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

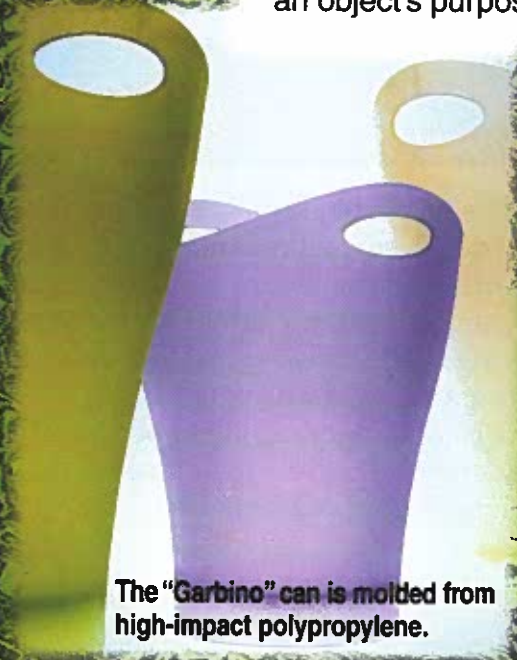
Materials

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

Reading Target

Finding the Meaning of Unknown Words

Before you read this chapter, skim through it briefly and identify any words you do not know. Record these words using the Reading Target graphic organizer at the end of the chapter. Then read the chapter carefully. Use the context of the sentence to try to determine what each word means. Record your guesses in the graphic organizer also. After you read the chapter, follow the instructions with the graphic organizer to confirm your guesses.

Key Terms

acids
alloy
bamboo
bases
biobased
biodegradable
biomaterial
bioplastics
ceramics
composite
conductors
engineered wood
ferrous
hardwoods
insulators
magnetic
nanomaterials
nanotubes
nonferrous
opaque
pH scale
photosynthesis
plasticizers
polymer
primary materials
refractory material
semiconductor
sintered
smart materials
softwoods
synthetic
thermal conductivity
thermal expansion
thermoplastics
thermoset plastics
translucent
transparent

Objectives

After reading this chapter, you will be able to:

- List the principle properties of materials.
- Explain the properties of acids and bases.
- Identify the types of primary (natural) materials.
- Describe how natural materials are processed into manufactured materials.
- Describe the properties of various advanced materials.

Useful Web site:
www.karimrashid.com

Designing and making products always involves the use of materials. Concrete is used for walkways, cotton for clothing, fiberglass for insulation, copper for electrical wiring, and plastic for bottles. See **Figure 4-1.**

Designers need to know about the properties of many different materials in order to choose the most appropriate material for the product being designed. The following are some examples of questions a designer might ask:

- Does the product have to withstand heat?
- Is color important?
- Should it be heavy or light?
- How strong does it have to be?
- Must it withstand bad weather?
- Does it have to conduct electrical current?
- What is the impact on the environment of using this material?

The material from which a product is made can affect how users perceive (see) the product. Most people think glass drinking utensils are more attractive than plastic. Wood has a warm appearance and feel.

The choice of materials also affects the function of a product. Most toothbrushes now incorporate one or more silicone inserts on the handle. These inserts not only feel more inviting but also help the user grip the toothbrush when the handle is wet.

Consumers are increasingly concerned with the environmental impact of materials. For example, there is an increasing demand for plastic products that are biodegradable. Some manufacturers are moving away from using plastics and are returning to wood and metal, which are less environmentally harmful.

Figure 4-1. Designers choose materials that have properties they want to use in their designs. What special property of acrylic did the designer use in the shape of this stool?

Properties of Materials

Designers and engineers judge materials by their properties. A material's properties affect how the material performs. Properties of materials can be grouped as follows:

- Physical
- Mechanical
- Thermal
- Chemical
- Optical
- Acoustical
- Electrical
- Magnetic

Physical Properties

Physical properties include a material's size, density, porosity, and surface texture. You can describe any material or product using its physical properties. Consider a pencil eraser, for example. It may be 2½" long, 1" wide, and ⅜" thick (64 × 25 × 10 mm). It is not very dense. Therefore, its mass is small. Its surface is smoother than a pine board. However, it is not as smooth as glass.

