SECTION 4

Heat Technology

You probably wouldn't be surprised to learn that the heater in your home is an example of heat technology. But did you know that automobiles, refrigerators, and air conditioners are also examples of heat technology?

What You Will Learn

- Analyze several kinds of heating systems.
- Describe how a heat engine works.
- Explain how a refrigerator keeps food cold.
- List some effects of heat technology on the environment.

Vocabulary

insulation
heat engine
thermal pollution

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

It's true! You can travel long distances, you can keep your food cold, and you can feel comfortable indoors during the summer—all because of heat technology.

Heating Systems

Many homes and buildings have a central heating system that controls the temperature in every room. On the next few pages, you will see some different central heating systems.

Hot-Water Heating

The high specific heat of water makes it useful for heating systems. A hot-water heating system is shown in **Figure 1.** A hot-water heater raises the temperature of water, which is pumped through pipes that lead to radiators in each room. The radiators then heat the colder air surrounding them. The water returns to the hot-water heater to be heated again.

Figure 1 A Hot-Water Heating System

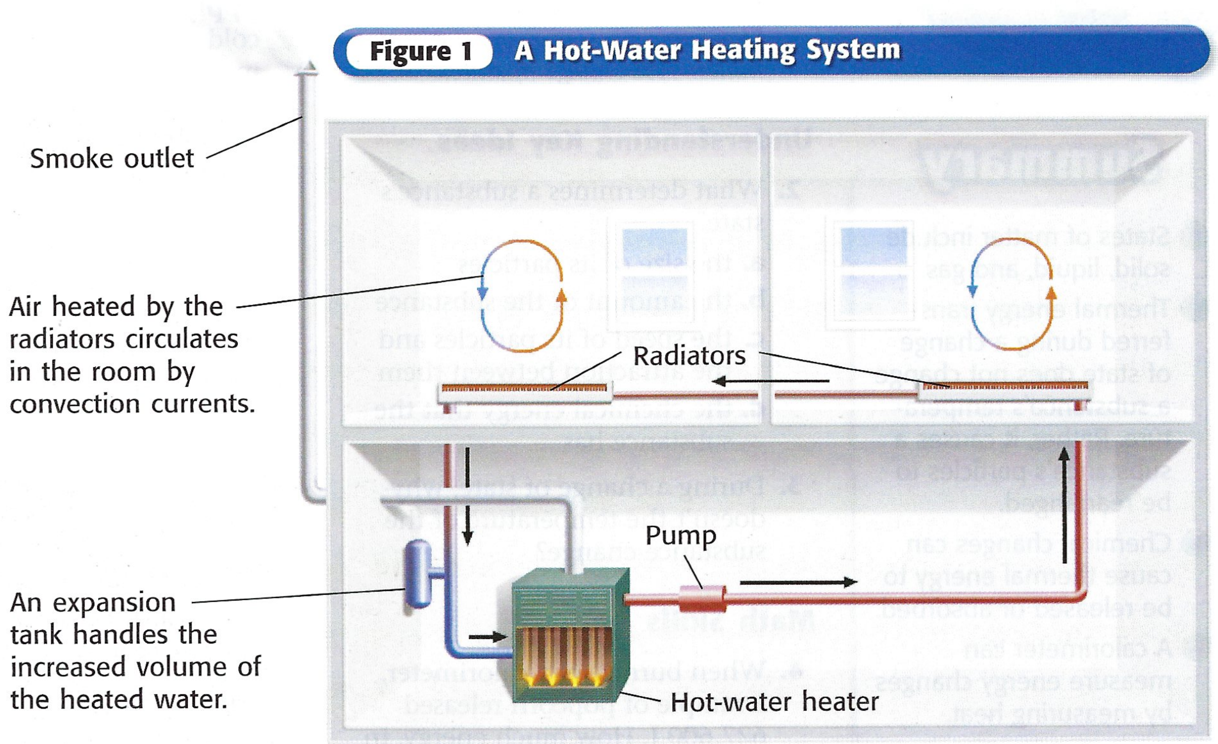
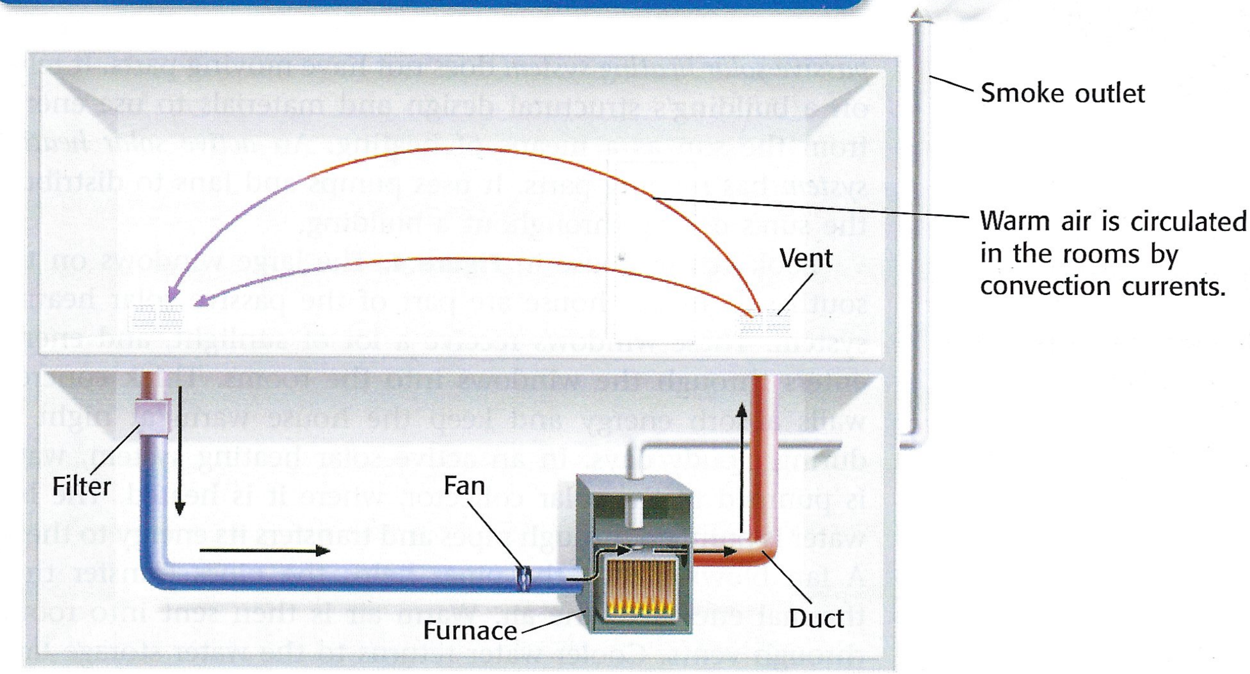


