STEM Applications

1. **ENGINEERING** Make an engineering design journal in which you can store design ideas. To start the journal, record the design ideas you created for this chapter. Start each design on a new page. Include sketches drawn to scale and notes to explain your ideas. As you work through this course, add all of your design ideas to this journal.
2. **ENGINEERING** Work with a team of four other students. Brainstorm ideas for a product that will make one task easier for a person with a special need, such as a handicapped or elderly person. Use an engineering design process to build the device. Demonstrate your design in class and ask for comments and suggestions. Document your design and any changes you make. Place the documentation in your design portfolio.
3. **MATH** Look around and find an object in nature that has the proportions of the golden mean. Draw a sketch of the object. Include dimensions to show how the object satisfies the size requirements of the golden mean.

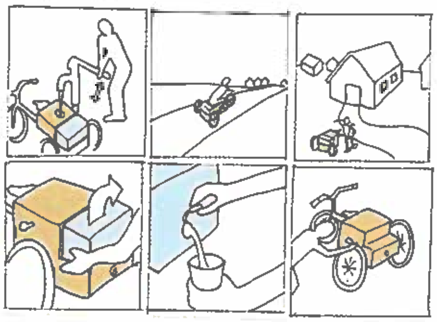
CHAPTER 3

Communicating Design Ideas

Better by Design

The IDEO team uses 2D and 3D models to communicate ideas

Designers use 2D and 3D modeling to communicate and evaluate their design ideas. The team of Adam Mack, John Lai, Eleanor Morgan, Paul Silberschatz, and Brian Mason at IDEO first built a 3D model of the Aquaduct using cardboard, masking tape, and a hot glue gun. They used a ***storyboard*** to visualize how the Aquaduct cycle might be used. They drew detailed plans and modeled parts. Next, they built a full-size working model for testing. The next step is to involve the end users in the design process to help ensure that the product meets their needs.



Storytelling can showcase the proposed design solution to the user.

"Prototyping allows for quick and inexpensive exploration of potential solutions to problems."
— Tom Kelley

The IDEO team created the first 3D model of the Aquaduct from readily available objects.

Reading Target

Preview and Prediction

Before you read this chapter, glance through it and read only the headings of each section. Based on this information, try to guess, or predict, what the chapter is about. Use the Reading Target graphic organizer at the end of the chapter to record your predictions.

Key Terms

3D printing
additive fabrication
alphabet of lines
carbon footprint
circumference
communication
communication technology
computer-aided design (CAD)
concurrent engineering
construction lines
diameter
drafting
freehand sketching
isometric axes
isometric sketching
line drawings
orthographic projection
perspective sketching
rapid manufacturing systems
rapid prototyping (RP)
scale drawing
storyboard
symbol
views
virtual reality

Objectives

After reading this chapter, you will be able to:

- Explain the three basic types of communication technology.
- List various forms of communication.
- Communicate ideas using isometric and perspective sketches.
- Draw simple objects using orthographic projection.
- Demonstrate standard drawing techniques.
- Explain the advantages of computer-aided design.
- Summarize the principle of concurrent engineering.
- Identify uses for 3D printing.

Useful Web site:
other90.cooperhewitt.org/

The exchange of information or ideas between two or more living beings is known as *communication*. This is a big word for a simple act. It came from the Latin, *communo*. It means to "pass along."

Communication is more than just sending a message. The message must be received and understood. If this does not happen, there is no communication. *Communication technology* is the process of transmitting and receiving of information using technical means. This chapter introduces you to the skills and equipment used in many kinds of communication.

Types of Communication

There are three types of communication. All are based on our sense of hearing and sight.

- Visual communication presents ideas in a form we can see. Thoughts are changed into words, symbols, and pictures. Stoplights, street signs, photographs, and books give out visual messages. See Figure 3-1.
- Audio communication consists of messages that can be heard but not seen. A buzzer tells you class is over. A doorbell at your home tells you someone is at the door. Telephones, radios, and CD players rely on audio communication. See Figure 3-2.
- Audiovisual communication can be both seen and heard. You are receiving audiovisual messages when you watch and listen to television, DVDs, and movies.

Figure 3-1. Some street signs communicate a clear message to all people regardless of the language they speak. What is being communicated here?

Figure 3-2. We hear messages that are transmitted using audio communication. What sources of audio communication do you use?

Forms of Communication

All forms of communication use a code or symbols. For example, *dog* and *perro* are letter symbols that communicate the idea of a certain animal. However, the same message can be given in a quite different "language." See **Figure 3-3**.

Hand Signals and Sounds

Simple movements or sounds can replace spoken and written messages. Look at **Figure 3-4A**. These are signals that most people anywhere in the world would understand. Can you think of other signals that you might use? What about the signal to be quiet?

What about sound signals? If you know any Morse code, you will recognize the dots and dashes being sent out by the ship in **Figure 3-4B** as "S.O.S.," the international distress signal. People of all languages know this signal.

Humans are not the only earth dwellers that exchange messages with sounds and body language. Sea animals, such as dolphins and whales, have systems of sound to exchange messages among themselves. Deer and beaver use their tails to signal danger.

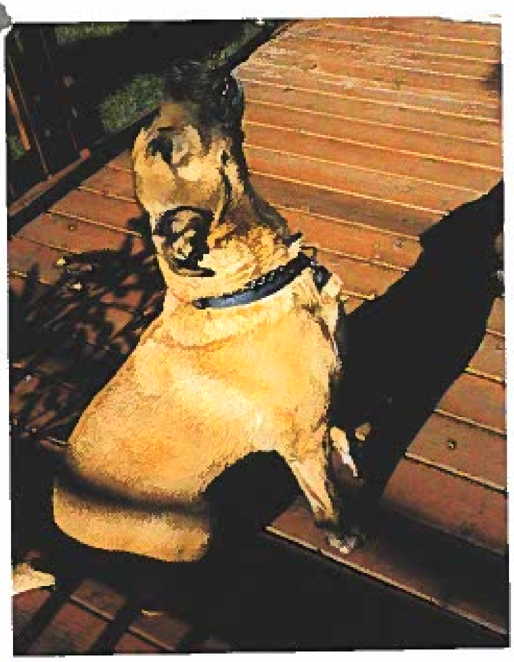


Figure 3-3. Dogs can communicate various messages, such as when a stranger approaches, when they need to go outside, or when they are hungry.

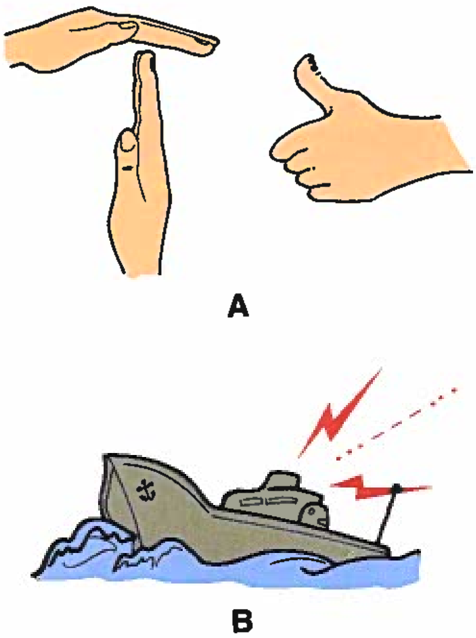


Figure 3-4. Many hand signals and sounds have well-known meanings. What message is being sent in each of these pictures?

Symbols and Signs

Simple pictures and shapes are one of the most effective methods of communication. These *symbols* can warn, instruct, and direct without using words. They "speak" in a hundred languages all at the same time. See **Figure 3-5**.

Electronic Communication

Today, people increasingly send wireless transmissions that bounce off satellites. This allows you to access information or people no matter where you happen to be.

Electronic communication takes many forms. You may decide to establish a MySpace.com™ or Facebook® profile, or send a text message to someone's phone. You could establish or contribute to a blog. You might decide to use an online chat program or check out an e-commerce site. You can communicate using an instant messaging program or check out an online community. YouTube is a site that offers amateur or professional videos that vary from funny to autobiographical.

Figure 3-5. Signs often have symbols that are easily understood at a glance. What message is communicated by each of these symbols?

Think Green

Reducing Carbon Footprint through Communication

A *carbon footprint* is the amount of carbon dioxide and other greenhouse gases a person or organization produces over a specific period of time. Many companies are now using satellite and video communication systems to hold business meetings across the country. This reduces their carbon footprint by avoiding the fossil fuel emissions needed to travel across the country—or across the world—by automobile, train, or airplane.

Think about your daily routines. Can you think of any way to use communication to reduce your personal carbon footprint?

Sketching

Communication is central to design and making products. Objects and ideas are often represented using lines and shapes such as the ones shown in **Figure 3-6**. These are known as *line drawings*. Designers, drafters, technicians, engineers, and architects must be able to make such line drawings. It would be impossible to explain the parts in **Figure 3-7** without drawings.

