INTRODUCTION TO TECHNOLOGY & ENGINEERING

(Adapted from AMSCO *MCAS Science & Technology/Engineering*)

Materials, Tools, and Machines

You have wanted a dog for a long time. After demonstrating to your parents that you are responsible enough to feed, train, and take care of a pet, they finally agreed to go to the local animal shelter to pick out a puppy. Home with your new puppy, you and your parents realize that he is going to need a doghouse, so you decide to build one. It is important to start this project correctly, so you need to plan what to do.

One of the first things you have to determine is what type of materials and tools are available that you will need to complete the project. Knowing what materials and tools are available for a project is an important first step in planning any project.

Choosing the Right Material

You have decided to build the doghouse and have chosen its location in your backyard. What are the best materials you can use to shelter your puppy? The following is a list of materials and how they are appropriately used, based on their characteristics and properties. You carefully consider this list.

- *Wood*—Wood has many uses in construction. Many homes are framed with pine. Flooring, cabinetry, or furniture may be made of hard woods such as cherry, maple, oak, or walnut. Recently, the trend has been to use bamboo as a building supply, especially for floors, because of its durability. Wood is a renewable resource and is used in many applications.
- *Paper*—Paper is used for writing and the packaging of materials. Most of the time, paper is made from wood pulp. Newer methods use recycled materials to make paper. As a building material, paper is limited in its use because it is easily destroyed when exposed to moisture.
- *Plastic*—Plastics are polymers. Polymers are chemical compounds that are created in a laboratory or factory. Plastic is strong, durable, flexible, and easily molded into different shapes. Plastics have different uses in construction. They are used in products such as vinyl siding and appliances within a home. Plastics may also be shaped into forms that are used to attach different materials together.

- ***Aggregates***—When discussing construction material, the term aggregate refers to materials such as sand, stone, and gravel. Aggregates are used in materials such as concrete and asphalt. Aggregates form a strong, sturdy base for many construction projects.
- ***Ceramics***—Ceramics are products (such as bricks, tiles, porcelain, and earthenware) made from nonmetal materials (such as clay) that are formed by a manufacturing process using high temperatures. Ceramic materials have many applications in construction.
- ***Metals***—Metals, such as steel, aluminum, chrome, titanium, gold, and silver, have different applications in the building process. Steel is an alloy made of iron, which is used in the structural frames of buildings, very tall buildings in particular. Titanium is also used for structural uses, but it is expensive. Other metals are used only for decoration and ornamentation, due to their properties and high costs. The use of metals in construction is beneficial, because they are usually lightweight, strong, and able to be shaped (malleable).
- ***Solvents***—A solvent is a substance, typically a liquid or a gas, that will dissolve another substance. Water is a well-known solvent. Many substances, such as salt and sugar, for example, will dissolve in water. However, many solvents used commercially release toxic fumes and must be used in well-ventilated areas, and away from open flames. Solvents are commonly used in paints and paint thinners.
- ***Adhesives***—An adhesive is a type of compound that is used to join two substances together. Adhesives can be natural or synthetic. Adhesives are used in construction and other manufacturing processes.
- ***Shingles***—Shingles are another material you might consider to use on the roof of your doghouse.

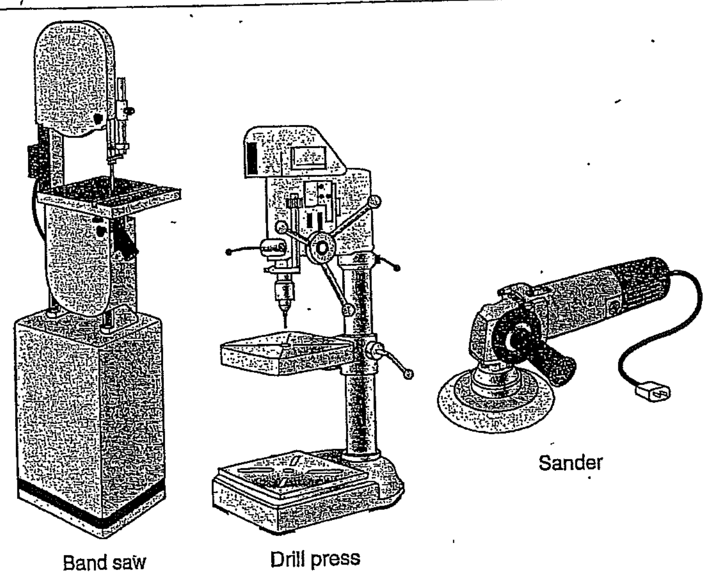
Your decision? You think wood may be a good choice for your doghouse. It is relatively inexpensive, available in many stores, and is easy to work with. A doghouse could be built out of sturdy cardboard, but this is not a good idea unless the doghouse is inside and not exposed to various weather conditions. It is possible that you may need to use some plastic parts in your doghouse. These may be in the form of plastic ties, or some sort of covering for the roof. Chances are the plastic materials you use will already be shaped and pre-cut into the size you need. Depending on how permanent you want your doghouse to be, you may wish to add a base of aggregate material before building it. You could consider constructing part of the roof of your doghouse out of metal, but you would want to make sure it was located in a shady area. A metal roof, without proper ventilation, could make the interior of the doghouse too hot. If you decide to paint your final product—your doghouse when it is complete—it would be a good idea to do it outside in the backyard. This also allows you to customize the doghouse. And it is possible that you will use glues to assemble parts of the doghouse.

Tools

So, now that you have thought about the materials you will need to build your doghouse, what tools will you need? A tool is a device that helps you do your job. Tools come in all shapes and sizes, and most have very specific applications. A few of the more commonly used tools are listed below. Notice that some tools may be used for measuring, some are hand tools that need no electricity, and some are machines that use electricity. The size and type of tools you choose to use will depend on the size and type of the job you need to do. (See Figure 12-1.)

- *Band saw*—A band saw is a cutting tool with a thin, long, flexible blade. Band saws are often mounted on a table. They can also come in handheld models. Band saws are used in metal working and woodworking. They are particularly useful for cutting materials into irregular shapes.
- *Drill press*—A drill press is a tool used for making holes in hard materials. The drill usually is held on a spindle above the material in which the hole is to be drilled. The material is clamped to a table to prevent it from slipping. The drill press is lowered and raised by a lever.
- *Sanders*—Sanders are usually used to smooth wood or metal. Some may be handheld, while others are larger and are mounted onto a large table. Sandpaper can be attached to the sander. When using a sander (and many other tools), you should wear a dust mask to prevent dust from entering your lungs. You should also wear eye protection, such as goggles, to prevent dust or pieces of wood from entering your eyes.