Figure 2 **A Warm-Air Heating System**



Warm-Air Heating

Air cannot hold as much thermal energy as water can. But warm-air heating systems are used in many homes and offices in the United States. In a warm-air heating system, shown in **Figure 2,** air is heated by burning fuel (usually natural gas) in a furnace. The warm air travels through ducts to different rooms. The warm air heats air in the rooms. Cooler air sinks below the warm air and enters a vent near the floor. Then, a fan forces the cooler air into the furnace. The air is heated and returned to the ducts. An air filter cleans the air as it moves through the system.

insulation a substance that reduces the transfer of electricity, heat, or sound

Heating and Insulation

Heat may quickly escape out of a house during cold weather, and during hot weather a house may heat up. To keep the house comfortable, a heating system must run much of the time during the winter. Air conditioners often must run most of the time in the summer to keep a house cool. This can be wasteful. Insulation can help reduce the energy needed to heat and cool buildings. Fiberglass insulation is shown in **Figure 3.** **Insulation** is a material that reduces the transfer of thermal energy. When insulation is used in walls, ceilings, and floors, less heat passes into or out of the building. Insulation helps a house stay warm in the winter and cool in the summer.

Reading Check **How does insulation help reduce energy costs?** (*See the Appendix for answers to Reading Checks.*)

Figure 3 *Millions of tiny air pockets in this insulation help prevent thermal energy from flowing into or out of a building.*

Solar Heating

The sun gives off a huge amount of energy. Solar heating systems use this energy to heat houses and buildings. A *passive solar heating system* does not have moving parts. It relies on a building's structural design and materials to use energy from the sun as a means of heating. An *active solar heating system* has moving parts. It uses pumps and fans to distribute the sun's energy throughout a building.

Look at the house in **Figure 4.** The large windows on the south side of the house are part of the passive solar heating system. These windows receive a lot of sunlight, and energy enters through the windows into the rooms. Thick concrete walls absorb energy and keep the house warm at night or during cloudy days. In an active solar heating system, water is pumped to the solar collector, where it is heated. The hot water is pumped through pipes and transfers its energy to them. A fan blowing over the pipes helps the pipes transfer their thermal energy to the air. Warm air is then sent into rooms through vents. Cooler water returns to the water storage tank to be pumped back through the solar collector.

SCHOOL to HOME

WRITING SKILL **Home Heating and Cooling**

Find out from an adult what kinds of systems are used in your home for heating and cooling. In your **science journal,** describe how these systems work. Also, describe any energy-saving methods used in your home.