Mechanical Properties

Mechanical properties are the ability of a material to withstand mechanical forces. An elastic band will stretch and return to its original shape. A diving board will spring back. The head of a hammer will withstand sharp blows. The common mechanical properties are shown in Figure 4-2.

Thermal Properties

Thermal properties control how a material reacts to heat or cold. Materials will generally expand when heated and shrink when cooled. Some materials will also conduct heat.

Sometimes the expansion and contraction of metals causes problems. On an extremely hot day, steel railroad tracks may expand and buckle. The heat makes the molecules in the steel vibrate faster. Increased vibrations create more space between the molecules, increasing the size of the rail. The opposite happens in cold weather. In steel bridge construction, engineers add expansion joints to allow for movement.

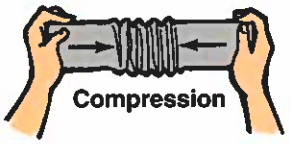
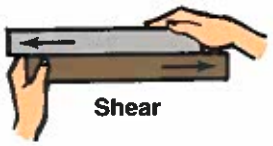
Strength		***Strength*** is a material's ability to withstand a mechanical force. Tension is a pulling force. A material that resists being pulled apart has tensile strength. An elastic band holding a package together is under tension.
		Compression is a squeezing force. A material that resists being crushed has compressive strength. The concrete pillars for a bridge are in compression due to the mass of the materials and the traffic on the bridge.
		Shear is a sliding and separating force. A material that resists separation has shear strength.
		Torsion is a twisting force. A material that resists torsion has torsional strength. A screwdriver blade must resist torsion when force is being applied to screws.
Elasticity		***Elasticity*** is the ability to stretch or flex but return to an original size or shape. A material that resists elasticity has stiffness. A rubber band is elastic. A piece of glass has high stiffness.
Plasticity		***Plasticity*** is the ability to flow into a new shape under pressure and to remain in that shape when the force is removed. Plasticity can be measured in two ways: 1. Ductility is a material's ability to be pulled out under tension. Chewing gum is very ductile. 2. Malleability is a material's ability to be pushed (compressed) into shape. Potter's clay is very malleable. The opposite of plasticity is brittleness. Glass is very brittle.
Hardness		***Hardness*** is the ability to resist cuts, scratches, and dents. Harder materials wear less under use. Cutting tools such as knives, scissors, and drills should be hard. Diamonds are the hardest of all materials.
Toughness		***Toughness*** is the ability to resist breaking. A hammer head should be tough so it will not shatter when it strikes other materials.
Fatigue		***Fatigue resistance*** is the ability to resist constant flexing or bending. A springboard must have high fatigue strength.

Figure 4-2. Some common mechanical properties of materials.

Engineering Application

Material Fatigue

Most of us have experienced a moment when a light bulb suddenly burns out or a shoelace snaps. The bulb may have been turned on and off hundreds of times and the shoes could have been tied every day for months, but there comes a time when the material fails.

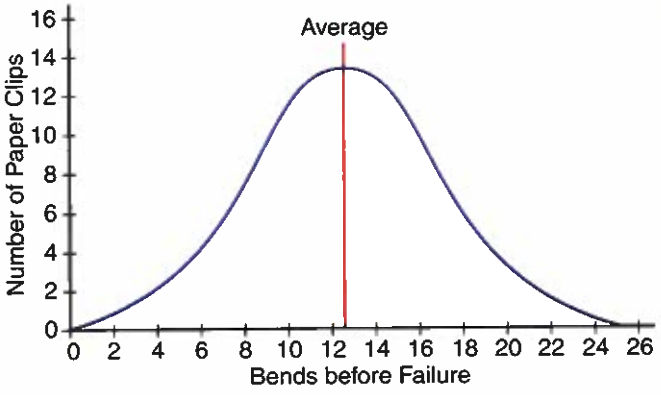
Engineers refer to this situation as ***material fatigue***. In technical terms, it is the sudden breaking of a component after a period of cyclic loading. ***Cyclic loading*** is the repetitive movement that occurs in the normal use of a product. Failure often occurs due to the growth of a crack, usually at the site of a stress concentration on the surface.

