## Part 2 Short Response/Grid In

*Record your answers on the answer sheet provided by your teacher or on a sheet of paper.*

**10.** As you throw a ball, you exert a force on ball of 4.2 N. You exert this force on the ball while the ball moves a distance of 0.45 m. The ball leaves your hand and travels a horizontal distance of 8.5 m to your friend. How much work have you done on the ball?

**Use the illustration below to answer questions 11–13.**

**11.** What is the ideal mechanical advantage of the pulley system shown in the figure to the right?

**12.** If the block supported by the pulley system shown above has a weight of 20 N, what is the input force on the rope?

**13.** If an additional pulley were included in the system shown in the illustration, what would the input force be?

**14.** A machine does 760 J of work in 32 s. What is the machine's power?

**15.** Write an equation for the efficiency of a lever if you know the lever's input force and distance as well as the output force and distance.

**16.** A centripetal force is exerted in a direction perpendicular to the motion of an object in circular motion. Is work done by a centripetal force? Why or why not?

## Part 3 Open Ended

*Record your answers on a sheet of paper.*

**17.** Is the following statement true? If so, give an example that supports it. If not, explain why.

*When work is done, a transfer of energy always occurs, but a transfer of energy does not always mean that work has been done.*

**18.** What are three ways that simple machines can make work easier? For each one, give an example of a machine that makes work easier in that way.

**19.** Explain what causes friction in a machine and how a lubricant reduces a machine's friction. Describe the change a lubricant would make in the efficiency of a machine.

**20.** Use the law of conservation of energy to explain why it is impossible for the output work of a machine to be greater than the machine's input work.

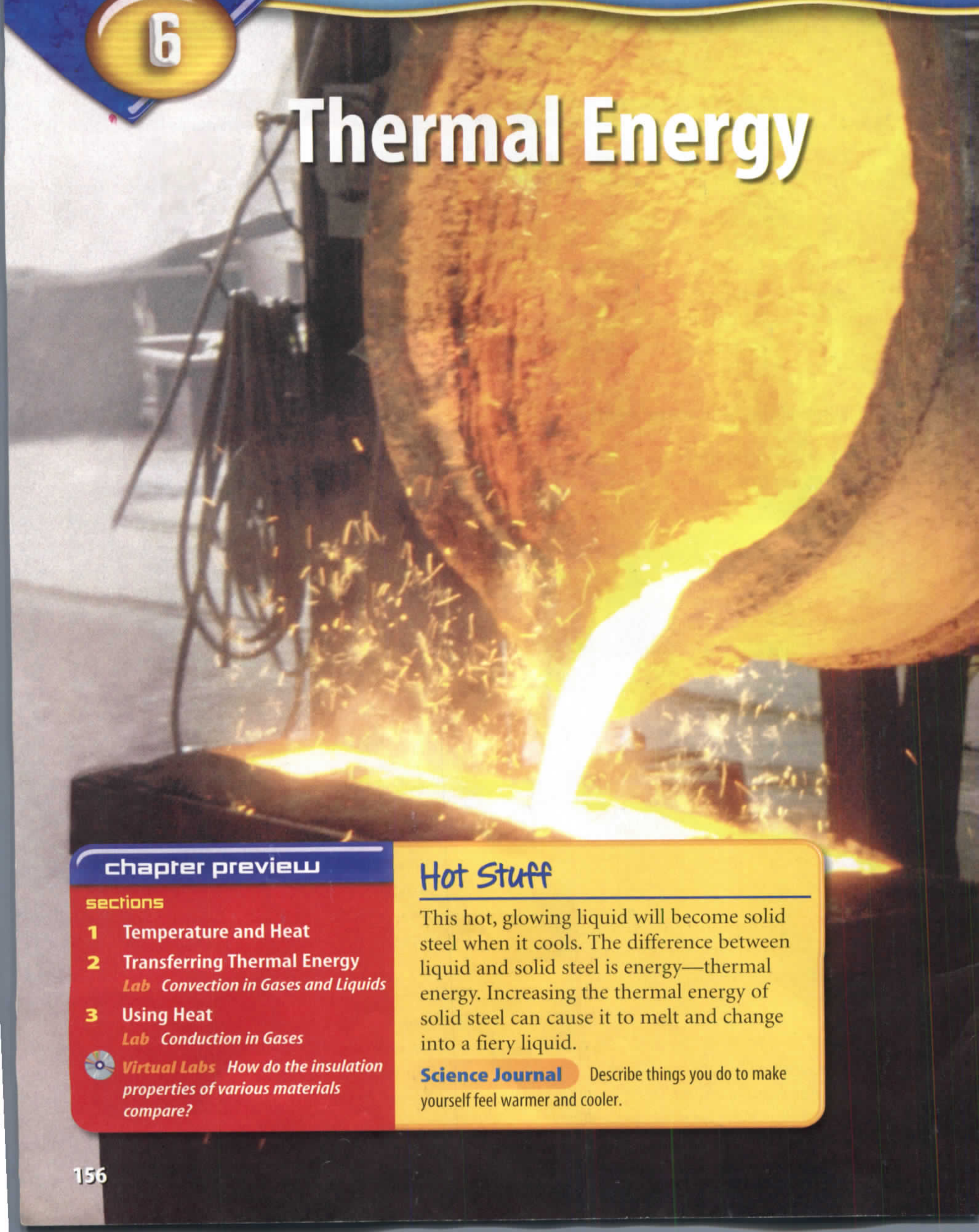
**Use the illustration below to answer questions 21 and 22.**

**21.** The boy in the photograph to the right is carrying a box to the top of the stairs. Describe how the work that the boy does on the box is related to the energy transfer that occurs. How does the energy of the box change form as the boy carries the box up the stairs?

**22.** Explain how the work, power, and energy would change if the boy walked faster. How would the work, power, and energy change if the steps were the same height but steeper?

chapter 6

# Thermal Energy



## chapter preview

### sections



## Hot Stuff

This hot, glowing liquid will become solid steel when it cools. The difference between liquid and solid steel is energy—thermal energy. Increasing the thermal energy of solid steel can cause it to melt and change into a fiery liquid.

**Science Journal** Describe things you do to make yourself feel warmer and cooler.

# Start-Up Activities

## Launch LAB

### Temperature and Kinetic Energy

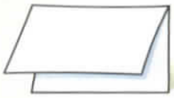
Hot water can burn your skin, but warm water doesn't. How is hot water different from warm water? You know that the temperature of hot water is higher. The temperature depends on the energy of the water molecules. In hot water, molecules of water are moving faster than they are in warm water. As a result, the kinetic energy of water molecules in hot water is larger. The difference in kinetic energy also has other effects, as you'll see in this lab.

1. Pour 200 mL of room-temperature water into a beaker.
2. Pour 200 mL of water into a beaker and add some ice.
3. Put one drop of food coloring into each beaker.
4. Compare how quickly the food coloring causes the color of the water to change in each beaker.
5. **Think Critically** Write a paragraph describing the results of your experiment. Infer why the food coloring spread throughout the water in the two beakers at different rates.

## FOLDABLES™ Study Organizer

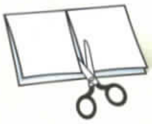
**Thermal Energy and Heat** Make the following Foldable to help you understand thermal energy and heat.

**STEP 1** **Fold** a vertical sheet of paper in half from top to bottom.

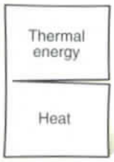


**STEP 2** **Fold** in half from side to side with the fold at the top.

**STEP 3** **Unfold** the paper once. **Cut** only the fold of the top flap to make two tabs.



**STEP 4** **Turn** the paper vertically and **label** the front tabs as shown.




**Find Main Ideas** As you read the chapter, write the main ideas you find about thermal energy and heat under the appropriate tab.

Science Online Preview this chapter's content and activities at gpscience.com

section 1

# Temperature and Heat

## Reading Guide

### *What* You'll Learn

- **Define** temperature.
- **Explain** how thermal energy depends on temperature.
- **Explain** how thermal energy and heat are related.
- **Calculate** the change in thermal energy.

### *Why* It's Important

Cars, buses, trucks, and airplanes could not operate without thermal energy.

### Review Vocabulary

**kinetic energy:** the energy an object has due to its motion

### New Vocabulary

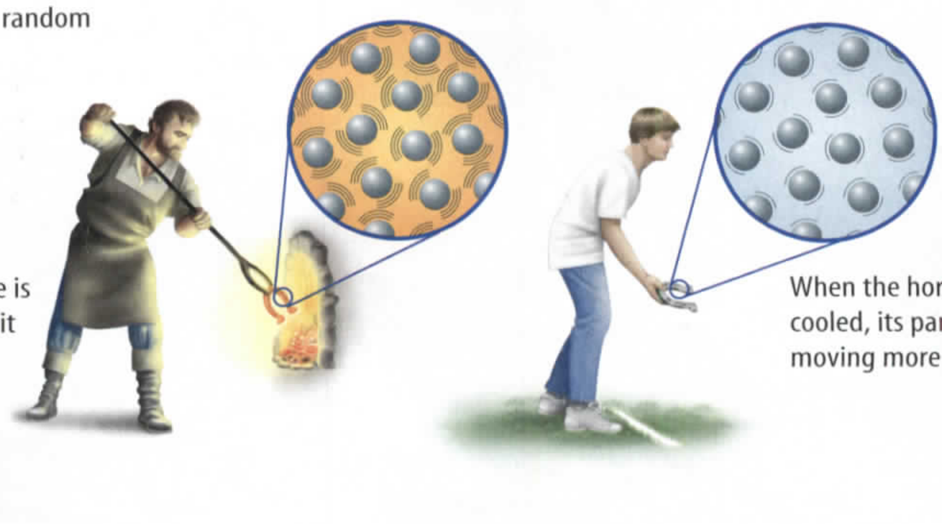
- temperature
- thermal energy
- heat
- specific heat

## Temperature

You use the words hot and cold to describe temperature. Something is hot when its temperature is high. When you heat water on a stove, its temperature increases. How are temperature and heat related?

**Matter in Motion** The matter around you is made of tiny particles—atoms and molecules. In all materials these particles are in constant, random motion; moving in all directions at different speeds. Because these particles are moving, they have kinetic energy. The faster they move, the more kinetic energy they have. **Figure 1** shows that particles move faster in hot objects than in cooler objects.

**Figure 1** The particles in an object are in constant random motion.



When the horseshoe is hot, the particles in it move faster.

When the horseshoe has cooled, its particles are moving more slowly.

**Temperature** The temperature of an object and the kinetic energy of its atoms and molecules are related. The **temperature** of an object is a measure of the average kinetic energy of the particles in the object. As the temperature of an object increases, the average speed of the particles in random motion increases. The temperature of hot tea is higher than the temperature of iced tea because the particles in the hot tea are moving faster on average. In SI units, temperature is measured in kelvins (K). A more commonly used temperature scale is the Celsius scale. One kelvin degree is the same size as one Celsius degree.

## Thermal Energy

If you let cold butter sit at room temperature for a while, it warms and becomes softer. Because the air in the room is at a higher temperature than the butter, particles in air have more kinetic energy than butter particles. Collisions between particles in butter and particles in air transfer energy from the faster-moving particles in air to the slower-moving butter particles. The butter particles then move faster and the temperature of the butter increases.