ACTIVITY

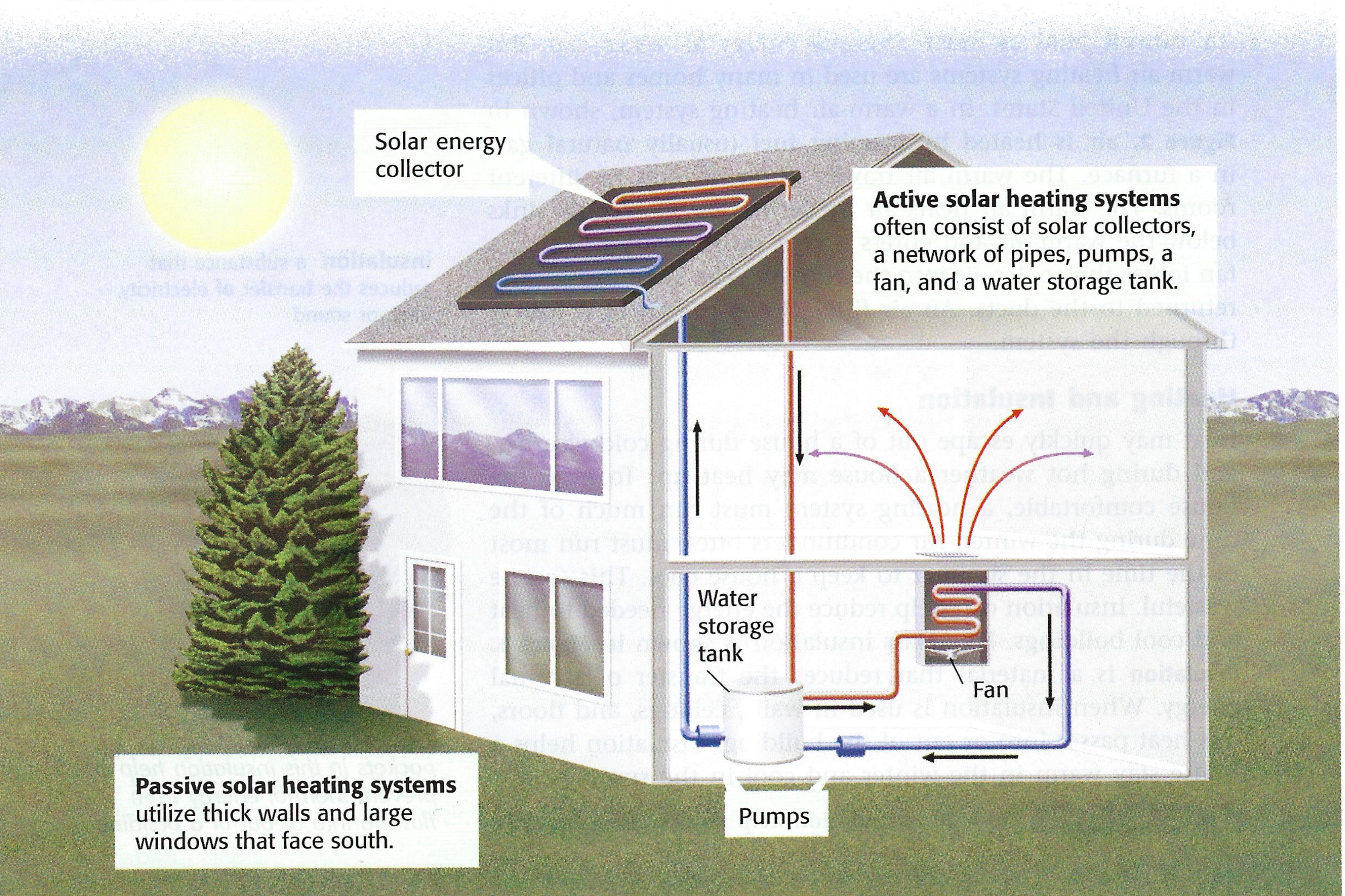


Figure 4 *Passive and active solar heating systems work together to use the sun's energy to heat an entire house.*

Heat Engines

Did you know that automobiles work because of heat? A car has a **heat engine,** a machine that uses heat to do work. In a heat engine, fuel combines with oxygen in a chemical change that releases thermal energy. Heat engines burn fuel through this process, called *combustion*. Heat engines that burn fuel outside the engine are called *external combustion engines*. Heat engines that burn fuel inside the engine are called *internal combustion engines*. In both types of engines, fuel is burned to release thermal energy that can be used to do work.

heat engine a machine that transforms heat into mechanical energy, or work

✓ Reading Check **What kind of energy do combustion engines use?**

External Combustion Engines

A simple steam engine, shown in **Figure 5,** is an example of an external combustion engine. Coal is burned to heat water in a boiler and change the water to steam. The steam expands, which pushes a piston. The piston can be attached to other parts of the machine that do work.

