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Chapter 10
Developing Design Solutions

Learning Objectives

After studying this chapter, you will be able to:

- Name the two major areas in which designers develop solutions to technological problems and opportunities.
- List the three main steps followed in developing technological designs.
- Identify the ways in which ideas can be stimulated when developing design solutions.
- Differentiate between kinds of design sketches.
- List the three major types of information required for detailed sketches when building models.
- Identify the three types of pictorial sketches used in product design.

Technological devices are designed to meet identified problems and opportunities. These problems and opportunities, as shown in **Figure 10-1,** can be divided into two major areas:

- System design problems and opportunities
- Product design problems and opportunities

No matter what the area, though, developing design solutions involves three major steps. We will discuss those steps after we differentiate between system design and product design.

System Design

System design deals with the arrangement of components to produce a desired result. For example, automotive braking systems are a result of system design efforts. Look at the drum brake system shown in **Figure 10-2.** This design brings together mechanical and hydraulic components into a speed-reduction system. The brake pedal unit is a mechanical linkage. When the pedal is depressed, a plunger in the master cylinder is moved. This motion causes the fluid to move in the hydraulic system that connects the master cylinder to the wheel cylinders. The fluid movement pushes the pistons outward in the wheel cylinders. These pistons are

attached to the brake shoes. The piston movement causes the shoe to be forced against the brake drum. This mechanical action creates friction between the shoe and the drum, which slows the automobile.

System design can be used in all technological areas. For example, it is an important part of construction technology, **Figure 10-3.** Electrical, heating and cooling, plumbing, and communication systems are designed for buildings. In manufacturing, the methods of production, warehousing, and material handling must be designed. Messages are carried over fiber optic and microwave communication systems. Transportation systems combine manufactured vehicles and other components to move goods and passengers from place to place. Irrigation systems are used to water crops. Pipelines are part of natural gas distribution systems. Doctors and hospitals provide patient care in health care systems.

Figure 10-1. Designers create both systems and products. (Harris Corp., Zenith Data Systems)

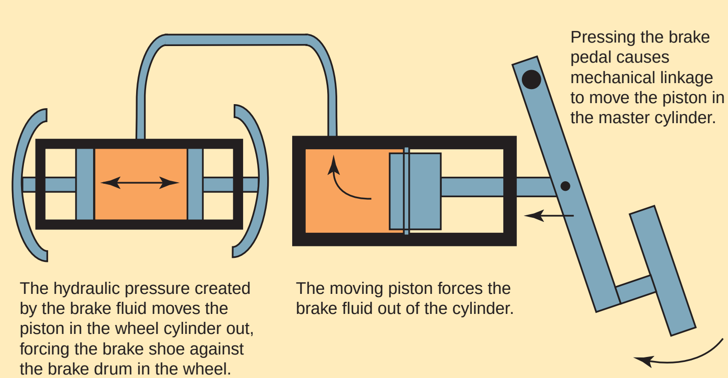

Figure 10-2. This brake system was the result of system design efforts.

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Product Design

Product design deals with two areas: manufactured products (involving designers) and constructed structures (involving architects), **Figure 10-4.** The goal of both activities is to develop a product or structure that meets the customer's needs. This task means that the product or structure must function well, operate safely and efficiently, be easily maintained and repaired, have a pleasant appearance, and deliver good value.

In addition, products and structures must be designed so that they can be produced economically and efficiently. They must also be sold in a competitive environment. In short, the product or structure must be designed for:

- Function: Easy and efficient to operate and maintain
- Production: Easy to manufacture or construct
- Marketing: Appealing to the end user

Developing Design Solutions

System and product designs start with a clear definition of the situation or opportunity. We learned the procedures for developing the definition in the previous chapter. This problem definition leads to the next step in product design—developing design solutions. These solutions often evolve through three steps, as shown in **Figure 10-5:**

- Developing preliminary solutions
- Isolating and refining the best solution
- Detailing the best solution

Figure 10-3. System designers devise heating and cooling, plumbing, communication, and electrical systems for buildings. (General Electric Co.)