Figure 12-1. *Some commonly used tools.*

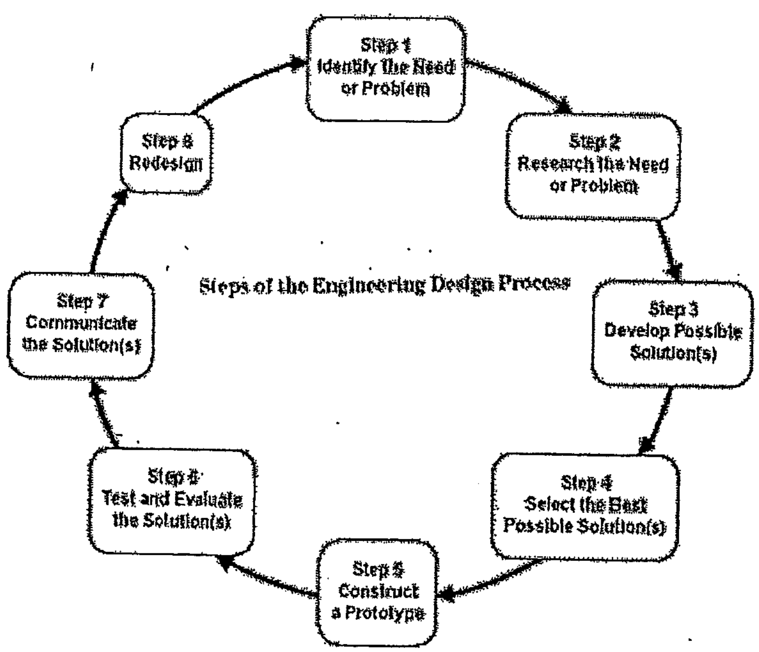


So, what tools do you think you will need to build your doghouse? Since most doghouses are square without a lot of curves or fancy woodworking, you most likely will not need to use a band saw. You may need to use a drill press or a hand drill to drill holes in the wood in order to attach the pieces of wood together or mount a sign on your doghouse. To make a comfortable home for your puppy, you may want to sand down the rough edges on the boards so the puppy—and you, too!—won't get splinters and cuts.

Some other common tools that you will probably need are a hammer (eye protection is recommended when using hammers and solvents), paintbrushes, screws (for wood and metal), a screwdriver, a pair of pliers, a tape measure, and nails.

Engineering Design

You have decided to build a doghouse in the backyard for your new puppy. After some consideration, you have decided to build your doghouse out of wood. You also have decided to use some discarded vinyl siding for the sides of the doghouse, and some discarded asphalt shingles on the roof. Your parents have the tools you need for the project and have agreed to help you use them. You are ready to design it.



The Design Process

You have now entered into what is called the design process of a construction project. When entering into the engineering design process, the following series of steps should be followed:

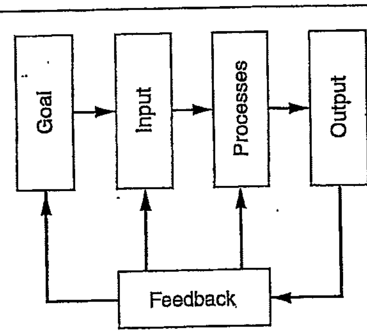
1. **Identify the need or problem.** It is important to make sure that the need or problem you are about to tackle is real. Spending time, money, and resources on a problem that does not need to be solved is a waste of those resources. With your doghouse project, you have already done this. You know you need a place for your dog to sleep and stay while it is outdoors.
2. **Research the problem.** It is necessary to know the issues surrounding the project you are about to begin. You might consider looking at some other doghouses in your neighborhood, talking to your local pet store owner, or consulting some websites dedicated to caring for dogs, or some companies that build doghouses.
3. **Develop possible solutions.** Brainstorming various solutions and techniques will help you pinpoint the plan of attack you should follow. You and your team (your parents and your brother) need to discuss what type of features the doghouse needs. Does it need to have a window as well as a door? Does the roof need to be three feet or four feet high? (How big will your puppy be when fully grown?)
4. **Select the best possible solution, or solutions.** Keep an open mind. There may be more than one solution to your problem. Consider combining ideas from several plans to come up with the best plan. Now that you have identified what features your doghouse should have, you need to set about making the plans for the actual structure. Try to include all the features that your entire team identified as necessary.
5. **Construct a *prototype*.** That is, build a model of your design. This will not only help you locate weaknesses of the design, but it also can be used to show the design to other people who might also be interested in building a doghouse.
6. **Test and evaluate the prototype.** Make sure that your design accomplishes its goal. In this case, you may want to build a smaller-scale doghouse out of similar materials so you can see not only how it will look, but also to make sure it will accomplish its purpose. For example, you could leave it out in the rain to make sure that the materials do not leak, or you could leave it out in the hot sun to make sure that the interior does not get too warm.
7. **Communicate the solution.** Present your solution to others. Be prepared to promote your idea to other team members. For example, you want to use a special waterproof material for the doghouse roof.
8. **Reevaluate and redesign if necessary.** At this point, it is still possible to tweak or adjust your design if you feel it is necessary. To fix the leaking roof, you may have to redesign a new one out of a different material.

Universal Systems Model

A **universal systems model** will help you and your team come up with a design or product that will suit the needs of the project. The parts of a universal systems model work together to meet the goals of a proposed project. There are five elements to a universal systems model. They are the goal, inputs, processes, outputs, and feedback. These steps are outlined below and shown in Figure 12-2.

1. The *goal* of your project is to create a shelter for your new puppy. This shelter should be able to be outside, be waterproof, and be large enough to hold the puppy when it is fully grown.
2. The *inputs* of a project are the various elements and resources that must come together to get a project started. They include: the materials to be used, the necessary tools, the human resources needed to complete the project, the funding for the project, the time for it to take place, and the motivation to get the job done.
3. The *processes* of the project occur when the inputs are arranged and assembled to make the project happen.
4. The *output* is the final completed project. This will be the doghouse that you have designed and built.
5. *Feedback* is a system set up to monitor the project to ensure that the original goals have been met. Feedback should be given throughout the project to ensure that the project is on track. In this way, any possible problems can be dealt with when they occur. You should be constantly talking to your parents and your brother as you build your doghouse to make sure it is being built according to the plan you all agreed to. Is it tall enough? Is the type of wood you chose sturdy enough? Is the door in the right place and large enough? What about the window? Is it high enough?

Figure 12-2. *The universal systems model. Feedback should occur at every step of the process.*



Representing Your Design

In the planning stages of a new product or device, it is necessary to create plans or drawings to illustrate your design. There are several ways to do this. The first option is to produce a sketch. A sketch is a rough drawing of the design. A sketch of your doghouse is shown in Figure 12-3. The sketch should highlight the major features, dimensions, or sizes, but it will not necessarily be drawn to scale or include all the minor details.

