECTIONS

- 3.1 Why Freehand Sketches?
- 3.2 Freehand Sketching Fundamentals
- 3.3 Basic Freehand Sketching
- 3.4 Advanced Freehand Sketching
- Key Terms

### OBJECTIVES

- Explain why freehand sketching is important in design
- Freehand sketch lines and circles
- Sketch an oblique 3-D projection
- Sketch an isometric 3-D projection
- Sketch an orthographic multiview projection

## OVERVIEW

In this chapter you will learn useful techniques for freehand sketching to create both two-dimensional orthographic sketches and three-dimensional pictorial sketches. You will learn how to quickly make rough sketches to convey a concept and how to make more refined sketches of objects that are more complex.

### 3.1 WHY FREEHAND SKETCHES?

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An integral part of the creative design process is *ideation*, the generation of concepts or ideas to solve a design problem. Often freehand sketching can be used to explore and communicate mental concepts that come about in the mind's eye. The process of sketching can solidify and fill out rough concepts. Furthermore, sketching captures the ideas in a permanent form that can be used to communicate the concept to others. In this way, sketches often act as stepping stones to refine and detail the original concept or generate new ideas. Many great design ideas are first sketched on the back of an envelope or in a lab notebook, such as the freehand sketch of one of helicopter inventor Igor Sikorsky's designs, (Figure 3.1).

While computers are the workhorses for engineering graphics, initially generating ideas on a computer screen is very rare. A more common scenario is sketching an idea on paper and subsequently refining the concept on paper using more rough sketches. This often occurs simply because all that is needed for a freehand sketch is a pencil and a paper. Freehand sketching *quickly* translates the image of the concept in the mind's eye to paper. Engineers often communicate via rough freehand sketches to refine and improve the design. Sketches are much more useful than detailed CAD drawings early in the design process, because they are informal, quickly and easily changed, and less restrictive. It is only after clarifying the design concept by iterating through several freehand sketches that it is possible to draw the object using computer graphics. In fact, often an engineer will sit down to create a CAD drawing of an object using a freehand sketch as a guide.

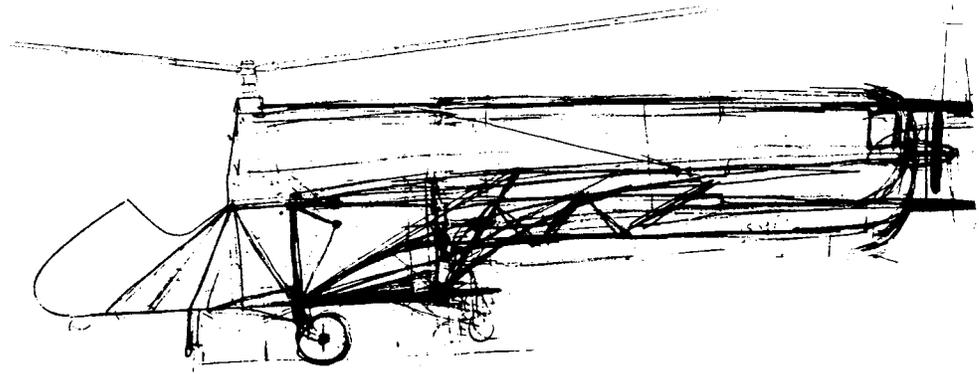
This chapter focuses on the rudimentary elements of freehand technical sketching, because in many ways freehand sketching is the first step in CAD.

### 3.2 FREEHAND SKETCHING FUNDAMENTALS

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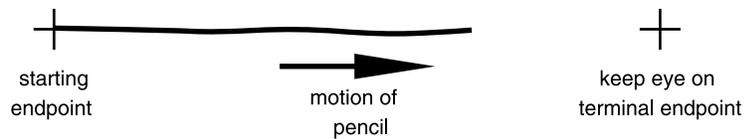
Freehand sketching requires few tools: just a pencil and paper. It may be tempting to use straight-edged triangles or rulers for drawing straight lines and a compass to draw circles. But these instruments often slow down the process and distract from the purpose of sketching, which is to create a quick, rough graphical representation of the image in the mind's eye. Generally sketching has three steps, although the steps are usually subconscious. First, the sketch is planned by visualizing it in the mind including the size of the sketch on the paper, the orientation of the object, and the amount of detail to be included in the sketch. Second, the sketch is outlined using very light lines to establish the orientation, proportion, and major features of the sketch. Finally, sharpening and darkening object lines and adding details develops the sketch.

All sketches are made up of a series of arcs and lines, so the ability to draw circles and straight lines is necessary. A straight line is sketched in the following way. First, sketch the endpoints of the line as dots or small crosses. Then place your pencil on the



**Figure 3.1** Helicopter inventor Igor Sikorsky's sketch of an early helicopter prototype demonstrates the visual impact of freehand sketching. (Used with permission of the Sikorsky Aircraft Corporation, Stratford, CT. ["Straight Up," by Curt Wohleber, *American Heritage of Invention and Technology*, Winter, 1993, pp. 26-39.]

starting endpoint. Keeping your eyes on the terminal point, use a smooth continuous stroke to draw the line between the points as shown in Figure 3.2. Nearly horizontal or vertical lines are frequently easier to draw than inclined lines, so it may be helpful to shift the paper to draw the line horizontally or vertically. For long lines, it may be helpful to mark two or three points along the line and use the procedure between consecutive points or to make two or three shorter passes lightly with the pencil before a final darker line.