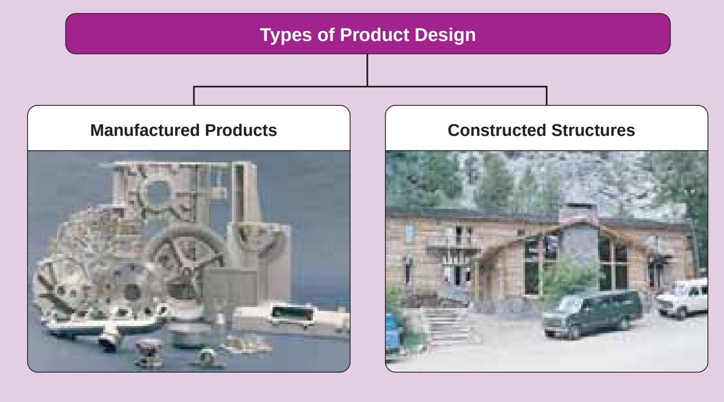

Figure 10-4. Manufactured parts and structures are designed using product design procedures.

This process can be described as "*imagineering.*" First, the designer uses his or her imagination to develop a number of unique solutions or designs. These solutions are then engineered back to reality through design refinement and detailing activities. The first step starts with broad thinking. This kind of thinking is called ***divergent thinking.*** It seeks to think of as many different (divergent) solutions as possible. The most promising solutions are then refined and reduced until one "best" answer is found. The refinement of ideas requires ***convergent thinking.*** The goal is to narrow and focus (converge) the ideas until the most feasible solution is found.

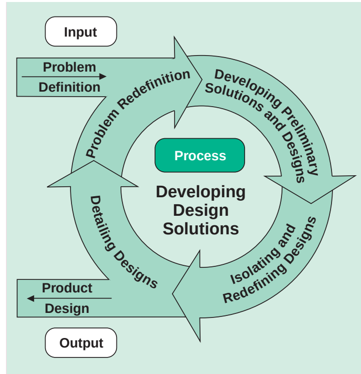

Figure 10-5. The process of developing design solutions evolves through three steps.

Keep in mind that the best solution may not be the one that works best or is the least expensive. As we noted earlier, criteria and constraints can compete with one another; trade-offs often occur among appearance, function, and cost. Many of us cannot always afford the very best answer. Our budget and the length of time we expect to keep the product enter into our product choices. For example, you might find it unwise to purchase a $900 racing bicycle because you are only going to use the bicycle to ride occasionally to the park. If you regularly ride a bicycle to work or go on cycling vacations, however, you

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might be able to justify the expense. Likewise, the "snapshot" photographer would probably not need the most expensive digital camera. The professional photographer would choose such a camera, however.

Product design activities produce a wide range of products. This variety allows the consumer to select one that meets his or her performance needs and financial resources.

Developing Preliminary Solutions

Designs start in the minds of designers, engineers, or architects. Ideas can be stimulated in various ways. Three popular techniques are brainstorming, classification, and "what if" scenarios. Then, after people have put forth their ideas, they record the ideas in rough sketches.

Brainstorming

Brainstorming is a process that requires at least two people, although most people find that having three or more participants in the process is usually more productive. ***Brainstorming*** involves seeking creative solutions to an identified problem. Members of the group offer individual solutions that they think will work. Proposed solutions will often cause other members of the group to think of more ideas. The strategy uses a concept called ***synergism***. It builds on the individual contributions of the participants to make a larger whole. The number of ideas generated by the group is more than the number they could develop if everyone worked alone.

Brainstorming activities work best when the group accepts some basic rules. These rules include:

- *Encourage wild, far-out ideas.* There are no "bad" or "stupid" ideas. Wild but promising ideas can always be engineered back to reality.
- *Record the ideas without reacting to them.* Many people will stop offering some of their ideas if they are criticized. To avoid criticism, they will provide only those ideas they think the group will like.
- *Seek quantity, not quality.* The chances of good ideas emerging are increased as the number of ideas increases.
- *Keep up a rapid pace.* A rapidly paced session will keep the mind alert and reduce the chance of judging the ideas.

Classification

Classification can be conducted by one person or a group of people. ***Classification*** involves dividing the problem into major segments. Then each segment is reduced into smaller parts. For example, buildings could be classified as business and commercial, homes, and industrial. Homes could be further classified as houses, apartments, and condominiums, for example. A house could then be classified by its major features: foundations, floors, walls, ceilings, roof, doors, windows, and so on. Foundations could then be classified as poured concrete, concrete block, wood posts, timber, and so on. This process might result in a classification chart. This type of chart is often developed as a tree chart with each level having a number of branches below it, as shown in **Figure 10-6.** It would end up looking much like a family tree that people use to trace their ancestors.