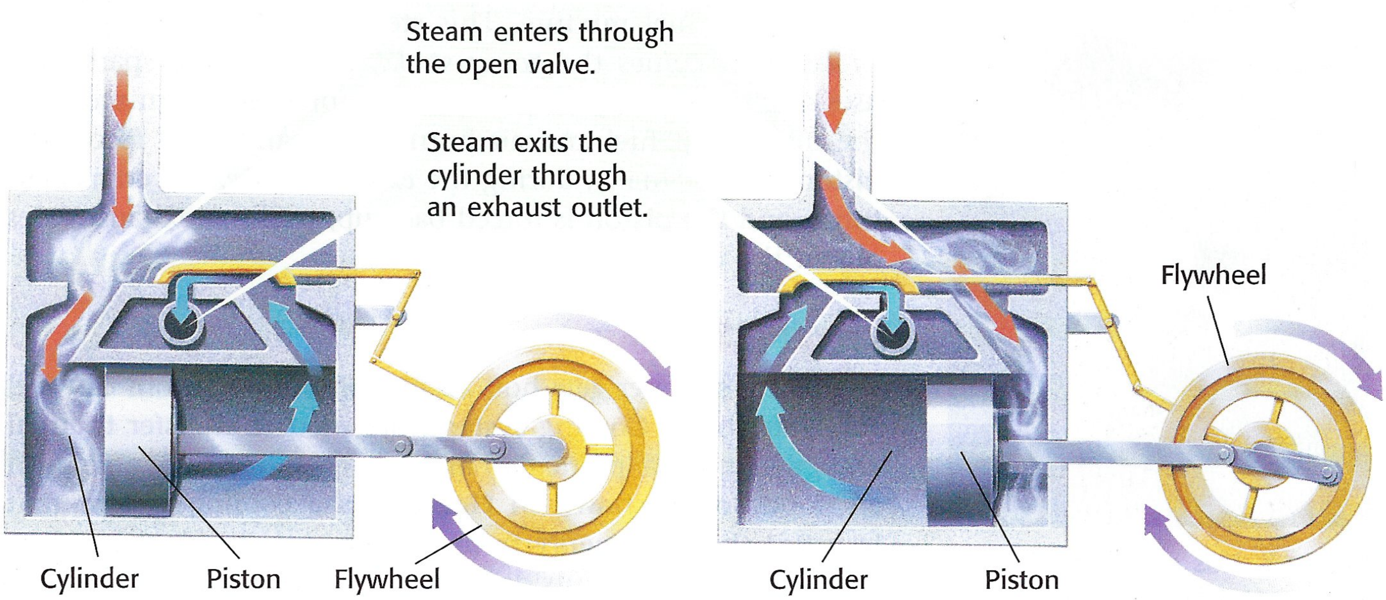
Modern steam engines, such as those used to generate electrical energy at a power plant, drive turbines instead of pistons. In the case of generators that use steam to do work, thermal energy is converted into electrical energy.

CONNECTION TO Oceanography

Energy from the Ocean
Ocean engineers are developing a new technology called *Ocean Thermal Energy Conversion,* or OTEC. OTEC uses temperature differences between surface water and deep water in the ocean to generate electrical energy. Research more information about OTEC, and make a model or a poster demonstrating how it works.

ACTIVITY

Figure 5 **An External Combustion Engine**



1 The expanding steam enters the cylinder from one side. The steam does work on the piston, forcing the piston to move.

2 As the piston moves to the other side, a second valve opens, and steam enters. The steam does work on the piston and moves it back. The motion of the piston turns a flywheel.