Another way to represent the solution to a particular design problem is to produce an orthographic projection. This is a way to show a 3-D object in only two dimensions. Figure 12-4(a) on page 276 shows an orthographic projection of a simple rectangle. Notice that the orthographic projection shows each side of the three-dimensional rectangle. It is almost as if you were able to cut along the sides of the rectangle and then lay it flat on the table.

Figure 12-4(b) on page 276 shows the orthographic projection of the doghouse. Notice how the orthographic projection highlights the different sides of the doghouse. In this form, it is possible to see the shapes and relative sizes of each of the pieces of the doghouse.

It also may be helpful to represent your design with multi-view drawings. Multi-view drawings show various aspects of the project. When constructing a new home, you can prepare multi-view drawings to show the floor plan, the plumbing, the electrical system, and the framing plan. The multi-view diagrams of your doghouse might include a materials plan, a floor plan with dimensions, and a framing plan. (See Figure 12-5 on page 276.)

Representing Your Prototype

Once you have decided on your design for your new product or device (in this case your doghouse), you then build a prototype. A prototype is a

Figure 12-3. *A sketch of a proposed doghouse.*

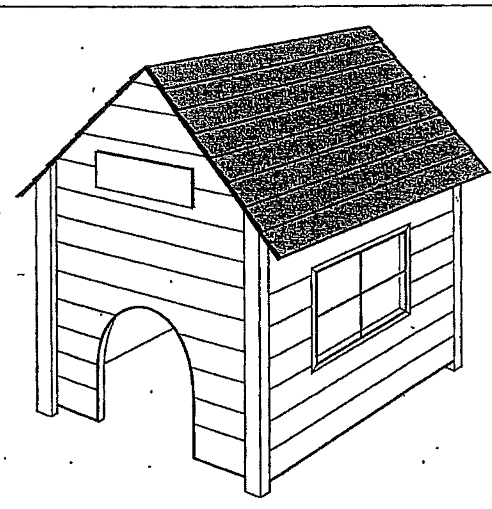
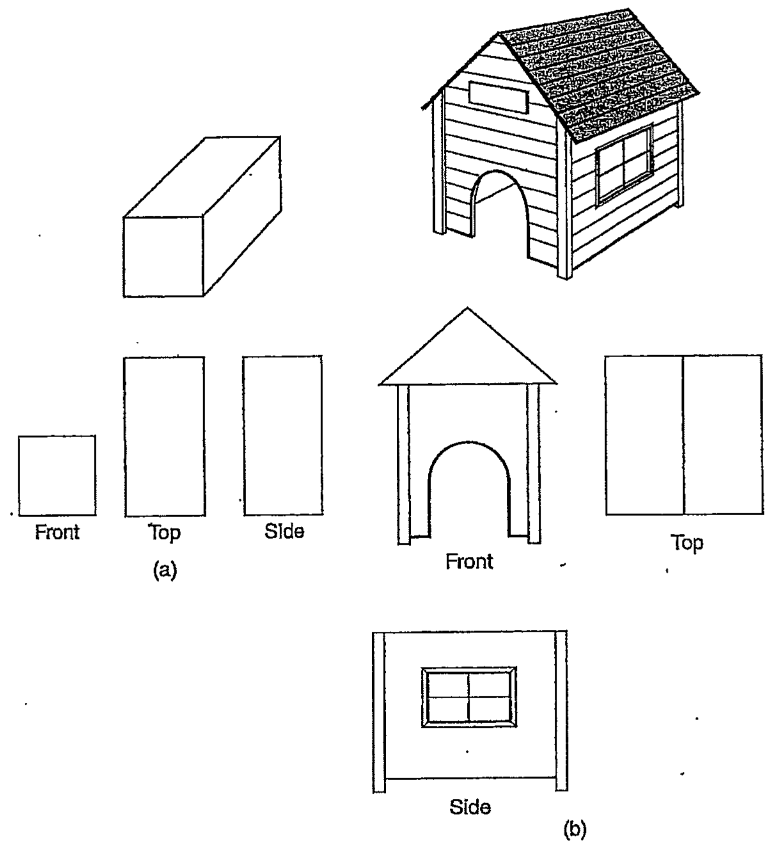
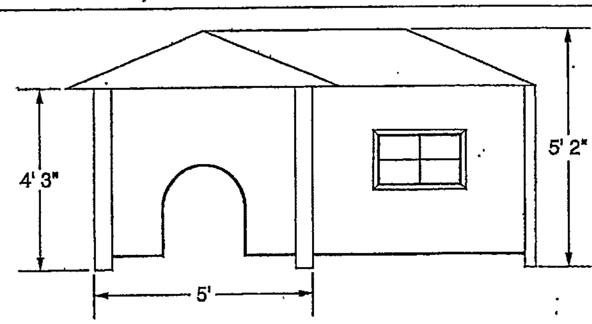


Figure 12-4. *Orthographic projections of (a) a rectanglar box and (b) a doghouse.*



working model of the actual product. A prototype can be used as a test to see if the product will work the way in which it is intended. Sometimes, a prototype may be a smaller version of the end product.

Figure 12-5. *This floor plan of a doghouse shows just one aspect of the project. In a real home, you would also view drawings of the plumbing and electrical systems.*



Generally, when considering the idea of constructing any prototype, you should consider the following factors:

- the size, shape, and weight of the prototype
- the ultimate purpose of constructing the prototype
- the cost of construction of the prototype

You and your team (your parents and your brother) will need to look carefully at these factors to determine if a prototype of the doghouse is worth building. For example, will the cost be reasonable? Will it help you pinpoint problems before you construct the final product? Do you have enough time and materials to build a prototype? On the other hand, a detailed and thoughtful prototype will help ensure that the final product is successful.

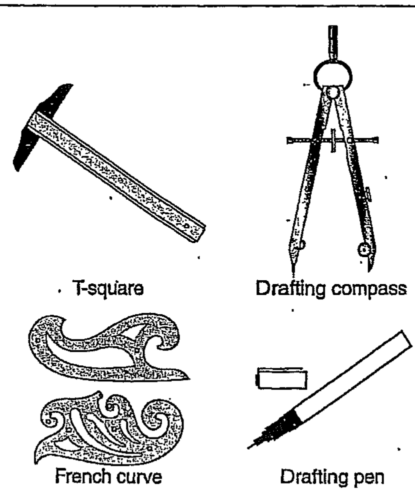
Producing Design Solutions

The more you and your family work on the doghouse, the more you like the design. You begin to think that other people with new puppies might be interested in using it, too. You want to communicate your ideas and show your design to them. But how? There are a number of different tools, machines, and electronic devices that are used to create, produce, and communicate designs.

