Section 4

Uses of Heat

Reading Preview

Key Concepts

- How do heat engines use thermal energy?
- How do refrigerators keep things cold?

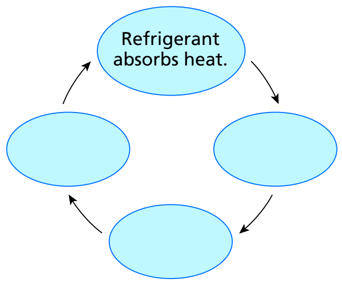
Key Terms

- heat engine
- external combustion engine
- internal combustion engine
- refrigerant

Target Reading Skill

Sequencing A sequence is the order in which the steps in a process occur. As you read, make a cycle diagram that shows how refrigerators work. Write each phase of the cooling system's cycle in a separate circle.

How Refrigerators Work



Lab zone Discover Activity

What Happens at the Pump?

1. Obtain a bicycle pump and a deflated basketball or soccer ball.
2. Feel the pump with your hand. Note whether it feels cool or warm to the touch.
3. Use the pump to inflate the ball to the recommended pressure.
4. As soon as you stop pumping, feel the pump again. Observe any changes in temperature.

Think It Over

Developing Hypotheses Propose an explanation for any changes that you observed.

For more than 100 years, the steam locomotive was a symbol of power and speed. It first came into use in the 1830s, and was soon hauling hundreds of tons of freight faster than a horse could gallop. Today, many trains are pulled by diesel locomotives that are far more efficient than steam locomotives.

Heat Engines

To power a coal-burning steam locomotive, coal is shoveled into a roaring fire. Heat is then transferred from the fire to water in the boiler. But how can heat move a train?

The thermal energy of the coal fire must be transformed to the mechanical energy, or energy of motion, of the moving train. You already know about the reverse process, the transformation of mechanical energy to thermal energy. It happens when you rub your hands together to make them warm.

The transformation of thermal energy to mechanical energy requires a device called a **heat engine.** Heat engines usually make use of combustion. Recall from Chapter 5 that combustion is the process of burning a fuel, such as coal or gasoline. During combustion, chemical energy that is stored in fuel is transformed to thermal energy. **Heat engines transform thermal energy to mechanical energy.** Heat engines are classified according to whether combustion takes place outside the engine or inside the engine.

Lab zone Discover Activity

Skills Focus Developing hypotheses L1

Materials bicycle pump, deflated basketball or soccer ball

Time 10 minutes

Tip Caution students to avoid over-inflating the ball, which could cause it to burst. Remind students that the pump uses mechanical energy to inflate the ball.

Expected Outcome Students should find that the temperature of the pump has increased after pumping.

Think It Over Sample answer: The pump's temperature increased because work done by the piston went into the thermal energy of the gas (due to compression) and the thermal energy of the pump (due to friction).

Section 4

Uses of Heat

Objectives

After this lesson, students will be able to

M.6.4.1 Describe how heat engines use thermal energy.

M.6.4.2 Describe how refrigerators keep things cold.

Target Reading Skill

Sequencing Explain that organizing information from beginning to end helps students understand a step-by-step process.

Answers

Sample cycle diagram: Refrigerant absorbs heat. Compressor increases refrigerant's temperature. Refrigerant releases heat. Expansion valve decreases refrigerant's temperature.

All in One Teaching Resources

- Transparency M56

Preteach

Build Background Knowledge L2

Heat Engines Use Thermal Energy

Ask: **How does the hood of a car that has just been driven feel?** *(It feels warm.)* **Where does the heat come from?** *(Combustion in the engine releases thermal energy.)*

Instruct

Heat Engines

Teach Key Concepts L2

Energy Conversions in Heat Engines

Focus Tell students that most heat engines convert thermal energy to mechanical energy.

Teach Direct students' attention to Figures 15 and 16. Have them note the location of the combustion in each engine.