"What If" Scenarios

"What if" scenarios start with a wild proposal. Then its good and bad points are investigated. The good points can be used to develop solutions. For example, peeling paint is a problem for house painters. They must remove the old paint from a house before repainting. A wild solution would suggest mixing an explosive material with the paint before it is applied. Whenever the building is ready to be repainted the old

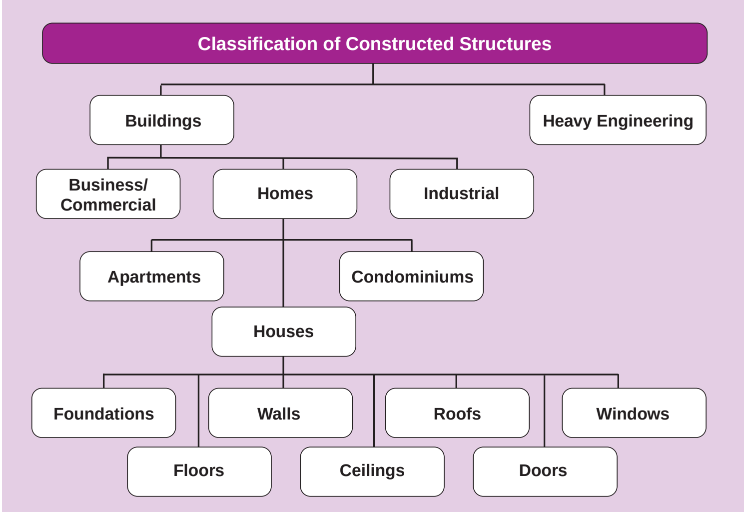

Figure 10-6. A classification chart divides the design problem or opportunity into segments to develop solutions more easily. This type of chart is called a tree chart.

paint could be blown off the building. Obviously, exploding house paint is ridiculous. The proposal, however, could lead to a solution. Paint sticks to a house through the adhesion between the paint and the siding. Maybe a material could be mixed with the paint that would cause it to lose adhesion when a special chemical is applied. At repainting time, the chemical could be sprayed on to loosen the paint. The paint could then be easily removed from the siding.

Rough Sketching

Once designers have conceived of a number of ideas in their minds they must record the ideas. The most common recording method is to develop ***rough sketches*** of the products, structures, or system components, as shown in **Figure 10-7.** These sketches are as much a part of the thinking process as they are a communication medium. Designers are forced to think through concepts such as size, shape, balance, and appearance. The sketches then become a library of ideas for later design efforts.

The term *rough* is not used to describe the quality of the drawing. Rough sketches are not necessarily crude. They often represent good sketching techniques. The term *rough* describes the state of the design ideas. It suggests that the designs are incomplete and unrefined.

Isolating and Refining Design Solutions

The rough sketches allow designers to capture a wide variety of solutions for the design problem or opportunity. The sketches are like books in a library: they

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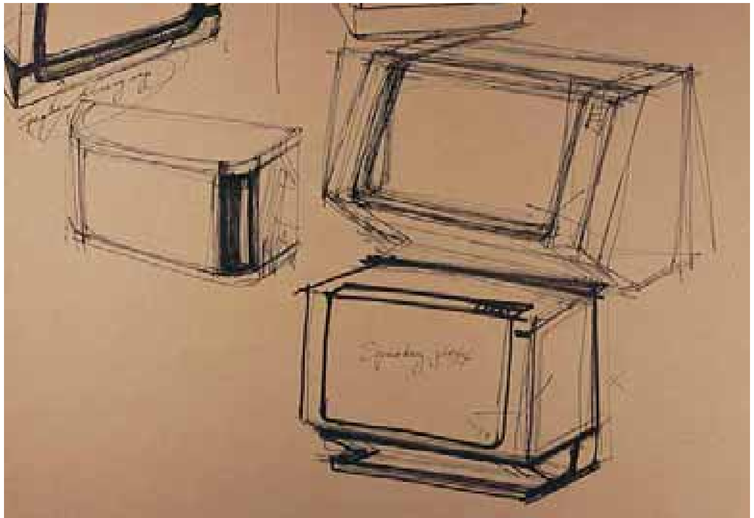

Figure 10-7. Designers develop rough sketches to record their ideas.

contain a number of different thoughts, views, and ideas. They can be selected, refined, grouped together, or broken apart.