The easiest and quickest way to communicate your ideas and products to others is to use a digital camera. Digital technology has made cameras affordable, easy to use, and an effective tool for passing along information.

Often, companies use drawing tools to produce a set of engineering drawings. Drawing tools include a sliding ruler called a *T-square*, a technical pen, compass, and French curve. (See Figure 12-6.)

Figure 12-6. *Tools used to make engineering drawings.*



Today, many engineers and drafts people create engineering plans and designs and technical drawings with ***c**omputer-**a**ided **d**esign* (CAD), a software system used on a computer. CAD is also used to show the probable motion of objects, or it might be used to show how air flows over objects, for example, the flow of air over a wing of an airplane when it takes off. (See Figure 12-7.)

Figure 12-7. *This Boeing employee is using CAD technology.*

Manufacturing Technology

You and your team (your brother and your parents) built a doghouse for your new puppy. The puppy seems comfortable there, and your neighbor noticed the doghouse. He asked if you would build one for his dog. Other neighbors began inquiring as well, and then suddenly, you found yourself in business. The orders for the doghouse have been rolling in, and you are starting to get special orders for doghouses of different sizes, shapes, and of various materials. Publicity spread by word-of-mouth, and you also placed an advertisement in the local paper. Soon you are getting more orders than you and your team can handle. What should you do now?

The problem you are facing is a good one to have, and is one faced by many small businesses that are experiencing success and must produce more goods to meet growing customer demand. Often they turn to manufacturing technology to help them solve this problem. These technologies, discussed in the following sections, can streamline the production process and make a business more productive.

Mass and Custom Production

One of these technologies is the use of mass production. ***Mass production*** is the way in which goods or products are made in great quantities at the same time in the same location. As a result, the cost to the consumer is kept down. Many mass production operations involve an ***assembly line,*** where people, or robots, work at a particular stage in the assembly process. Each part is assembled by a series of workers, eventually creating one finished product. The automobile industry was one of the first to use mass production practices and assembly lines to create numerous, identical automobiles at low cost.

The manufacturing process of mass-produced goods is often made easier with the use of ***interchangeable parts***. These are parts or tools that can fit in several places within a product, or they can be used in similar products as well. When you think about interchangeable parts, think about a replacement part that you can purchase at a store. For example, you can go to the store and buy a set of windshield wipers for your car. These will fit your car, and many other cars. The windshield wipers are an interchangeable part. This idea transformed the manufacturing process. Prior to the introduction of interchangeable parts, if a piece of equipment broke, then the entire equipment would need to be purchased. In other words, you couldn't just buy the windshield wipers; you'd either have to buy a whole new car or drive with broken windshield wipers. (In our doghouse example, if the doghouse had a door, and the door broke, your customers could buy a new door without having to buy an entire new doghouse.) The introduction of the concept of interchangeable parts also made it possible to solve other production problems as well.

Custom production is quite different from mass production. In a *custom production* setting, each piece is created individually. The end product may be tailored to an individual plan or goal. As a result, not as many products can be produced, and costs are usually higher for the consumer. The consumer may have more input in the design of the product, however. Many woodworkers make custom furniture. Each piece of furniture is individualized and can be tailored to specific needs or tastes. You may have seen ads on TV that allow people to customize the cars they want right on their computers. (In your doghouse business, since there are many different sizes of dogs, some of your customers may want a bigger doghouse than others.)

The Manufacturing Organization

There are many people who have to work together to create, produce, and distribute a product. All these employees and their roles create the *manufacturing organization*. A manufacturing organization follows a corporate structure. In this corporate structure, there is a division of labor. Each individual, as part of the team, performs a specific duty to make sure that the product is developed, manufactured, and distributed in the most cost-effective manner possible. Following is a list of the different divisions or departments that might exist in a manufacturing organization:

- *Research and development*—The research and development team (or R&D team as they are usually called) is in charge of identifying a need for a certain product. The R&D team analyzes the market, checks out competitors' products, and works on developing the plans and prototypes of their product. (In your neighborhood, is there anyone else selling doghouses? How can you make yours more attractive to potential customers?)
- *Production*—The role of the production team is to create— using tools, materials, and human resources— the product that is being manufactured. This is where the actual manufacturing and assembly of a product is done. Human resources may be tapped, and parts of the process may be automated through the use of robotics and other technology. (Who is going to actually make your doghouses? How many people will it take? What tools do they need?)
- *Marketing*—The marketing team develops creative strategies to try to get others to buy, rent, or otherwise use the finished product. Marketing people may work with advertisers. They might also talk to the users, or potential users, of a product to anticipate problems, concerns, or changing needs in the market. (Do your customers have particular concerns about the doghouses they want in their neighborhood? Do they have to look a certain way or be a certain height? Do they have to be waterproof? Air-conditioned? Easily moved? Will they be used for one or two dogs? Perhaps more people in your neighborhood own cats instead of dogs. How would that impact your business?)

people in your neighborhood own cats instead of dogs. How would

- ***Quality control***—The quality control team (QC) ensures that the product that is being produced meets the requirements to which it was built (the specifications). The quality control team also looks to see if the product possibly exceeds expectations. This team will monitor the product throughout the production process to ensure that goals and plans are being met. (Is your doghouse big enough? Too big? Sturdy enough? Really waterproof?)

- ***Distribution***—The distribution team in the manufacturing process may act as the middle person between the manufacturer and the retailers of the product. Distributors may help set the price for the product, may assist in the marketing of the product, and will ensure that the product reaches the intended audience. (Your distribution team might sell a dozen doghouses to the pet store owner—the retailer—for a set price. The pet store owner will price the doghouses according to the going rate in the neighborhood, but above the price the pet store owner paid for them in order to earn a profit.)

Manufacturing Steps

The following steps are often part of the actual physical manufacturing of a product:

- Cutting—Often, the raw materials used to manufacture a product must be cut into smaller or specialized pieces. You may need to use a band saw or a hand saw for this step. In some cases, if great accuracy is required, lasers may be used to cut materials.
- Shaping—Materials, once cut, may need to be shaped or changed into different forms. This may involve bending or heating materials to mold them into new shapes.
- Assembling—In this step, all the pieces that have been cut or shaped are put together. Products are usually assembled using tools, such as screwdrivers and wrenches, and fasteners, such as nails, screws, or bolts.
- Joining—This is a step that involves the fastening of the assembled pieces together with a type of glue or other fastener.
- Finishing—Once assembled, a product may need to be sanded or polished. The end product may also need to be painted or stained. This is the finishing stage of the manufacturing process. Finishing is the final step in preparing the product for distribution.
- Safety—The product must be checked to make sure that it meets, or exceeds, all safety standards. This ranges from checking to make sure all the bolts are fastened tightly, to ensuring that all the rough edges have been removed, to making sure that no toxic paints or finishes were used.
- Quality control—This step, as mentioned previously, is conducted throughout the manufacturing process to make sure that all guidelines and standards are being met as the product is being made.