Particles in the butter can exert attractive forces on each other. Recall that Earth exerts an attractive gravitational force on a ball. When the ball is above the ground, the ball and Earth are separated, and the ball has potential energy. In the same way, atoms and particles that exert attractive forces on each other have potential energy when they are separated. The sum of the kinetic and potential energy of all the particles in an object is the **thermal energy** of the object. Because the kinetic energy of the butter particles increased as it warmed, the thermal energy of the butter increased.

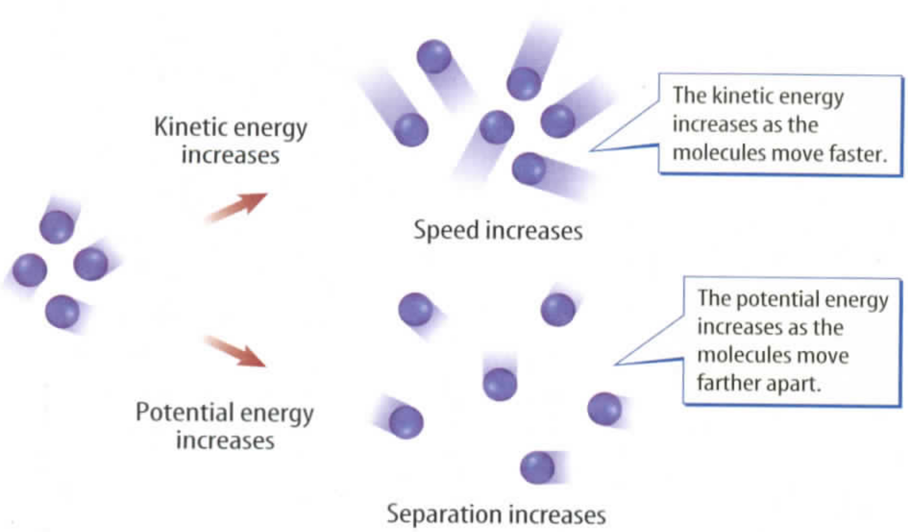



**Figure 2** The thermal energy of a substance is the sum of the kinetic and potential energy of its molecules.
**Infer** *why increasing the temperature of an object increases its thermal energy.*

Science Online

**Topic: Weather Satellites**
Visit gpscience.com for Web links to information about how weather satellites use thermal energy to acquire weather data.

**Activity** Draw a diagram showing how a satellite uses thermal energy to produce images.

**Thermal Energy and Temperature** Thermal energy and temperature are related. When the temperature of an object increases, the average kinetic energy of the particles in the object increases. Because thermal energy is the total kinetic and potential energy of all the particles in an object, the thermal energy of the object increases when the average kinetic energy of its particles increases. Therefore, the thermal energy of an object increases as its temperature increases.

**Thermal Energy and Mass** Suppose you have a glass and a beaker of water that are at the same temperature. The beaker contains twice as much water as the glass. The water in both containers is at the same temperature, so the average kinetic energy of the water molecules is the same in both containers. But there are twice as many water molecules in the beaker as there are in the glass. So the total kinetic energy of all the molecules is twice as large for the water in the beaker. As a result, even though they are at the same temperature, the water in the beaker has twice as much thermal energy as the water in the glass does. If the temperature doesn't change, the thermal energy in an object increases if the mass of the object increases.

## Heat

Can you tell if someone has been sitting in your chair? Perhaps you've noticed that your chair feels warm, and maybe you concluded that someone has been sitting in it recently. The chair feels warmer because thermal energy from the person's body flowed to the chair and increased its temperature.

**Heat** is thermal energy that flows from something at a higher temperature to something at a lower temperature. Heat is a form of energy, so it is measured in joules—the same units that energy is measured in. Heat always flows from warmer to cooler materials. How did the ice cream in **Figure 3** become cold? Heat flowed from the warmer liquid ingredients to the cooler ice-and-salt mixture. The liquid ingredients released enough thermal energy to become cold enough to form solid ice cream. Meanwhile, the ice-and-salt solution absorbed thermal energy, causing some of the ice to melt.


**Figure 3** Heat flows from the warmer ingredients inside the container to the ice-and-salt mixture.

**Reading Check** *How are heat and thermal energy related?*

## Specific Heat

If you are at the beach in the summertime, you might notice that the ocean seems much cooler than the air or sand. Even though energy from the Sun is falling on the air, sand, and water at the same rate, the temperature of the water has changed less than the temperature of the air or sand has.

As a substance absorbs heat, its temperature change depends on the nature of the substance, as well as the amount of heat that is added. For example, compared to 1 kg of sand, the amount of heat that is needed to raise the temperature of 1 kg of water by 1°C is about six times greater. So the ocean water at the beach would have to absorb six times as much heat as the sand to be at the same temperature. The amount of heat that is needed to raise the temperature of 1 kg of some material by 1°C is called the **specific heat** of the material. Specific heat is measured in joules per kilogram degree Celsius [J/(kg °C)]. **Table 1** shows the specific heats of some familiar materials.

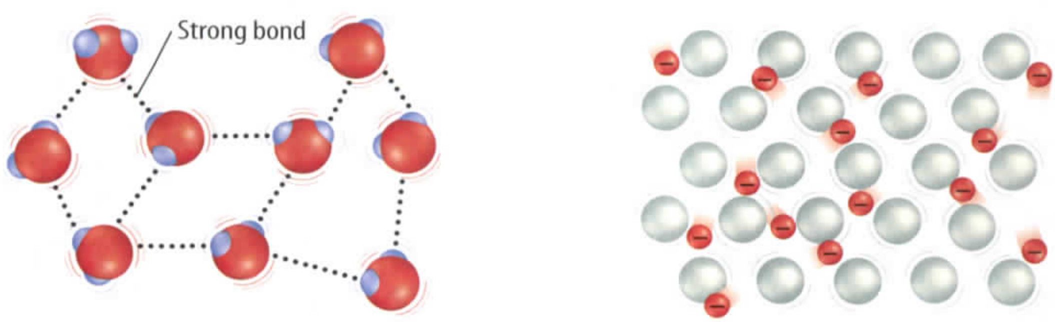
**Table 1 Specific Heat of Some Common Materials**

| Substance | Specific Heat [J/(kg°C)] |
|---|---|
| Water | 4,184 |
| Wood | 1,760 |
| Carbon (graphite) | 710 |
| Glass | 664 |
| Iron | 450 |

**Reading Check** *What is the specific heat of a material?*

**Water as a Coolant** Compared with the other common materials in **Table 1,** water has the highest specific heat. **Figure 4** shows why this is. Because water can absorb heat without a large change in temperature, it is useful as a coolant. A coolant is a subtance that is used to absorb heat. For example, water is used as the coolant in the cooling systems of automobile engines. As long as the water temperature is lower than the engine temperature, heat will flow from the engine to the water. Compared to other materials, the temperature of water will increase less.

**Figure 4** The specific heat of water is high because water molecules form strong bonds with each other.




When heat is added, some of the added heat has to break some of these bonds before the molecules can start moving faster.

In metals, electrons can move freely. When heat is added, no strong bonds have to be broken before the electrons can start moving faster.

INTEGRATE Earth Science

**Coastal Climates** The high specific heat of water causes large bodies of water to heat up and cool down more slowly than land masses. As a result, the temperature changes in coastal areas tend to be less extreme than they are farther inland.

**Changes in Thermal Energy** The thermal energy of an object changes when heat flows into or out of the object. If $Q$ is the change in thermal energy and $C$ is specific heat, the change in thermal energy can be calculated from the following equation:

**Thermal Energy Equation**

change in thermal energy (J) =
mass (kg) × change in temperature (°C) × specific heat $\left(\frac{\text{J}}{\text{kg°C}}\right)$

$$Q = m(T_f - T_i)C$$

## Applying Math — Solve a Simple Equation

**CHANGE IN THERMAL ENERGY** Find the change in thermal energy of a 20-kg wooden chair that warms from 15°C to 25°C if the specific heat of wood is 700 J/(kg °C).

**IDENTIFY** known values and the unknown value

**Identify the known values:**

A wooden chair with a mass of 20 kg → means → $m = 20$ kg

warms from 15°C to 25°C → means → $T_i = 15$°C and $T_f = 25$°C

the specific heat of wood is 700 J/(kg °C) → means → $C = 700$ J/(kg °C)

**Identify the unknown value:**

What is the change in thermal energy → means → $Q = ?$ J

**SOLVE** the problem

Substitute the known values into the thermal energy equation:

$$Q = m(T_f - T_i)C = (20\text{ kg})(25°\text{C} - 15°\text{C})\left(700\frac{\text{J}}{\text{kg °C}}\right)$$

$$= (20\text{ kg})(10°\text{C})\left(700\frac{\text{J}}{\text{kg °C}}\right) = 140{,}000\text{ kg °C}\frac{\text{J}}{\text{kg °C}} = 140{,}000\text{ J}$$

**CHECK** your answer

Does your answer seem reasonable? Check your answer by dividing the change in thermal energy you calculated by the mass and the specific heat given in the problem. The result should be the difference in temperature given in the problem.

### Practice Problems

The air in a living room has a mass of 72 kg and a specific heat of 1,010 J/(kg °C). What is the change in thermal energy of the air when it warms from 20°C to 25°C?

**For more practice problems go to page 834, and visit gpscience.com/extra_problems.**

## Measuring Specific Heat

The specific heat of a material can be measured using a device called a calorimeter, shown in **Figure 5.** The specific heat of a material can be determined if the mass of the material, its change in temperature, and the amount of heat absorbed or released are known. In a calorimeter, a heated sample transfers heat to a known mass of water. The energy absorbed by the water can be calculated by measuring the water's temperature change. Then the thermal energy released by the sample equals the thermal energy absorbed by the water.

**Using a Calorimeter** To measure the specific heat of a material, the mass of a sample of the material is measured, as is the initial temperature of the water in the calorimeter. The material is then heated, its temperature measured, and the sample is placed in the water in the inner chamber of the calorimeter. The sample cools as heat is transferred to the water, and the temperature of the water increases. The transfer of heat continues until the sample and the water are at the same temperature. Then the initial and final temperatures of the water are known, and the amount of heat gained by the water can be calculated.

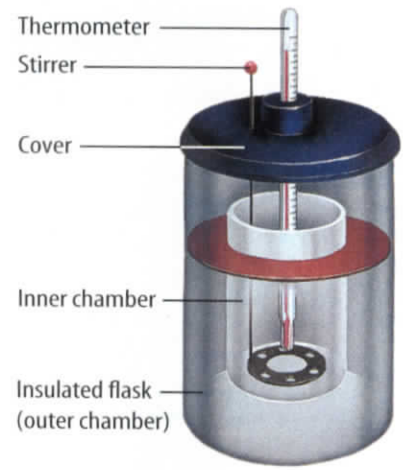



**Figure 5** A calorimeter can be used to measure the specific heat of materials. The sample is placed in the inner chamber.

## section 1 review

### Summary

**Temperature**

- The temperature of an object is a measure of the average kinetic energy of the particles that make up the object.

**Thermal Energy and Heat**

- Thermal energy is the sum of the kinetic and potential energy of all the particles in an object.
- If temperature is constant, the thermal energy increases when the mass increases.
- Heat is thermal energy that is transferred from an object at a higher temperature to an object at a lower temperature.