Isolating and refining original designs in the "library of ideas" is the second step in developing a design solution, **Figure 10-8.** Promising ideas are chosen and then studied and improved. This process might involve working with one or more good rough sketches. The size and shape of the product or structure might be changed and improved. Details might be added, and the shape might be reworked. In short, the design is becoming refined as problems are worked out and the proportions become more balanced.

Refined design ideas might also be developed by merging ideas from two or more rough sketches into a ***refined sketch.*** The overall shape might come from one sketch, and specific details might come from others. This approach is one of integration, which blends the different ideas into a unified whole. The new idea may not look anything like the original rough sketches.

Detailing Design Solutions

Rough and refined sketches do not tell the whole story. Look back at the sketches shown in Figure 10-8. What size is the product in the sketch? You cannot tell. The sketches communicate shape and proportion. They do not communicate size. For this task, we need to add more details, and thus we need a third type of sketch, called a ***detailed sketch.*** It communicates the information needed to build a model of the product or structure. Detailed sketches can also be used as a guide to prepare engineering drawings for manufactured products and architectural drawings for

Figure 10-8. In this refined product sketch, the shape has been worked out and shading has been added to improve the looks of the sketch. (RCA)

constructed structures. Engineering and architectural drawings will be discussed in Chapter 12.

Detailed sketches are helpful when models of products or structures are made. Building models requires three major types of information. These types, as shown in **Figure 10-9,** are:

- *Size information:* Explains the overall dimensions of the object or the size of features on an object. This information might include the thickness, width, and length of a part, the diameter and depth of a hole, or the width and depth of a groove.
- *Location information:* Gives the position of features within the object. This information may establish the location of the center of a hole, the edge of a groove, or the position of a taper.
- *Geometry information:* Describes the geo-

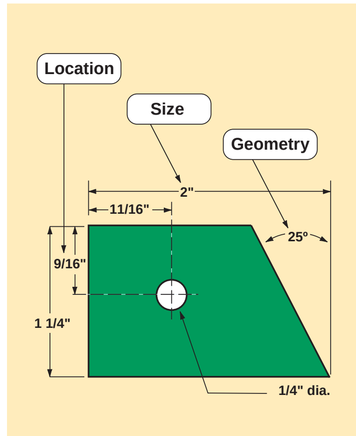

Figure 10-9. The types of information provided on detailed sketches are size, location, and geometry.

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Connections to Technology: **Mathematics**

Solid Geometry

Designers should be familiar with some basic geometric concepts in order to create effective pictorial sketches. Designers use the concepts of solid geometry, for example, when drawing such three-dimensional images as pyramids, cones, cylinders, and cubes.

A pyramid, to use the first example, is a solid figure with a *polygon* as a base. A polygon, as you might recall from earlier geometry lessons, is a closed plane figure bounded by three or more straight lines. (The word *polygon* comes from the prefix poly-, meaning many, and the suffix *-gon,* meaning angle. Thus a polygon is a many-angled figure.) The faces (surface) of the pyramid are triangles with a common vertex, or point where they intersect.

In a regular pyramid the base is a regular polygon, and the faces are *congruent* triangles. Again, as you might remember from earlier geometry, congruent means equal in size and shape.

The other three-dimensional images share some characteristics but differ in others. For example, in what way or ways is a cone like a pyramid, and in what way or ways is it different?

metric shape or relationship of features on the object. This information could communicate the relationship of intersecting surfaces (square or 45º angle, for example), the shapes of holes (rectangular or round, for example), or the shapes of other features.

Designers often use pictorial sketching techniques to capture and further refine product design ideas. These techniques try to show the artifact much like the human eye would see it. Therefore, a single view is used to show how the front, sides, and top would appear.

Designers produce three different kinds of pictorial sketches when refining ideas. These sketches are:

- Oblique sketches
- Isometric sketches
- Perspective sketches

Oblique Sketches

Oblique sketches are the easiest pictorial sketches to produce. ***Oblique sketches*** show the front view as if a person was looking directly at it. The sides and top extend back from the front view. They are shown with parallel lines that are generally drawn at 45º to the front view.