ENGINEERING CAREERS: Fields of Technology & Engineering

(Adapted from AMSCO *MCAS Science & Technology/Engineering*)

Communication Technology

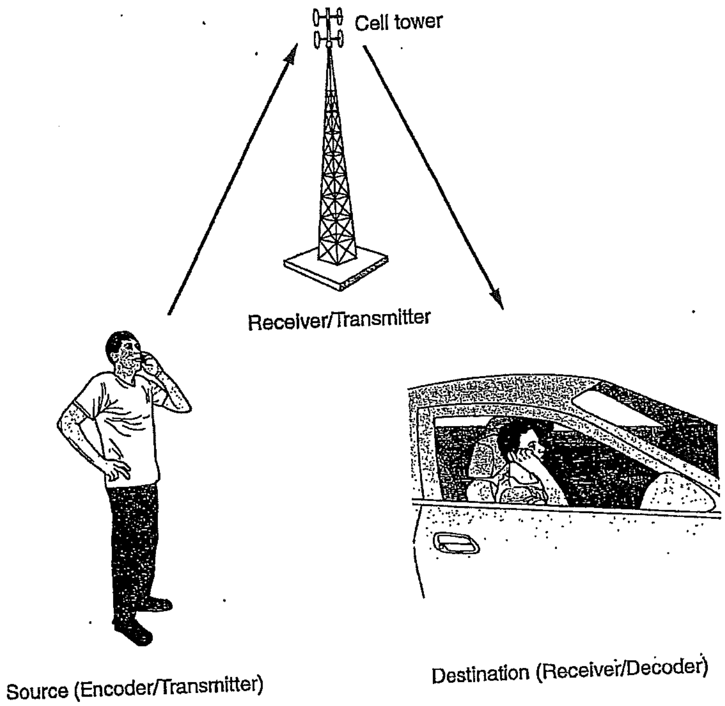
We communicate information in many different ways, for example, by radio, television, and the Internet. You probably communicate daily (if not more!) with your friends by cell phone. Street signs also communicate information, as do symbols and icons. An ***icon*** is a picture that represents an idea or thought. Some of the different technologies that we use to communicate information will be covered in this section.

Communication Systems

Chances are you already have used some sort of telecommunication device today. Telecommunication systems are used in cell and land phones, satellites, Internet connections in your home computer, and in radio and television transmission. What happens when you call your friend on your cell phone? There are several parts of this communication system that must work together in order for the two of you to have a conversation. These are listed below:

1. *Source*—The source of a communication system is the place where the signal is sent from, or where the information begins. In the case of our example, the source is you and your cell phone.
2. *Encoder*—The encoder then takes that signal and converts it to a code. For example, the signal that is sent out from a television or radio station is compressed and changed into a code in the encoder for easier and faster transmission. There is a device within your cell phone that converts your voice or data (if you are texting) into a code.
3. *Transmitter*—The transmitter then takes the code from the encoder and sends it out. Transmitters usually have a large antenna and can send out signals for radio, television, and other telecommunications. Your cell phone actually acts as the transmitter as well as the source. It sends the signal to a cell tower. The cell tower also functions as a transmitter.
4. *Receiver*—The receiver takes in the signal transmitted by the transmitter. The cell tower closest to your friend will pick up the signal from your phone.
5. *Decoder*—The decoder changes the incoming code into useful information, such as sound, or the text you may have sent. You could think of the decoder as having the opposite job of the encoder.
6. *Destination*—This is the end point of your communication. Your friend answers his phone and you can talk.

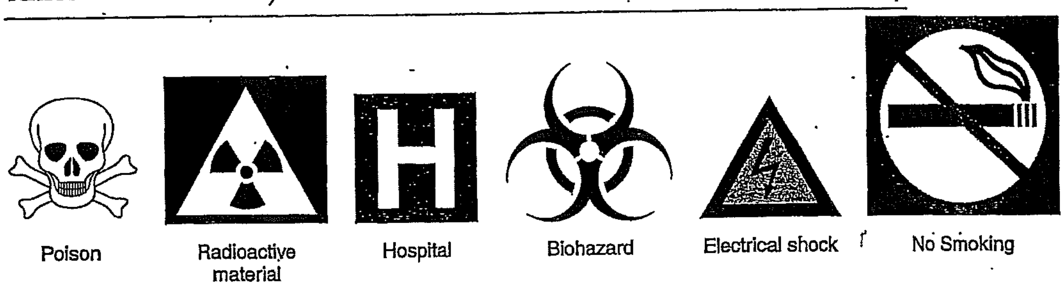
Figure 12-8. *The movement of a signal through a communications system.*



Symbols and Icons

The next time you are driving in a car or walking on a city street, take a look around and observe how often *symbols* and *icons* are used. These are pictures or shapes that are used to get a message across quickly without using words. For example, you learned when you were young that if you saw a skull and crossbones on a bottle that you better not drink it because it is poisonous. Today, there are numerous icons you can use when you text message with your friends. Other symbols and icons may communicate which direction to go, where danger may lurk, where help may be found, and where the nearest gas station or restroom is located. They are easily understood by many people because they are not based on language. Table 12-1 shows some symbols and icons that convey information. How many are you familiar with? Can you think of any others?

Table 12-1. *Some Symbols and Icons*



Construction Technology

The Parts of a Building Structure

When constructing a building or some other structure, it is necessary to understand the different parts of the structure and the role these parts play in the overall structure. All building structures, whether they are single-family homes, skyscrapers, or bridges, have several different parts that have specific functions, as described below: (See Figure 13-1.)