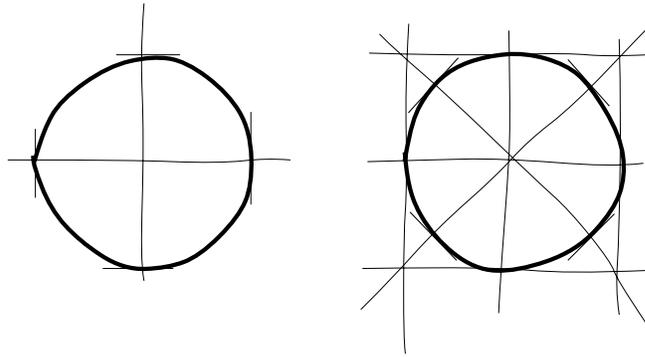
**Figure 3.2**

A circle can be sketched using the following steps, illustrated in Figure 3.3. First, draw light horizontal and vertical lines crossing at the center of the circle. Second, lightly mark the radius of the circle on each line. Finally, connect the radius marks with a curved line to form a circle. Another technique is to lightly draw a square box the same size as the circle diameter as shown in Figure 3.3. Then lightly draw diagonals of the box and centerlines between midpoints of the sides of the box. The diagonals and centerlines should intersect at the center of the circle. Mark the radius on these lines, and sketch the circle within the box. It is sometimes helpful to mark the radius on the edge of a scrap paper and mark the radius at as many points as desired in addition to the marks on the centerlines and diagonals. Arcs are sketched in much the same way as circles, except that only a portion of the circle is sketched. It is generally easier to sketch an arc with your hand and pencil on the concave side of the arc.

### 3.3 BASIC FREEHAND SKETCHING

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Many times, particularly during the conceptual stage of design, it is necessary to immediately communicate a graphical image to others. It has been said that some of the best



**Figure 3.3**

design engineers are the ones who can sketch an idea clearly in a minute or so. The goal of the sketch in this case is not to show the details of the part, but to provide another person with a clear concept of the idea. For example, a design engineer may need to show a sketch to a manufacturing engineer to get input on the manufacturability of a part. If the concept is at an early phase, CAD drawings would not have been created yet. So the design engineer needs to use a freehand sketch of the part.

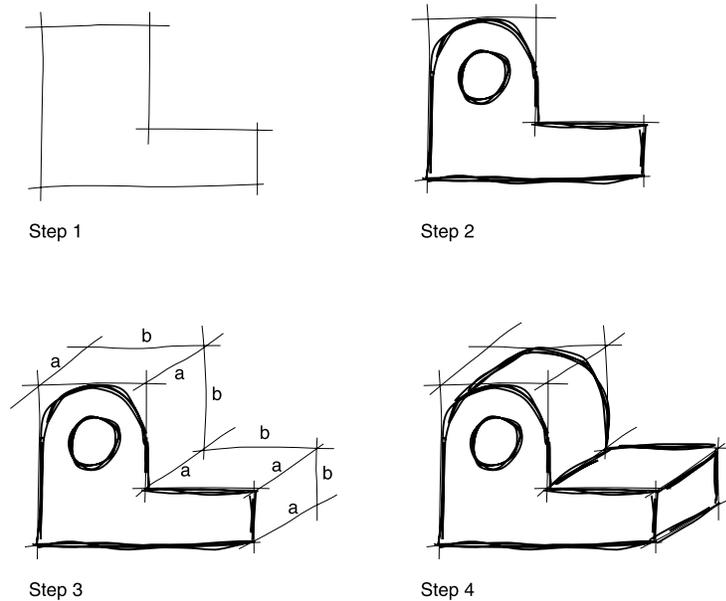
The sketch of Sikorsky's helicopter in Figure 3.1 exemplifies the power of freehand sketching. A brief glance at this sketch provides immediate insight to the concept that is being shown. One does not need to study the sketch to know what is being sketched, even if the viewer has never seen the concept before. These quick ideation sketches are not difficult to draw and require no artistic talent, just some practice.

Two types of pictorial sketches are used frequently in freehand sketching: oblique and isometric. The *oblique projection* places the principal face of the object parallel to the plane of the paper. The *isometric projection* tilts the part so that no surface of the part is in the plane of the paper. The advantage of the oblique projection is that details in the front face of the object retain their true shape. This often makes oblique freehand sketching easier than isometric sketching, where no plane is parallel to the paper. The disadvantage of the oblique projection is that it does not appear as "photorealistic" as an isometric projection. In other words, an isometric projection is similar to what a photograph of the object would look like.