To produce an oblique sketch, the designer completes steps like those shown in **Figure 10-10.**

1. Lightly draw a rectangle that is the overall width and height of the object.
2. Lightly extend parallel lines from each corner of the box back at 45º.
3. Lightly mark the extension lines at a point equal to the depth of the object.
4. Lightly connect the depth lines to form a box.

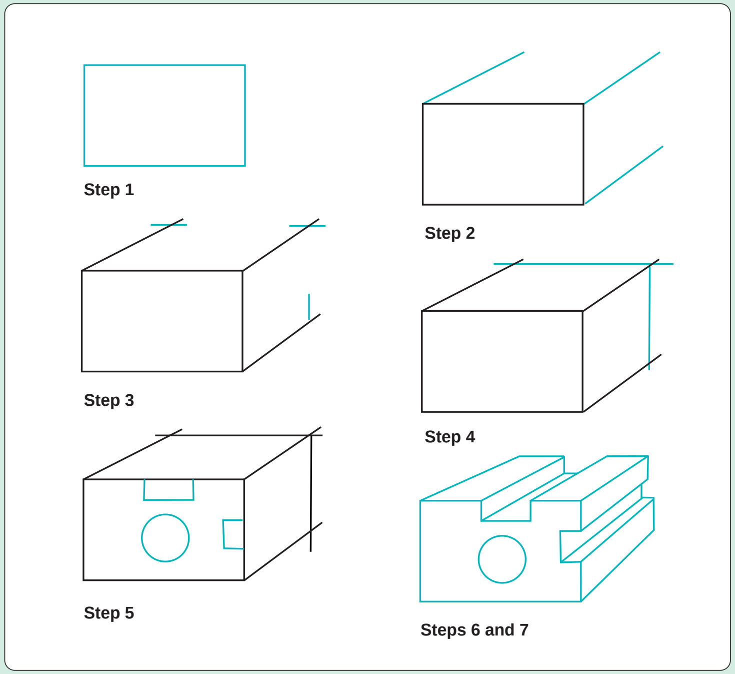

Figure 10-10. Designers create oblique sketches through a series of steps.

5. Add any details such as holes, notches, and grooves onto the front view.
6. Extend the details the depth of the object.
7. Complete the sketch by darkening in the object and detail outlines.

The procedure listed above will produce a cavalier oblique drawing. This type of drawing causes the sides and top to look deeper than they are. To compensate for this appearance designers often use cabinet oblique drawings, as shown in **Figure 10-11.** This type of drawing shortens the lines that project back from the front to one-half their original lengths.

Isometric Sketches

Isometric sketches are the second type of pictorial drawings used to produce refined sketches. The word *isometric* means equal measure. ***Isometric sketches*** get their name from the fact that the angles formed by the lines at the upper-right corner are equal—each is 120º.

Designers use isometric sketching when the top, sides, and front are equally important. The object is shown as if it were viewed from one corner.

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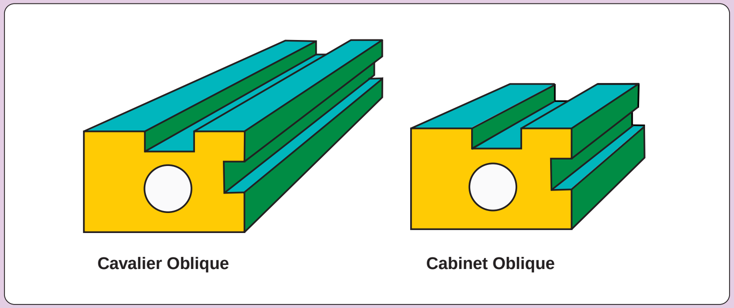

Figure 10-11. The two types of oblique drawings are cavalier oblique and cabinet oblique. Cabinet oblique drawings use one-half the depth of the object for a more natural appearance.

