# *Energy and Energy Transformations*

## Thermal Energy on the Move

### Before You Read

**What do you think?** Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

| Before | Statement | After |
|---|---|---|
| | **5.** Warm water sinks below cool water when they are in the same container. | |
| | **6.** Wearing a coat slows the loss of thermal energy from your body. | |

### Read to Learn

## Heat

Have you ever seen a glassblower at work? The glassblower begins with a blob of melted glass at nearly 1,000°C on the end of a hollow pipe. The glassblower blows air through the pipe that goes into the glass blob at the other end of the pipe. The glass blob inflates. The glass is then worked into the desired shape.

During this glassblowing process, the glass loses thermal energy to the cool air around it. This cooling process involves the loss of heat. **Heat** *is thermal energy moving from a region of higher temperature to a region of lower temperature.* The movement of thermal energy occurs in several ways.

### Heat and Thermal Energy

The everyday meaning of *heat* often differs from its scientific meaning. To avoid confusion, this chapter explains concepts in terms of thermal energy whenever possible. It is important not to confuse heat and thermal energy. Objects contain thermal energy, not heat. Heat is thermal energy moving from a warmer object or temperature to a cooler object or temperature. Once the thermal energy moves, it is no longer considered heat.

**Key Concepts**

- What is heat?
- How is thermal energy transferred?

**Study Coach**

**Write and Answer Questions** On a sheet of paper, write each main head as a question. Then answer each question using the text under each head. Use your questions and answers to review the lesson.

**Key Concept Check**

**1. Define** How is heat related to thermal energy?

## Math Skills

A *rate* tells how quickly something changes. The rate of temperature change is calculated using this equation:

$$\textbf{\textit{rate}} = \frac{T_{final} - T_{initial}}{t}$$

where

$T_{final}$ = final temperature (in °C)

$T_{initial}$ = initial temperature (in °C)

$t$ = time (in s, min, or h)

The rate will have units of °C/s, °C/min, or °C/h.

**2. Solve an Equation**
Water at 22°C is heated to 76°C in 10 min. What is the rate of temperature change?

## Temperature Change

Have you ever started eating hot soup and been interrupted? When you returned to the bowl to finish your soup, was it cool? Thermal energy always moves from a higher temperature to a lower temperature.

Look at the teacup on the left in the figure below. It is an example of thermal energy always moving from a higher temperature to a lower temperature. Thus, thermal energy flows from the hot tea to the cooler air around it. The particles in the tea, on average, are moving faster than the particles in the air. Faster-moving particles on the surface of the tea collide with the slower particles in the air. The collisions transfer kinetic energy to particles in the air.

The movement of thermal energy causes changes in temperature. Particles on the surface of the tea collide with particles in the air. These collisions transfer kinetic energy from the tea to particles in the air. As a result, the tea cools and the air warms.

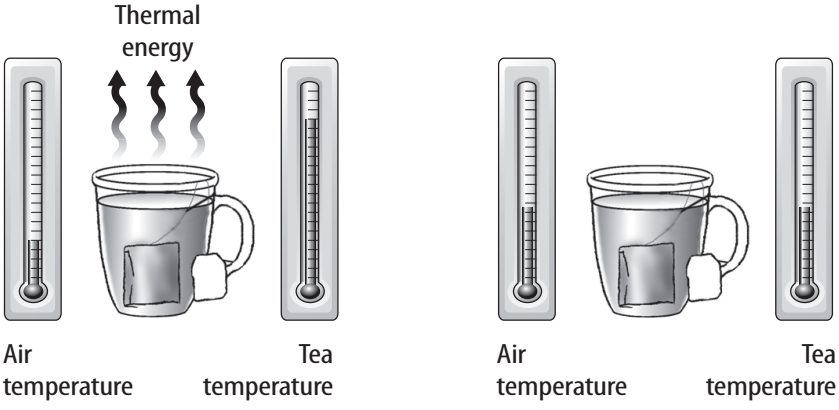
Imagine that you pour half the tea into another cup. The temperature does not change because the average kinetic energy of the remaining tea is unchanged. The tea's thermal energy, however, decreases by half. Why? Because the amount of tea decreased by half.

## Thermal Equilibrium

As the tea cools and the air warms, the difference in their temperatures decreases. Eventually the tea and the air around it reach the same temperature, as shown below in the figure on the right. Two objects in contact with each other at the same temperature are said to be in thermal equilibrium.