The bulb burning out probably did not cause an accident unless, in the dark, you ran into a wall. However, if the cable connecting the brake handle on your bicycle to the brake mechanism snaps, or the metal rods in a reinforced concrete bridge fail, a terrible accident could happen.

Engineering Activity

Use a metal paper clip to simulate material fatigue. Follow these steps:

1. First straighten out the bends in the paper clip so it is flat.
2. Bend it back and forth, as far open and as far closed as possible, until it breaks. Count how many times you can bend the paper clip before it fails.
3. Repeat your experiment with additional paper clips, or ask your teacher to record the results of every class member's experiment. Be sure to use the same type of paper clip for all the trials. Plot the class's results on a graph.
4. Review the overall results. You will probably notice how the information is clustered. Many of you will have similar results. However, a few clips will break earlier, and a few will break later. If everyone's results are plotted on paper, or on the chalkboard, the result will be a bell-shaped curve.
5. Write a paragraph about your conclusions from this experiment. Explain how an engineer might use this knowledge to design products that do not fail. What information should be given to the consumer about possible failures?



A bell-shaped curve occurs when most of the results fall within a certain range, with fewer results above and below that range. The curve for your class results may look similar to the one shown here.

This characteristic of metals, called *thermal expansion*, can be useful. A fire alarm is an example. A strip of one metal, such as brass, is joined to a strip of a second metal that has a different rate of thermal expansion, such as steel. When a fire causes this bimetal strip to heat up, one metal expands more than the other. Thus, a change in temperature causes the bimetal strip to bend. This movement closes an electrical circuit that activates the fire alarm. See **Figure 4-3.**

Thermal conductivity is a measure of how easily heat flows through a material. All metals conduct heat. Some do it better than others. Copper is a good conductor of heat. The copper bottom of a frying pan quickly conducts heat from the stove element to the pan. The metal pan then conducts this heat to the food.

Thermal insulators are materials that do not conduct heat well. Nonmetallic materials are generally thermal insulators. Plastic and wood handles on saucepans prevent heat from being conducted from the hot metal to your hand. A cooler used for preserving food on camping trips may have a casing filled with polyurethane foam to keep out heat. Foam panels or fiberglass batts are used to insulate walls and ceilings to reduce heat losses in a home. See **Figure 4-4.**

Chemical Properties

In order to understand how materials react to their environment, it is necessary to study atoms and molecules. An atom is the smallest unit of an element. Atoms are so small that several million could fit into the period at the end of this sentence. Chemical bonds between atoms form molecules and compounds. Molecules are made of specific combinations of atoms. For example, the first row (Formula) in **Figure 4-5** shows that oxygen molecules are made up of two oxygen atoms. Compounds are molecules that contain atoms from at least two different elements. Carbon dioxide is made of one carbon atom and two oxygen atoms. Water (H_2O) is the most abundant compound on earth.

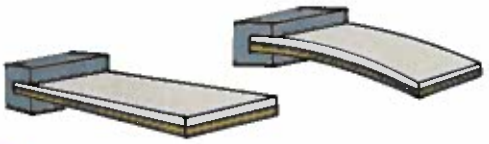


Figure 4-3. Thermal expansion makes a bimetal strip bend.

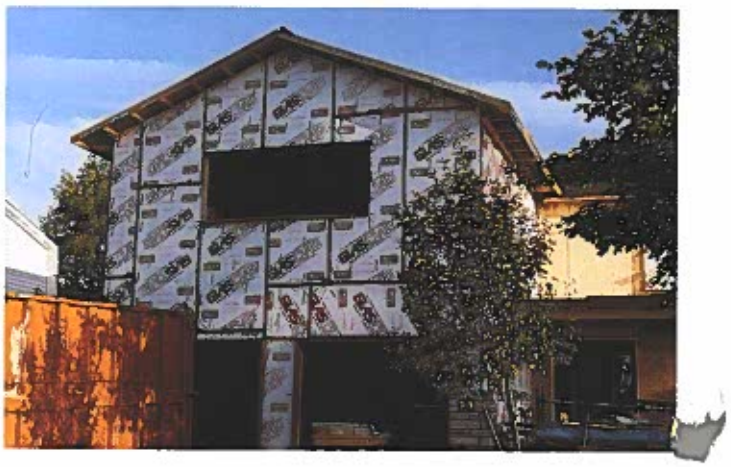


Figure 4-4. Insulating materials help slow the passage of heat or cold through walls of homes.