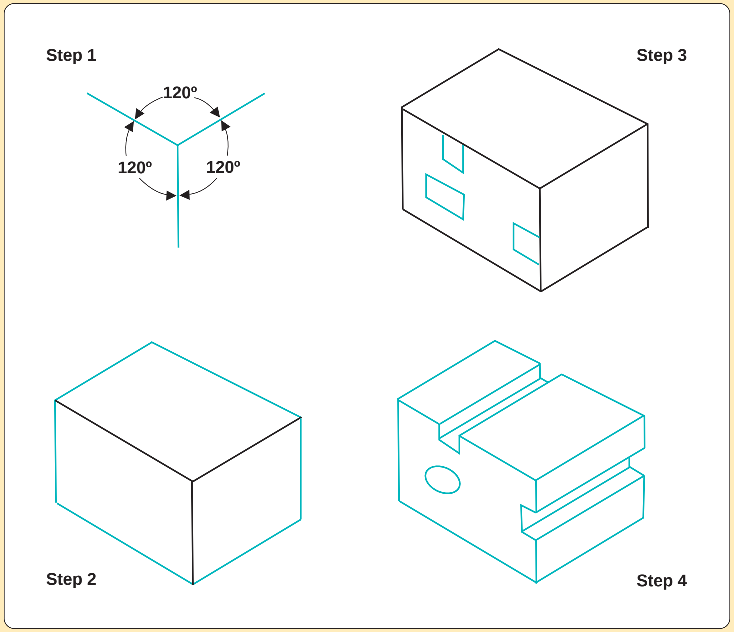

Figure 10-12. Designers follow four major steps when creating isometric sketches.

Designers follow four major steps when producing an isometric drawing. These steps, as shown in **Figure 10-12,** are:

1. Lightly draw the upper-right corner of an isometric box that will hold the object.
2. Complete the box by lightly drawing lines parallel to the three original lines.
3. Locate the major features such as notches, tapers, and holes.
4. Complete the drawing by darkening the features and darkening the object outline.

Perspective Sketches

Perspective sketches show the object as the human eye or a camera would see it. This realism is obtained by having parallel lines meet at a distant vanishing point. If you look down a railroad track you will see a similar effect. The rails remain the same distance apart, yet your eye sees them converge (come together) in the distance.

Three major types of perspective views exist: one point, two point, and three point. The difference between these types is determined by the number of vanishing points used, **Figure 10-13.**

A one-point perspective shows an object as if you were directly in front of it. All the lines extending away from the viewing plane converge at one point. The one-point perspective is like an oblique drawing with tapered sides and top.

A two-point perspective shows how an object would appear if you stood at one corner. It is constructed much like an isometric drawing. Again, the sides are tapered as the lines extend toward the vanishing points.

A three-point perspective shows how the eye sees the length, width, and height

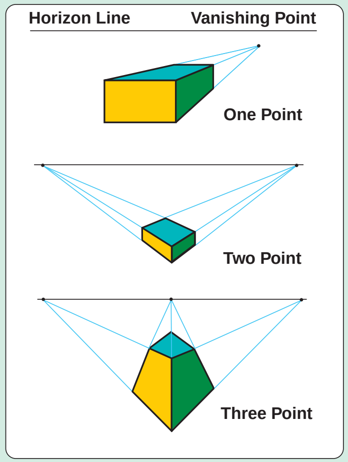

Figure 10-13. The three types of perspective drawings are one point, two point, and three point.

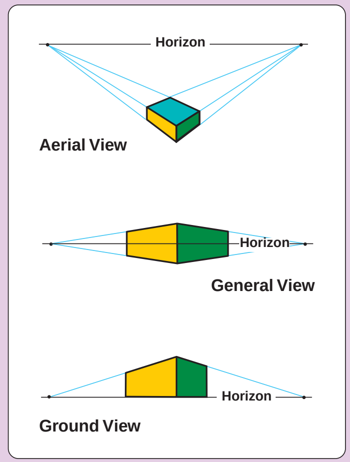

Figure 10-14. Changing the location of the horizon changes the appearance of a perspective drawing.

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of an object. All lines in this drawing extend toward a vanishing point.

The appearance of a perspective drawing changes as the horizon changes, **Figure 10-14.** Changing the position of the horizon line can cause the object to be seen as if the observer was looking down on the object (aerial view), directly at it (general view), or up at it (ground view). The designer must decide which of these views best suits the object and the audience who will see the sketch.

When developing the basic structure for one-, two-, or three-point perspective sketches, designers follow the same basic steps. These steps, as shown in **Figure 10-15,** are:

1. Establish the horizon line, vanishing point(s), and the front of the object. Connect the front line(s) to the vanishing point(s).
2. Establish the depth of the objects along the lines that extend to the vanishing point(s).
3. Connect the depth lines to the vanishing point(s). Darken in the object.

Designers then add details to complete the sketch. Perspective sketches are often shaded to add to their communication value.

