7.5 Living with Thermal Expansion and Contraction

Materials in our world are exposed to changing temperatures. Computer chips warm up when a computer is turned on and cool down when it is turned off. Buildings and bridges warm up during the day, and then cool down again at night. Buildings also have to withstand the changes that occur between the seasons. Materials expand and contract, sometimes dramatically, during temperature changes. When different materials are used to build a structure, designers must understand how the materials behave when they are heated or cooled.

Expansion and Contraction of Solids

Figure 1 The steel rods (at the worker's feet) used to reinforce concrete are designed to expand and contract in the same way the concrete expands and contracts.

It is important to choose the right materials when designing structures that are exposed to changing temperatures. Imagine that designers choose to use two solids that expand or contract differently when heated or cooled. The structure could be damaged by the different amounts of expansion and contraction. For example, the concrete used to build bridges and buildings is reinforced by steel rods (Figure 1). The steel used to make the rods is designed to expand at the same rate as the concrete. If the rods expanded at a different rate, the concrete would crack. The structure could, over time, crumble and fail. In the same way, when a dentist fills a decayed tooth, the filling material must change its volume to the same degree as the tooth itself. Some scientists specialize in the development of dental filling materials that expand and contract just like real teeth.

Bridges and sidewalks are built in segments. They have spaces called expansion joints between them. The expansion joints allow the concrete and steel to expand without buckling and cracking (Figure 2). The thumping sound you hear when you drive over a bridge in a car or bus is the sound of the tires going over the expansion joints.

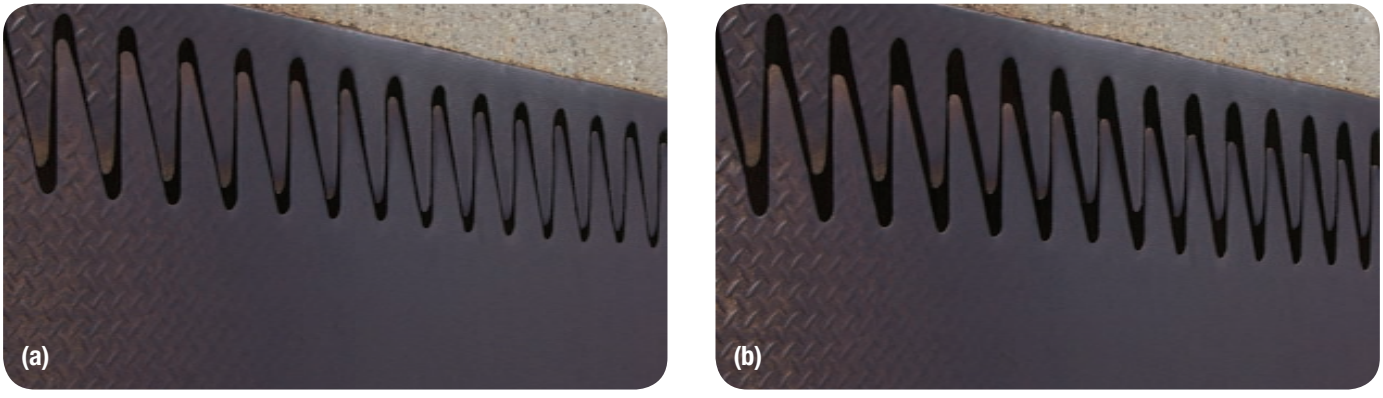

Figure 2 **(a)** The expansion joints narrow when bridge segments expand in hot weather. **(b)** Expansion joints in a bridge separate when the side-by-side segments of a bridge contract in cold weather.

Expansion and Contraction of Gases

When a gas in a container is heated, the kinetic energy of the gas particles increases. The particles of the warmer gas hit the walls of the container more often and with greater force. If the walls of the container are flexible, as in a balloon, the more frequent and faster collisions may cause the walls of the container to expand (Figure 3).