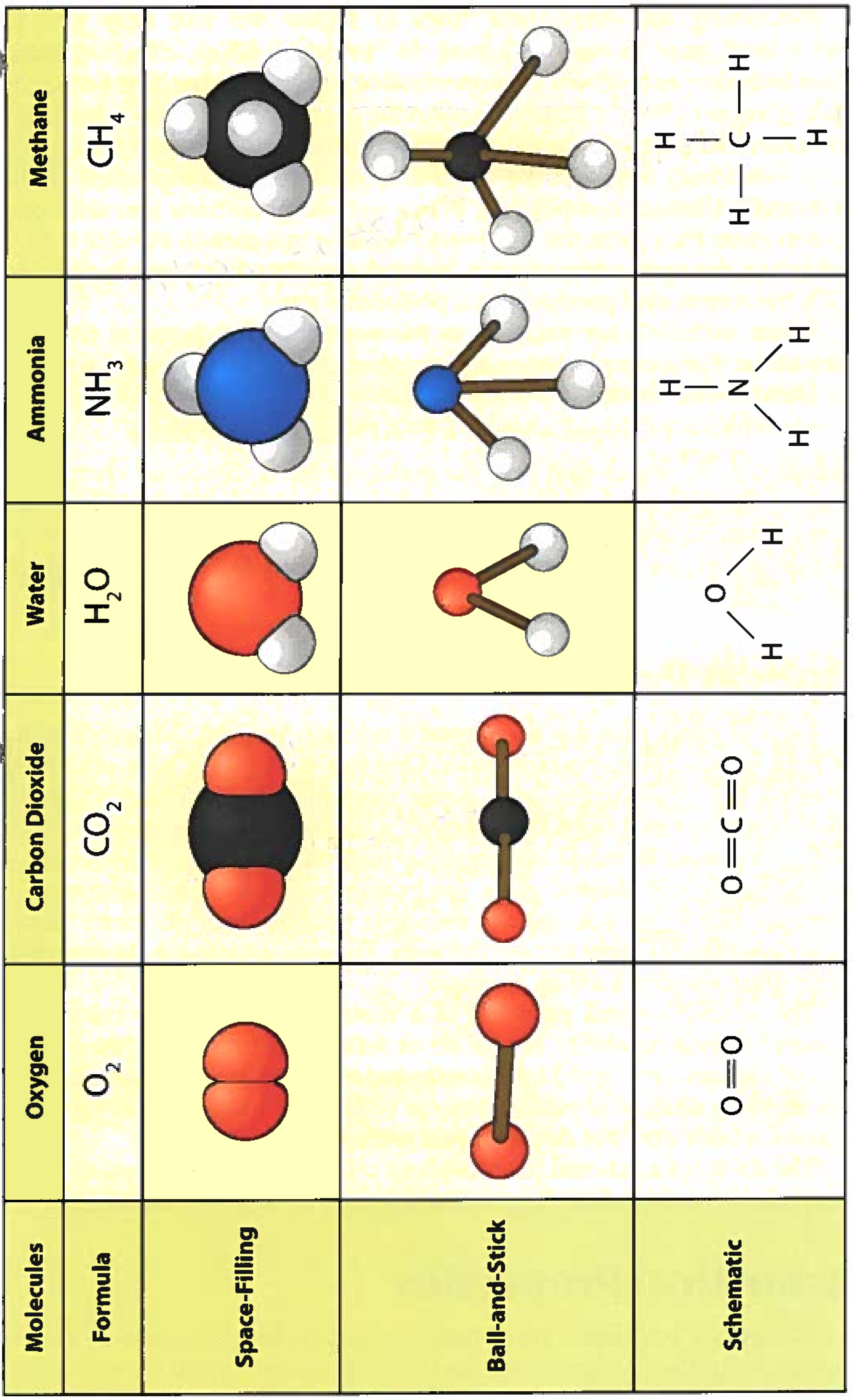


Figure 4-5. Atoms and molecules can be represented in different ways.