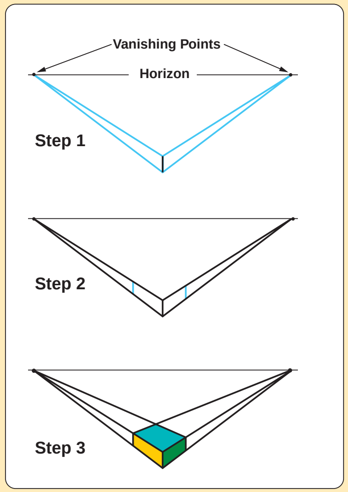

Figure 10-15. Designers follow three basic steps in developing perspective sketches.

Developing the perspective, or "human eye" view is more difficult than developing the oblique or isometric views. Note, however, that perspectives are the most realistic of the three pictorial sketches.

Summary

Design problems and opportunities in technological areas can be divided into two major areas: systems and products. System design deals with the arrangement of components to produce the desired result. Product design deals with manufactured products and constructed structures. In both system and product design, though, designers must first study the definition of the problem or opportunity before developing design solutions. Then, they must generate a number of possible solutions and create rough sketches of their ideas. These sketches become a library of design ideas. From this library, designers select specific ideas and refine them to bring the solution into focus. Finally, they describe the refined ideas through detailed sketches.

Key Terms

brainstorming
classification
convergent thinking
detailed sketches
divergent thinking
isometric sketches
oblique sketches
perspective sketches
refined sketch
rough sketches
synergism
"what if" scenarios

Test Your Knowledge

Write your answers on a separate piece of paper. Please do not write in this book.

1. What are the two major areas in which designers develop solutions to technological problems and opportunities?
2. List the three steps followed in developing design solutions.
3. What is the difference between divergent and convergent thinking?
4. *True or false?* The best solution is always the one that is the least expensive.
5. Name one of the rules used for effective brainstorming.
6. Define the term "classification" as it is used in developing design solutions.
7. What is a "what if" scenario?
8. Describe the difference between rough sketches, refined sketches, and detailed sketches.
9. List the three types of information required in detailed sketches when building models.

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For Questions 10–18, match the type of pictorial sketch on the right to the correct definition on the left. (Note: Some letters will be used more than once.)

Definition	Pictorial Sketch
10. _____Used when the top, sides, and front are equally important	a. Oblique
11. _____Shows the object as the human eye would see it	b. Isometric
12. _____Sides extend back at 45°	c. Perspective
13. _____The angles formed by the lines at upper-right corner are equal	
14. _____Shows front view as if you were looking at it	
15. _____Most difficult of three sketches to develop	
16. _____Parallel lines meet at distant vantage point	
17. _____Always has one corner made up of three 120° angles	
18. _____The two types are cavalier and cabinet	

19. What is the primary difference between one-point, two-point, and three-point perspective sketches?
20. *True or false?* The appearance of a perspective drawing will change as the horizon changes.

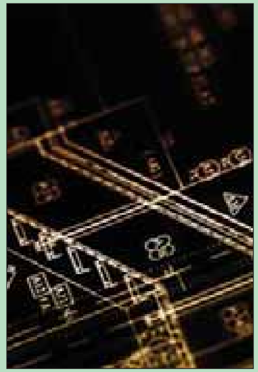
Applying Your Knowledge

1. Develop a set of rough sketches for the following design definition:

> Problem or opportunity: The director of the school cafeteria would like a holder that would contain a salt shaker, a pepper shaker, twenty rectangular (1″ x 1 1/2″) packages of sugar, and a bottle of ketchup. The holder should be easily removable from the table at the end of the lunch period.

2. Refine the best sketch that you produced for the lunchroom table organizer.
3. Develop a detailed sketch for your lunchroom table organizer.
4. Select a device in the technology laboratory and develop a perspective sketch of it.

Career Corner
Drafters



Drafters prepare engineering and architectural drawings and plans that manufacturing and construction workers use. They communicate technical details using rough sketches, drawings, and specifications. Most drafters use computer-aided design (CAD) systems to prepare their drawings. There is a number of different types of drafters, including aeronautical, architectural, electrical and electronic, and mechanical drafters.

Many drafting positions require postsecondary school training in drafting, which can be acquired at technical institutes, community colleges, and four-year colleges and universities. Entry-level drafters usually do routine work under close supervision. More experienced drafters do difficult work with less supervision.