**Specific Heat**

- The specific heat of a material is the amount of heat needed to raise the temperature of 1 kg of the material 1°C.
- The change in thermal energy of an object can be calculated from this equation

$$Q = m(T_f - T_i)C$$

### Self Check

1. **Explain** how energy moves when you touch a block of ice with your hand.
2. **Describe** how the thermal energy of an object changes when the object's temperature changes.
3. **Infer** When heat flows between two objects, does the temperature increase of one object always equals the temperature decrease of the other object? Explain.
4. **Explain** why the specific heat of water is higher than the specific heat of most other substances.
5. **Think Critically** Explain whether or not the following statement is true: for any two objects, the one with the higher temperature always has more thermal energy.

**Applying Math**

6. **Calculate** the change in thermal energy of the water in a pond with a mass of 1,000 kg and a specific heat of 4,184 J/(kg °C) if the water cools by 1°C.
7. **Calculate** the specific heat of a *metal if* 0.5 kg of the metal absorb 9,000 J of heat as it warms by 10°C.

section 2

# Transferring Thermal Energy

## Reading Guide

### What You'll Learn

- **Compare and contrast** the transfer of thermal energy by conduction, convection, and radiation.
- **Compare and contrast** thermal conductors and insulators.
- **Explain** how insulators are used to control the transfer of thermal energy.

### Why It's Important

You must be able to control the flow of thermal energy to keep from being too hot or too cold.

### Review Vocabulary

**density:** the mass per unit volume of a substance

### New Vocabulary

- conduction
- convection
- radiation
- insulator

## Conduction

Thermal energy is transferred from place to place by conduction, convection, and radiation. **Conduction** is the transfer of thermal energy by collisions between particles in matter. Conduction occurs because particles in matter are in constant motion.

**Collisions Transfer Thermal Energy** Thermal energy is transferred when one end of a metal spoon is heated by a Bunsen burner, as shown in **Figure 6.** The kinetic energy of the particles near the flame increases. Kinetic energy is transferred when these particles collide with neighboring particles. Thermal energy is transferred by collisions between particles with more kinetic energy and particles with less kinetic energy. As these collisions continue, thermal energy is transferred from one end of the spoon to the other end of the spoon. When heat is transferred by conduction, thermal energy is transferred from place to place without transferring matter. Thermal energy is transferred by the collisions between particles, not by movement of matter.

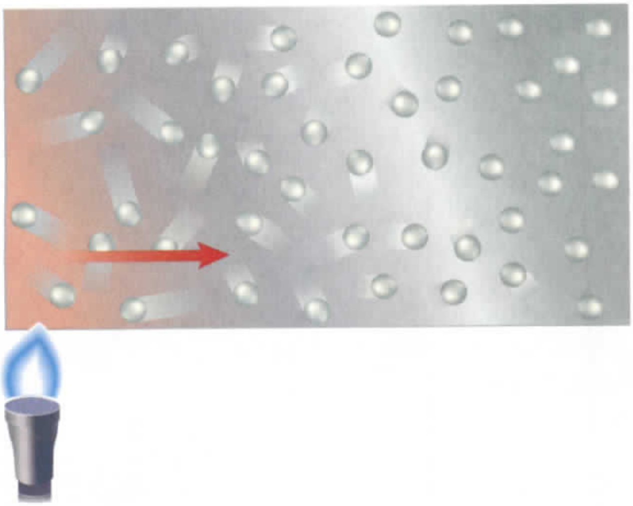


**Figure 6** Conduction occurs within a material as faster-moving particles transfer thermal energy by colliding with slower-moving particles.

**Heat Conductors** Although heat can be transferred by conduction in all materials, the rate at which heat moves depends on the material. Heat moves faster by conduction in solids and liquids than in gases. In gases, particles are farther apart, so collisions with other particles occur less frequently than they do in solids or liquids.

The best conductors of heat are metals. In a piece of metal, there are electrons that are not bound to individual atoms, but can move easily through the metal. Collisions between these electrons and other particles in the metal enable thermal energy to be transferred more quickly than in other materials. Silver, copper and aluminum are among the best conductors of heat.

## Convection

Unlike solids, liquids and gases can flow and are classified as fluids. In fluids, thermal energy can be transferred by convection. **Convection** is the transfer of thermal energy in a fluid by the movement of warmer and cooler fluid from place to place. When conduction occurs, more energetic particles collide with less energetic particles and transfer thermal energy. When convection occurs, more energetic particles move from one place to another.

As the particles move faster, they tend to be farther apart. As a result, a fluid expands as its temperature increases. Recall that density is the mass of a material divided by its volume. When a fluid expands, its volume increases, but its mass doesn't change. As a result, its density decreases. The same is true for parts of a fluid that have been heated. The density of the warmer fluid, therefore, is less than that of the surrounding cooler fluid.

**Heat Transfer by Currents** How does convection occur? Look at the lamp shown in **Figure 7.** Some of these lamps contain oil and alcohol. When the oil is cool, its density is greater than the alcohol, and it sits at the bottom of the lamp. When the two liquids are heated, the oil becomes less dense than the alcohol. Because it is less dense than the alcohol, it rises to the top of the lamp. As it rises, it loses heat by conduction to the cooler fluid around it. When the oil reaches the top of the lamp, it has become cool enough that it is denser than the alcohol, and it sinks. This rising-and-sinking action is a convection current. Convection currents transfer heat from warmer to cooler parts of the fluid. In a convection current, both conduction and convection transfer thermal energy.

**Reading Check** *How are conduction and convection different?*

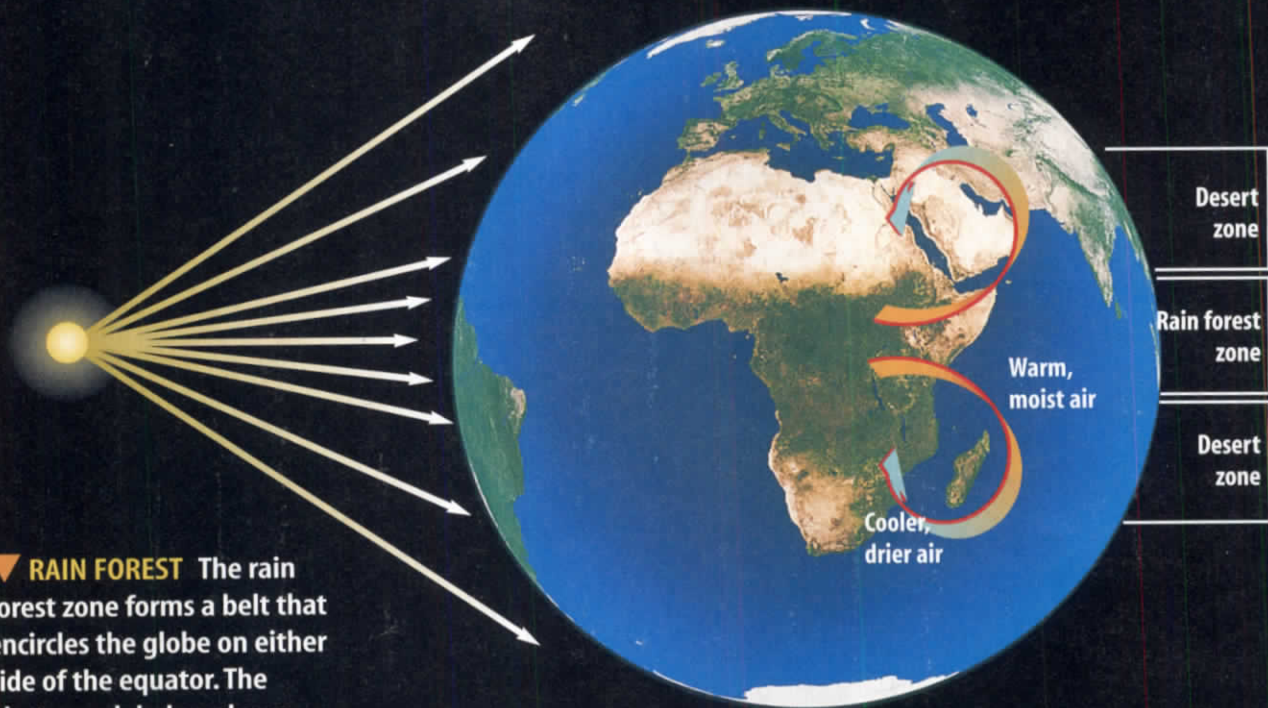
**Figure 7** The heat from the light at the bottom of the lamp causes one fluid to expand more than the other. This creates convection currents in the lamp. **Explain** *why the substances in the lamp rise and sink.*

NATIONAL GEOGRAPHIC

# VISUALIZING CONVECTION CURRENTS

**Figure 8**

When the Sun beats down on the equator, warm, moist air begins to rise. As it rises, the air cools and loses its moisture as rain that sustains rain forests near the equator. Convection currents carry the now dry air farther north and south. Some of this dry air descends at the tropics, where it creates a zone of deserts.




**RAIN FOREST** The rain forest zone forms a belt that encircles the globe on either side of the equator. The photograph below shows a rain forest near the Congo River in central Africa.

**DESERT** Like many of the great desert regions of the world, the Sahara, in northern Africa, is largely a result of atmospheric convection currents. Here, a group of nomads gather near a dried-up river in Mali.

**Desert and Rain Forests** Earth's atmosphere is made of various gases and is a fluid. The atmosphere is warmer at the equator than it is at the north and south poles. Also, the atmosphere is warmer at Earth's surface than it is at higher altitudes. These temperature differences create convection currents that carry heat to cooler regions. **Figure 8** shows how these convection currents create rain forests and deserts over different regions of Earth's surface.

## Radiation

Earth gets heat from the Sun, but how does that heat travel through space? Almost no matter exists in the space between Earth and the Sun, so heat cannot be transferred by conduction or convection. Instead, the Sun's heat reaches Earth by radiation.