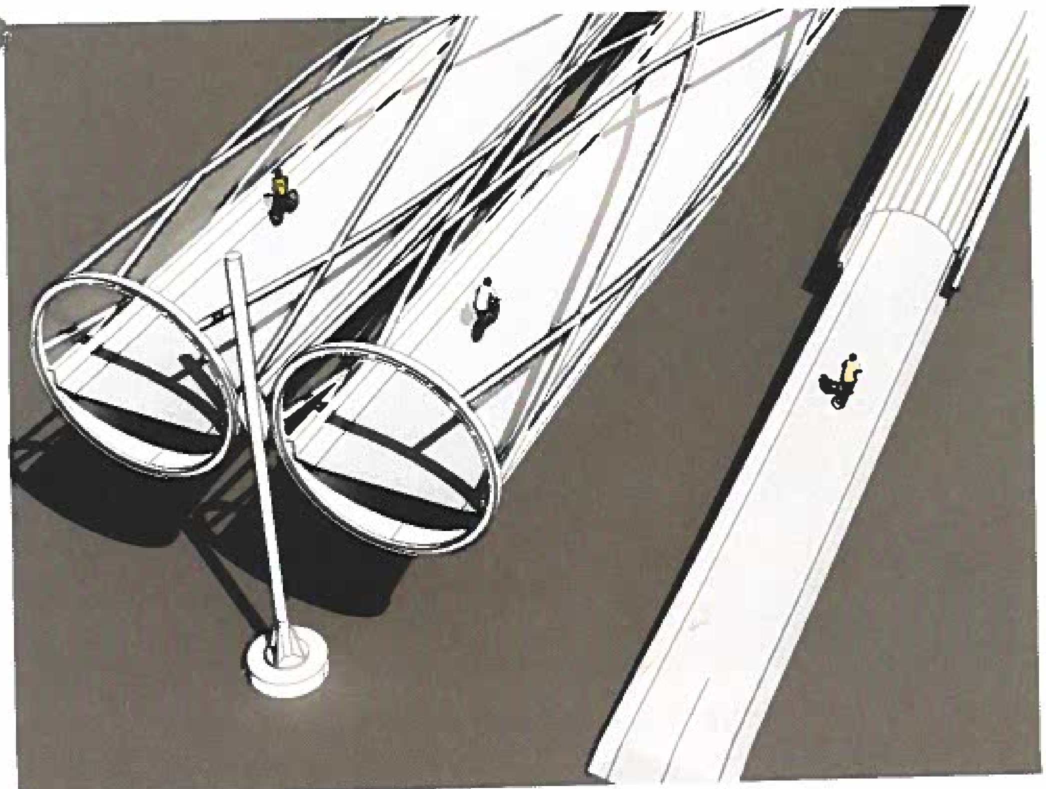


Figure 3-6. Designers use line drawings to communicate their ideas to others.

The process of creating drawings to specify the exact size, shape, and features of a design idea is called *drafting*. Drafting has always been known as the "language of industry." It prevents confusion about the size and shape of an object or structure.

The three types of drawings are isometric, perspective, and orthographic projection. These three types are summarized in **Figure 3-8**. All three may be produced freehand. This is known as sketching. All three may also be drawn using manual drafting equipment or computer-aided drafting systems.

Freehand Sketching

Freehand sketching is an essential step when designing a product. First, it allows you to record your ideas rapidly so you don't forget them. Sketching is a way of talking to yourself. Second, it allows you to share and discuss your ideas with other people. Third, it makes it easier to develop ideas. Whether you set out to design a running shoe, a sofa, or a boat, generating alternative ideas should start with small sketches. For example, the designer of the riverboard explored his early ideas by making the sketches shown in **Figure 3-9**.

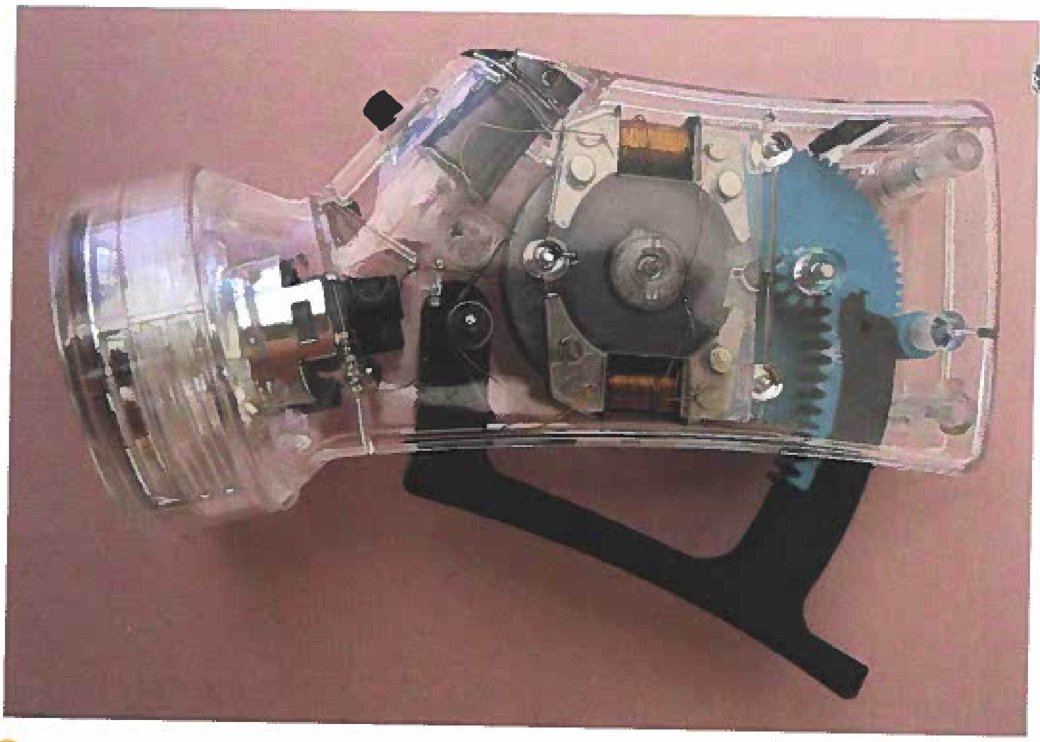


Figure 3-7. Several drawings will be needed to describe the parts of this flashlight so others can make it.

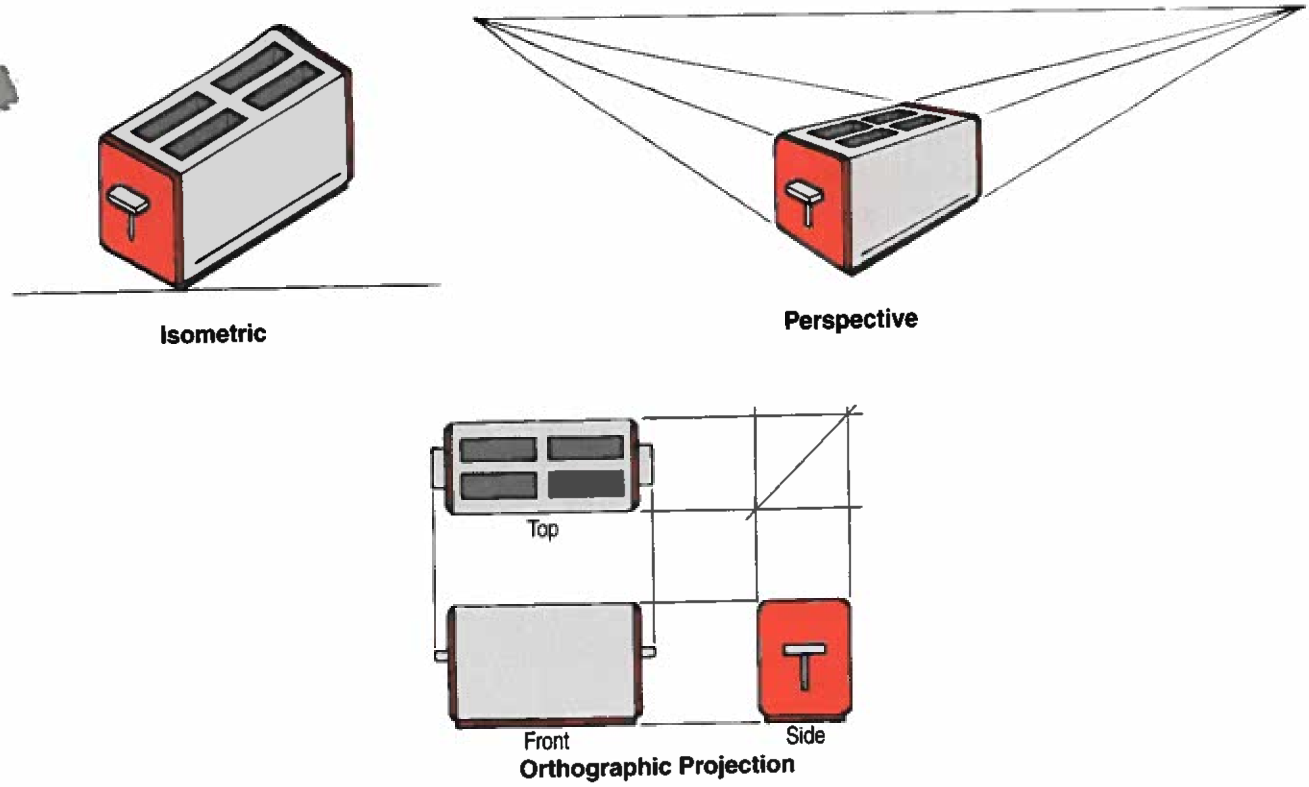


Figure 3-8. Different types of drawings are used for different purposes. Which type of drawing provides the most realistic image? Which provides the most information?

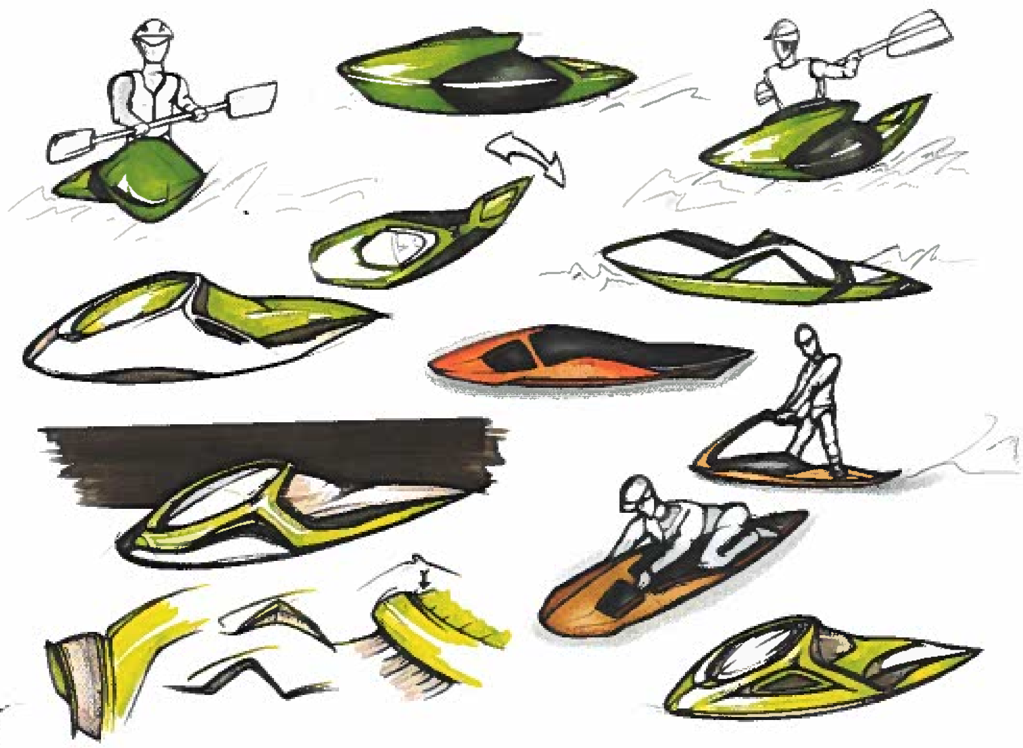


Figure 3-9. Sketches allow the designer to explore many ideas.