### 3.3.1 Oblique Sketching

Often freehand sketching begins with light thin lines called *construction lines* that define enclosing boxes for the shape that is being sketched. Construction lines are used in several ways. First, the construction lines become the path for the final straight lines of the sketch. Second, the intersection of construction lines specify the length of the final lines. Third, points marked by the intersection of construction lines guide the sketching of circles and arcs. And finally, construction lines guide the proportions of the sketch. This last item is of crucial importance if the sketch is to clearly represent the object. For example, if an object is twice as wide as it is high, the proportions in the sketch must reflect this. Proper proportions of the boxes defined by the construction lines will result in proper proportions of the sketch.

An oblique freehand sketch is easy, since it begins with a two-dimensional representation of the face of the object. Figure 3.4 shows the steps in quickly sketching a part with a circular hole.



**Figure 3.4**

*Step 1:* Horizontal and vertical construction lines are lightly drawn to outline the basic shape of the main face of the part. This is known as *blocking-in* the sketch. If you are using a pencil or felt-tip marker, press lightly when drawing the construction lines to produce a thin or light line. If you are using a ball-point pen, draw a single, light line.

*Step 2:* Sketch in the face of the part using the construction lines as a guide. How you sketch the outline of the part depends on the type of pen or pencil that you are using. The idea is to thicken the lines of the part compared to the construction lines. If you are using a pencil or a felt-tip marker, pressing hard for the outline of the part will result in heavy or dark lines. If you are using a ball-point pen, the line width does not depend much on how hard you press. In this case, the outline of the part is sketched with a back and forth motion of the pen to thicken the lines of the part compared to the construction lines as shown in Figure 3.4. The straight lines are usually sketched first, followed by the arcs. The circle for the hole in the part is added last to complete the face of the part.

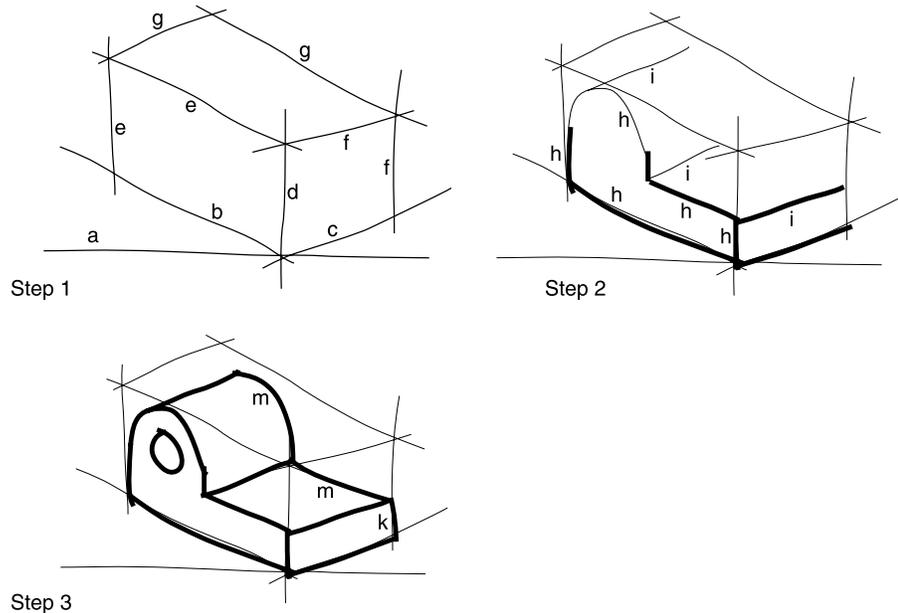
*Step 3:* Sketch *receding construction lines* (lines into the plane of the paper labeled *a*) at a convenient angle. All of the receding lines must be parallel to each other and are usually at an angle of  $30^\circ$  to  $45^\circ$ . The receding lines end at the appropriate depth for the object. Then vertical and horizontal lines at the back plane of the part are added (lines labeled *b*). This blocks in the three-dimensional box enclosing the object.

*Step 4:* Sketch in and darken the lines outlining the part. Again it is usually easiest to sketch in the straight lines first, then the arcs, and finally any details. Because the construction lines are light compared to the outline of the part, they are not erased.

The final sketch, while rough and lacking detail, clearly shows the design intent for the part.

### 3.3.2 Isometric Sketching

Isometric freehand sketches are somewhat more difficult to master than oblique sketches because no face is in the plane of the paper in an isometric view. The steps to construct a simple freehand isometric sketch are shown in Figure 3.5.



**Figure 3.5**

*Step 1:* Sketch a light horizontal line (*a*). From this line draw two intersecting lines at an angle of approximately  $30^\circ$  to the horizontal (*b* and *c*). Then draw a vertical line (*d*) through the intersection of the previous three lines. The three lines labeled *b*, *c*, and *d* form the isometric axes of the sketch. Next sketch the box to block in the front face of the part (*e*). These lines should be parallel to axes *b* and *d*. Similarly, sketch the lines to block in the right face (*f*) making sure that the lines are parallel to axes *c* and *d*. Finish this step by sketching lines parallel to the axes to complete the box that encloses the part (*g*).