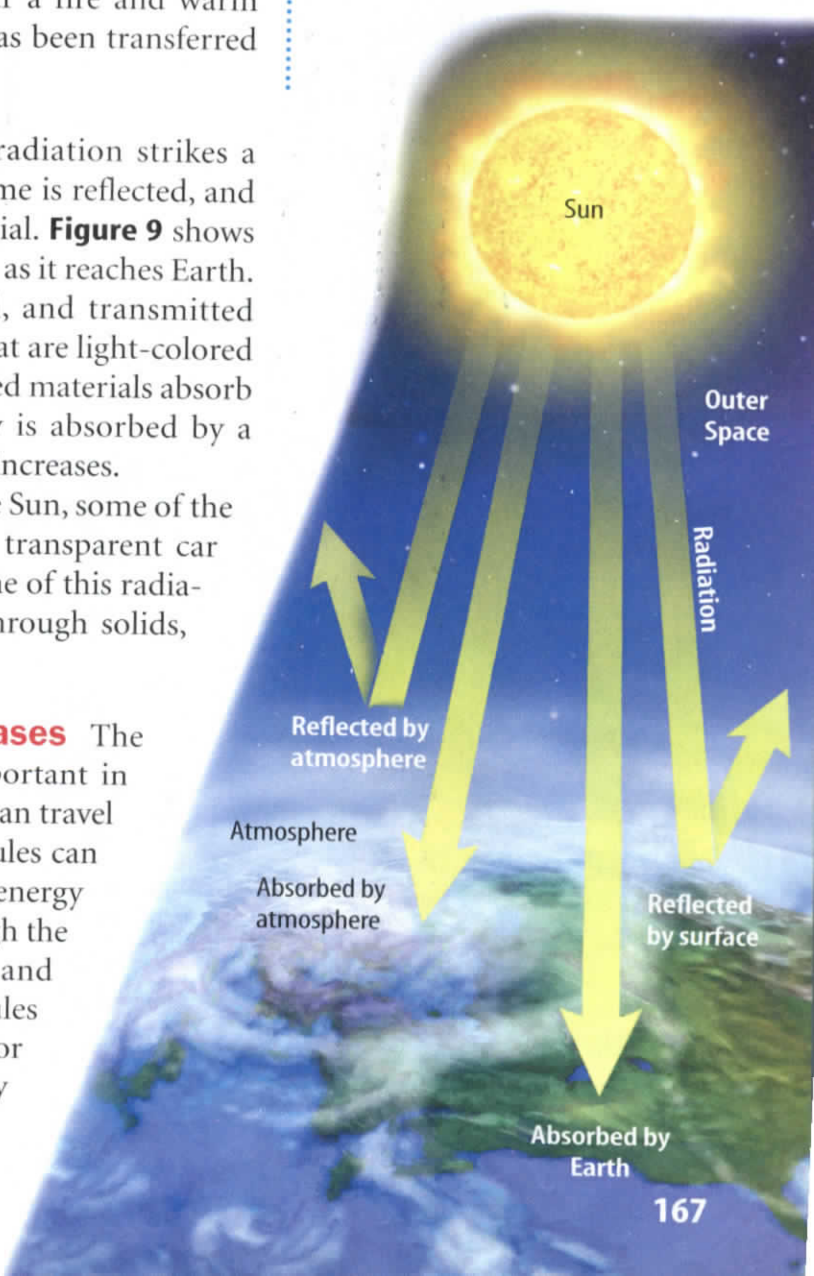
**Radiation** is the transfer of energy by electromagnetic waves. These waves can travel through space even when no matter is present. Energy that is transferred by radiation often is called radiant energy. When you stand near a fire and warm your hands, much of the warmth you feel has been transferred from the fire to your hands by radiation.

**Radiant Energy and Matter** When radiation strikes a material, some of the energy is absorbed, some is reflected, and some may be transmitted through the material. **Figure 9** shows what happens to radiant energy from the Sun as it reaches Earth. The amount of energy absorbed, reflected, and transmitted depends on the type of material. Materials that are light-colored reflect more radiant energy, while dark-colored materials absorb more radiant energy. When radiant energy is absorbed by a material, the thermal energy of the material increases.

For example, when a car sits outside in the Sun, some of the radiation from the Sun passes through the transparent car windows. Materials inside the car absorb some of this radiation and become hot. Radiation can pass through solids, liquids, and gases.

**Radiation in Solids, Liquids, and Gases** The transfer of energy by radiation is most important in gases. In a solid, liquid or gas, radiant energy can travel through the space between molecules. Molecules can absorb this radiation and emit some of the energy they absorbed. This energy then travels through the space between molecules, and is absorbed and emitted by other molecules. Because molecules are much farther apart in gases than in solids or liquids, radiation usually passes more easily through gases than through solids or liquids.

**Figure 9** Not all of the Sun's radiation reaches Earth. Some of it is reflected by the atmosphere. Some of the radiation that does reach the surface is also reflected.



**Mini LAB**

### Observing Heat Transfer by Radiation

**Procedure**

1. On a sunny day, go outside *and* place the back of your hand in **direct sunlight** for 2 min.
2. Go inside and find a **window exposed to direct sunlight.**
3. Place the back of your hand in the sunlight that has passed through the window for 2 min.

**Analysis**

1. Explain how heat was transferred from the Sun to your skin when you were outside.
2. Compare how warm your skin felt inside and outside.
3. Was thermal energy transferred through the glass in the window? Explain.

Try at Home

## Controlling Heat Flow

You might not realize it, but you probably do a number of things every day to control the flow of heat. For example, when it's cold outside, you put on a coat or a jacket before you leave your home. When you reach into an oven to pull out a hot dish, you might put a thick, cloth mitten over your hand to keep from being burned. In both cases, you used various materials to help control the flow of heat. Your jacket kept you from getting cold by reducing the flow of heat from your body to the surrounding air. And the oven mitten kept your hand from being burned by reducing the flow of heat from the hot dish.

As shown in **Figure 10,** almost all living things have special features that help them control the flow of heat. For example, the antarctic fur seal's thick coat and the emperor penguin's thick layer of blubber help keep them from losing heat. This helps them survive in a climate in which the temperature is often below freezing. In the desert, however, the scaly skin of the desert spiny lizard has just the opposite effect. It reflects the Sun's rays and keeps the animal from becoming too hot. An animal's color also can play a role in keeping it warm or cool. The black feathers on the penguin's back, for example, allow it to absorb radiant energy. Can you think of any other animals that have special adaptations for cold or hot climates?

**Reading Check** ***What are two animal adaptations that control the flow of heat?***

**Figure 10** Animals have different features that help them control heat flow.

The antarctic fur seal grows a coat that can be as much as 10 cm thick.

The emperor penguin has a thick layer of blubber and thick, closely spaced feathers, which help reduce the loss of body heat.

The scaly skin of the desert spiny lizard not only reflects sunlight but it also prevents water loss. This is important in a dry environment.

**Figure 11** The tiny pockets of air in fleece make it a good insulator. They help reduce the flow of the jogger's body heat to the colder outside air.

## Insulators

A material in which heat flows slowly is an **insulator.** Examples of materials that are insulators are wood, some plastics, fiberglass, and air. Materials, such as metals, that are good conductors of heat are poor insulators. In these materials, heat flows more rapidly from one place to another.

Gases, such as air, are usually much better insulators than solids or liquids. Some types of insulators contain many pockets of trapped air. These air pockets conduct heat poorly and also keep convection currents from forming. Fleece jackets, like the one shown in **Figure 11,** work in the same way. When you put the jacket on, the fibers in the fleece trap air and hold this air next to you. This air slows down the flow of your body heat to the colder air outside the jacket. Gradually, the air trapped by the fleece is warmed by your body heat, and underneath the jacket you are wrapped in a blanket of warm air.

**Reading Check** *Why does trapped air make a material like fleece a good insulator?*

**Insulating Buildings** Insulation, or materials that are insulators, helps keep warm air from flowing out of buildings in cold weather and from flowing into buildings in warm weather. Building insulation is usually made of some fluffy material, such as fiberglass, that contains pockets of trapped air. The insulation is packed into a building's outer walls and attic, where it reduces the flow of heat between the building and the surrounding air.

Insulation helps furnaces and air conditioners work more effectively, saving energy. In the United States, about 55 percent of the energy used in homes is used for heating and cooling.

### Mini LAB

### Comparing Thermal Conductors

**Procedure**

1. Obtain a **plastic spoon,** a **metal spoon,** and a **wooden spoon** with similar lengths.
2. Stick a small **plastic bead** to the handle of each spoon with a dab of **butter or wax.** Each bead should be the same distance from the tip of the spoon.
3. Stand the spoons in a **beaker,** with the beads hanging over the edge of the beaker.
4. Carefully pour **boiling water** to a depth of about 5 cm in the beaker holding the spoons.

**Analysis**

1. In what order did the beads fall from the spoons?
2. Describe how heat was transferred from the water to the beads.
3. Rank the spoons in their

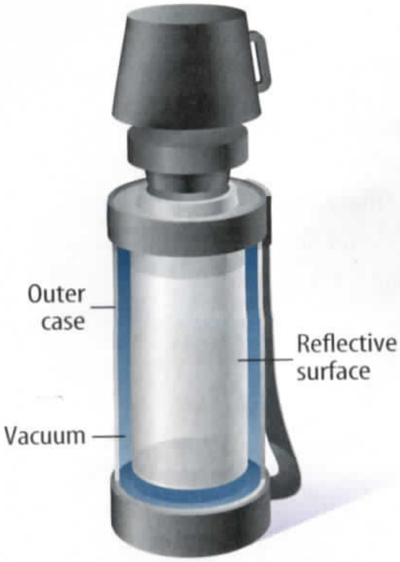



**Figure 12** A thermos bottle uses a vacuum and reflective surfaces to reduce the flow of heat into and out of the bottle. The vacuum prevents heat flow by conduction and convection. The reflective surfaces reduce the heat transfer by radiation.

**Reducing Heat Flow in a Thermos** You might have used a thermos bottle, like the one in **Figure 12,** to carry hot soup or iced tea. A thermos bottle reduces the flow of heat into and out of the liquid in the bottle, so that the temperature of the liquid hardly changes over a number of hours. To do this, a thermos bottle has two glass walls. The air between the two walls is removed so there is a vacuum between the glass layers. Because the vacuum contains almost no matter, it prevents heat transfer by conduction or convection between the liquid and the air outside the thermos.

To further reduce the flow of heat into or out of the liquid, the inside and outside glass surface of a thermos bottle is coated with aluminum to make each surface highly reflective. This causes electromagnetic waves to be reflected at each surface. The inner relective surface prevents radiation from transferring heat out of the liquid. The outer reflective surface prevents radiation from transferring heat into the liquid.

Think about the things you do to stay warm or cool. Sitting in the shade reduces the heat transferred to you by radiation. Opening or closing windows reduces heat transfer by convection. Putting on a jacket reduces the heat transferred from your body by conduction. In what other ways do you control the flow of heat?

## section 2 review

### Summary

**Conduction**

- Conduction is the transfer of thermal energy by collisions between more energetic and less energetic particles.
- Conduction occurs in solids, liquids, and gases. Metals are the best conductors of heat.

**Convection**

- Convection is the tranfer of thermal energy by the movement of warmer and cooler material.
- Convection occurs in fluids. Rising of warmer fluid and sinking of cooler fluid forms a convection current.

**Radiation**

- Radiation is the transfer of energy by electromagnetic waves.

**Controlling Heat Flow**

- Insulators are used to reduce the rate of heat transfer from one place to another.

### Self Check

1. **Explain** why materials that are good conductors of heat are poor insulators.
2. **Explain** why the air temperature near the ceiling of a room tends to be warmer than near the floor.
3. **Predict** whether plastic foam, which contains pockets of air, would be a good conductor or a good insulator.
4. **Describe** how a convection current occurs.
5. **Think Critically** Several days after a snowfall, the roofs of some homes on a street have almost no snow on them, while the roofs of other houses are still snow-covered. Describe what would cause this difference.

**Applying Math**

6. **Calculate Solar Radiation** Averaged over a year in the central United States, radiation from the sun transfers about 200 W to each square meter of Earth's surface. If a house is 10 m long by 10 m wide, how much solar energy falls on the house each second?



Science Online gpscience.com/self_check_quiz

LAB

# Convection in Gases and Liquids

A hawk gliding through the sky will rarely flap its wings. Hawks and some other birds conserve energy by gliding on columns of warm air rising up from the ground. These convection currents form when gases or liquids are heated unevenly, and the warmer, less dense fluid is forced upward.

## Real-World Question

How can convection currents be modeled and observed?

### Goals

- **Model** the formation of convection currents in water.
- **Observe** convection currents formed in water.
- **Observe** convection currents formed in air.

### Materials

burner or hot plate
water
candle
500-mL beaker
black pepper

### Safety Precautions

**WARNING:** *Use care when working with hot materials. Remember that hot and cold glass appear the same.*

## Procedure

1. Pour 450 mL of water into the beaker.
2. Use a balance to measure 1 g of black pepper.
3. Sprinkle the pepper into the beaker of water and let it settle to the bottom of the beaker.
4. Heat the bottom of the beaker using the burner or by placing it on the hotplate.
5. **Observe** how the particles of pepper move as the water is heated, and make a drawing showing their motion in your Science Journal.
6. Turn off the hot plate or burner. Light the candle and let it burn for a few minutes.
7. Blow out the candle, and observe the motion of the smoke.
8. Make a drawing of the movement of the smoke in your Science Journal.