Extend Ask: **What type of energy is stored in gasoline?** *(Chemical energy)* **What type of energy is this converted to during combustion?** *(Thermal energy)* **What type of energy is this converted to by the engine?** *(Mechanical energy)* **learning modality: logical/mathematical**

Lab zone Teacher Demo

Mechanical Energy From Steam L2

Materials teakettle, water, hot plate, pinwheel

Time 10 minutes

Focus Tell students that steam is used in some external combustion engines.

Teach Fill the teakettle with water, and place it on the hot plate. Heat the water until it boils and steam escapes from the spout. Hold the pinwheel in the escaping steam, so students can see the blades of the pinwheel turn. Explain that the hot plate is used in place of combustion in this demonstration.

Apply Ask: **What type of energy does the moving pinwheel have?** *(Mechanical energy, or kinetic energy)* **learning modality: visual**

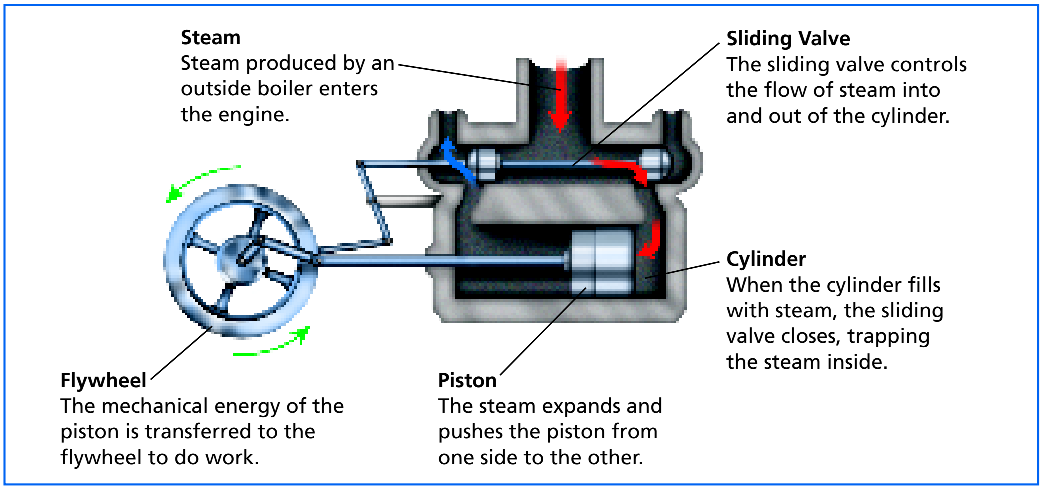
Independent Practice L2

All in One Teaching Resources

- Guided Reading and Study Worksheet: *Uses of Heat*
- Transparency M57

Student Edition on Audio CD

FIGURE 15
External Combustion Engine
In a steam-powered external combustion engine, expanding steam pushes a piston back and forth inside a cylinder. The steam's thermal energy is transformed to mechanical energy.



External Combustion Engines Engines that burn fuel outside the engine in a boiler are called **external combustion engines.** A steam engine, like the one shown in Figure 15, is an example of an external combustion engine. The combustion of wood, coal, or oil heats water in a boiler. As its thermal energy increases, the liquid water turns to water vapor, or steam. The steam is then passed through a sliding valve into the engine, where it pushes against a metal plunger called a piston. Work is done on the piston as it moves back and forth in a tube called a cylinder. The piston's motion turns a flywheel.

Internal Combustion Engines Engines that burn fuel in cylinders inside the engine are called **internal combustion engines.** Diesel and gasoline engines, which power most automobiles, are internal combustion engines. A piston inside a cylinder moves up and down, turning a crankshaft. The motion of the crankshaft is transferred to the wheels of the car.

Each up or down movement by a piston is called a stroke. Most diesel and gasoline engines are four-stroke engines, as shown in Figure 16. Automobile engines usually have four, six, or eight cylinders. The four-stroke process occurs in each cylinder, and is repeated many times each second.

Reading Checkpoint How many cylinders do automobiles usually have?