Isometric Sketching

In *isometric sketching*, three sides of the item are shown in a single view. Vertical lines show the height of the item. Lines representing the width and depth of the item are set at 30° from the horizontal. Refer again to Figure 3-8. Isometric sketches can be made on plain paper. However, when you are first learning to make isometric sketches, it is helpful to use isometric paper. This type of paper contains lines at the proper isometric angles to make sketching easier.

To sketch an isometric box that is six squares long, three squares wide, and four squares high:

1. Draw the front edge of the block. This is line 1 in Figure 3-10.
2. Draw lines 2 and 3 to show the bottom edges of the box. The three lines you have drawn represent the *isometric axes*.
3. Mark off the height, width, and depth of the object on the three axes, as shown in Figure 3-11. For this sketch, we are measuring in squares. You could also use inches, centimeters, or any other unit of measurement.
4. Draw the left and right vertical edges of the box, as shown in Figure 3-12.
5. Draw the top edges of the box. See Figure 3-13.
6. Darken the outline of the box. You may also want to add color to define the box more clearly. For a neater sketch, you may also want to remove *construction lines* that extend beyond the boundaries of the box. See Figure 3-14.

Whatever the shape of the object to be drawn, it is usually easiest to begin by drawing a box. In most cases, however, you will have to remove parts of the box to create the shape. See Figure 3-15.

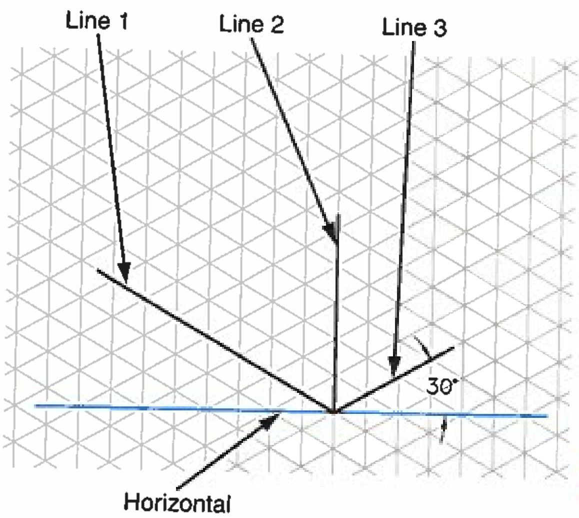


Figure 3-10. To begin an isometric sketch, make these three lines to set up the isometric axes.

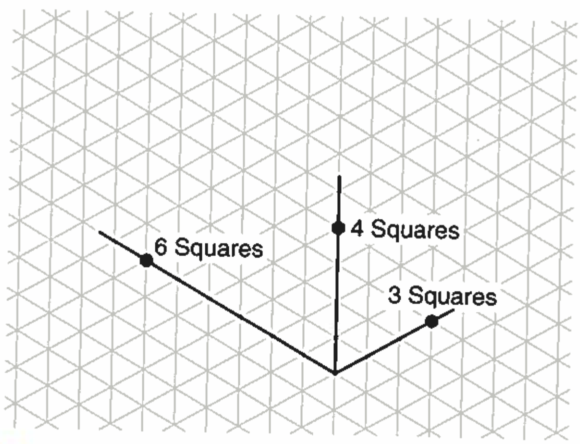


Figure 3-11. Establish the three dimensions of the object. In this case, height = 4 squares, width = 3 squares, and depth = 6 squares.

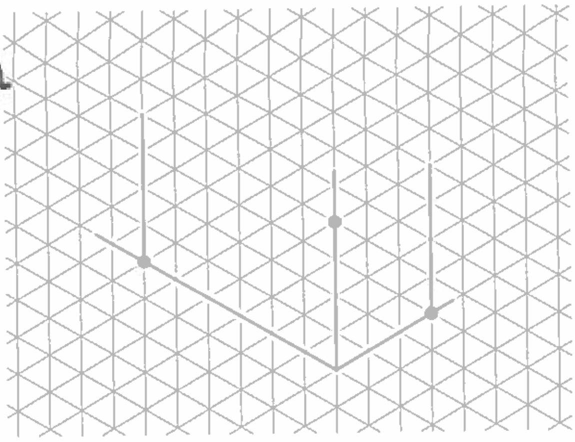


Figure 3-12. Add two more vertical lines to represent the visible vertical edges of the box.

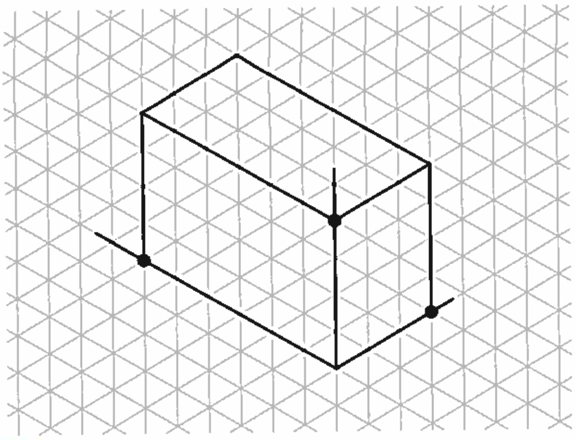


Figure 3-13. Sketch in the top edges of the box.

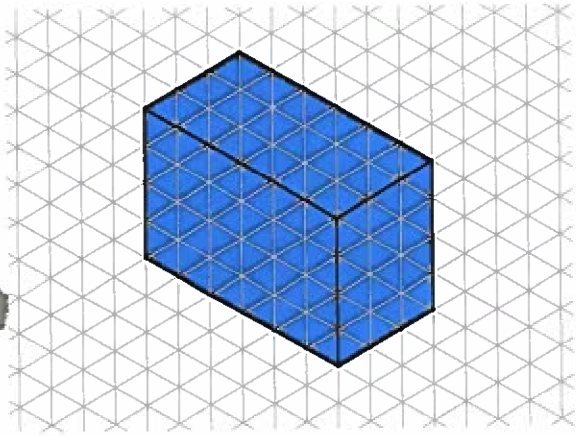


Figure 3-14. The completed isometric sketch of a box.

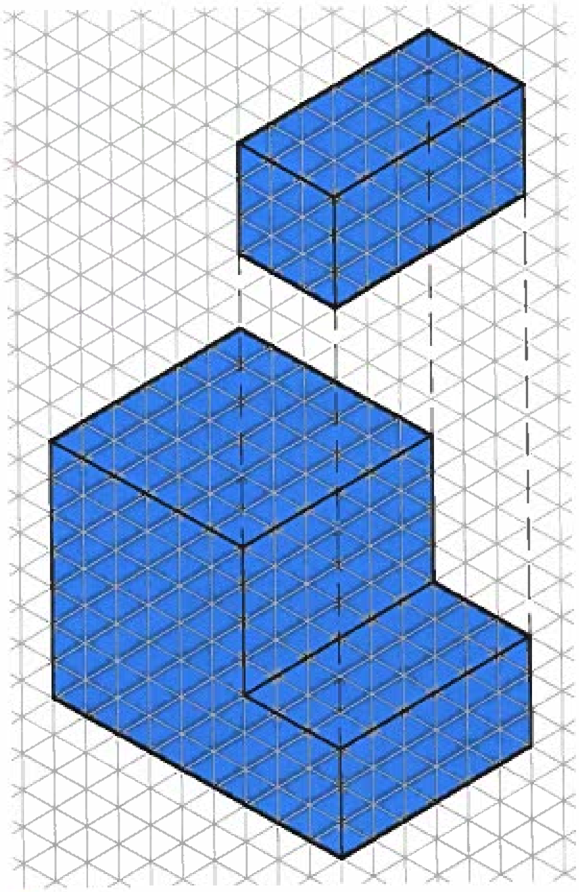


Figure 3-15. Removing part of a rectangular box creates a new shape.

Sometimes you will want to add a piece. For example, you could make a sketch of a box with a small block added to one side. This method of isometric sketching may be used to draw a simplified house.

1. Lightly construct an isometric box eight squares long, four squares wide, and six squares high, as shown in Figure 3-16.
2. Construct the basic shape of the house by removing a corner of the box. Add lines for the roof. See Figure 3-17.
3. Add details, including windows and doors, as shown in Figure 3-18.
4. Complete the line work by removing unnecessary construction lines. Darken the remaining lines to form the building's shape. Add color if desired. See Figure 3-19.

While isometric paper makes sketching easy, it has one disadvantage. It leaves grid lines on the final drawing. These could confuse someone looking at your drawing. Designers often prefer to sketch on plain paper. To make a freehand isometric sketch of a rectangular block on plain paper, use the method shown in Figure 3-20.

Perspective Sketching

Look at the photograph of the railroad tracks in Figure 3-21. Notice that the parallel lines of the tracks appear to converge. The columns on the station platform that are farther away appear shorter, and the platform seems narrower at a distance. Of course, railroad tracks don't converge, columns don't get shorter, and platforms don't become narrower.