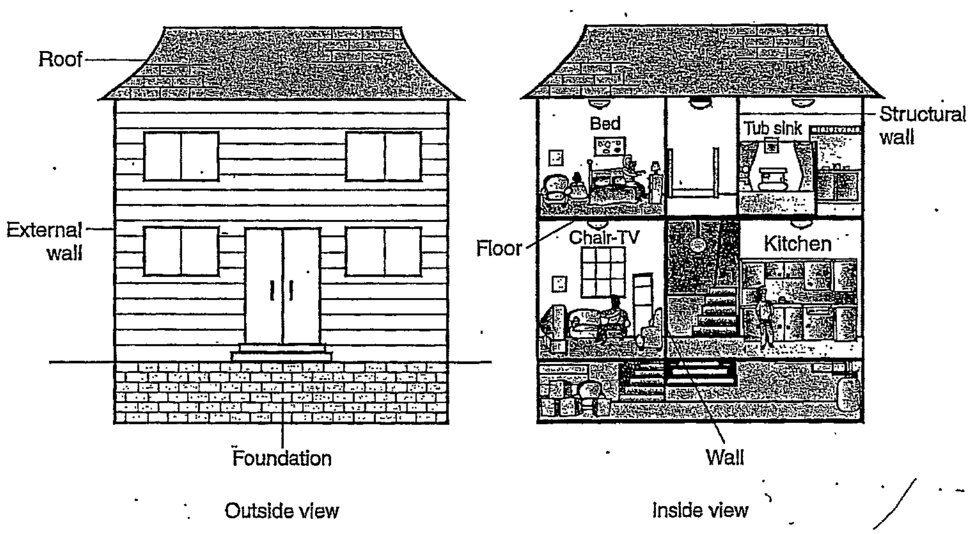
Foundation—The foundation of a structure is the part that rests the load of the structure on the ground. The type of foundation that is needed to support a structure depends on the size and use of the structure.

- A shallow foundation is needed for smaller structures, such as a single-family home. A shallow foundation may be built a few feet into the soil. Shallow foundations are typically constructed from concrete and are designed to transfer the weight of the walls to the soil.
- A deep foundation is needed for larger structures, such as skyscrapers. Deep foundations may be built into bedrock with the use of steel and concrete.

Flooring—The floor provides the lower surface of a room or story, and also helps support the structure. Typically, a sub-floor is built that is framed out of wood, concrete, or steel and covered with a layer of plywood. Then a layer of flooring material (such as linoleum, carpet, or tile) is placed over it.

Decking—Decking is typically similar to a floor. It is a flat surface that is able to support the weight of walls. However, decks are usually built outside. Some decks may be enclosed for a porch or left open for an

Figure 13-1. *Parts of a building structure.*



open-air space. Decks, therefore, need to be treated with a finish that can withstand various weather conditions.

Walls—Walls serve several purposes in a structure. Walls can be divided into three categories: structural walls, external walls, and retaining walls.

- Structural walls support the upper floors and the roof of a structure. Other structural walls are used to separate large spaces, or to create smaller rooms or divisions. Structural walls are usually built of wood, insulated, and then covered with drywall. Drywall—or wallboard as it is sometimes called—is a sheet of material that forms the outside of the walls. This is the basis for what you see in the walls of your home. Paint and wallpaper can be applied directly to the drywall.
- External walls protect the interior of a building from various weather conditions. These walls may be made of brick, stone, or wood that is covered in an exterior finish.
- Retaining walls are found inside or outside of a building and act as a barrier between the building and soil and water. These walls are typically made of concrete, stone, or brick.

Roofing systems—The roof of a structure is the uppermost boundary of a structure. It protects the inside of the structure from various weather conditions. Most roofs are pitched, that is, they are built at an angle. This prevents a build-up of debris or snow or the collection of rainwater on the roof. Roofs are usually covered with asphalt shingles or some other material that helps to strengthen and protect them.

Bridges

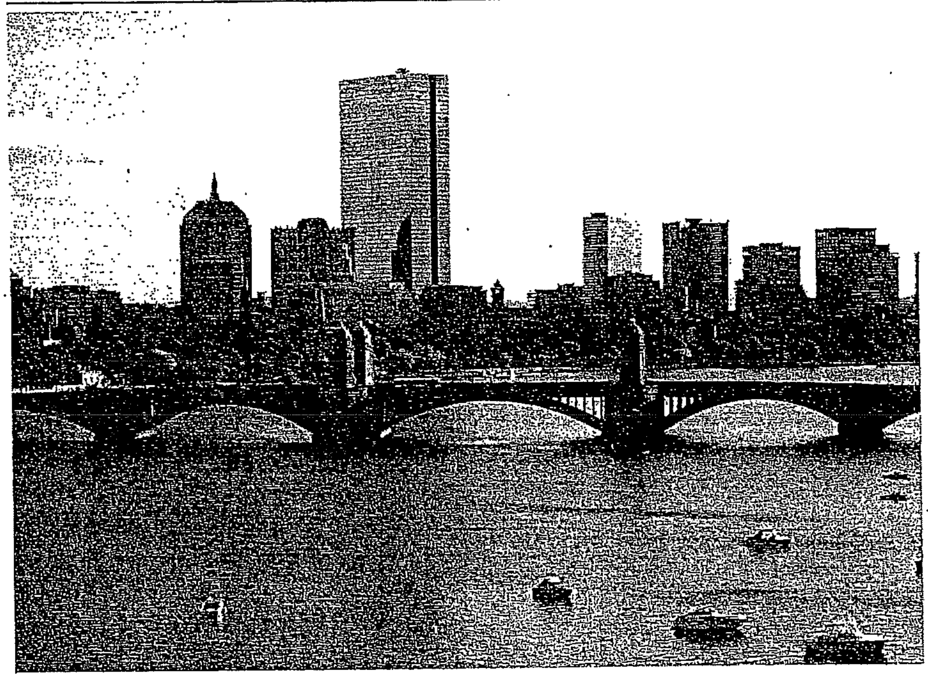
In this section, we will discuss the three major types of bridges and their appropriate uses. We will also investigate how various forces and loads affect them,

There are three main types of bridges: arch bridges, beam bridges, and suspension bridges. Each is constructed differently for a specific purpose. The three types of bridges are described below:

Arch bridges—Arch bridges have the appearance of an arch or semicircle, as seen in Figure 13-2. They have a flat portion on top, supported by an arch beneath. The places where the bridge touches the ground are called *abutments*. The arch in this type of bridge redistributes the load from the top of the arch to the abutments. The abutments of an arch bridge experience forces that are known as ***compressional forces***. Tension along the arch increases as the arch becomes wider. Arch bridges are often fancy or decorative.