Lab zone Try This Activity

Shake It Up

How does work relate to temperature?

1. Place a handful of dry sand in a metal container that has a cover.
2. Measure the temperature of the sand with a thermometer.
3. Cover the can and shake it vigorously for a minute or two.
4. Predict any change in the temperature of the sand. Was your prediction correct?

Classifying Identify any energy transformations and use them to explain your observations.

Lab zone Try This Activity

Skills Focus Classifying L3

Materials dry sand, metal container such as a coffee can with a plastic lid, thermometer

Time 15 minutes

Tips Caution students not to force the thermometer into the sand. Remind students that some thermal energy escapes when they open the lid.

Expected Outcome The sand's temperature should increase slightly from shaking because mechanical energy is converted to thermal energy.

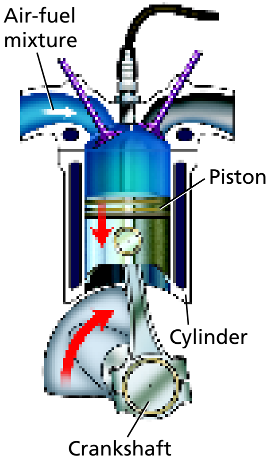
Extend Challenge students to find a way to reduce heat loss when the temperature is checked. *(Insert the thermometer into the lid)* **learning modality: kinesthetic**

FIGURE 16

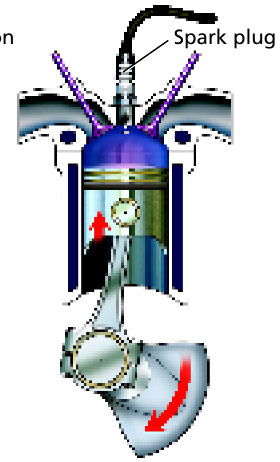
Four-Stroke Engine

Most automobiles use four-stroke engines. These four strokes occur repeatedly in each of the engine's cylinders.

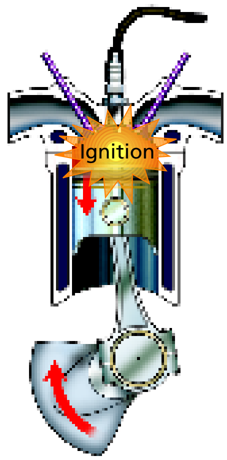
Interpreting Diagrams *During which stroke is thermal energy transformed to mechanical energy?*



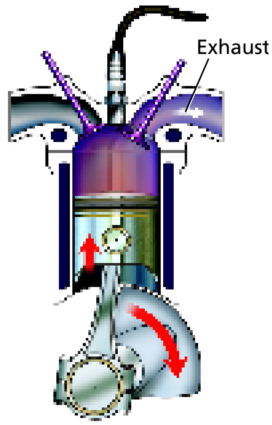
1 Intake Stroke
A mixture of fuel and air is drawn into the cylinder as the piston moves down.



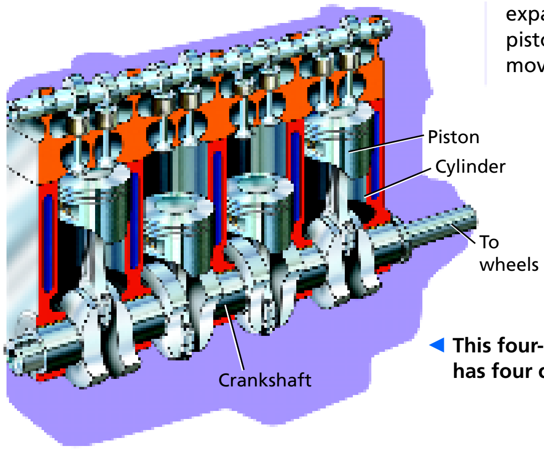
2 Compression Stroke
The mixture is compressed into a smaller space as the piston moves back up.



3 Power Stroke
A spark plug ignites the mixture. The heated gas expands and pushes the piston down. The piston moves the crankshaft.