Examining the other three rows in Figure 4-5 will help you to understand how atoms are joined. In the space-filling diagram, each atom is drawn as a sphere in proportion to its relative size. The ball-and-stick diagram gives a three-dimensional perspective. In the schematic, bonds are shown by straight lines and multiple bonds by double or triple lines. What may appear to be small changes to these compounds result in entirely different compounds. When two oxygen atoms join with one carbon atom they form the relatively harmless gas carbon dioxide (CO_2), but when the same elements are bonded together as carbon monoxide (CO) the compound produced is a poisonous gas.

When materials are exposed to the environment, chemical changes may occur. For example, when iron or steel contact both air and water, a chemical change occurs:

Iron + Oxygen + Water = Iron Oxide (Rust) + Water

Sometimes the water that hits the metal contains dissolved chemicals, such as the salt used on roads to melt snow or the salt present in sea spray. Then rusting occurs much faster. Since water and air cause certain metals to rust, we can prevent rusting by covering the metal with paint, oil, or grease.

Optical Properties

Optical properties are a material's reaction to light. Materials react to light in several important ways. One has to do with how well they transmit light that strikes them. Some materials cannot transmit light at all. When a material stops light, we say it is *opaque*. A roller blind in your bedroom should be made of an opaque material. *Translucent* materials—waxed paper and stained glass, for example—allow some light to pass through. However, you cannot see clear images through them. Other materials allow all light to pass through. These materials are *transparent*. Clear glass windows are an example.

The second optical property of a material is color. The color of a material affects its ability to absorb or reflect light. (Light is the visible part of the sun's energy.) Light is reflected by shiny, smooth surfaces. It is absorbed by dark, dull surfaces. A car with black upholstery is far more uncomfortable on a hot day than one with a white interior.

The ability of a material to absorb heat can be useful. The pipes of a solar panel are painted black so the panel will absorb more heat from the sun.

Acoustical Properties

Acoustical properties in a material control how it reacts to sound waves. Sound waves are pressure waves that are carried by air, water, and other materials. They are what the ears "hear."

Apply Your Knowledge

1. Choose three objects you use every day that are made of different materials. State whether the materials used are appropriate for the item. Explain your answer.
2. Collect pictures of objects that are made of layered, fiber, and particle composites. Label the pictures to name the materials used in each composite.
3. Work with two or three classmates to collect samples of five different materials. Choose one material property. As a team, design and build an apparatus to test the materials for the property you have chosen.
4. Search the Internet to find three current applications for smart materials. Write a report describing these applications.
5. 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. **SCIENCE** Describe the fundamental difference between thermoplastics and thermoset plastics in terms of the way their molecular chains are formed. Create models of the molecular structures to illustrate this concept.
2. **ENGINEERING** Research the materials used in tires made for specific purposes, such as winter use, summer use, or running while flat. Create a diagram that clearly shows the layers of material used in one type of tire and explain why engineers chose each material.

CHAPTER 5

Processing Materials

Bamboo is very suitable for casual clothing. What other clothing, recreational, and home products could be made using bamboo?

Better by Design

Bonnie Siefers

Bonnie Siefers is an American fashion designer and eco-designer who believes that clothing must look chic and feel luxurious. But Bonnie also believes that fashion designers have a responsibility toward the environment and must begin to use certified organic or eco-friendly fabrics (ecotextiles). So Bonnie designs apparel made from ecoKashmere®, a soft, silky fabric that incorporates the pulp of bamboo grass. The result is clothes that are soft and flowing. Also, because bamboo absorbs water rapidly, it produces fabrics that "wick" moisture at twice the rate of cotton. Bamboo-based fabrics are also highly breathable, anti-static, and naturally antibacterial, making them helpful to people with sensitive or allergy-prone skin.

Ecotextiles such as bamboo, flax, cotton, and jute are renewable, biodegradable, and sustainable.

"A pure, natural environment is vital to children of all ages. Organic [textiles] are not only gentle on the skin, but also safer for the people who make the clothes, for the farmers who grow the crops, and for the environment." —Bonnie Siefers