## Conclude and Apply

1. **Describe** how the particles of pepper moved as the water became hotter.
2. **Explain** how the motion of the pepper particles is related to the motion of the water.
3. **Explain** how a convection current formed in the beaker.
4. **Explain** why the motion of the pepper changed when the heat was turned off.
5. **Predict** how the pepper would move if the water were heated from the top.
6. **Describe** how the smoke particles moved when the candle was blown out.
7. **Explain** why the smoke moved as it did.

## Communicating Your Data

**Compare** your conclusions with other students in your class. **For more help, refer to the Science Skill Handbook.**

section 3

# Using Heat

## Reading Guide

### What You'll Learn

- **Describe** common types of heating systems.
- **Describe** the first and second laws of thermodynamics.
- **Explain** how an internal combustion engine works.
- **Explain** how a refrigerator transfers thermal energy from a cool to a warm temperature.

### Why It's Important

Imagine your life without heating systems, cooling systems, and cars.

### Review Vocabulary

**work:** the product of the force exerted on an object and the distance the object moves in the direction of the force

### New Vocabulary

- solar collector
- thermodynamics
- first law of thermodynamics
- second law of thermodynamics
- heat engine
- internal combustion engine

## Heating Systems

Almost everywhere in the United States air temperatures at some time become cold enough that a source of heat is needed. As a result, most homes and public buildings contain some type of heating system. The best heating system for any building depends on the local climate and how the building is constructed.

All heating systems require some source of energy. In the simplest and oldest heating system, wood or coal is burned in a stove. The heat that is produced by the burning fuel is transferred from the stove to the surrounding air by conduction, convection, and radiation. One disadvantage of this system is that heat transfer from the room in which the stove is located to other rooms in the building can be slow.

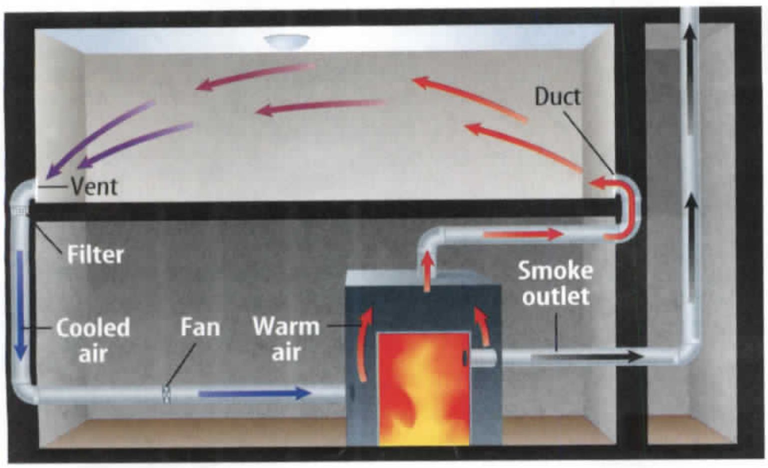



**Figure 13** In forced-air systems, air heated by the furnace gets blown through ducts that usually lead to every room.

**Forced-Air Systems** The most common type of heating system in use today is the forced-air system, shown in **Figure 13.** In this system, fuel is burned in a furnace and heats a volume of air. A fan then blows the warm air through a series of large pipes called ducts. The ducts lead to openings called vents in each room. Cool air returns through additional vents to the furnace, where it is reheated.

**Radiator Systems** Before forced-air systems were widely used, many homes and buildings were heated by radiators. A radiator is a closed metal container that contains hot water or steam. The thermal energy contained in the hot water or steam is transferred to the air surrounding the radiator by conduction. This warm air then moves through the room by convection.

In radiator heating systems, fuel burned in a central furnace heats a tank of water. A system of pipes carries the hot water to radiators in the rooms of the building. After the water cools, it flows through the pipes back to the water tank and is reheated. In some radiator systems, the water is heated to produce steam that flows through the pipes to the radiators. As the steam cools, it condenses into water and flows back to the tank.

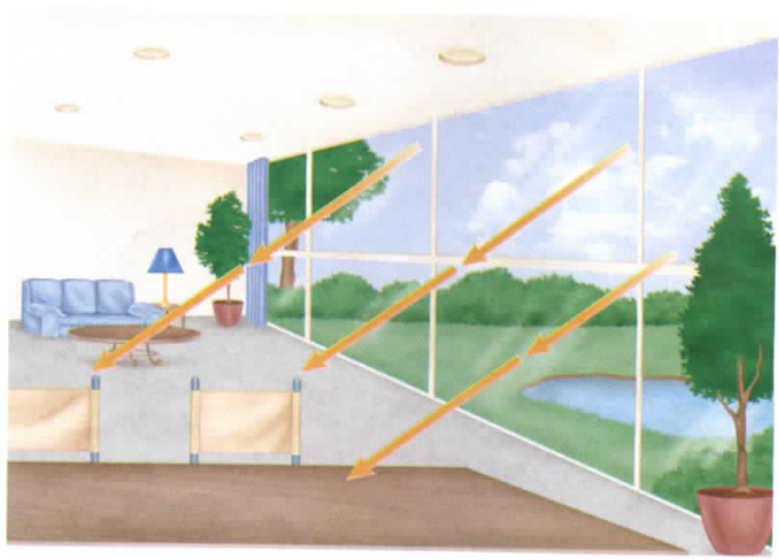
**Electric Heating Systems** An electric heating system has no central furnace. Instead, electrically heated coils placed in floors and in walls heat the surrounding air by conduction. Heat is then distributed through the room by convection. Electric heating systems are not as widely used as forced-air systems. However, in warmer climates the walls and floors of some buildings may not be thick enough to contain pipes and ducts. Then an electric heating system might be the only practical way to provide heat.

## Solar Heating

The Sun emits an enormous amount of radiant energy that strikes Earth every day. The radiant energy from the Sun can be used to help heat homes and buildings. There are two types of systems that use the Sun's energy for heating—passive solar heating systems and active solar heating systems.

**Passive Solar Heating** In passive solar heating systems, materials inside a building absorb radiant energy from the Sun during the day and heat up. At night when the building begins to cool, thermal energy absorbed by these materials helps keep the room warm. **Figure 14** shows a room in a house that uses passive solar heating. Walls of windows receive the maximum amount of sunlight during the day. The other walls are heavily insulated and have few or no windows to reduce heat loss at night.

**Figure 14** In a passive solar heating system, radiant energy from the Sun is transferred to the room through windows. Windows also prevent air inside from mixing with cooler air outside.
**Infer** *in which regions of the United States passive solar systems would be practical.*



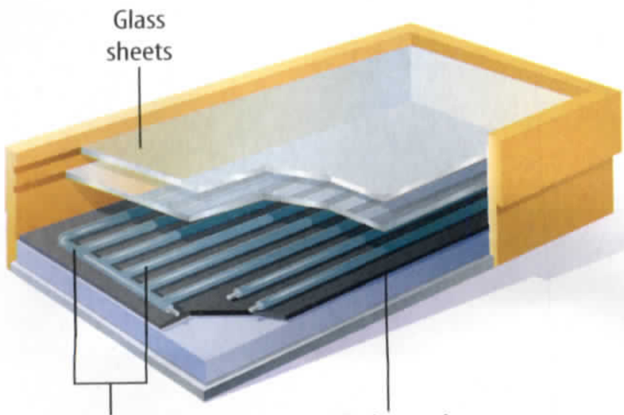



**Figure 15** This active solar heating system uses solar collectors mounted on the roof to absorb solar energy. The absorbed energy heats a liquid that is circulated throughout the house.

**Active Solar Heating** Active solar heating systems use **solar collectors** that absorb radiant energy from the Sun. The collectors usually are installed on the roof or south side of a building. Radiant energy from the Sun heats air or water in the solar collectors. One type of active solar collector is shown in **Figure 15.** The black metal plate absorbs radiant energy from the Sun. The absorbed energy heats water in pipes just above the plate. A pump circulates the hot water to radiators in rooms of the house. The cooled water then is pumped back to the collector to be reheated.

## Thermodynamics

There is another way to increase the thermal energy of an object besides adding heat. Have you ever rubbed your hands together to warm them on a cold day? Your hands get warmer and their thermal energy and temperature increase, even though there is no heat flowing to them. You did work on your hands by rubbing them together. The work you did caused the thermal energy of your hands to increase. Thermal energy, heat, and work are related, and the study of the relationship among them is **thermodynamics.**

**Heat and Work Increase Thermal Energy** You can warm your hands by placing them near a fire, so that heat is added to your hands by radiation. If you rub your hands and hold them near a fire, the increase in thermal energy of your hands is even greater. Both the work you do and the heat transferred from the fire increase the thermal energy of your hands.

In the example above your hands can be considered as a system. A system can be a group of objects such as a galaxy, or a car's engine, or something as simple as a ball. In fact, a system is anything you can draw a boundary around, as shown in **Figure 16.** The heat transferred to a system is the amount of heat flowing into the system that crosses the boundary. The work done on a system is the work done by something outside the system's boundary.

**Science Online**

**Topic: Solar Heating**

Visit gpscience.com for Web links to information about systems that use solar energy to heat buildings.

**Activity** Draw a diagram showing how an active solar heating system is used to heat a home.

**The First Law of Thermodynamics** According to the **first law of thermodynamics,** the increase in thermal energy of a system equals the work done on the system plus the heat transferred to the system. Doing work on a system is a way of adding energy to a system. As a result, the temperature of a system can be increased by adding heat to the system, doing work on the system, or both. The first law of thermodynamics is another way of stating the law of conservation of energy. The increase in energy of a system equals the energy added to the system.

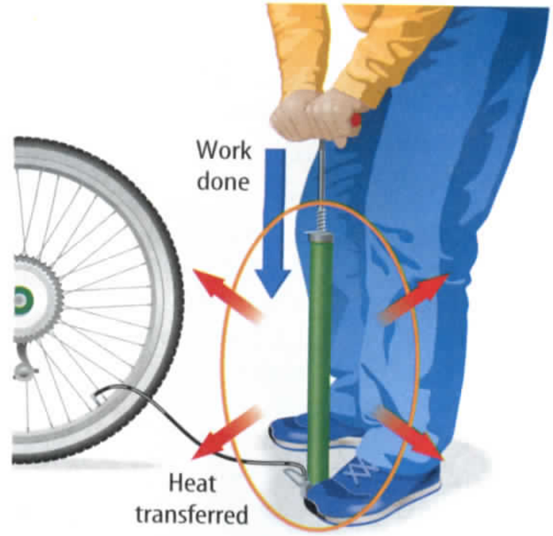



**Figure 16** A bicycle air pump can be a system. Work is done on the system by pushing down on the handle. This causes the pump to become warm, and heat is transferred from the system to the outside air.

**Closed and Open Systems** A system is an open system if heat flows across the boundary or if work is done across the boundary. Then energy is added to the system. If no heat flows across the boundary and there is no outside work done, then the system is a closed system. According to the first law of thermodynamics, the thermal energy of a closed system doesn't change. There may be processes going on in the system that are converting one form of energy into another, but the total energy of the system doesn't change. Because energy cannot be created or destroyed, the total energy stays constant in a closed system.