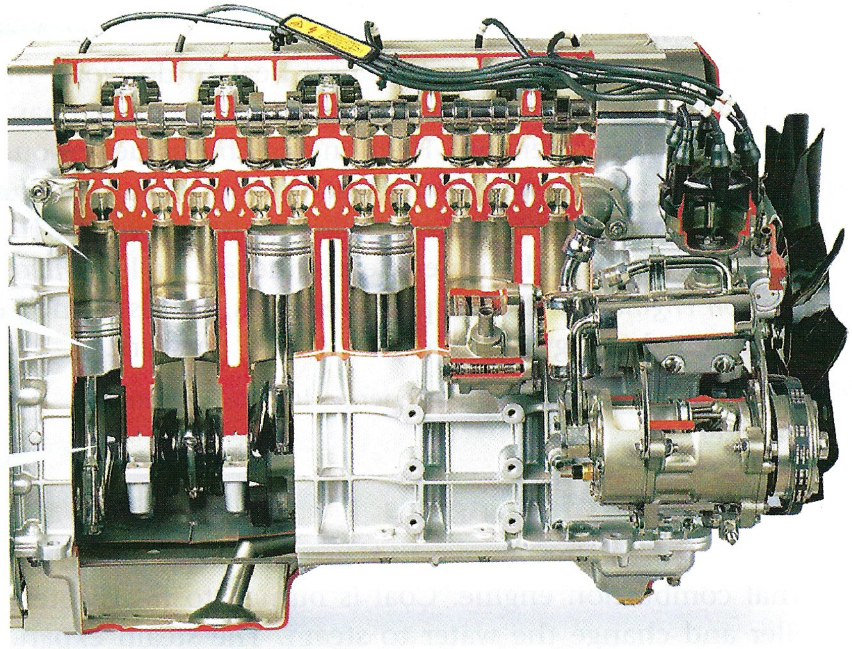


Figure 6 *The continuous cycling of the four strokes in the cylinders converts thermal energy into the kinetic energy needed to make a car move.*

Internal Combustion Engines

The six-cylinder car engine shown in **Figure 6** is an internal combustion engine. Fuel is burned inside the engine. The fuel used is gasoline, which is burned inside the cylinders. The cylinders go through a series of steps in burning the fuel.

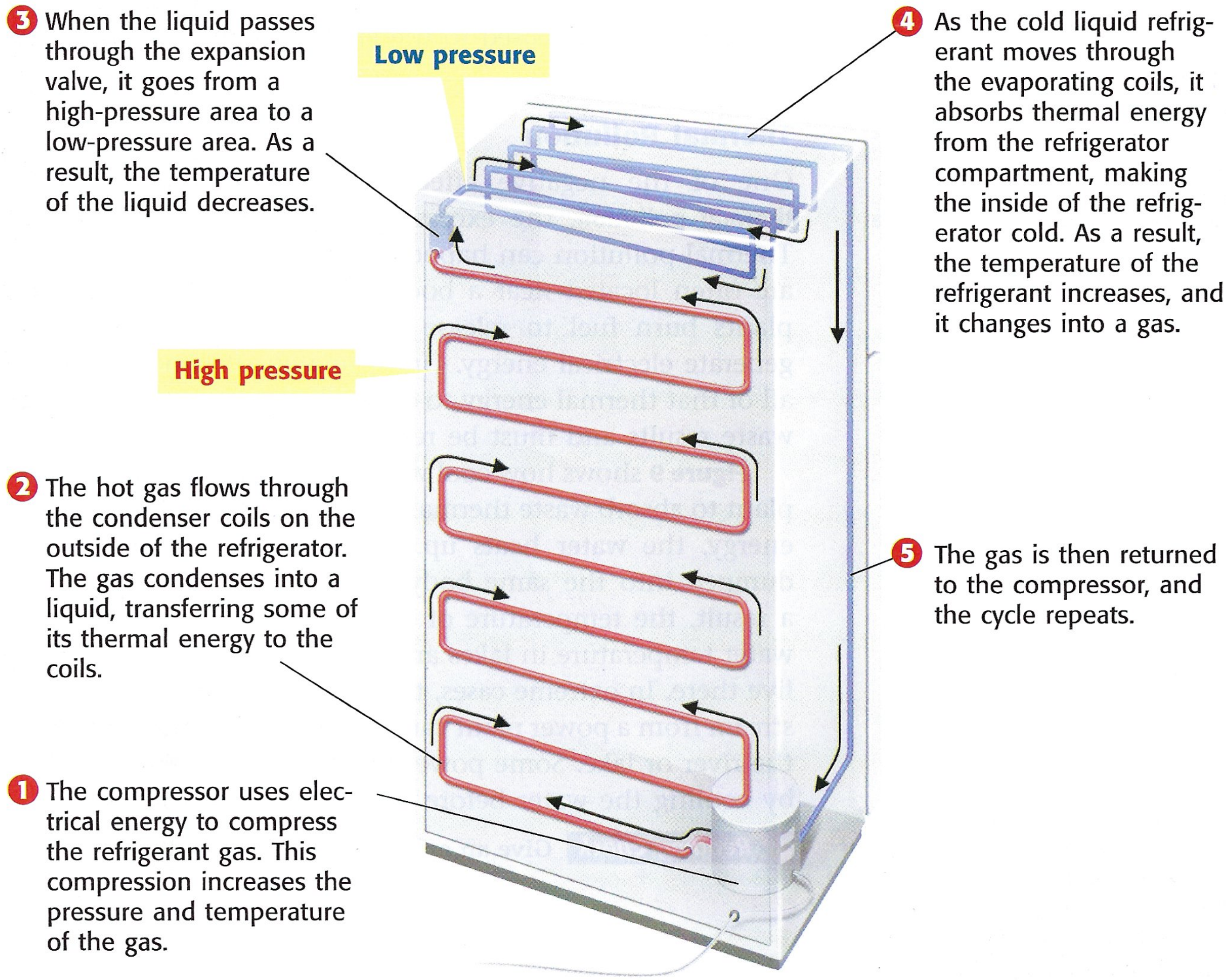
First, a mixture of gasoline and air enters each cylinder as the piston moves down. This step is called the *intake stroke*. Next, the crankshaft turns and pushes the piston up, compressing the fuel mixture. This step is called the *compression stroke*. Next comes the *power stroke,* in which the spark plug uses electrical energy to ignite the compressed fuel mixture. As the mixture of fuel and air burns, it expands and forces the piston down. Finally, during the *exhaust stroke,* the crankshaft turns, and the piston is forced back up, pushing exhaust gases out of the cylinder.