Beam bridges—Beam bridges are composed of a flat, road surface that is supported on both ends by a support structure. (See Figure 13-3 on

Figure 13-2. *An arch bridge spans Boston Bay.*



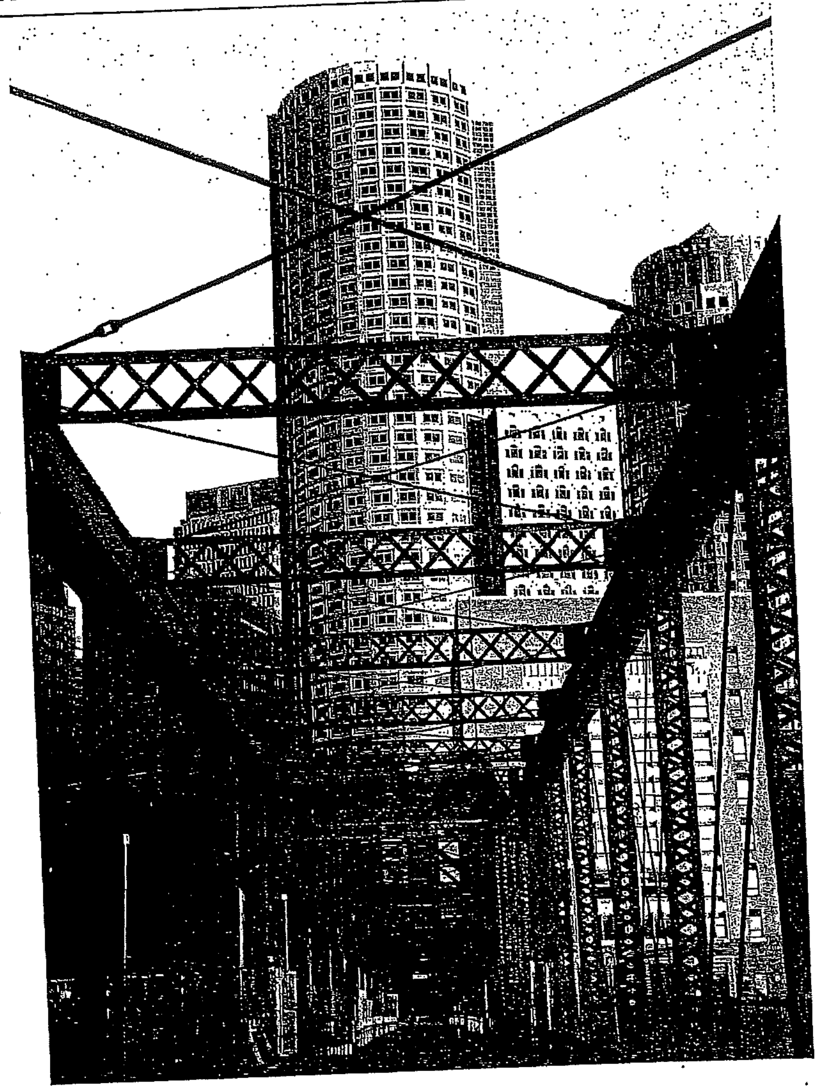
page 294.) The loads created by the building materials of the bridge and any traffic going over the bridge are supported by the support columns. Compression forces particularly affect the horizontal road surface. The lower portion of the bridge surface undergoes tension. As a result, the upper portion is longer, while the lower portion is shorter.

Suspension bridges—Suspension bridges are used to span great distances. In particular, suspension bridges are used to cross water or canyons. Suspension bridges have their load-bearing portions hanging from suspension cables. (See Figure 13-4 on page 295.) Today, most suspension bridges are built with two large columns to which the cables are tied. These columns absorb a lot of the compressional forces that are transmitted to them by the cables. Suspension bridges, due to their structure, are particularly susceptible to *torsion* (see below), especially at times of high winds. The cables are the part of the bridge that experiences the *tensional* forces of the system. The Brooklyn Bridge in New York City and the Golden Gate Bridge in San Francisco are examples of suspension bridges.

Forces That Affect Bridges

You learned in physical science that gravity is a constant, static force (a push or a pull). Bridges are built to withstand two different types of forces or *loads*: static loads and dynamic loads. ***Static loads*** are forces that build up over time

Figure 13-3. *A beam bridge on Old North Avenue in Boston.*

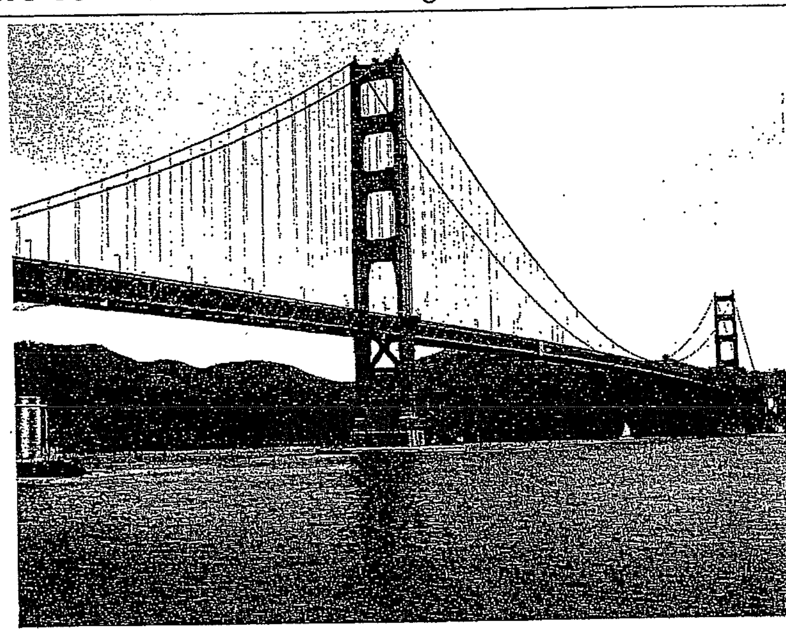


on a bridge. These are the forces that remain relatively constant. The force of the weight of the materials exerts a static force on the bridge. ***Dynamic loads*** are forces that are constantly changing. When a large truck crosses over a bridge, the bridge must be able to support changing, variable weight.

All bridges are built to withstand certain forces. As previously discussed, each of the three major types of bridges is better suited to certain functions than others. But each bridge must be built to counteract the following forces:

- ***Tension***—Tension is a pulling force. Wood can withstand a pulling force quite well if the tension force is parallel to the grains. However, if a tensional (pulling) force is applied perpendicular to the wood grains, the wood is not as strong.
- ***Compression***—Compression is a pushing force. This can be illustrated by the following example. Imagine you are holding a drink-

Figure 13-4. *The Golden Gate Bridge in San Francisco.*

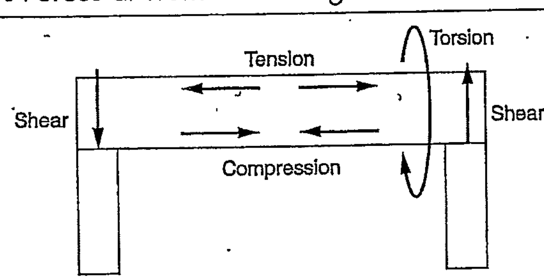


ing straw between your two hands. If you pull on each end, the straw becomes thinner in the middle and it bends very easily. However, if you hold the straw in your two hands and then push the ends toward each other, the straw becomes very strong in the middle. This is due to the force of *compression.* This force is taken into account when building bridges. Long spans do not hold up very well to compressional forces. For that reason, shorter spans are often built between supports on bridges. Bridge materials hold up better to compressional forces in shorter spans.