**The Second Law of Thermodynamics** When heat flows from a warm object to a cool object the thermal energy of the warm object decreases and the thermal energy of the cool object increases. According to the law of conservation of energy or the first law of thermodynamics, the increase in thermal energy of the cool object equals the decrease in thermal energy of the warm object.

Can heat flow spontaneously from a cold object to warm object? This process never happens, but it wouldn't violate the first law of thermodynamics. The first law would require only that the decrease in thermal energy of the cool object would be equal to the increase in thermal energy of the warm object.

**Reading Check** *How does heat flow from a warm to a cool object satisfy the first law of thermodynamics?*

However, the flow of heat spontaneously from a cool object to a warm object never happens because it violates another law—the second law of thermodynamics. One way to state the **second law of thermodynamics** is that it is impossible for heat to flow from a cool object to a warmer object unless work is done. For example, if you hold an ice cube in your hand, no work is done. As a result, heat flows only from your warmer hand to the colder ice.

**INTEGRATE Earth Science**

**Nature's Heat Engines** Hurricanes are storms that form over the ocean in regions of low pressure. Because hurricanes use heat from warm ocean water to produce strong winds, they are sometimes called nature's heat engines. Research hurricanes and draw a diagram showing how they are like a heat engine.

## Converting Heat to Work

If you give a book sitting on a table a push, the book will slide and come to a stop. Friction between the book and the table converted the work you did on the book to heat. As a result, the book and the table became slightly warmer.

In the example above, work was converted completely into heat. Is it possible to do the reverse, and convert heat completely into work? Even though this process would not violate the first law of thermodynamics, it also is forbidden by the second law of thermodynamics. The second law of thermodynamics makes it impossible to build a device that converts heat completely into work.

**Reading Check** *Why can't heat be convered completely into work?*

A device that converts heat into work is a **heat engine.** A car's engine is an example of a heat engine. A car's engine converts the chemical energy in gasoline into heat. The engine then transforms some of the thermal energy into work by rotating the car's wheels, as shown in **Figure 17.** However, only about 25 percent of the heat released by the burning gasoline is converted into work, and the rest is transferred to the engine's surroundings.

**Internal Combustion Engines** The heat engine in a car is an **internal combustion engine** in which fuel is burned inside the engine in chambers or cylinders. Automobile engines usually have four, six, or eight cylinders. Each cylinder contains a piston that moves up and down. Each up-and-down movement of the piston is called a stroke. Automobile and diesel engines have four different strokes. **Figure 18** shows the four-stroke cycle in an automobile engine.

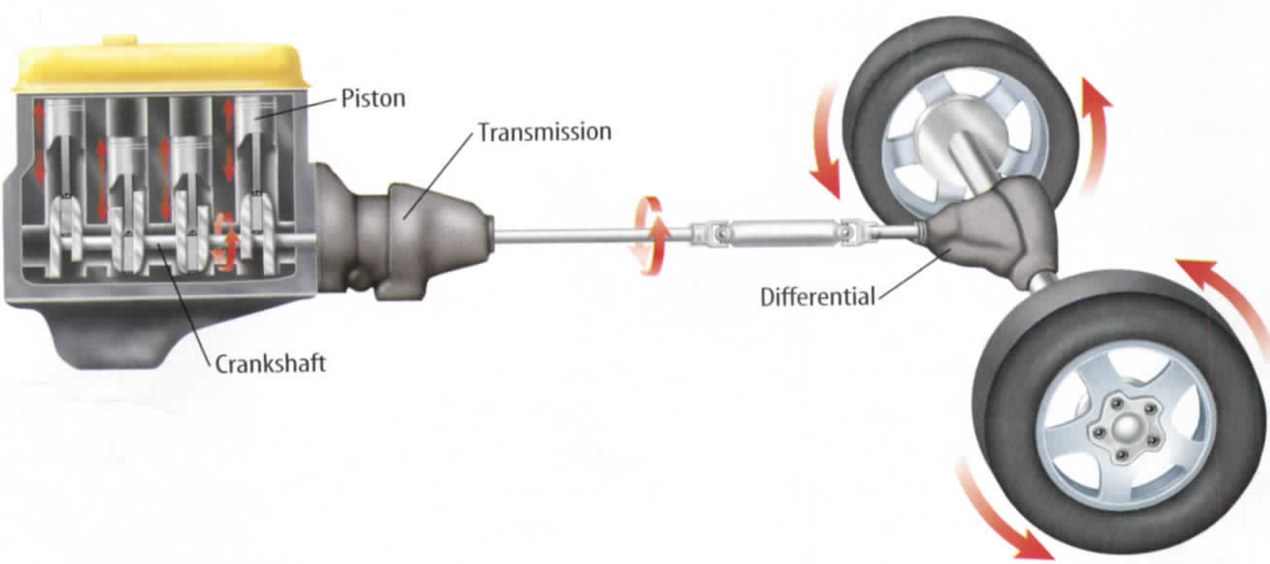
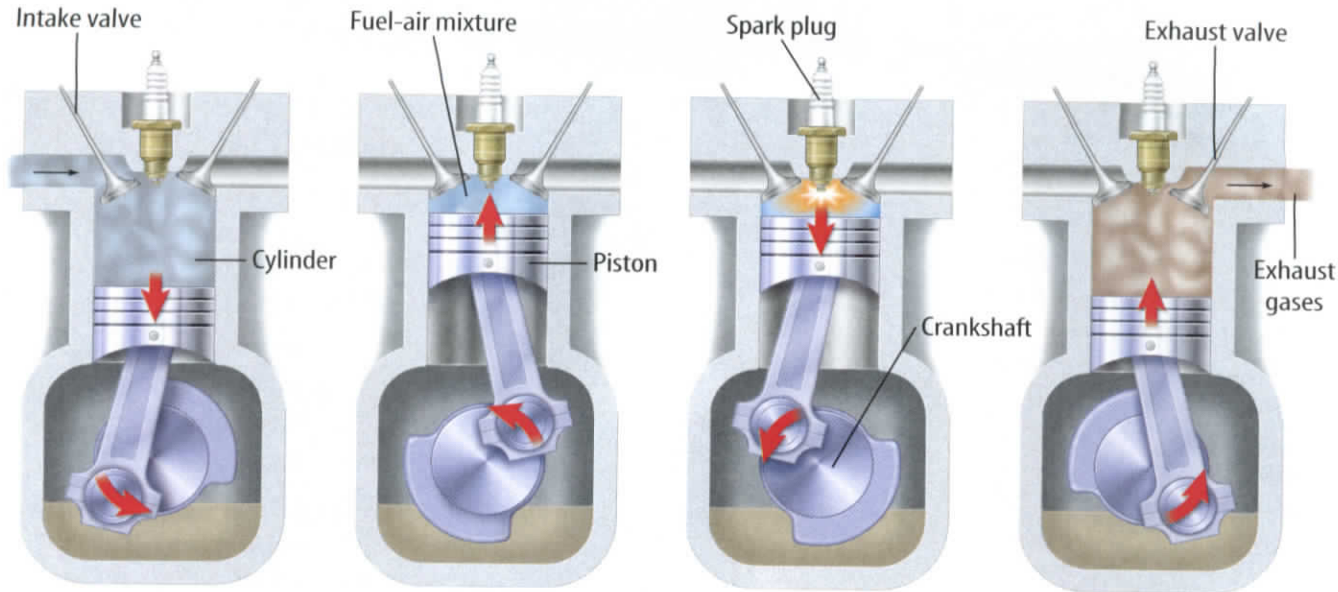



**Figure 17** Burning fuel in the engine's cylinders produces thermal energy that is converted into work as the pistons move up and down. The crankshaft, transmission, and differential convert the up and down motion of the pistons into rotation of the wheels.




**A Intake stroke** The intake valve opens as the piston moves downward, drawing a mixture of gasoline and air into the cylinder.

**B Compression stroke** The intake valve closes as the piston moves upward, compressing the fuel-air mixture.

**C Power stroke** A spark plug ignites the fuel-air mixture. As the mixture burns, hot gases expand, pushing the piston down.

**D Exhaust stroke** As the piston moves up, the exhaust valve opens, and the hot gases are pushed out of the cylinder.

**Figure 18** The up-and-down movement of a piston in an automobile engine consists of four separate strokes. These four strokes form a cycle that is repeated many times a second by each piston. **Determine** *whether eliminating friction would make the engine 100 percent efficient.*

**Friction and the Efficiency of Heat Engines** Almost three fourths of the heat produced in an internal combustion engine is not converted into useful work. Friction between moving parts causes some of the work done by the engine to be converted into heat. However, even if friction were totally eliminated, a heat engine still could not convert heat completely into work and be 100 percent efficient. Instead, the efficiency of an internal combustion engine depends on the difference in the temperature of the burning gases in the cylinder and the temperature of the air outside the engine. Increasing the temperature of the burning gases makes the engine more efficient.

## Heat Movers

How can the inside of a refrigerator stay cold? The second law of thermodynamics prevents heat from spontaneously flowing from inside the refrigerator to the warmer room. However, the second law of thermodynamics allows heat to move from a cold to a warm object if work is done in the process. A refrigerator does work as it moves heat from inside the refrigerator to the warmer room. The energy to do the work comes from the electrical energy the refrigerator obtains from an electrical outlet. You can think of a refrigerator as a heat mover that does work to move heat from a cooler temperature to a warmer temperature.

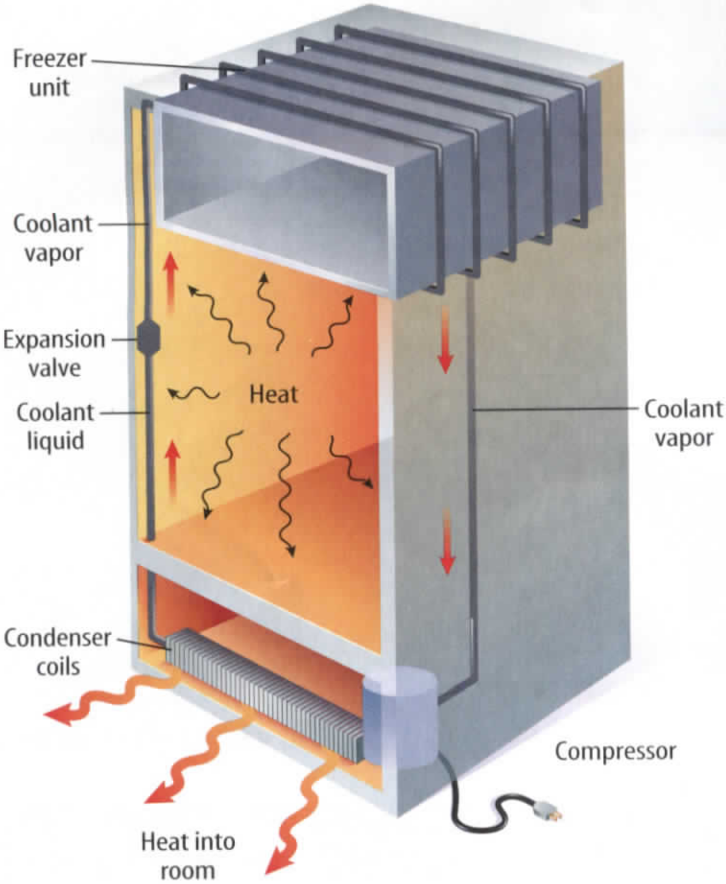



**Figure 19** A refrigerator must do work on the coolant in order to transfer heat from inside the refrigerator to the warmer air outside. Work is done when the compressor compresses the coolant vapor, causing its temperature to increase.