Figure 7 *This air-conditioning unit keeps a building cool by moving thermal energy from inside the building to the outside.*

Cooling Systems

When the summer gets hot, an air-conditioned room can feel very refreshing. Cooling systems are used to transfer thermal energy out of a particular area so that it feels cooler. An air conditioner, shown in **Figure 7,** is a cooling system that transfers thermal energy from a warm area inside a building or car to an area outside. Thermal energy naturally tends to go from areas of higher temperature to areas of lower temperature. So, to transfer thermal energy outside where it is warmer, the air-conditioning system must do work. It's like walking uphill: if you are going against gravity, you must do work.

Figure 8 **How a Refrigerator Works**



Cooling and Energy

Most cooling systems require electrical energy to do the work of cooling. The electrical energy is used by a device called a compressor. The *compressor* does the work of compressing the refrigerant. The *refrigerant* is a gas that has a boiling point below room temperature, which allows it to condense easily.

To keep many foods fresh, you store them in a refrigerator. A refrigerator is another example of a cooling system. **Figure 8** shows how a refrigerator continuously transfers thermal energy from inside the refrigerator to the condenser coils on the outside of the refrigerator. That's why the area near the back of a refrigerator feels warm.

✓ Reading Check **How does the inside of a refrigerator stay at a temperature that is cooler than the temperature outside the refrigerator?**

Heat Technology and Thermal Pollution

Heating systems, car engines, and cooling systems all transfer thermal energy to the environment. Unfortunately, too much thermal energy released to the environment can have a negative effect.

Thermal Pollution

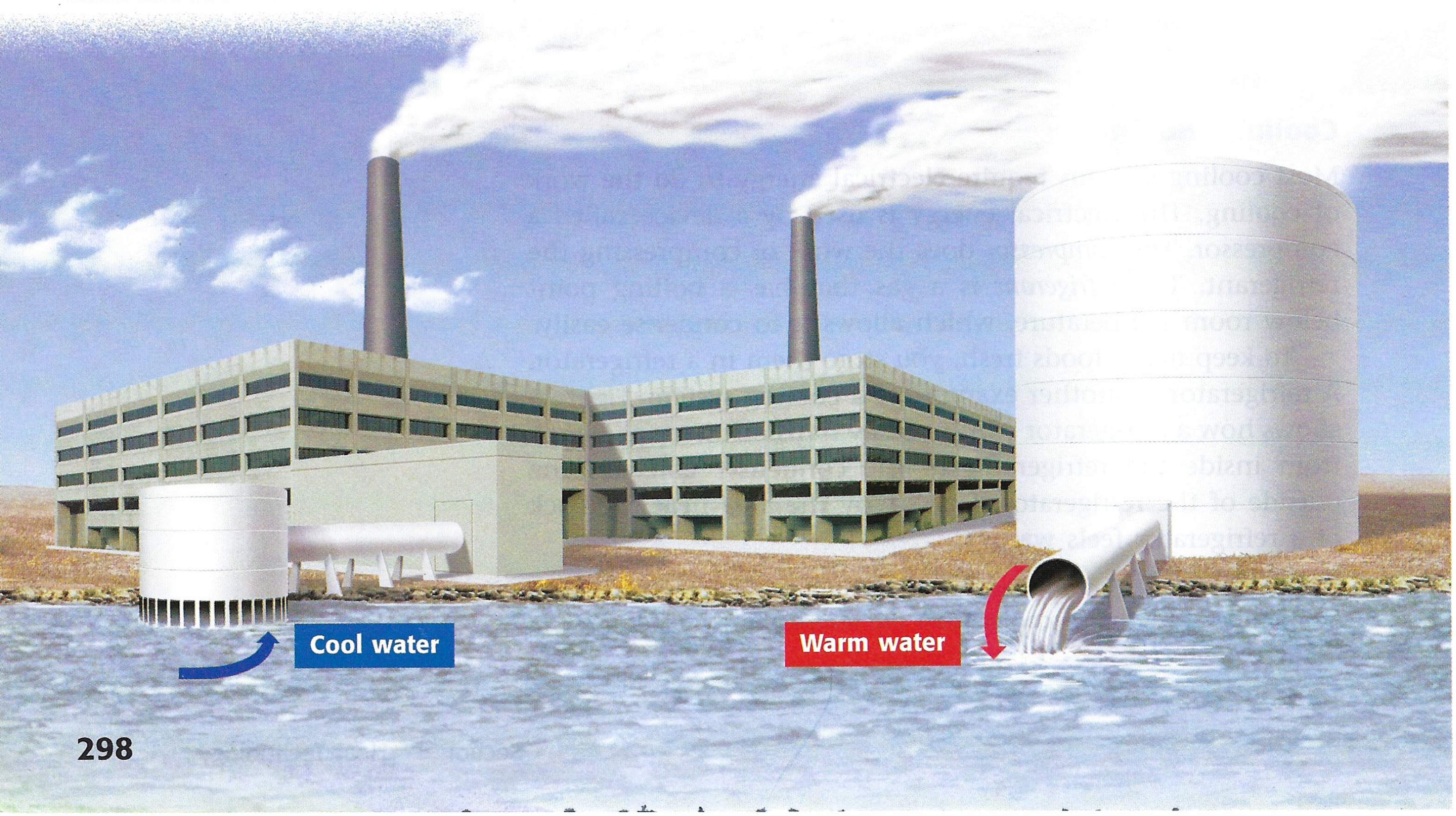
thermal pollution a temperature increase in a body of water that is caused by human activity and that has a harmful effect on water quality and on the ability of that body of water to support life