*Step 2:* The outline for the front face is added by sketching in lines and curves (*h*). Then outline the front face using heavy lines. In this case, a single heavy line such as might be produced from pressing hard on a pencil or felt-tip marker is used. Next, lines are sketched to indicate the depth of the features of the front view (*i*). These lines should be parallel to axis *c*. They can be darkened after they are drawn lightly.

*Step 3:* Finally, a line is added to complete the back corner of the part (*k*). Lines and arcs are added to complete the back face of the part (*m*). Then the hole detail is added. Circular holes appear as ellipses in isometric views, as discussed in the next section.

The choice of whether to use an oblique projection or an isometric projection is often arbitrary. Because the oblique projection is easier to sketch, it is sometimes preferred. On the other hand, an isometric projection provides a more photorealistic image of the object.

## 3.4 ADVANCED FREEHAND SKETCHING

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The sketching methods described in the previous section were focused on sketches in which the face of the object is in a single plane. Freehand sketching is somewhat more difficult when the face of the object is not in a single plane. The difficulty here is accurately depicting the depth of the object. Oblique and isometric projections are still useful, though somewhat more complicated than those in the previous section. In addition, orthographic projections are also valuable.

### 3.4.1 Freehand Oblique Sketching

An example of the steps leading to an oblique freehand sketch of a complicated object are shown in Figure 3.6. Because the face of the base of the object and the face of the upper portion of the object are in different planes, it is necessary to begin with a box that encloses the entire object before sketching either face. Some of the construction lines are removed after they are used in this example. This was done here to make the sketch more clear. However, this is not necessary in practice, if the construction lines are drawn as light lines.

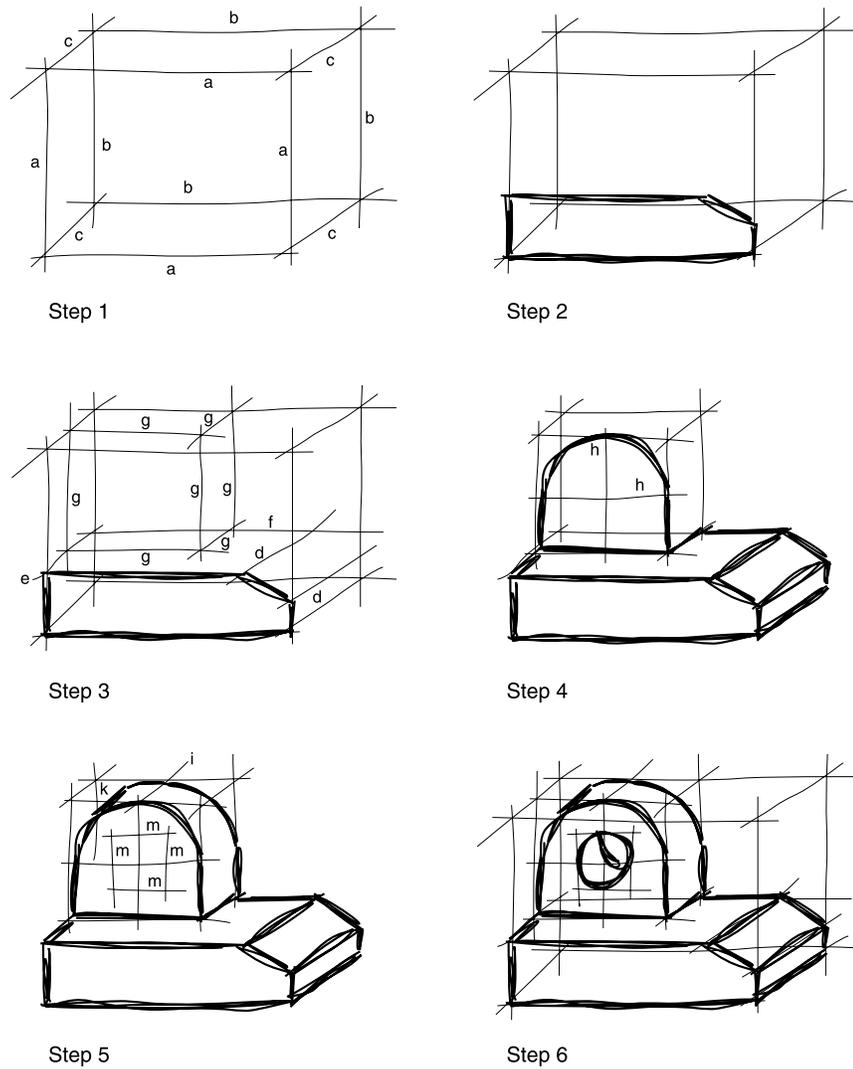
*Step 1:* To begin, construction lines to form a box that encloses the object are drawn to block-in the sketch. Notice that the front and back faces of the box are rectangular with horizontal and vertical sides. The receding construction lines are parallel and at an angle of  $30^\circ$  to  $45^\circ$  to horizontal. The easiest way to draw this box is to first draw the front rectangle (*a*). Then draw an identical second rectangle above and to the right of the first rectangle (*b*). Finally connect the corners with receding construction lines (*c*).