4 Exhaust Stroke
The piston moves back up, pushing the heated gas out. This makes room for new fuel and air, so that the cycle can be repeated.



◀ **This four-stroke engine has four cylinders.**

Go Online *active art*

For: Four-Stroke Engine activity
Visit: PHSchool.com
Web Code: cgp-3064

Use Visuals L2

Four-Stroke Engines

Focus Tell students that most automobiles use four-stroke engines.

Teach Have students read the numbered descriptions within the figure. Ask volunteers to describe each step in their own words while the other students follow the diagrams in Figure 16.

Apply Ask: **In what step shown in the figure does combustion take place?** *(In Step 3, when the spark plug ignites the mixture of fuel and air)* **learning modality: visual**

All in One **Teaching Resources**

- Transparency M58

Go Online *active art*

For: Four-Stroke Engine activity
Visit: PHSchool.com
Web Code: cgp-3064

Students can interact with diagrams of a four-stroke engine online.

Differentiated Instruction

Less Proficient Readers L1

Organizing Information Have students organize the information in Figure 16 onto four index cards. Students should name the stroke on the front of each card and decribe the stroke on the back. Students can use the cards for review or to quiz others. **learning modality: verbal**

Special Needs L1

Reviewing Key Concepts Have students listen to the section on the **Student Edition on Audio CD.** When the students have finished listening, have them locate and read the boldface sentences in the section. Students can work with a partner to complete this activity. **learning modality: verbal**

Monitor Progress L2

Skills Check Ask students to predict what will happen in a four-stroke engine if a spark plug does not fire. *(The fuel-air mixture will not be ignited, and the heated gas will not push down on the piston.)*

Answers

Figure 16 Thermal energy is converted to mechanical energy during the power stroke.

Reading Checkpoint Four, six, or eight

Cooling Systems

Teach Key Concepts L2

How Cooling Systems Work

Focus Ask: **In what direction does thermal energy flow?** *(From warm substances to cooler substances)*

Teach Tell students that refrigerators and air conditioners work by transferring thermal energy from a cool area to a warm area using a substance called a refrigerant. Direct students' attention to Figure 17. Ask: **What happens to the state of the refrigerant as it passes through the steps shown in Figure 17?** *(It undergoes phase changes, from a liquid to a gas, and then from a gas to a liquid.)*

Apply Ask: **Why does keeping the refrigerator open for long time periods of time cause the refrigerator to use more electricity?** *(When the door is open, the temperature inside the refrigerator rises, therefore there is more thermal energy to be removed.)* **learning modality: visual**