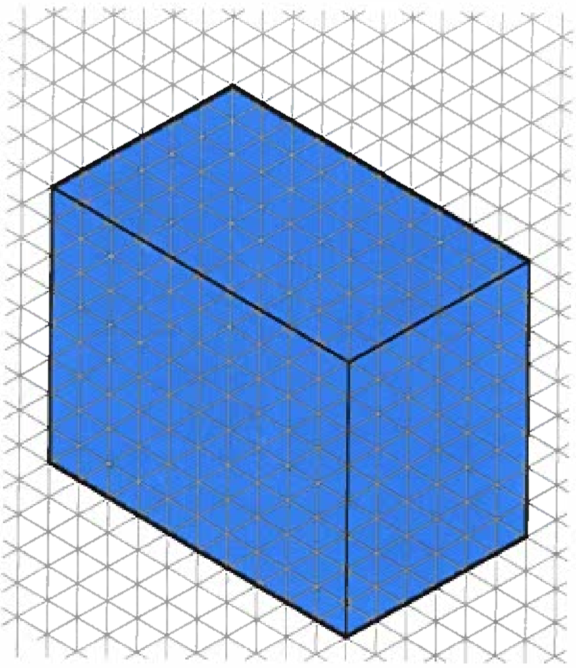


Figure 3-16. To draw a house, make a box on an isometric grid.

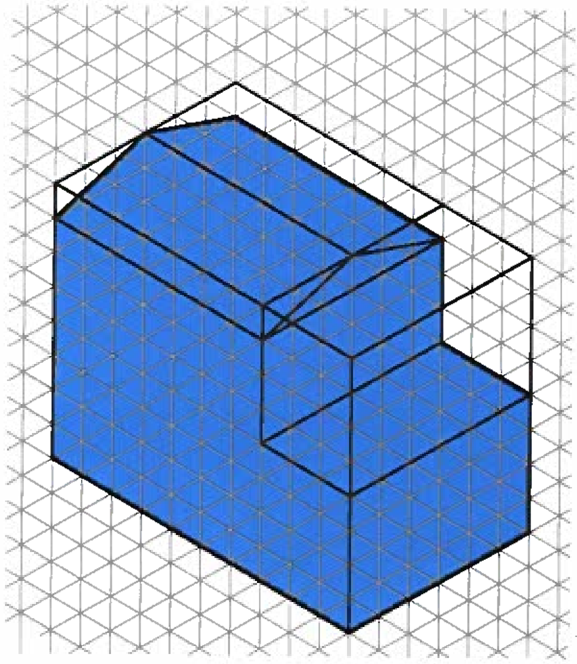


Figure 3-17. Add and remove lines to shape the house. See how points on the grid are used to draw the roof lines.

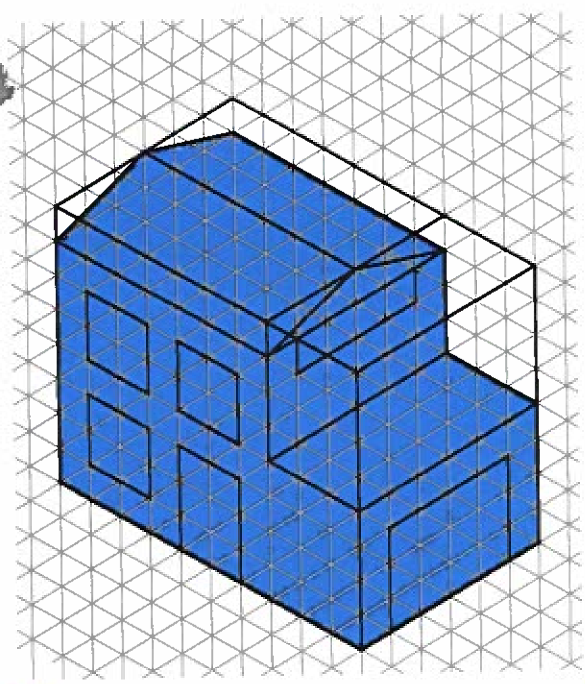


Figure 3-18. Add details such as doors and windows.

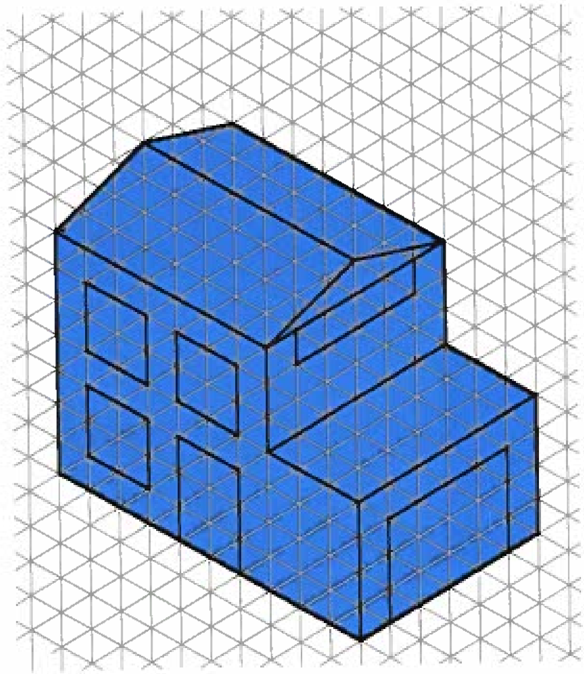


Figure 3-19. Remove construction lines to complete the house.

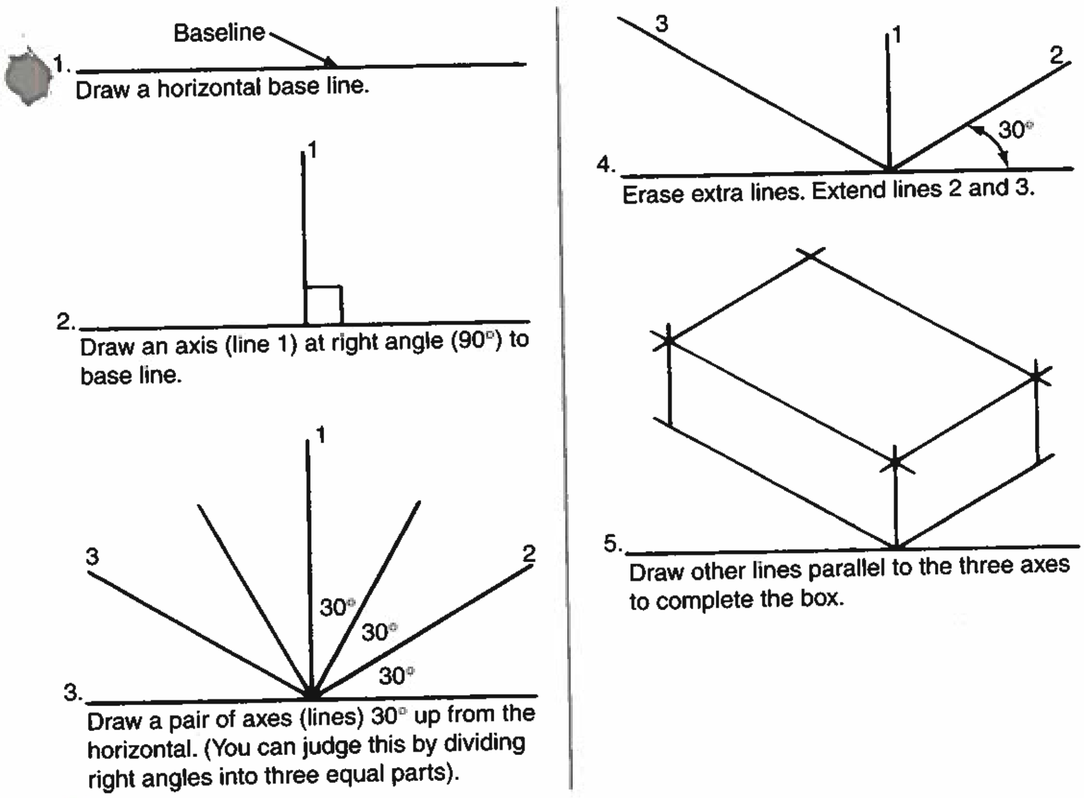


Figure 3-20. You can make a freehand isometric sketch by following these steps.

Figure 3-21. In real life, objects at a distance seem narrower or shorter than they are close up.

Perspective sketching provides the most realistic picture of objects. The sketches are drawn to show objects as we would actually see them. Parallel lines converge and vertical lines become shorter as they disappear into the distance. Refer to Figure 3-22 as you read the following steps for drawing a perspective sketch of a block:

1. Draw a faint horizontal line to represent the horizon. Mark two points, one at each end of the line. These are vanishing points (VP).
2. Draw the front vertical edge of the block.
3. Draw faint lines from each end of the vertical edge to the vanishing points.
4. Draw vertical lines to represent the left and right edges of the block. The length of these vertical sides will be shorter than the real object.
5. Join the top of these vertical lines to the vanishing points. Darken the outline of the object.

Orthographic Projection

You have learned that isometric and perspective sketches are quick methods of recording your ideas and communicating them to other people. They give a general idea of the shape and features of an object. Unfortunately, there are some disadvantages to isometric and perspective sketches. For example, they do not describe the shape of an object exactly because of distortion at the corners, nor do they provide complete information for the object to be made.

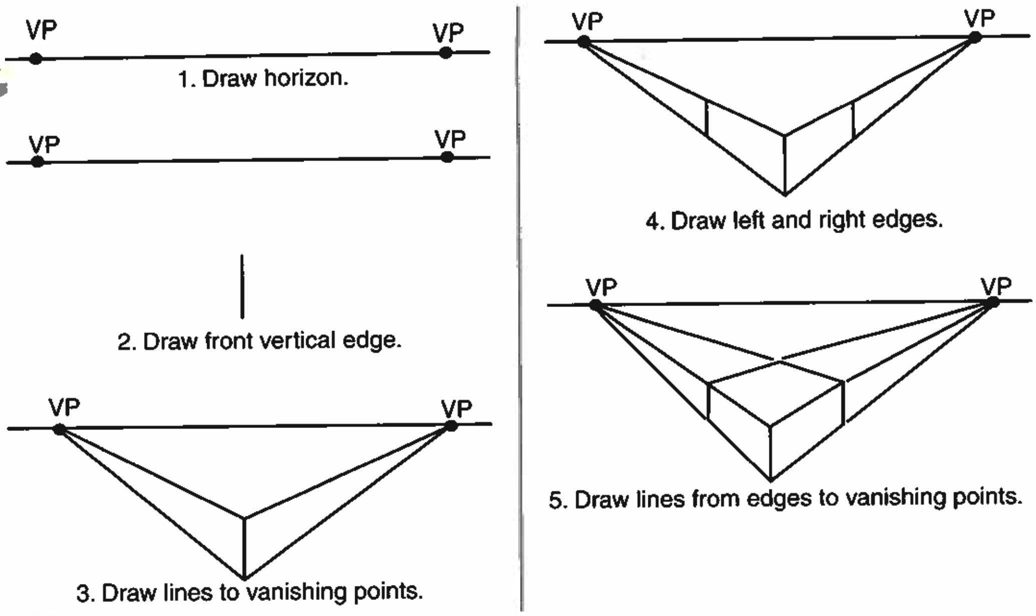


Figure 3-22. In a perspective sketch, lines become shorter as they recede into the distance.