*Step 2:* Now the front face of the base of the object can be sketched in the front rectangle. The lines are appropriately darkened.

*Step 3:* Certain features of the front face of the base extend backward along or parallel to the receding construction lines. For example, the lines (*d*) forming the chamfer (angled cut on the right side of the base) can be sketched parallel to receding lines. Likewise the receding line for the upper left corner of the base can be sketched (*e*). Then the base can be finished with a horizontal line on the back face (*f*). Now it is possible to block in the upper rounded portion of the object to create a box (*g*) that encloses the upper protrusion within the larger box that encloses the entire object.

*Step 4:* The front face of the upper portion of the object can be sketched in this box. Then receding lines corresponding to the chamfer and the left edge of the base can be darkened. In addition, the lines forming the back face can be sketched. Note that the line forming the back edge of the chamfer is parallel to the line forming the front edge of the chamfer. Construction lines (*h*) on the front face of the upper portion are drawn to center of the circle for the hole.

*Step 5:* A receding construction line (*i*) extending from the peak of the front face to the plane of the back face is sketched to aid in aligning the curved outline of the back of the upper portion. The back face is identical to the front face except that it is shifted upward and to the right. This results in the left side of the back face being hidden. A darkened receding line (*k*) finishes the left side of the upper portion of the object. Finally, four construction lines (*m*) are sketched to block in the circle for the hole.



**Figure 3.6**

*Step 6:* Now the hole can be sketched in and darkened. The back edge of the hole is also added to complete the sketch. The construction lines may be erased, but usually the construction lines are retained if they are made properly as light lines.

Oblique sketching is often aided by the use of graph paper with a light, square grid. The process is identical to that shown in Figure 3.6, but it is easier to keep the proportions correct by counting the number of boxes in the grid to correspond to the approximate dimensions of the part. Graph paper further improves the sketch by helping keep lines straight as well as more accurately horizontal or vertical.

### 3.4.2 Isometric Sketching

Isometric freehand sketches of more complex objects start with an isometric box to block in the sketch. Then faces are sketched and additional features are blocked in.

Finally details are added. The steps to construct an isometric sketch are shown in Figure 3.7. Some of the construction lines are removed after they are used, to make the sketch more clear in this figure. Normally, removing construction lines is not necessary.

*Step 1:* To begin, sketch a light horizontal line (*a*). From this line draw two intersecting lines at an angle of approximately  $30^\circ$  to the horizontal (*b* and *c*) and a vertical line (*d*) through the intersection of the previous three lines to form the isometric axes of the sketch. Finish blocking in by sketching lines (*e*) to complete the box so that it will completely enclose the object. Unlike the oblique sketch, it is often better not to sketch hidden construction lines when blocking in.

*Step 2:* Block in the front face of the part (*f*) so that the construction line is parallel to the isometric axis. Similarly, sketch the line to block in the right face (*g*).

*Step 3:* Sketch the left face and the right face and darken the lines. This completes the faces that are in the front planes of the box. Now sketch in three lines (*h*) parallel to the isometric axis (*c*). The left line (*h*) is the top edge of the base. The middle line (*h*) finishes the chamfer. The right line (*h*) is used to aid in sketching a construction line for the back edge of the base (*i*), which is sketched next.

*Step 4:* Now the face of the chamfer can be darkened and the angled line at the back edge of the chamfer can be added. This completes the angled face of the chamfer. Next the protrusion above the base can be blocked in with seven lines (*k*).