**Refrigerators** A refrigerator contains a coolant that is pumped through pipes on the inside and outside of the refrigerator. The coolant is a special substance that evaporates at a low temperature. **Figure 19** shows how a refrigerator operates. Liquid coolant is pumped through an expansion valve and changes into a gas. When the coolant changes to a gas, it cools. The cold gas is pumped through pipes inside the refrigerator, where it absorbs thermal energy. As a result, the inside of the refrigerator cools.

The gas then is pumped to a compressor that does work by compressing the gas. This makes the gas warmer than the temperature of the room. The warm gas is pumped through the condenser coils. Because the gas is warmer than the room, thermal energy flows from the gas to the room. Some of this heat is the thermal energy that the coolant gas absorbed from the inside of the refrigerator. As the gas gives off heat, it cools and changes to a liquid. The liquid coolant then is changed back to a gas, and the cycle is repeated.

**Reading Check** *How does a refrigerator do work on the coolant?*

**Air Conditioners and Heat Pumps** An air conditioner is another type of heat mover. It operates like a refrigerator, except that warm air from the room is forced to pass over tubes containing the coolant. The warm air is cooled and is forced back into the room. The thermal energy that is absorbed by the coolant is transferred to the air outdoors. Refrigerators and air conditioners are heat engines working in reverse—they use mechanical energy supplied by the compressor motor to move thermal energy from cooler to warmer areas.

A heat pump is a two-way heat mover. In warm weather, it operates as an air conditioner. In cold weather, a heat pump operates like an air conditioner in reverse. The coolant gas is cooled and is pumped through pipes outside the house. There, the coolant absorbs heat from the outside air. The coolant is then compressed and pumped back inside the house, where it releases heat.

INTEGRATE Life Science

**The Human Coolant** After exercising on a warm day, you might feel hot and be drenched with sweat. But your temperature would be close to your normal body temperature of 37°C. Your body uses evaporation to keep its internal temperature constant. When a liquid changes to a gas, energy is absorbed from the liquid's surroundings. As you exercise, your body generates sweat from tiny glands within your skin. As the sweat evaporates, it carries away heat, as shown in **Figure 20,** making you cooler.

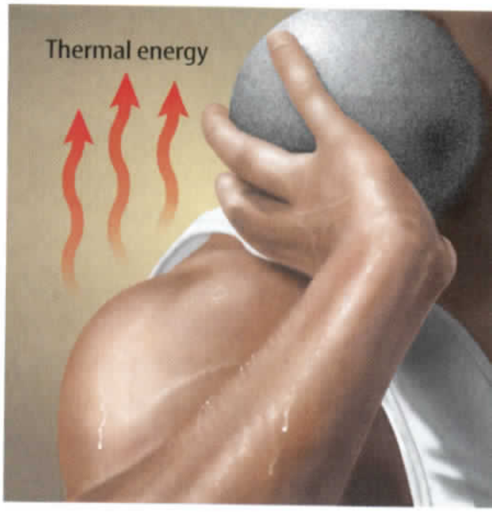



**Figure 20** As perspiration evaporates from your skin, it carries heat away, cooling your body.

**Energy Transformations Produce Heat** Every day many energy transformations occur around you that convert one form of energy into a more useful form. However, usually when these energy transformations occur, some heat is produced. For example, friction converts mechanical energy into thermal energy when the shaft of an electric motor or an electric generator rotates. The thermal energy produced in these energy transformations is no longer in a useful form and is transferred into the surroundings by conduction and convection.

## section 3 review

### Summary

**Heating Systems**

- A forced-air heating system uses a fan to force air heated by a furnace through a system of ducts.
- Radiator and electric heating systems transfer heat to rooms by conduction and convection.
- Solar heating systems convert radiant energy from the Sun to thermal energy.

**Thermodynamics**

- The first law of thermodynamics states that the increase in thermal energy of a system equals the work done on the system plus the heat added to the system.
- One way to state the second law of thermodynamics is that heat will not flow from a hot to a cold object unless work is done.

**Converting Heat to Work**

- The second law of thermodynamics states that heat cannot be converted completely into work.
- A heat engine converts heat into work.
- A refrigerator moves heat by doing work on the coolant.

### Self Check

1. **Explain** how the thermal energy of a closed system changes with time.
2. **Compare and contrast** an active solar heating system with a radiator system.
3. **Explain** whether or not a heat engine could be made 100 percent efficient by eliminating friction.
4. **Diagram** how the thermal energy of the coolant changes as it flows in a refrigerator.
5. **Think Critically** Suppose you vigorously shake a bottle of fruit juice. Predict how the temperature of the juice will change. Explain your reasoning.

### Applying Math

6. **Calculate Change in Thermal Energy** You push down on the handle of a bicycle pump with a force of 20 N. The handle moves 0.3 m, and the pump does not absorb or release any heat. What is the change in thermal energy of the bicycle pump?
7. **Calculate Work** The thermal energy released when a gallon of gasoline is burned in a car's engine is 140 million J. If the engine is 25 percent efficient, how much work does it do when one gallon of gasoline is burned?

Science Online gpscience.com/self_check_quiz

LAB

# Conduction in Gases

### Goals

- **Measure** temperature changes in air near a heat source.
- **Observe** conduction of heat in air.

### Materials

thermometers (3)
foam cups (2)
400-mL beakers (2)
burner or hot plate
paring knife
thermal mitts (2)

### Safety Precautions

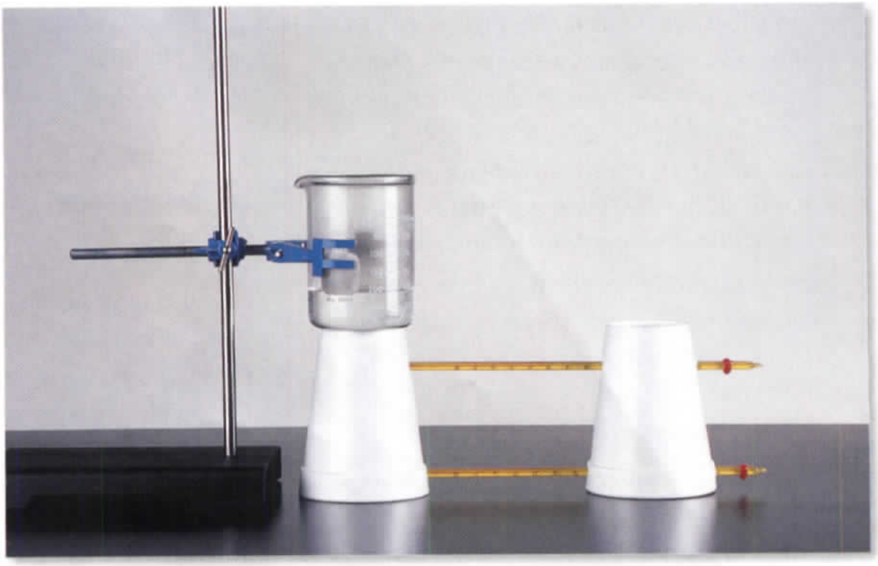
**WARNING:** *Use care when handling hot water. Pour hot water using both hands.*

## Real-World Question

Does smog occur where you live? If so, you may have experienced a temperature inversion. Usually the Sun warms the ground, and the air above it. When the air near the ground is warmer than the air above, convection occurs. This convection also carries smoke and other gases emitted by cars, chimneys, and smokestacks upward into the atmosphere. If the air near the ground is colder than the air above, convection does not occur. Then smoke and other pollutants can be trapped near the ground, sometimes forming smog. How does the insulating properties of air cause a temperature inversion to occur?

## Procedure

1. Using the paring knife, carefully cut the bottom from one foam cup.
2. Use a pencil or pen to poke holes about 2 cm from the top and bottom of each foam cup.
3. Turn both cups upside down, and poke the ends of the thermometers through the upper holes and lower holes, so both thermometers are supported horizontally. The bulb end of both thermometers should extend into the middle of the bottomless cup.



4. Heat about 350 mL of water to about 80°C in one of the beakers.
5. Place an empty 400-mL beaker on top of the bottomless cup. Record the temperature of the two thermometers in your data table.
6. Add about 100 mL of hot water to the empty beaker. After one minute, record the temperatures of the thermometers in a data table like the one shown here.
7. Continue to record the temperatures every minute for 10 min. Add hot water as needed to keep the temperature of the water at about 80°C.

**Air Temperatures in Foam Cup**

| Time (min) | Upper Thermometer (°C) | Lower Thermometer (°C) |
|---|---|---|
| 0 | | |
| 1 | Do not write in this book. | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |

## Analyze Your Data

1. **Graph** the temperatures measured by the upper and lower thermometers on the same graph. Make the vertical *y*-axis the temperature and the horizontal *x*-axis the time.
2. **Calculate** the total temperature change for both thermometers by subtracting the initial temperature from the final temperature.
3. **Calculate** the average rate of temperature change for each thermometer by dividing the total temperature change by 10 min.

## Conclude and Apply

1. **Explain** whether convection can occur in the foam cup if it's being heated from the top.
2. **Describe** how heat was transferred through the air in the foam cup.
3. **Explain** why the average rate of temperature change was different for each thermometer.

### Communicating Your Data

**Compare** your results with other students in your class. **Identify** the factors caused the average rate of temperature change to be different for different groups.

# SCIENCE Stats

# Surprising Thermal Energy

## Did you know...

**... The average amount of solar energy** that reaches the United States each year is about 600 times greater than the nation's annual energy demands.

**... When a space shuttle reenters** Earth's atmosphere at more than 28,000 km/h, its outer surface is heated by friction to nearly 1,650°C. This temperature is high enough to melt steel.

**... A lightning bolt heats the air** in its path to temperatures of about 25,000°C. That's about 4 times hotter than the average temperature on the surface of the Sun.

### Applying Math

1. The highest recorded temperature on Earth is 58°C and the lowest is −89°C. What is the range between the highest and lowest recorded temperatures?
2. What is the average temperature of the surface of the Sun? Draw a bar graph comparing the temperature of a lightning bolt to the temperature of the surface of the Sun.
3. The Sun is almost 150 million km from Earth. How long does it take solar energy to reach Earth if it travels at 300,000 km/s?

# chapter 6 Study Guide

## Reviewing Main Ideas

### Section 1 Temperature and Heat

1. The temperature of a material is a measure of the average kinetic energy of the molecules in the material.
2. Heat is thermal energy that flows from a higher to a lower temperature.

3. The thermal energy of an object is the total kinetic and potential energy of the molecules in the object.
4. The specific heat is the amount of heat needed to raise the temperature of 1 kg of a substance by 1°C.

### Section 2 Transferring Thermal Energy

1. Conduction occurs when thermal energy is transferred by collisions between particles. Matter is not transferred when conduction occurs.
2. Convection occurs in a fluid as warmer and cooler fluid move from place to place.
3. Radiation is the transfer of energy by electromagnetic waves. Radiation can transfer energy through empty space.
4. Heat flows more easily in materials that are conductors than in insulators.
5. Some insulating materials contain pockets of trapped air that reduce the flow of heat.