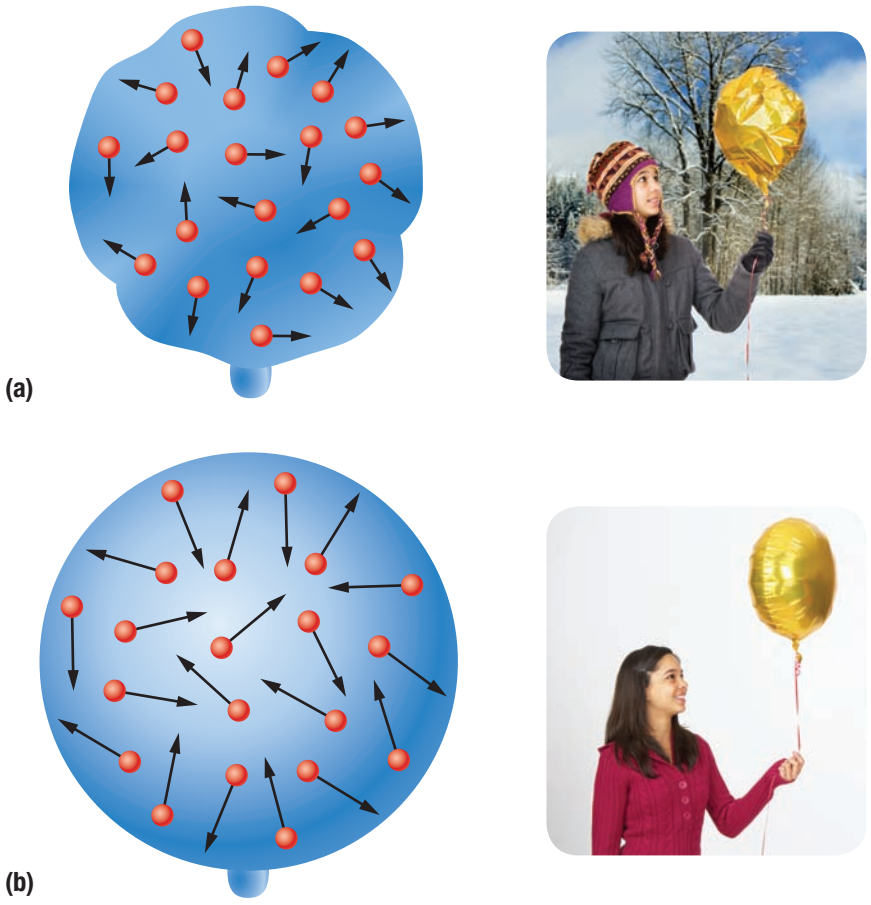

Figure 3 The helium gas in a mylar balloon expands a great deal when the balloon is taken from the cold outdoors into a warm room.

(a) At a low temperature, the average kinetic energy of the particles in the balloon is low, so the frequency and force of collisions on the inside walls of the balloon are low.

(b) As the temperature of the gas inside the balloon rises, the particles collide more often with the walls of the balloon. They are also travelling faster. These stronger collisions cause the balloon to expand.

Thermal expansion and contraction affect the volume and pressure of tires, volleyballs, and basketballs. When cars are moving quickly, the rubbing between the tires and the road increases the temperature of the air in the tires. This causes the tires to expand. Tires must be inflated according to manufacturers' recommendations. If they are over-inflated when cool, they can burst when they warm up. Volleyballs and basketballs left out in the cold become smaller and softer because of the thermal contraction of the air inside.

TRY THIS: Hot and Cold Balloons

SKILLS MENU: hypothesizing, observing, measuring, analyzing

In this activity, you will observe the thermal expansion and contraction of the air in rubber balloons.

Equipment and Materials: 3 rubber balloons (same type and same size); black marker; flexible tape measure; refrigerator/freezer

1. Read the procedure, and then write a hypothesis about how the volume of an air-filled rubber balloon may change when it is (a) placed at room temperature for 10 min, (b) placed in a cold freezer for 10 min, and (c) immersed in hot tap water for 10 min. Your hypotheses should include both a prediction and an explanation.
2. Number the balloons 1, 2, and 3.
3. Blow up the balloons to the same volume. Tie the openings to seal the balloons.
4. Using a flexible tape measure, measure and record the circumference at the widest point of each balloon.
5. Expose the balloons to the conditions described in step 1.
6. After 10 min, measure and record the circumference at the widest point of each balloon. (Quickly measure the balloon in the freezer without removing it from the freezer compartment.)

A. Compare the volumes of balloons 1, 2, and 3 before and after the treatments in step 5.

B. Evaluate your hypotheses by comparing them to the evidence you gathered in steps 4 to 6.

Expansion and Contraction of Liquids

LINKING TO LITERACY

Making a Connection

Relating things you have read to events or issues happening in the world is a text-to-world connection. Make a text-to-world connection by asking yourself, "What are some effects of rising sea levels?"

Thermal expansion and contraction affect the volumes of liquids that are used every day. Cars provide a good example of this. Cold gasoline in a car's gas tank expands in hot weather. If the tank is filled to the brim, the gas may overflow. Also, if a car engine is filled with cold liquid coolant, the coolant will warm up and expand when the car is running, and may overflow.

Studies over the past 100 years show that the average temperature of Earth's oceans has been steadily increasing. As the ocean water warms up, its volume increases due of thermal expansion. The greater volume leads to rises in sea levels. This could lead to floods in coastal cities.

Unit Task How can you apply what you have learned about thermal expansion and contraction of solids to the design of your doghouse?

CHECK YOUR LEARNING

1. Carefully read the following statements and decide if they are true or false. If the statement is false, then rewrite the statement to make it true. (Do not simply restate the statement in the negative.)
   - **(a)** The particles of a material get bigger when heated.
   - **(b)** The particles of a material move faster when heated.
   - **(c)** Of the three states of matter, gases expand the least.
   - **(d)** The particles of a solid vibrate.
2. A metal entrance door swings freely in the winter, but when the weather turns warm, the door sticks and seems too big for the doorframe. Using your knowledge of particle theory, explain what is happening.
3. When building a device or structure, engineers must carefully consider how the materials they choose will change when heated and cooled. List four situations where thermal expansion and contraction could be a problem.
4. List three unique examples of situations in your daily life where expansion and contraction occur.
5. You want to inflate an air mattress to use in a swimming pool on a hot summer day. Should you fill the mattress with as much air as possible? Why or why not?