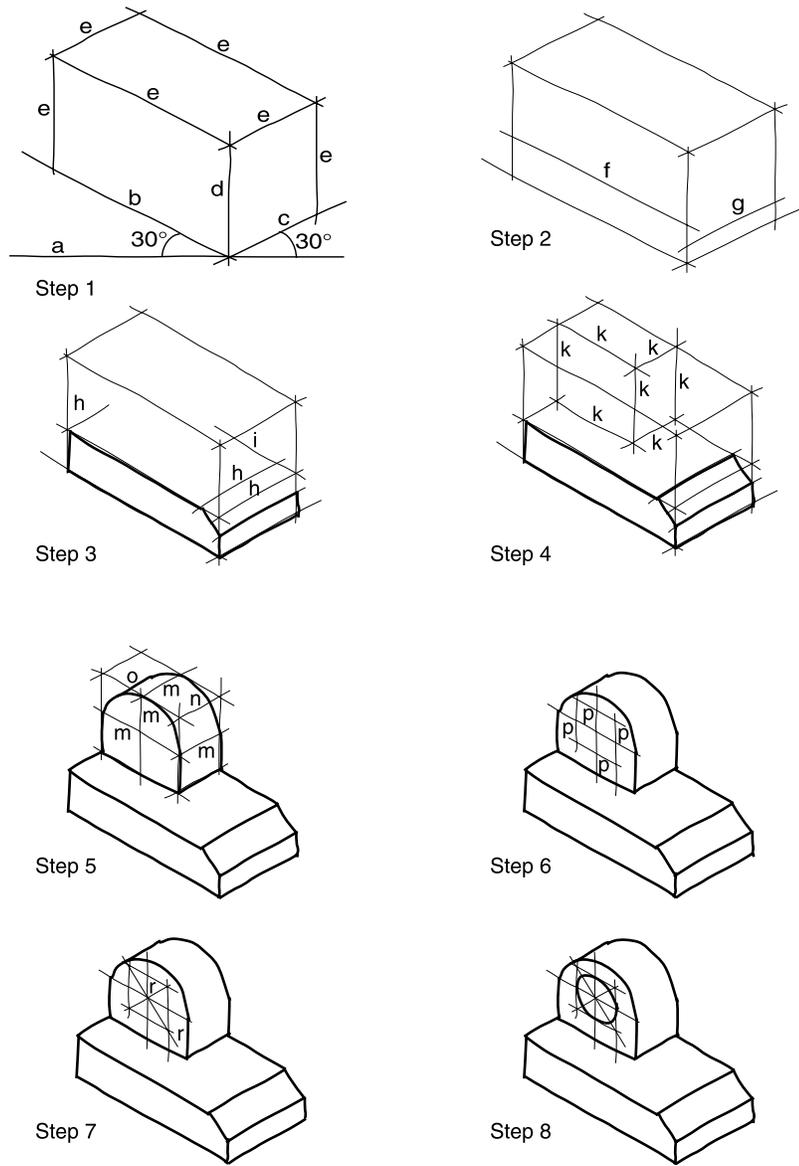
*Step 5:* The front face of the upper protrusion is sketched first using light lines. Construction lines (*m*) are added to help identify the location of the endpoints of the arc of the front and back faces of the protrusion. The rounded rear face (*n*) is sketched lightly to be identical to the front face, except that part of it is not visible. The line at the top left edge of protrusion (*o*) is added. Then all lines forming the upper portion of the object are darkened. In addition, the line forming the top edge of the base on the back side is darkened.

*Step 6:* The details related to the hole are added next. Circles in isometric projections are difficult to draw because they appear as ellipses with their major axes at an angle to horizontal. The center of the hole is where two lines (*m*) intersect on the front face of the upper portion of the object. The lines (*p*) forming the parallelogram to enclose the ellipse for the hole are added. Each side of the parallelogram should be parallel to one of the isometric axes. The sides should be equal in length to one another.

*Step 7:* To help in sketching the ellipse, construction lines forming the diagonals of the parallelogram (*r*) are added.

*Step 8:* Now the ellipse that represents the circular hole can be sketched. A few simple points help in sketching ellipses more easily. The major axis and minor axis of the ellipse are perpendicular to one another. The major and minor axes also coincide with the diagonals of the parallelogram enclosing the ellipse (*r*). The ellipse touches the parallelogram at the midpoints of the sides of the parallelogram. Start drawing the hole by sketching short elliptical arcs between the midpoints of the parallelogram on either side of the minor axis. Finish the hole by sketching sharply curved elliptical arcs between the midpoints of the parallelogram on either side of the major axis of the hole. Finally, darken and make heavy the lines outlining the hole and any remaining edges of the part.

Isometric sketching is made substantially easier by the use of isometric grid paper. This paper has a grid of lines at horizontal and  $30^\circ$  to horizontal (corresponding to lines



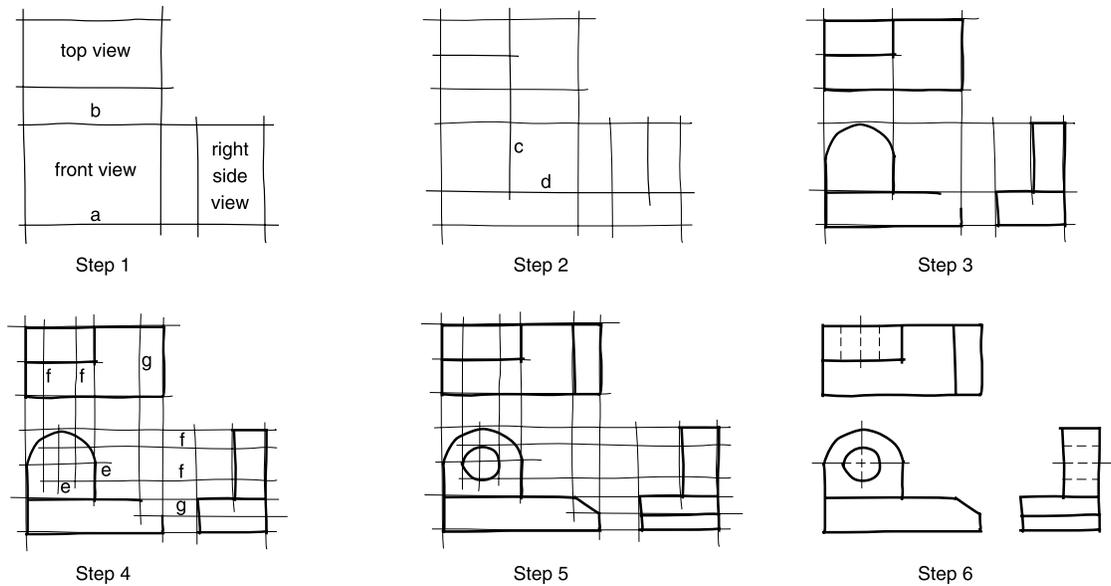
**Figure 3.7**

b, c, and d in Figure 3.7). The procedure for using isometric grid paper is the same as that described above, but using the isometric grid paper keeps proportions of the part consistent. One simply counts grid boxes to approximate the dimensions of the object. The grid paper also aids in sketching straight lines parallel to the isometric axes.