Orthographic projection overcomes both these problems. This kind of drawing shows each surface of the object separately, as if you were looking straight at it. The viewing angle is at right angles to the surface. In this way, you see the exact shape, or view, of each surface. Complete information is usually given by drawing three *views*: front, top, and right side. To understand how a view is produced, imagine that you are the person in Figure 3-23. Because you are looking at the object "square on," you will only see the area that is colored red. Since this is the front of the object, this view is called the *front view*.

To produce a top view, imagine you are above the object looking down at it. The view you would see is shown in blue. The right-side view, shown in green, is drawn by looking at the right side square on. These three views are always arranged as shown in Figure 3-24.

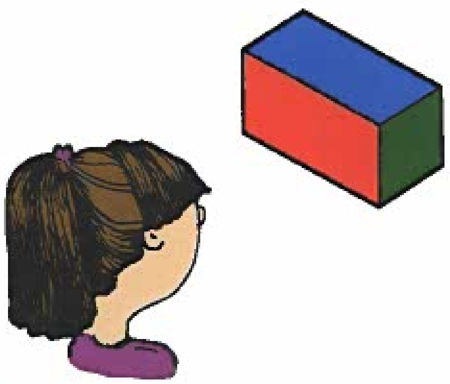


Figure 3-23. An orthographic view shows only one side of an object. This person can see only the side of the block shaded red.

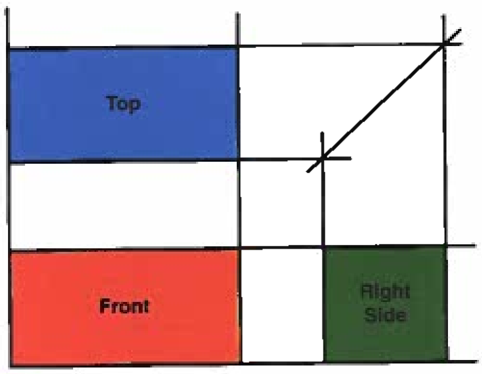


Figure 3-24. The proper arrangement for orthographic views of an object.

To draw an orthographic projection of the house in **Figure 3-25**, complete the steps described in **Figure 3-26**. It is easiest to learn to make orthographic projection drawings by working freehand on square grid paper.

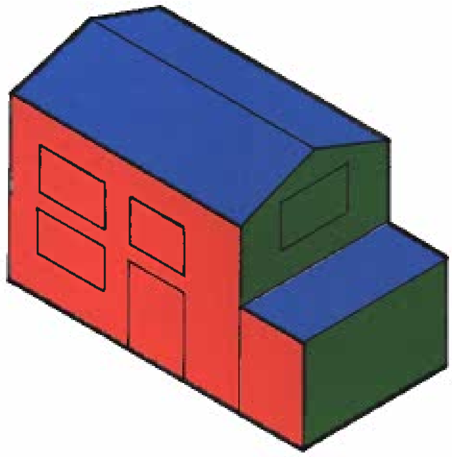


Figure 3-25. The house shown in this isometric view is shown in orthographic views in Figure 3-27.

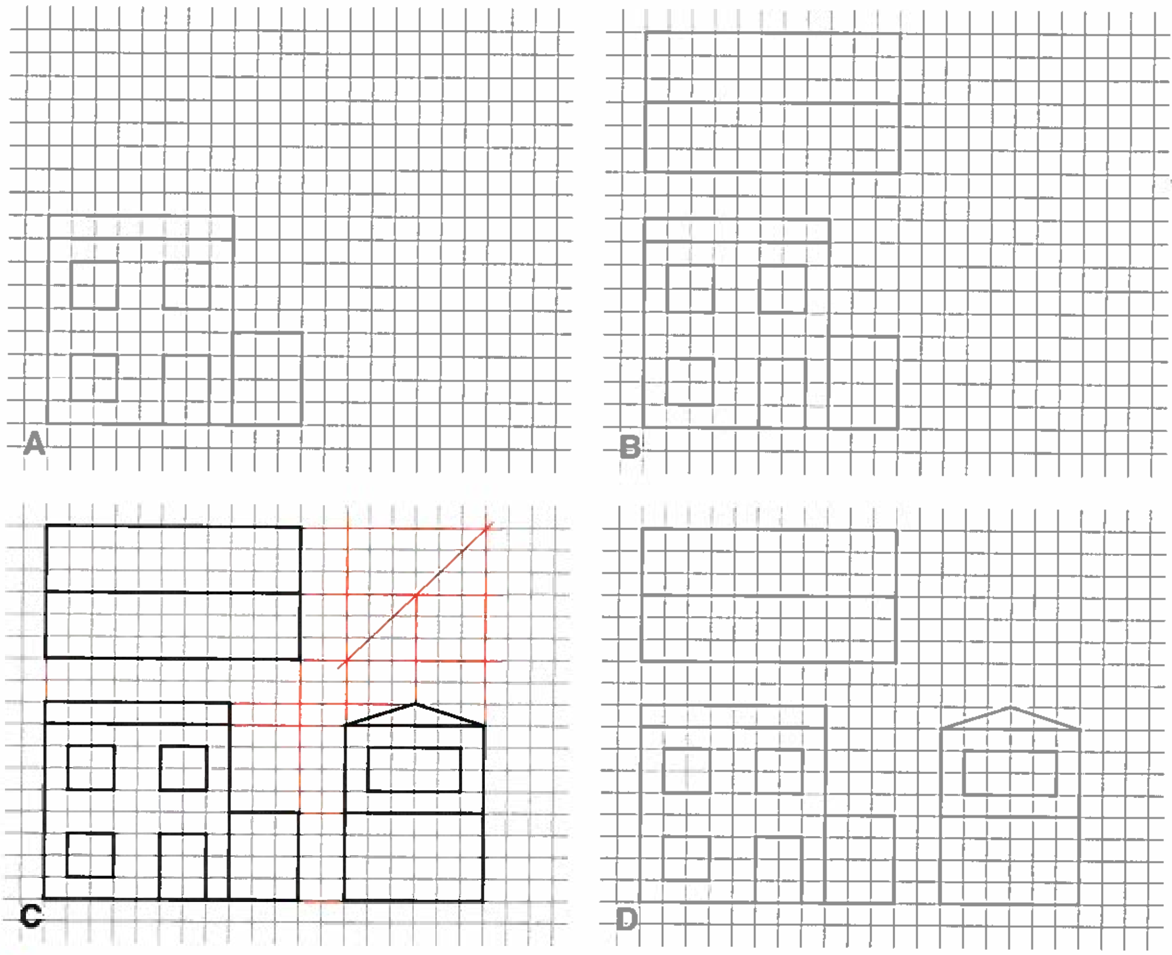


Figure 3-26. To develop an orthographic sketch, follow these steps. A—Draw the front view. B—Project the vertical lines of the front view above the drawing and draw the top view. C—Draw projection lines as shown to complete the right-side view. D—Darken object lines and erase projection lines.

Drawing Techniques

Sketches are drawn freehand, with or without grid paper. To create a more accurate orthographic drawing, you can use plain paper and drawing instruments. The instruments most often used are the T-squares, 45° and 30°/60° triangles, compass, and scale (ruler). Techniques for drawing with these instruments include:

- As a general rule, when drawing lines with a T-square, draw in the direction the pencil is leaning, as shown in **Figure 3-27**.
- When drawing vertical lines with a drafting triangle, lean the pencil away from you and draw the lines from bottom to top. See **Figure 3-28**.
- When using a 45° or 30°/60° triangle, draw lines in the directions shown by the arrows in **Figure 3-29**.
- Hold a compass between the thumb and forefinger and rotate clockwise. Lean the compass slightly in the direction of the rotation as you draw a circle, as shown in **Figure 3-30**.

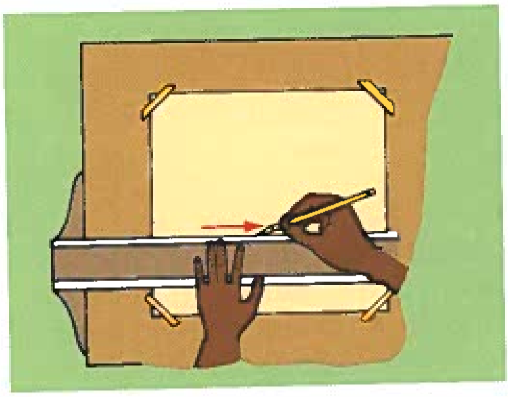


Figure 3-27. Draw in the direction the pencil is leaning.

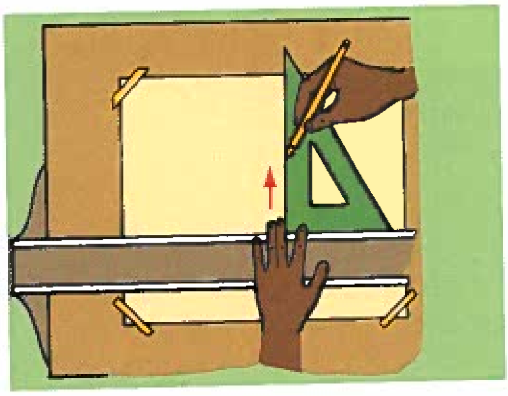


Figure 3-28. Note how the pencil is held to draw vertical lines using a triangle.