### Section 3 Using Heat

1. Conventional heating systems use air, hot water, and steam to transfer thermal energy through a building.


2. A solar heating system converts radiant energy from the Sun to thermal energy. Active solar systems use solar collectors to absorb the thermal radiant energy.
3. According to the first law of thermodynamics, the increase in the thermal energy of a system equals the work done on the system and the amount of heat added to the system.
4. The second law of thermodynamics states that heat cannot flow from a colder to a hotter temperature unless work is done, and that heat cannot be converted completely into work.
5. Heat engines convert heat into work. The efficiency of a heat engine can never be 100 percent. Refrigerators transfer heat from a cooler to a warmer temperature by doing work on the coolant.

**FOLDABLES** Use the Foldable that you made at the beginning of this chapter to help you review thermal energy.

# chapter 6 Review

## Using Vocabulary

| | |
|---|---|
| conduction p. 164 | radiation p. 167 |
| convection p. 165 | second law of thermodynamics p. 175 |
| first law of thermodynamics p. 175 | solar collector p. 174 |
| heat p. 160 | specific heat p. 161 |
| heat engine p. 176 | temperature p. 159 |
| insulator p. 169 | thermal energy p. 159 |
| internal combustion engine p. 176 | thermodynamics p. 174 |

*Complete each statement using a word(s) from the vocabulary list above.*

**1.** A _________ is a device that converts thermal energy into mechanical energy.

**2.** _________ is energy that is transferred from warmer to cooler materials.

**3.** A _________ is a device that absorbs the Sun's radiant energy.

**4.** The energy required to raise the temperature of 1 kg of a material 1°C. is a material's _________.

**5.** _________ is a measure of the average kinetic energy of the particles in a material.

**6.** Heat flows easily in a(n) _________.

## Checking Concepts

*Choose the word or phrase that best answers the question.*

**7.** Which is NOT a method of heat transfer?
**A)** conduction
**B)** specific heat
**C)** radiation
**D)** convection

**8.** In which of the following devices is fuel burned inside chambers called cylinders?
**A)** internal combustion engine
**B)** radiator
**C)** heat pump
**D)** air conditioner

**9.** During which phase of a four-stroke engine are waste gases removed?
**A)** power stroke
**B)** intake stroke
**C)** compression stroke
**D)** exhaust stroke

**10.** Which of the following materials is a poor insulator of heat?
**A)** iron
**B)** feathers
**C)** air
**D)** plastic

**11.** Which of the following devices is an example of a heat mover?
**A)** solar panel
**B)** refrigerator
**C)** internal combustion engine
**D)** diesel engine

**12.** Which term describes the measure of the average kinetic energy of the particles in an object?
**A)** potential energy
**B)** thermal energy
**C)** temperature
**D)** specific heat

**13.** Which of these is NOT used to calculate change in thermal energy?
**A)** volume
**B)** temperature change
**C)** specific heat
**D)** mass

**14.** Which of the following processes does NOT require the presence of particles of matter?
**A)** radiation
**B)** conduction
**C)** convection
**D)** combustion

**15.** Which of the following is the name for thermal energy that is transferred only from a higher temperature to a lower temperature?
**A)** potential energy
**B)** kinetic energy
**C)** heat
**D)** solar energy



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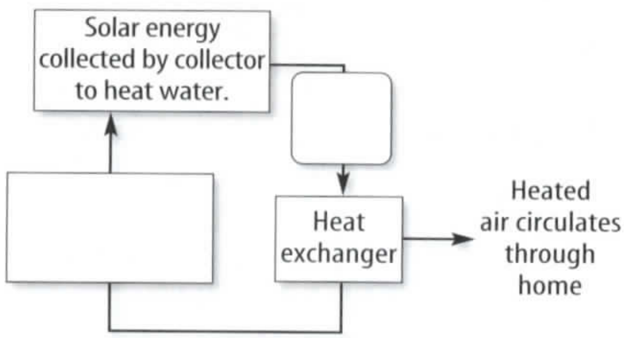
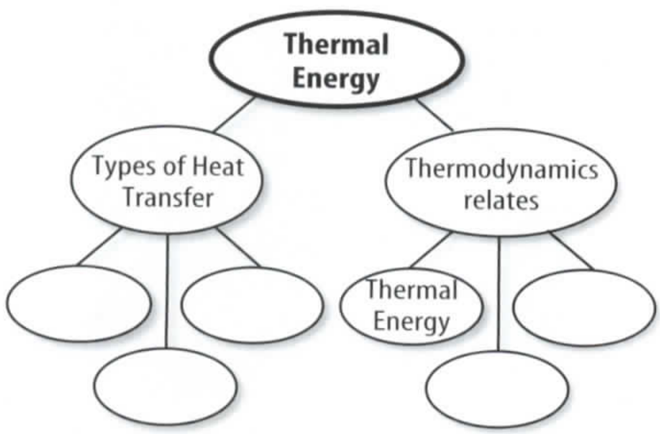
## Interpreting Graphics

16. Complete the following events-chain concept map to show how an active solar heating system works.




17. Copy and complete this concept map.




## Thinking Critically

18. **Explain** On a hot day a friend suggests that you can make your kitchen cooler by leaving the refrigerator door open. Explain whether leaving the refrigerator door open would cause the air temperature in the kitchen to decrease.

19. **Explain** Which has the greater amount of thermal energy, one liter of water at 50°C or two liters of water at 50°C?

20. **Explain** whether or not the following statement is true: If the thermal energy of an object increases, the temperature of the object must also increase.

21. **Predict** Suppose a beaker of water is heated from the top. Predict which is more likely to occur in the water—heat transfer by conduction or convection. Explain.

22. **Classify** Order the events that occur in the removal of heat from an object by a refrigerator. Draw the complete cycle, from the placing of a warm object in the refrigerator to the changes in the coolant.

## Applying Math

**Use the table below to answer questions 23 to 25.**

**Specific Heat of Materials**

| Material | Specific Heat (J/kg°C) |
|---|---|
| Water | 4,184 |
| Copper | 385 |
| Silver | 235 |
| Graphite | 710 |
| Iron | 450 |

23. **Calculate Thermal Energy** How much thermal energy is needed to raise the temperature of 4.0 kg of water from 25°C to 75°C?

24. **Calculate Temperature Change** How does the temperature of 33.0 g of graphite change when it absorbs 350 J of thermal energy?

25. **Calculate Mass** A hot iron ball is dropped into 200.0 g of cooler water. The water temperature increases by 2.0°C and the temperature of the ball decreases by 18.6°C. What is the mass of the iron ball?

# Standardized Test Practice

## Part 1 Multiple Choice

*Record your answers on the answer sheet provided by your teacher or on a sheet of paper.*

1. The difference between the boiling point and the freezing point of potassium is 695.72 K. What is the difference between the two points on the Celsius temperature scale?
   **A.** 100.00°C
   **B.** 275.15°C
   **C.** 422.57°C
   **D.** 695.72°C

**Use the table below to answer questions 2 and 3.**

| Material | Specific Heat [J/(kg °C)] |
|---|---|
| Copper | 385 |
| Gold | 449 |
| Lead | 129 |
| Tin | 228 |
| Zinc | 388 |

2. According to the table above, a 2-kg block of which of the following materials would require 898 joules of heat to increase its temperature by 1°C?
   **A.** gold
   **B.** lead
   **C.** tin
   **D.** zinc

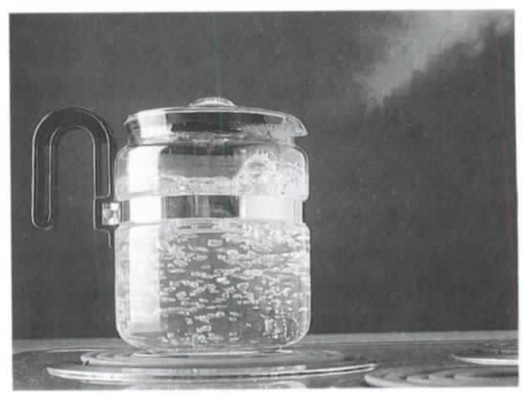
3. Which of the following materials would require the most heat to raise a 5-kg sample of the material from 10°C to 50°C?
   **A.** gold
   **B.** lead
   **C.** tin
   **D.** zinc

4. Automobile engines usually are four-stroke engines. During which stroke does the spark from a spark plug ignite the fuel-air mixture?
   **A.** the intake stroke
   **B.** the compression stroke
   **C.** the power stroke
   **D.** the exhaust stroke

5. A refrigerator is an example of what type of device that removes thermal energy from one location and transfers it to another location at a differrent temperature?
   **A.** condenser
   **B.** conductor
   **C.** heat mover
   **D.** heat pump

6. The temperature of a 24.5-g block of aluminum decreases from 30.0°C to 21.5°C. If aluminum has a specific heat of 897 J/(kg°C), what is the change in thermal energy of the block of aluminum?
   **A.** 187 J
   **B.** 2,590 J
   **C.** 5,820 J
   **D.** 187,000 J

**Use the figure below to answer question 7.**



7. The photograph above shows a pot of boiling water. What type of heat transfer causes the water at the top of the pot to become hot?
   **A.** conduction
   **B.** convection
   **C.** convection and radiation
   **D.** conduction and convection

### Test-Taking Tip

**Read All the Information** On a bar graph, line up each bar with its corresponding value by laying your pencil between the two points.

## Part 2 Short Response/Grid In

*Record your answers on the answer sheet provided by your teacher or on a sheet of paper.*

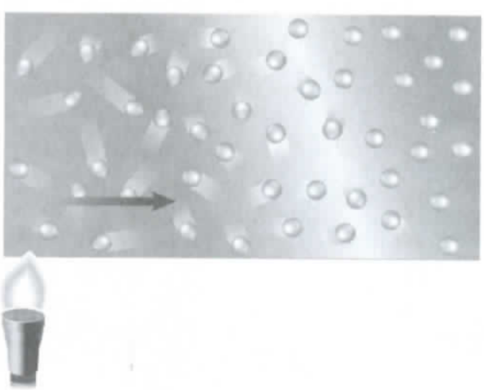
**8.** Define the term *heat* and tell what units are used to measure heat.

**9.** Give an example of how waves transfer energy by radiation. Give an example of how energy is transferred by conduction.

**10.** How is the color of a material related to its absorption and reflection of radiant energy?

**11.** What property of water makes it useful as a coolant?

**Use the figure below to answer questions 12 and 13.**



**12.** The illustration above shows a heat source below one end of a material. Heat is transferred from the warmer part of the material to the cooler part. Name and describe the type of heat transfer illustrated in the figure.

**13.** If the heat source were replaced by a block of ice, would cold be transferred through the material in the same way? Explain why or why not.

**14.** How is a heat pump different from an air conditioner?

## Part 3 Open Ended

*Record your answers on a sheet of paper.*

**Use the figure below to answer question 15.**

**15.** The calorimeter in the illustration above is composed of inner and outer chambers that surround a thick layer of air. Describe the process by which the calorimeter is used to measure the specific heat of materials.

**16.** Define the terms *temperature* and *thermal energy.* Explain how the temperature and thermal energy of an object are related.

**17.** Conduction can occur in solids, liquids, and gases. Explain why solids and liquids are better conductors of heat than gases.

**18.** Explain why radiation usually passes more easily through gases than through solids or liquids.

**19.** Suppose you have a glass half-filled with 250 mL of water at a temperature of 30°C. You then add 250 mL of water at the same temperature to the glass. Explain any changes in the water's temperature and thermal energy.

**20.** Explain how changes in a fluid's density enables convection to occur.