### 3.4.3 Orthographic Sketching

In some cases it is necessary to sketch orthographic projection views rather than oblique or isometric pictorial views. Because orthographic views are two-dimensional representations, they are not as difficult to sketch as pictorial views. But there are several techniques that make freehand sketching of orthographic views easier and more efficient.

The process for sketching three orthographic views of the object in the previous two figures is shown in Figure 3.8.



**Figure 3.8**

*Step 1:* Begin by blocking in the front, top, and side views of the object using the overall width, height, and depth. The construction lines extend between views to properly align the views and maintain the same dimension in different views. For instance, line (*a*) represents the bottom edge and line (*b*) represents the top edge in both the front view and the right-side view. The distance between lines (*a*) and (*b*) is the height dimension in both views. The space between the views should be large enough so that the drawing does not look crowded and should be the same between all views.

*Step 2:* In the second step the upper protrusion is blocked in. Note that line (*c*) extends across the top and front views, to assure that the width of the protrusion is consistent in both views. Likewise, line (*d*) extends across the front and right-side views.

*Step 3:* The outline of the object is darkened to clearly show the shape of the object in all three views. Care must be taken in darkening lines. For instance, the right corner of the front view should not be darkened, because the detail of the chamfer has not yet been added.

*Step 4:* Construction lines for the holes and other details are added next. The center of the hole is positioned with construction lines (*e*). Then construction lines that block in the hole (*f*) are drawn. These construction lines extend between views to project the hole to the top view and to the right-side view. Construction lines extending between views (*g*) are also added for the chamfer.

*Step 5:* Now the hole and chamfer are sketched and darkened to show the completed object.

*Step 6:* Finally, centerlines (long-dash, short-dash) that indicate the center of the hole are added. Hidden lines (dashed lines) that indicate lines hidden behind a surface are also added. Construction lines may be erased as was done in this figure, but this is not usually necessary.

The quality of the sketch can often be improved by using square grid graph paper to keep proportions and act as a guide for horizontal and vertical lines. Some engineers prefer to use a straight-edge to produce a nicer sketch, but this is usually not necessary with practice and sufficient care in sketching.

#### PROFESSIONAL SUCCESS

### Will Freehand Sketching Ever Become Obsolete?

CAD has almost totally eliminated pencil and paper drawings. But what about pencil and paper freehand sketching? Although many computers and palm-tops offer sketching programs, it is unlikely that freehand sketching will disappear soon. Just as it is easier to do a calculation in your head or on a piece of scratch paper rather than finding a calculator and punching in the numbers, it is easier to sketch an image on a piece of paper (or a napkin!) than to find a computer, log in, and start the appropriate “paint” program. Pencil and paper freehand sketches are quick, efficient, easily modified, and easily conveyed to others. And all that is needed is a pencil and a scrap of paper.

Even if the pencil and paper are totally replaced by palm-top computers some day, freehand sketching skills will still be useful. Instead of using a pencil on a piece of paper, we will use a stylus on a touch screen. The only difference is the medium. The freehand sketching techniques themselves are unlikely to change much. Perhaps one could imagine sketching software that assists in generating oblique or isometric sketches as they are drawn at some time in the future.

#### KEY TERMS

blocking-in  
construction lines

ideation

receding construction lines

#### Problems

For all of the problems, the items shown in Figure 3.9, Figure 3.10, and Figure 3.11 are 2 inches wide, 1.5 inches high, and 1 inch deep. The holes in Figure 3.9b, Figure 3.9c, Figure 3.9d, Figure 3.10c, and Figure 3.10d are through holes. The hole in Figure 3.10b is through the front face only.

1. Create freehand oblique sketches of the objects in Figure 3.9. (The objects are shown as oblique projections, so you must simply recreate the drawing by freehand sketching.)
2. Create freehand oblique sketches of the objects in Figure 3.10. (The objects are shown as isometric projections.)
3. Create freehand oblique sketches of the objects in Figure 3.11. (The objects are shown as orthographic projections.)
4. Create freehand isometric sketches of the objects in Figure 3.10. (The objects are shown as isometric projections, so you must simply recreate the drawing by freehand sketching.)
5. Create freehand isometric sketches of the objects in Figure 3.9. (The objects are shown as oblique projections.)
6. Create freehand isometric sketches of the objects in Figure 3.11. (The objects are shown as orthographic projections.)