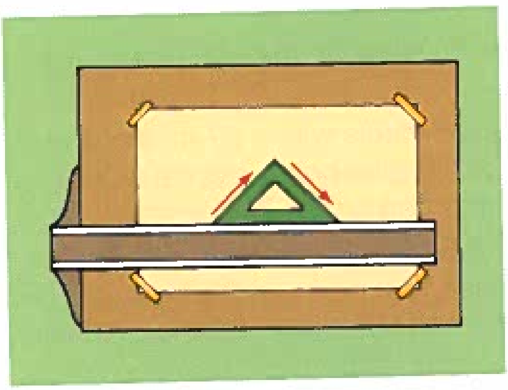


Figure 3-29. Draw sloping lines using a triangle, as shown here.

Figure 3-30. When using a compass, draw circles or arcs lightly at first. Make repeated turns to darken the line.

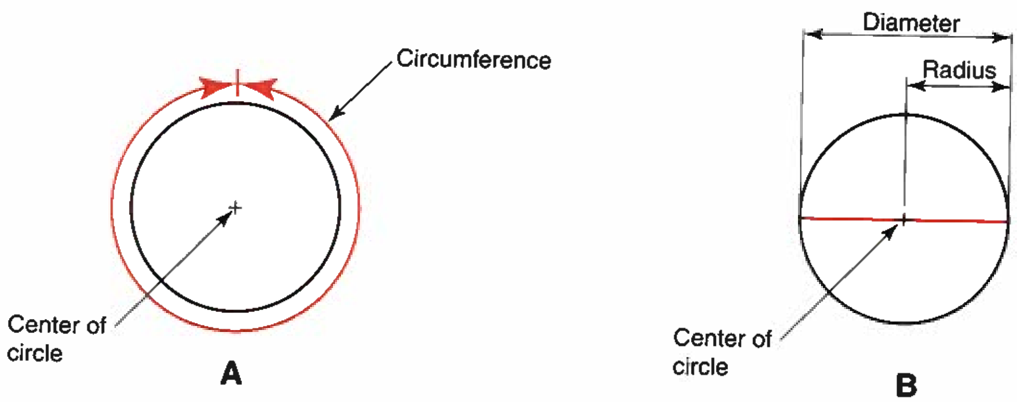
Math Application

Circumference of Circles

Many designs include circles or circular features, and the dimensions of these features must be included on your design drawings. This may involve mathematical calculations.

To find the length of a border that includes a circular shape, you need to find the ***circumference*** of, or distance around, the circle. See **Figure A**. The formula for calculating the circumference of a circle is $C = \pi \times D$ and is usually written:

$$C = \pi D$$



D stands for the ***diameter*** of the circle (the distance from one side of the circle to the other through the center). See **Figure B**. The symbol π (pronounced "pie") represents the number 3.14 (rounded to two decimal places). So, the circumference of a circle is 3.14 times its diameter.

For example, suppose your design includes a circle that is 8 inches in diameter. The circumference of the circle would be:

$$C = 3.14 \times 8 \text{ in.} = 25.12 \text{ in.}$$

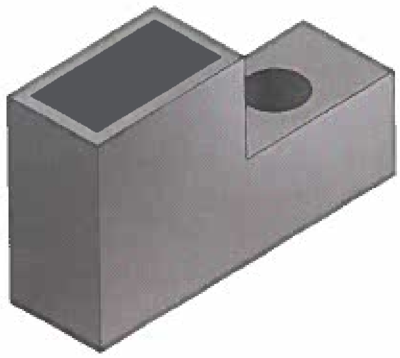
Math Activity

Apply the formula explained above to calculate the answers to the following problems.

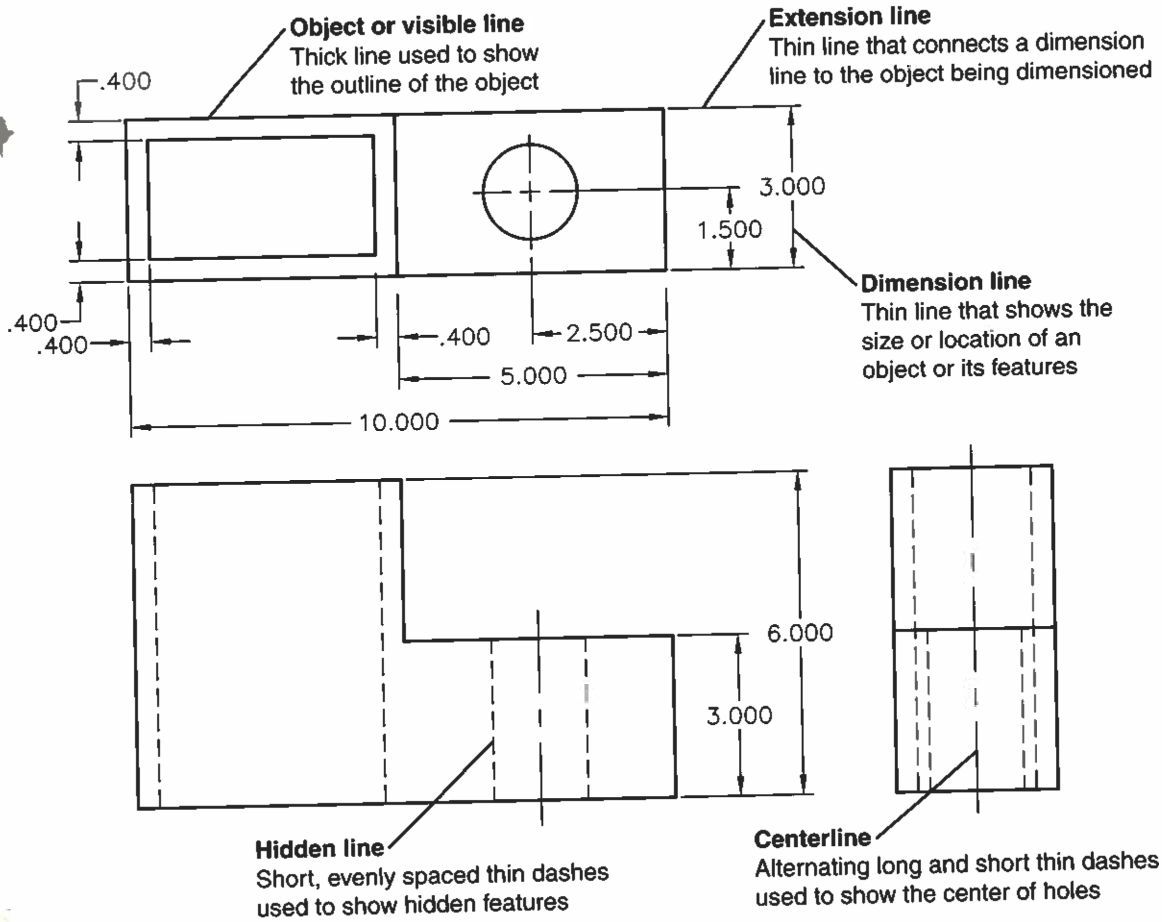
1. Most bicycles used on the road have wheels with a 27-in. diameter. Using the correct formula, calculate the distance a bicycle wheel travels on the pavement when it turns one revolution.
2. Suppose that you have created a new bicycle design that calls for 30-in. wheels. How far would a 30-in. wheel travel on the pavement in one revolution? After calculating the answer, think about the design implications. Which tire would last longer (cover more distance before failing)? Which tire would be more expensive to build? Why?

Alphabet of Lines

A number of different types of lines are used to produce orthographic drawings. Each line is used for a particular purpose and should not be used for anything else. Look at the casting in Figure 3-31A. The *alphabet of lines* can be used to produce the orthographic drawing of this casting shown in Figure 3-31B. The alphabet of lines consists of the standard line types and widths used on technical drawings.



A



B

Figure 3-31. A—An isometric view of a metal casting. B—The orthographic views of the casting shown in A. Note the types of lines and their uses.

A few extra rules apply to hidden lines, as shown in Figure 3-32. For example, they almost always begin and end with a dash touching with the line where they start and end (1). However, this rule is not followed when the dash would continue a visible line (2). Dashes should join at corners (3) and (4). The dashes of parallel hidden lines that are close together should be staggered (5).

Dimensioning

Most drawings include two types of dimensions: overall dimensions and detail dimensions. To fully describe the size and shape of the view in Figure 3-33A, you need two overall and two detail dimensions.

If a hole is added to this view, then you must add the dimensions shown in Figure 3-33B. One dimension shows the size, or diameter, of the hole. The other two dimensions show the exact location of the center of the hole.

Notice the position of the dimensions in Figure 3-33B. Smaller dimensions are placed inside the larger, overall dimensions. This is the preferred placement for dimensions.

Scale Drawings

Ideally, objects should be shown at their full size in an orthographic projection. However, some objects are too large to fit on a sheet of paper. Others are so small that if you show them at their actual size, the details are too small to see clearly. These objects are represented on paper using a *scale drawing*. The objects in a scale drawing are larger or smaller than the object by a fixed ratio. Examples of scaled drawings are an architect's drawing of a building, a map, and an electronic engineer's schematic of a printed circuit.

If you wanted to draw a full-size front view of the skateboard in Figure 3-34, you would need a piece of paper larger than the skateboard. Full-size is a scale of 1:1. Each inch of the drawing paper represents 1″ of the actual object. If you are working in metric, each centimeter of the drawing paper represents 1 centimeter of the actual object.

A drawing that is one-half of full size has a scale of 1:2. In this case, each inch (or each centimeter) on the drawing paper represents 2″ (or 2 cm) of the actual object. Thus, the actual object would be twice the size of the views on the drawing paper.