One of the negative effects of excess thermal energy is **thermal pollution,** the excessive heating of a body of water. Thermal pollution can happen near large power plants, which are often located near a body of water. Many electric-power plants burn fuel to release thermal energy that is used to generate electrical energy. Unfortunately, it is not possible for all of that thermal energy to do work. So, some thermal energy waste results and must be released to the environment.

Figure 9 shows how cool water is circulated through a power plant to absorb waste thermal energy. As the cool water absorbs energy, the water heats up. Sometimes the heated water is dumped into the same body of water that it came from. As a result, the temperature of the water can increase. Increased water temperature in lakes and streams can harm animals that live there. In extreme cases, the increase in temperature downstream from a power plant can adversely affect the ecosystem of the river or lake. Some power plants reduce thermal pollution by cooling the water before it is returned to the river.

✓ ***Reading Check*** **Give an example of thermal pollution.**

Figure 9 *Thermal pollution from power plants can result if the plant raises the water temperature of lakes and streams.*



SECTION Review

Summary

- Central heating systems include hot-water heating systems and warm-air heating systems.
- Solar heating systems can be passive or active. In passive solar heating, a building takes advantage of the sun's energy without the use of moving parts. Active solar heating uses moving parts to aid the flow of solar energy throughout a building.
- Heat engines use heat to do work.
- The two kinds of heat engines are external combustion engines, which burn fuel outside the engine, and internal combustion engines, which burn fuel inside the engine.
- A cooling system transfers thermal energy from cooler temperatures to warmer temperatures by doing work.
- Transferring excess thermal energy to lakes and rivers can result in thermal pollution.

Using Key Terms

1. Use each of the following terms in a separate sentence: *insulation, heat engine,* and *thermal pollution.*

Understanding Key Ideas

2. Which of the following describes how cooling systems transfer thermal energy?

a. Thermal energy naturally flows from cooler areas to warmer areas.

b. Thermal energy naturally flows from warmer areas to cooler areas.

c. Work is done to transfer thermal energy from warmer areas to cooler areas.

d. Work is done to transfer thermal energy from cooler areas to warmer areas.

3. Compare a hot-water heating system with a warm-air heating system.

4. What is the difference between an external combustion engine and an internal combustion engine?

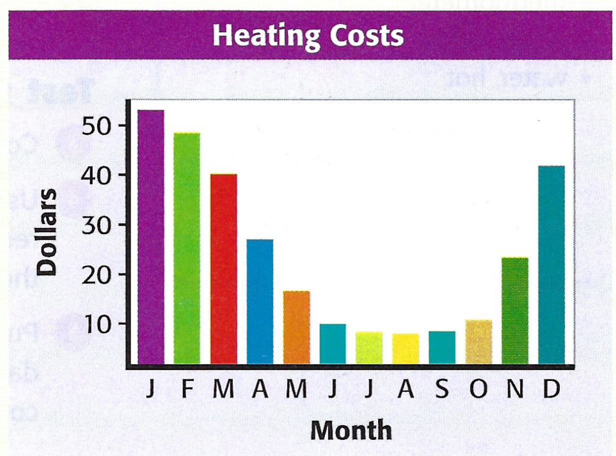
Critical Thinking

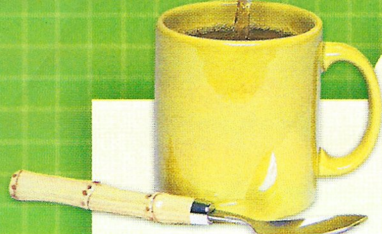
5. Identifying Relationships How are changes of state important in how a refrigerator works?