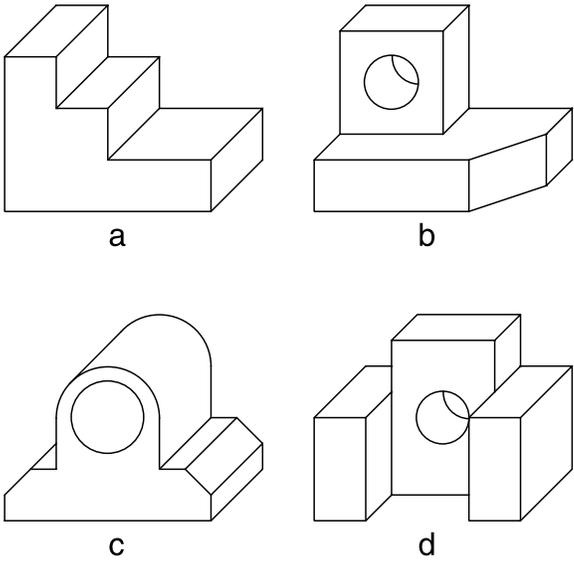


Figure 3.9

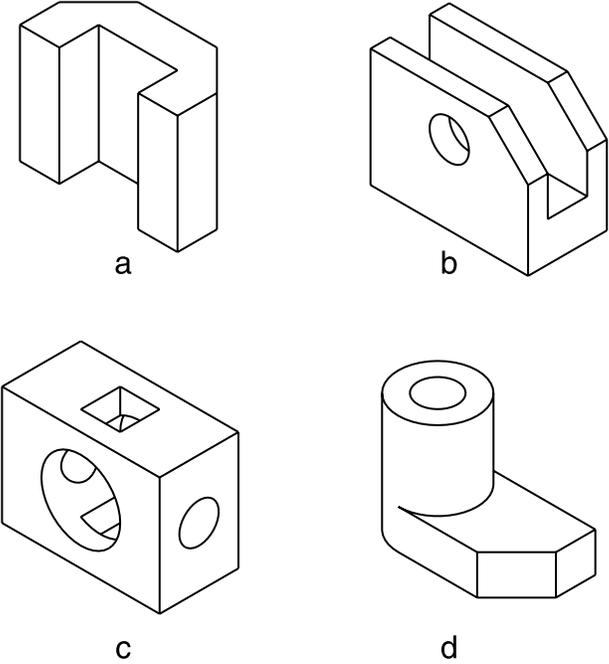
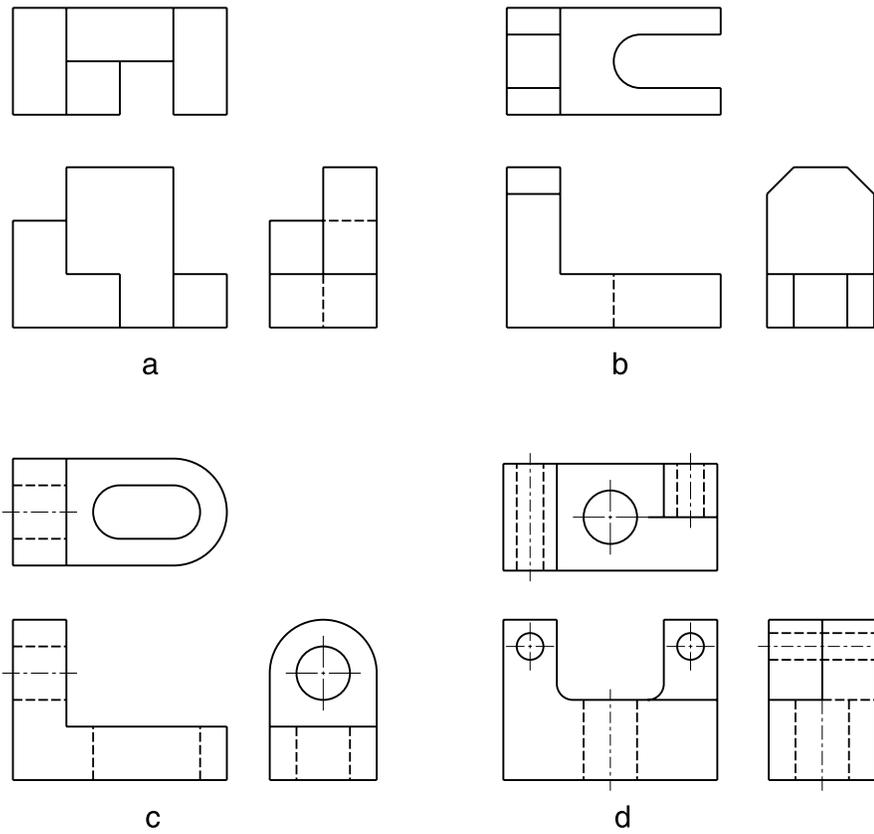


Figure 3.10

- 7. Create freehand orthographic sketches of the objects in Figure 3.11. (The objects are shown as orthographic projections, so you must simply recreate the drawing by freehand sketching.)
- 8. Create freehand orthographic sketches of the objects in Figure 3.9. (The objects are shown as oblique projections.)



**Figure 3.11**

9. Create freehand orthographic sketches of the objects in Figure 3.10. (The objects are shown as isometric projections.)