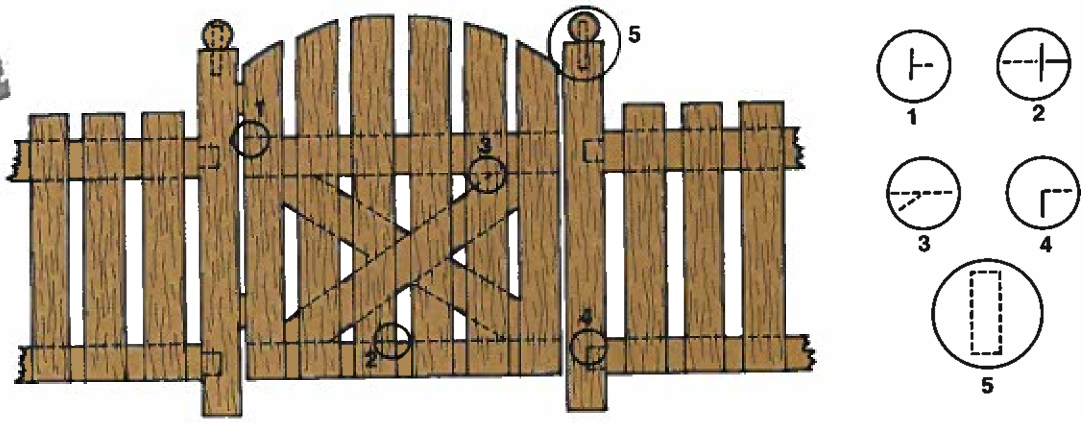


Figure 3-32. Rules for creating hidden lines in a drawing.

If an object to be drawn is very small, it may be necessary to prepare drawings to a scale larger than full size. Such a scale is referred to as an *enlarged scale*. For example, a drawing that is twice full size has a scale of 2:1. Each 2" (or each 2 cm) on the drawing paper represents 1" (or 1 cm) of the actual object. The parts of the compass shown in **Figure 3-35** are drawn twice their actual size.

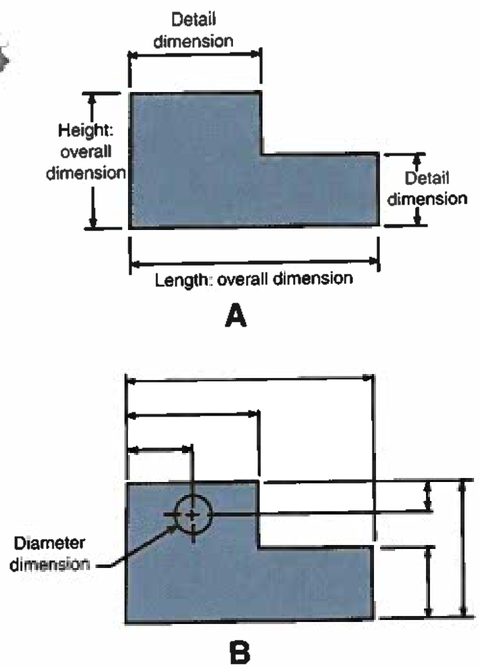


Figure 3-33. A—Overall and detail dimensions. B—Dimensioning the size and location of a circle.

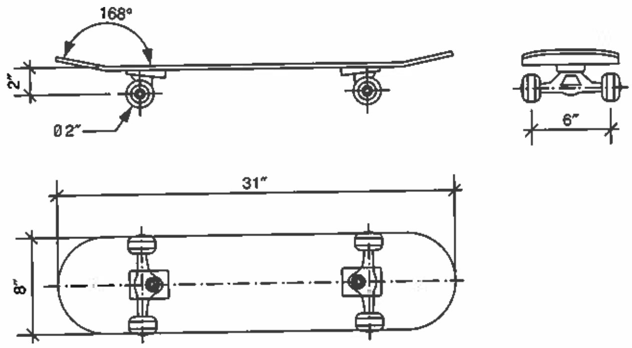


Figure 3-34. A scale drawing of a skateboard. In this case, the drafter included the bottom view instead of a top view because it shows more detail. Notice that the bottom view is placed below the front view in an orthographic drawing.

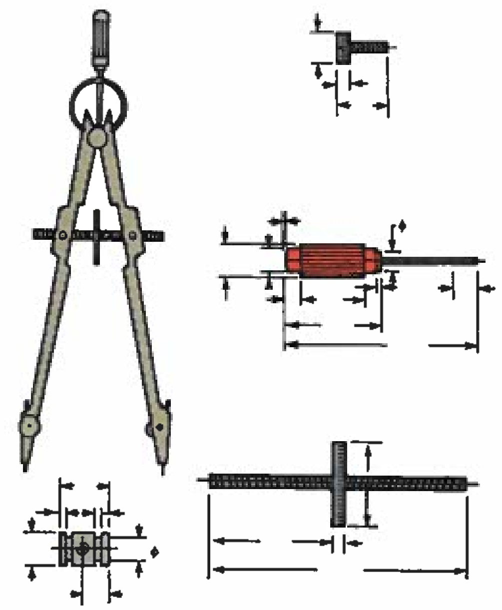


Figure 3-35. In this drawing, the compass is shown at full size (1:1). Because some of the individual parts are too small to see clearly at full size, they are shown separately, enlarged to a scale of 2:1.

Computer-Aided Design

In the past, people used the tools described previously in this chapter to create drawings. Now, however, very few drafters use drafting boards. They still need to know the types of drawings and how to construct them, but they make most drawings using computers.

This form of drawing is called *computer-aided design (CAD)*. A typical CAD system has three types of devices or parts:

- Input device—gives information or instructions to the computer.
- Processor—carries out the instructions.
- Output device—makes or displays the drawing.

Drawing commands are given by typing on a keyboard, selecting from a menu, or picking from a digitizing tablet. The designer can create the drawings, add details, and call up title blocks and other standard information. See Figure 3-36. Corrections can be made quickly. Also, nothing needs to be drawn more than once. Parts of a drawing that are used repeatedly can be stored in a file and loaded into the drawing when needed.

Other advantages of using a CAD system include the ability to rotate a 3D image and see it from various angles. CAD drawings can also be scaled up or down easily. In the case of a house, it can be viewed from any angle and the future owner can actually see how the finished building will look. In CAD programs designed for architectural drawing, the software can add the elevations (front and side views) automatically to a plan drawing (overhead view).

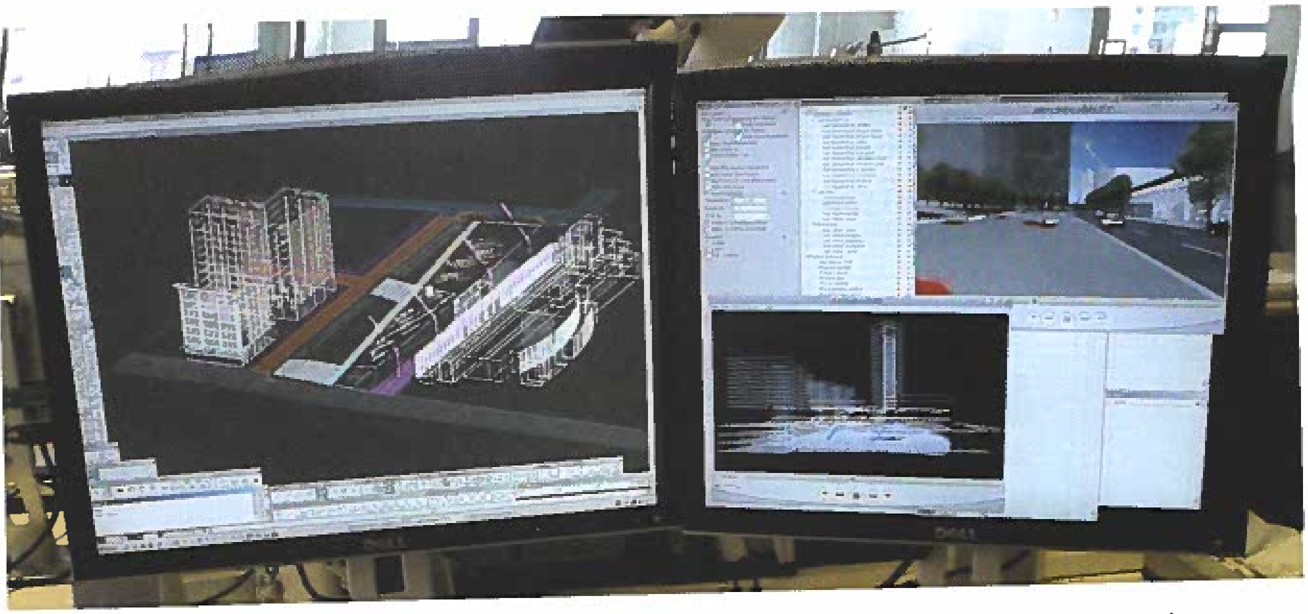


Figure 3-36. Computer-aided design can be used to develop complex drawings, such as these drawings of high-rise buildings..

The most advanced CAD systems create a virtual reality. ***Virtual reality*** is an artificial environment provided by a computer that creates sights and sounds in three-dimensional form. It is possible to do a virtual "walk-through" of a building to give the viewer a feeling of actually being in various rooms of the building. The viewer controls the path through the building and can look all around each room, up at the ceiling, down at the floor, or even out the windows. Virtual reality allows architects and engineers to spot errors before a building or device is built.

These advanced design systems have many advantages over drawing by hand. The computer works at high speed. The designer does not have to spend hours producing perfect line work and lettering. The CAD system makes them perfect the first time and every time, and it relieves the designer of repetitive tasks.

Some of the newer CAD programs integrate all aspects of designing, making, and supplying materials for a project. For example, an architect designing a building can find out, at any point, the cost of materials. The materials list can be sent directly to the building contractors, along with drawings and contract documents. Features like these leave more time for creative work. They also help all of the people working on the project communicate more effectively.

Other CAD programs link directly with computer-aided manufacturing software (CAD/CAM). Many types of CAD/CAM systems have been developed. In general, CAD/CAM systems allow computer-controlled machines to build parts from the information in CAD files.

Technology Application

Technical and Artistic Design

When you design a product or service, you need to keep in mind both function and appearance. Items must be solidly constructed, but they should also bring out feelings that make a potential buyer want to purchase them. For example, a potato peeler must peel potatoes easily and quickly, but it should also have an attractive shape that makes a user want to pick it up. A well-designed chair on display in a shop window must look like it can support its user and at the same time bring about a feeling that it could provide total comfort.

Technology Activity

Figure 3-34 is a technical drawing with details that would be used for its manufacture. If the skateboard were made using these measurements, it would probably work very well. However, it would not be very attractive. Your eye would not be drawn to look at it, because it lacks an interesting, appropriate design. It has a good shape and form, but it has no color or pattern. There is no sense of movement. It does not give the feeling that it would be a fast board if you were to buy it and use it.