- *Torsion*—Torsion is a twisting force. A pretzel stick breaks very easily if this twisting force is applied. A single piece of licorice bends and changes shape when twisted. Materials such as concrete do not withstand torsion as well as some metals or wood.
- *Shear forces*—Shear forces are horizontal forces where one end of an object moves in opposition to the other end.

These forces are illustrated in Figure 13-5.

Figure 13-5. *Forces at work on a bridge.*



Bioengineering Technology

Assistive Technology

Most technology is developed to make people's lives better. Think of how your daily life is improved by a car, a computer, a microwave, and a cellular phone. One branch of technology is dedicated to changing people's lives in dramatic ways. Adaptive and assistive devices are examples of technology that are used to improve or enhance the lives of people with disabilities or conditions that make daily tasks difficult. You might have a friend or relative or know someone whose life has been much improved because of these devices. And, after reading the list below, you might realize that you are also benefitting from assistive technology.

- Prosthetic devices—Prosthetic devices are artificial body parts that replace body parts that may have been lost because of accident, disease, or birth defect. You may be most familiar with prosthetic arms or legs.
- Wheelchairs—Wheelchairs are devices that provide mobility for people with disabilities that restrict their ability to walk or stand. Wheelchairs typically have a seat and four wheels (two large and two small). Occupants can be pushed easily by a companion, or they can push the wheels with their own hands, or wheelchairs may be battery operated.
- Eyeglasses—You may not have thought much about this, but eyeglasses are assistive devices. The technology behind the manufacturing of eyeglass lenses has made it possible for people with weakened eyesight to improve their vision.
- Grab bars—Grab bars are secure hand bars, usually made of metal, usually found near a stairway or step, or in the bath or bathroom. They provide assistance to people who have trouble maneuvering in these spaces. Grab bars are a common sight in public bathrooms, in movie theaters, malls, and ballparks.
- Hearing aids—Hearing aids, like eyeglasses, help improve the lives of many people. Hearing aids help amplify sounds for the wearers. While many hearing aids are worn outside the ear, today, with advances in technology, they can be inserted into the ear through a series of operations. Hearing aids have allowed countless numbers of people to continue to experience the sounds of life and to engage in everyday conversations with their family and friends. You might have older relatives who have benefitted from this device.
- Braces—Dental braces help straighten a person's teeth. Other assistive braces help in movement. For example, some leg braces extend the length of one leg because it is shorter than the other. This type of brace makes it more comfortable for people to walk.

Bioengineered Products

Bioengineering is the use of technology in the fields of biology and medicine. The goal of bioengineering is to help improve the lives of humans and other organisms that humans interact with. This can be in the form of improved foods and medicines, or in other health-related ways. This section discusses some current bioengineering technologies and issues, some of which might be familiar to you.

Recently, bioengineering practices have been applied to the growth of food. You might have heard this practice referred to as genetically modified foods. ***Genetically modified foods,*** or GM foods, have been modified in a laboratory setting to enhance one or more properties of the food. For example, GM foods may be more resistant to disease, may be more tolerant of cold or heat, may have an increased nutritional value, or may simply be able to be grown in larger quantities or look more attractive. Opponents of GM foods have several concerns. For example, critics of GM foods suggest they may decrease the effectiveness of some pesticides, may cause allergic reactions in some people, and may have other, unintended effects on people, not to mention on other animals and foods in the food chain. Some opponents of this technology contend that GM plants on the lower part of the food chain could impact the animals that eat them, and so on up the food chain. Also, the technology used in creating GM foods can be very expensive, which drives up food costs.

There has been a lot of discussion about the use of fossil fuels and the alternative use of biofuels. You are probably most familiar with *fossil fuels,* such as coal, oil, and natural gas. Fossil fuels such as these are sources of energy made up of the remains of plants and animals that lived and died long ago. Because fossil fuels are limited in supply and a nonrenewable resource, pollute the environment, and, in recent times, are very costly, governments and scientists are looking for alternative fuels. The use of *biofuels* is one such alternative. ***Biofuels*** are solid, liquid, or gaseous fuels that are composed of organic matter, most typically plant material. Two easily obtainable, less expensive sources of biofuels are corn and soybeans. Ethanol, a biofuel that can replace gasoline in cars, is made from corn and sugar cane. Soybeans can be heated to release their own natural oils, which then can be used in an engine specially designed for this use. Biofuels are typically produced from renewable resources and do not pollute the environment the way fossil fuels do.

Figure 13-6. *If you see this symbol (icon) on the packaging of foods, you know the food has been irradiated.*

Irradiation

Another use of bioengineering is irradiation. ***Irradiation*** is the process of treating foods with ionizing radiation to prevent spoilage and contamination and to increase shelf life. For example, tests have shown that irradiated strawberries can last several weeks longer in the refrigerator than strawberries that have not been irradiated. The irradiation of food is a very controversial issue, however, since it requires the use of radioactivity. Many people mistakenly think that this radioactivity is passed along to them when they consume such food. Products that have been irradiated must carry a symbol, as shown in Figure 13-6 on page 300. There must also be a statement on the food package explaining why the product was irradiated. For example, it may say that the product was irradiated in order to prevent spoilage. The display of this information allows the consumer to make an informed choice about whether or not to purchase irradiated food. In 2008, the Food and Drug Administration (FDA) issued a regulation allowing the irradiation of raw spinach and iceberg lettuce. The FDA determined that irradiation can kill *E. coli*, salmonella, and listeria, as well as lengthen the shelf life, without compromising the safety, texture, or nutrient value of these greens. While irradiation can kill bacteria, it doesn't kill viruses that may also contaminate produce.

Integrated Pest Management

Another use of bioengineering is a process called ***integrated pest management***, which is the control of insects, weeds, and other pests with minimal use of pesticides. Humans must take an active role in an integrated pest management plan, often by modifying their own behavior, and sometimes learning to live with pests. The steps to an integrated pest management program are the following:

1. Identify the pests and the type of damage they cause.
2. Keep track of the pest population over time.
3. Determine the economic or personal impact these pests have.
4. Choose a management plan.
5. Monitor the progress of the management plan you have chosen.

When devising a management plan, you may want to employ some or all of the following approaches:

- Use of live traps.
- Use of biological controls, such as pheromones; the addition of beneficial insects (for example, ladybugs).
- Modifying your own behavior to live with the pests. For example, wearing long sleeves and light colors in the yard to prevent mosquito and tick bites.
- Limited use of chemical pesticides or insecticides at particular stages of the pests' life cycle. Strategic use to reduce the population may reduce the need to use greater amounts of pesticides at a later time.