All in One Teaching Resources

- Transparency M59

Help Students Read L1

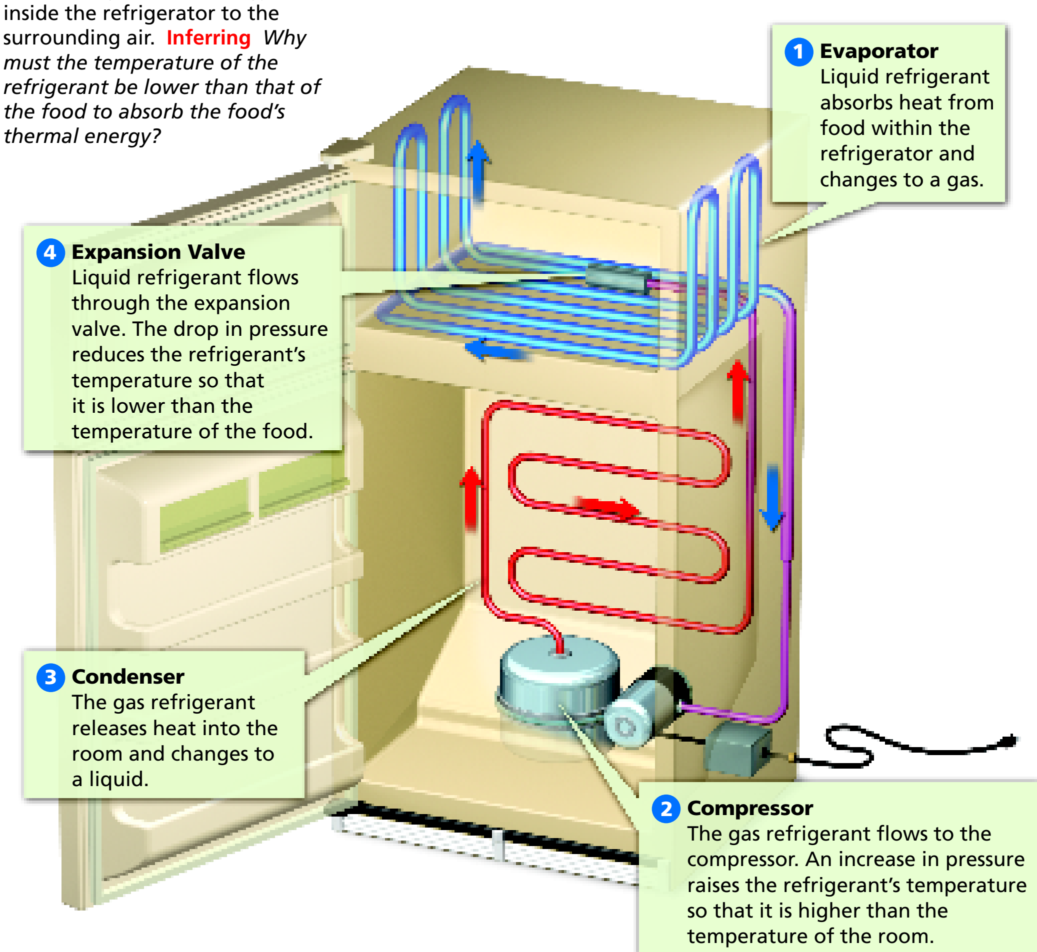
Relating Cause and Effect Have students examine Figure 17 to determine a cause and an effect within each numbered step in the diagram. Model this for students by showing the following example, for Step 1: Cause: Liquid refrigerant absorbs heat from food. Effect: Liquid refrigerant changes to a gas. Have the students complete this exercise for Steps 2, 3, and 4. *(Step 2: Cause: The compressor increases the pressure on the refrigerant. Effect: The refrigerant's temperature rises higher than room temperature. Step 3: Cause: The gas refrigerant releases heat into the room. Effect: The gas refrigerant changes to a liquid. Step 4: Cause: The expansion valve causes a drop in the pressure on the refrigerant. Effect: The refrigerant's temperature drops lower than the temperature of the food.)*

Cooling Systems

The transfer of heat can sometimes be used to keep things cool. Are you surprised? After all, heat naturally flows from a warm area to a cold area—not the other way around. But some devices, such as refrigerators, can transfer heat from cold areas to warm areas.

Refrigerators A refrigerator is cold inside. So where does the heat in the warm air rising from the back of a refrigerator come from? You may be surprised to learn that part of the heat actually comes from food in the refrigerator! **A refrigerator is a device that transfers thermal energy from inside the refrigerator to the room outside.** In doing so, the refrigerator transfers thermal energy from a cool area to a warm area.

FIGURE 17
Refrigerator
Inside a refrigerator, refrigerant moves through a system of pipes, transferring thermal energy from inside the refrigerator to the surrounding air. **Inferring** *Why must the temperature of the refrigerant be lower than that of the food to absorb the food's thermal energy?*



Differentiated Instruction

Less Proficient Readers L1

Active Listening Read aloud the text found in the insets in Figure 17. Ask students to follow along in their book as you read. When you have completed reading, challenge students to state facts or ask questions about the text. **learning modality: verbal**

Gifted and Talented L3

Communicating Information Have students research the history of refrigeration. Students can share what they have learned with the class in an oral presentation. **learning modality: verbal**

A substance called a **refrigerant** absorbs and releases heat in a refrigerator. As shown in Figure 17, the refrigerant moves through a closed system of pipes. These pipes run along the back of the refrigerator and inside where food is stored. The coiled pipes inside make up the evaporator. As the refrigerant enters the evaporator, it is a liquid. Because it is colder than the food, it absorbs the thermal energy of the food. The food's thermal energy raises the refrigerant's temperature, causing it to evaporate. Then, the gas refrigerant enters an electric pump called a compressor. The compressor increases the refrigerant's pressure, further raising its temperature.