Your task is to design a pattern that could be painted onto this skateboard. Follow these steps:

1. Draw the shape of the board to half scale on paper.
2. Ask yourself what design would give you a feeling of speed. How will this translate into the kind of pattern you will draw? Will it be geometric or a free-flowing design? Will it represent an actual object or will it be an abstract design? Will it be a traditional design or unconventional, like graffiti? It is your choice, but it must be appropriate for a skateboard!
3. Complete your pattern and present it to the class.

Concurrent Engineering

Concurrent engineering is a team effort that involves continuous communication among the entire design and production team from the very beginning of the design stage. The customer, project manager, and marketing staff also join in the process. Changes by any of these people are immediately passed on to others. Because of increased communication, concurrent engineering saves time. The product is produced quickly and meets the customer's needs.

3D Printing

Today, many industries use some form of *3D printing*. This term originally referred to small machines that could create plastic parts from a CAD file. Now, however, it can mean any system that uses *additive fabrication* to create a part from a CAD file. *Additive fabrication* is a long term that means the part is built by adding layer upon layer of plastic or metal powder. Design information is sent directly to the 3D printer. Here the data is numerically sliced into thin layers. The 3D printer then creates each two-dimensional cross section using a liquid, powder, or sheet material and bonds it to the previous layer. A complete part is built by stacking layer upon layer until the part is completed.

Specific 3D printing systems are often known by their output. For example, 3D printers that are used to create prototypes quickly during the design stage of product development are called *rapid prototyping (RP) systems*. See **Figure 3-37**. By using prototypes in real-life field tests, designers can better evaluate a product's strengths and weaknesses and avoid costly mistakes.

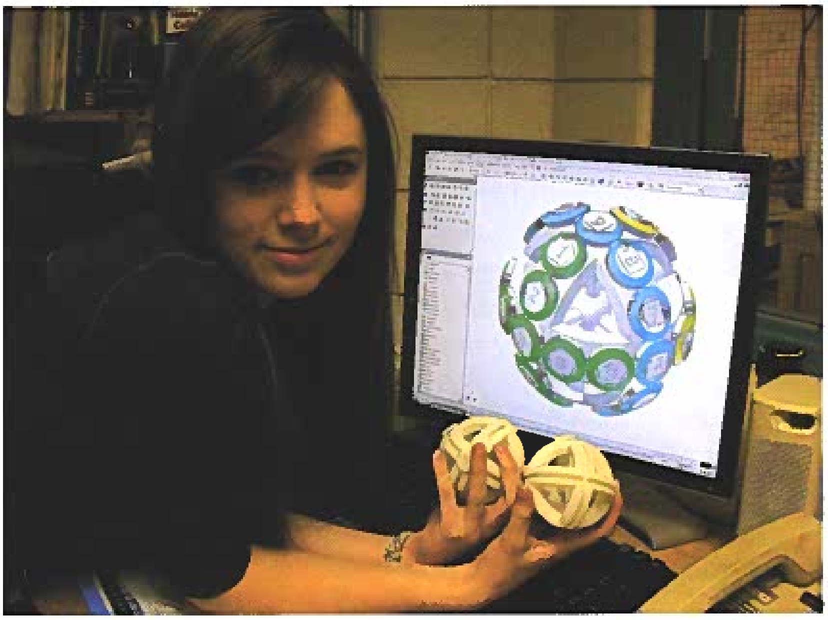


Figure 3-37. A student with her CAD file and 3D model of a three-dimensional puzzle she designed for the blind.

Some 3D printers can produce real parts that can be used in the actual products. These are called *rapid manufacturing systems*. This is an economical solution when only a few parts are needed. The manufacturer does not have to prepare expensive tooling. Instead, CAD information is sent directly to the 3D printer, which builds the part. A major advantage of these systems is on-demand manufacturing. The part is not manufactured until a customer orders it. This helps keep the manufacturer's costs down because no warehouse space is needed to store the part until it is purchased.

You do not have to own an expensive machine to take advantage of 3D printing technologies. 3D printers are becoming less expensive, and "personal" 3D printers are now available. See **Figure 3-38.** You can also create the CAD files and send them to a service provider for processing. The service provider has the machines capable of creating a part from your CAD files. For a fee, the service provider creates the part and sends it to you.

Figure 3-38. A personal 3D printer that builds physical models from CAD files.

End Note

Traditionally, drafters spent many hours creating exact drawings that could be used to manufacture a product. This process speeded up dramatically with the introduction of computer-aided drafting systems. Drawings could be more precise and took much less time to create.

3D printing has recently brought product design and manufacturing to a whole new level. They allow manufacturers to create a limited number of products for which demand is low. They no longer have to spend time and money creating the tooling to manufacture these products.

As 3D printer technology continues to improve, it will become more commonplace. You may even have a 3D printer in your home. In addition, scientists and technologists are considering 3D printing for applications such as organ transplants (bioprinting) and for home building, among others.

Summary

- The three basic types of communication technology are based on human hearing and sight.
- Many different forms of communication can be used to relay the same message.
- Design sketches can be isometric or perspective sketches. The purpose of a sketch determines which type you draw.
- Drawings created using orthographic projection contain all the views and information necessary to manufacture an object.
- Developing drawing techniques such as using the correct types of lines, dimensioning, and scaling drawings helps more people understand the message you want to convey.
- Freehand sketching remains an important skill for designers. However, computer-aided design (CAD) has replaced most types of manual drafting because it is faster and more accurate. Drawings and parts of drawings can also be reused, making this an efficient drafting process.
- Concurrent engineering is an efficient product development process in which all of the members of the design, development, and manufacturing teams are in communication from the very beginning of the project.
- 3D printing allows designers to experiment with prototypes. It also allows manufacturers to make low quantities of parts quickly and at a relatively low cost.

Reading Target

Preview and Prediction

Copy the following graphic organizer onto a separate sheet of paper. In the left column, record at least six predictions about what you will learn in this chapter. After you have read the chapter, fill in the other two columns of the chart.

What I Predict I Will Learn	What I Actually Learned	How Close Was My Prediction?

Test Your Knowledge

Write your answers to these review questions on a separate sheet of paper.

1. Name the three basic types of communication.
2. List at least three different forms of communication.
3. What is freehand sketching?
4. How many sides of a rectangular block are shown in an isometric drawing?
5. Which type of sketch provides the most realistic picture of an object?
6. What type of drawing describes the exact shape of each surface of an object?
7. What instruments are most commonly used in manual drafting?
8. Explain the process for creating a vertical line using a drafting triangle.
9. What is the alphabet of lines?
10. You have been asked to create a drawing of a printer that measures 14″ × 14″ × 8″. If you create the drawing at a scale of 1:2, how long will the overall length, width, and height lines be on your paper?
11. List the advantages of computer-aided design.
12. What is virtual reality?
13. Explain the concept of concurrent engineering.
14. What is a 3D printer?
15. What is the difference between rapid prototyping and rapid manufacturing systems?

Critical Thinking

1. Listen to a recording of whale or dolphin calls. Write an essay comparing and contrasting these calls to human speech.
2. Imagine that you are in a canoe in the middle of a large lake. You have been talking on your cell phone. While talking, you did not notice your paddle slip out of the canoe and float away. Unfortunately, you have run down the phone battery, so you can't call for help. You can see people on a dock at one end of the lake, but they do not seem to understand your shouts for help. How can you communicate a message for help?
3. Analyze the reasons for advances in drafting technology over the last 50 years. Prepare a report that answers the following questions. What factors or trends helped fuel the advances? What factors may have limited advances? Given the trends you have noted, what innovative technologies might you expect to be developed in the near future?
4. Write a persuasive paragraph explaining how the design of new communication technology does or does not depend on math and science skills.

Apply Your Knowledge

1. Create a symbol that can be used at a zoo to communicate the message: "Do not feed the animals!"
2. Design a logo (name or symbol) that you could use on your own personalized worksheets. Letters, geometric shapes, natural shapes, and simplified pictures are most appropriate for a logo.
3. Draw an isometric sketch, a perspective sketch, and an orthographic projection of a toothbrush.
4. Use a CAD system to make an isometric sketch of a tool you have used in the technology lab.
5. International Morse Code is a means of communication invented before telephone and e-mail. Check the symbols used. Then design a series of symbols that could be used to send a message by e-mail without using letters or words.
6. Research one career related to the information you have studied in this chapter. Create a report that states the following:
   - The occupation you selected
   - The education requirements to enter this occupation
   - The possibilities for promotion to a higher level
   - What someone with this career does on a daily basis
   - The earning potential for someone with this career

   You might find this information on the Internet or in your library. If possible, interview a person who already works in this field to answer the five points. Finally, state why you might or might not be interested in pursuing this occupation when you finish school.

STEM Applications

1. **TECHNOLOGY** In a group of four students, create a message to be transmitted to the rest of your class. Brainstorm ideas for ways to communicate the message. Develop as many of these ideas as possible. Use both electronic and nonelectronic methods. Present your message to the class in at least five different ways.
2. **ENGINEERING** In a group of four or five students, brainstorm ideas for a creative and futuristic communication system that may help solve current or future human needs. Select your best idea and present it to the class.
3. **MATH** Select an object you use or see every day. Using a tape measure or rule, measure the dimensions of the object very carefully. Create an orthographic drawing of the object using manual drafting or CAD techniques. If the object is too large or small to be shown adequately on paper, create a scale drawing. Include dimensions.

CHAPTER 4

Materials

Better by Design

Karim Rashid designed the Garbino2 and the Oh Chair

Karim Rashid is an industrial designer known for his work with new materials such as plastics, foams, and synthetic fabrics. Karim wants his work to inspire a sense of well-being through design. He thinks high-quality design should be accessible to everyone, not restricted to expensive, limited-run objects. He believes that an important aspect of good design is that it should be appealing to most people. His designs aim for the most simple, elegant shape that will meet the requirements of an object's purpose effectively and ergonomically.

The Oh Chair is a stackable chair that has a molded, high-impact polypropylene seat and powder-coated steel legs with nylon feet.

The "Garbino" can is molded from high-impact polypropylene.

"I want people to love objects the way they love clothing."
—Karim Rashid