6. Expressing Opinions Compare the advantages and disadvantages of solar heating systems. What do you think their overall benefits are, compared with those of other heating systems?

Interpreting Graphics

7. Look at the graph below. It shows the cost of heating a certain house month by month over the course of a year. During which times of the year is the most energy used for heating? Explain your answer.





Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1. *temperature* and *thermal energy*
2. *conduction* and *heat*
3. *conductor* and *insulator*
4. *states of matter* and *change of state*
5. *heat engine* and *thermal pollution*

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Which of the following temperatures is the lowest?
   - **a.** 100°C
   - **b.** 100°F
   - **c.** 100 K
   - **d.** They are all the same.
7. Which of the following materials would NOT be a good insulator?
   - **a.** wood
   - **b.** cloth
   - **c.** metal
   - **d.** rubber
8. In an air conditioner, thermal energy is
   - **a.** transferred from areas of higher temperatures to areas of lower temperatures.
   - **b.** transferred from areas of lower temperatures to areas of higher temperatures.
   - **c.** used to do work.
   - **d.** transferred into the building.
9. The units of energy that you read on a food label are
   - **a.** Newtons.
   - **b.** Calories.
   - **c.** Joules.
   - **d.** Both (b) and (c)
10. Compared wih the Pacific Ocean, a cup of hot chocolate has
    - **a.** more thermal energy and a higher temperature.
    - **b.** less thermal energy and a higher temperature.
    - **c.** more thermal energy and a lower temperature.
    - **d.** less thermal energy and a lower temperature.

Short Answer

11. How does temperature relate to kinetic energy?
12. What are the differences between conduction, convection, and radiation?
13. Explain how heat affects matter during a change of state.

Math Skills

14. The weather forecast calls for a temperature of 84°F. What is the corresponding temperature in degrees Celsius? in kelvins?
15. Suppose 1.3 kg of water is heated from 20°C to 100°C. How much energy was transferred to the water? (Water's specific heat is 4,184 J/kg•°C.)

CRITICAL THINKING

16 **Concept Mapping** Create a concept map using the following terms: *thermal energy, temperature, radiation, heat, conduction,* and *convection.*

17 **Applying Concepts** The metal lid is stuck on a glass jar of jelly. Explain why running hot water over the lid will help you get the lid off.

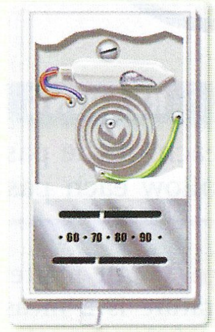
18 **Applying Concepts** How does a down jacket keep you warm? (Hint: Think about what insulation does.)

19 **Predicting Consequences** Would opening the refrigerator cool a room in a house? Explain your answer.

20 **Evaluating Assumptions** Someone claims that a large bowl of soup has more thermal energy than a small bowl of soup. Is this always true? Explain.

21 **Analyzing Processes** In a hot-air balloon, air is heated by a flame. Explain how this enables the balloon to float in the air.

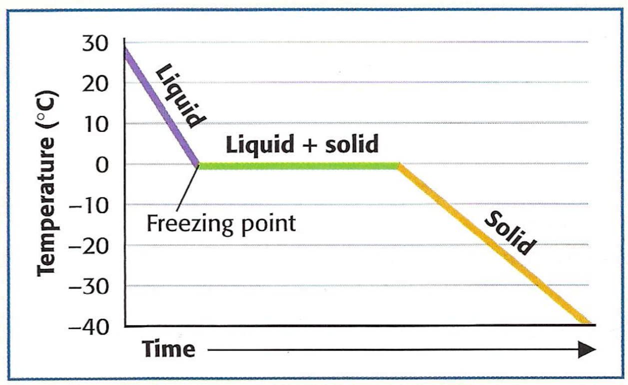
22 **Analyzing Processes** What is different about the two kinds of metal on the bimetallic strip of a thermostat coil?



23 **Making Comparisons** How is radiation different from both conduction and convection?

INTERPRETING GRAPHICS

Examine the graph below, and then answer the questions that follow.



24 What physical change does this graph illustrate?

25 What is the freezing point of this liquid?

26 What is happening at the point where the line is horizontal?