From the compressor, the gas refrigerant flows to the coiled pipes at the back of the refrigerator that make up the condenser. When it enters the condenser, the refrigerant is warmer than the air in the room. It releases heat into the air and its temperature drops, causing the refrigerant to condense. The pressure of the liquid refrigerant is decreased as it flows into a narrow opening called an expansion valve. The decreased pressure lowers the refrigerant's temperature further. The refrigerant recycles as it flows back to the evaporator.

Air Conditioners The air conditioners used in homes, schools, and cars cool air in the same way that a refrigerator cools food. Refrigerant in a system of pipes changes from a liquid to a gas and back again to transfer heat. Unlike a refrigerator, however, an air conditioner absorbs heat from the air inside a room or car and transfers it to the outdoors.

Reading Checkpoint **How are air conditioners and refrigerators similar?**

Section 4 Assessment

Target Reading Skill Sequencing Refer to your cycle diagram about cooling systems as you answer Question 2.

Reviewing Key Concepts

1. a. **Describing** What does a heat engine do?
   b. **Comparing and Contrasting** How are internal combustion engines different from external combustion engines? How are they similar?
   c. **Making Generalizations** Why do you think modern cars use internal rather than external combustion engines?
2. a. **Identifying** What changes of state occur in the refrigerant of a refrigerator?
   b. **Explaining** Where do the changes of state occur?
   c. **Predicting** If the compressor in a refrigerator stopped working, how would its failure affect the heat transfer cycle?

Writing in Science

Cause-and-Effect Paragraph The invention of the heat engine and refrigerator both had a great impact on society. Write about how daily life might be different if either system had not been invented.

Monitor Progress L2

Answers

Figure 17 Because thermal energy moves spontaneously from a warmer object to a cooler one.

Reading Checkpoint Both devices transfer heat from a cooler area to a warmer area.

Assess

Reviewing Key Concepts

1. a. A heat engine converts thermal energy to mechanical energy. **b.** In an internal combustion engine, fuel is burned inside the engine; in an external combustion engine, fuel is burned outside the engine. Both convert thermal energy to mechanical energy. **c.** Sample answer: Internal combustion engines are more efficient.
2. a. Condensation and evaporation
b. Condensation occurs in the condenser; evaporation occurs in the evaporator.
c. The refrigerant's pressure and temperature would not be increased sufficiently before it entered the condenser. Therefore, the refrigerant would not release enough heat (to the air outside the refrigerator) to condense. If the refrigerant did not condense, it could not evaporate later to cool foods inside the refrigerator.

Reteach L1

Have students use Figures 16 and 17 to review the processes involved in the function of a heat engine and a cooling system.

Performance Assessment L2

Writing Ask students to write advertisements for an air conditioning system. The advertisement should describe how the air conditioner cools a hot room.

All in One Teaching Resources

- Section Summary: *Uses of Heat*
- Review and Reinforcement: *Uses of Heat*
- Enrich: *Uses of Heat*

Lab zone Chapter Project

Keep Students on Track Students should build and test their containers. Make sure that students consider that they will need to access the aluminum can at the beginning of the test to add water and at the end of the test to measure the water's temperature.

Writing in Science

Writing Mode Exposition/Cause and Effect

Scoring Rubric

4 Exceeds criteria
3 Meets criteria
2 Includes little information on heat engines and refrigerators
1 Shows little effort and/or includes serious errors