**Visual Check**

**3. Identify** the areas of warmer temperatures in the figure by highlighting them with color. Then highlight areas of cooler temperatures with another color.



# Conduction

Have you ever burned your fingers on a hot pan while cooking? This painful experience was caused by conduction (kuhn DUK shun).

**Conduction** *is the transfer of thermal energy due to collisions between particles in matter.* Your fingers burned as thermal energy moved from the hot pan to your cooler skin. Conduction occurs in solids, liquids, and gases.

## The Process of Conduction

Think again about the hot pan. A burner on the stove heats the bottom of the pan. Faster-moving particles in the warmer, bottom part of the pan collide with slower-moving particles in nearby parts of the pan. Thermal energy transfers during these collisions. The slower-moving particles gain energy and speed up. As the collisions continue, the thermal energy is conducted through the pan.

## Thermal Conductors and Insulators

Thermal energy moves at different rates through different materials. *A material in which thermal energy moves quickly is a* **thermal conductor.** In general, solids are better thermal conductors than liquids and gases are. Most metals are excellent thermal conductors.

Not all materials conduct thermal energy well. *A material in which thermal energy moves slowly is a* **thermal insulator.** In general, gases are better thermal insulators than liquids and solids are.

## Using Conductors and Insulators

Thermal conductors and thermal insulators have many uses. Metals, for example, are excellent conductors. Cookware is often made of metals.

Thermal insulators are commonly used in winter coats. A winter coat filled with air-trapping material, such as fibers, is a good thermal insulator. The fibers in a winter coat trap pockets of air. This air, which is a mixture of gases, is a good thermal insulator. This is because the pockets of air between and inside the fibers slow the conduction of thermal energy away from the body. The thermal energy from the body moves slowly to the colder outside air.

### Reading Check

**4. Infer** Why does conduction occur more slowly in gases than in solids?

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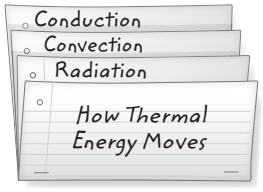
Make a layered book as shown below and use it to organize your notes on how thermal energy moves.




### Think it Over

**5. Evaluate** Why are fibers used in winter coats good thermal insulators?

## Think it Over

**6. Explain** Why doesn't convection take place in solids?

# Convection

Earth scientists know that air currents and water currents move matter across Earth's surface. These currents also transfer thermal energy. **Convection** *is the transfer of thermal energy by the movement of particles from one part of a material to another.* Convection occurs in liquids and gases, but not in solids.

## The Process of Convection

Convection begins when part of a liquid or gas becomes warmer than the rest of it. Inside a teapot, for example, the water closest to the burner is heated by conduction. The water expands as it is heated. As the heated water expands, its density decreases. A current forms as the cooler, denser water sinks, pushing the warmer, less dense water upward. The current carries particles of matter and thermal energy through the material. Convection does not occur in solids because the particles in solids cannot flow.

## Convection Currents

Think about a beaker of water being heated over a flame. The burner heats the water near the bottom of the beaker. As the temperature of the water increases, its density decreases. This causes the heated water to rise. Thermal energy transfers to the cooler water as the heated water rises. The cooler, denser water near the top of the beaker sinks. This water is then heated by the burner. The rising and sinking water form a loop. This constantly circulating loop is called a convection current. Convection currents carry thermal energy throughout the water in the beaker. This increases the rate at which the water is heated.

The metal radiators used in many classrooms work in a similar way. The radiators use convection currents in the air to warm the rooms.

**Key Concept Check**

**7. Describe** a process that transfers thermal energy.

# Radiation

Sunlight feels warm on the skin. This warmth is a result of radiation. **Radiation** *is the transfer of thermal energy from one object to another by electromagnetic waves*. Radiation transfers thermal energy through matter or through space, where no matter exists. Radiation differs from conduction and convection because it can occur between objects that are not touching. Electromagnetic waves carry thermal energy between objects. This is how thermal energy from the Sun reaches Earth.

## Electromagnetic Waves

All objects give off electromagnetic waves, but most of these waves are not visible. Objects at extremely high temperatures, however, emit visible light. Light is a type of electromagnetic wave. The Sun and glowing melted glass are examples. Except for light waves, all other types of electromagnetic waves are invisible.

## The Process of Radiation

Electromagnetic waves carry energy. Radiation transfers this thermal energy from objects at higher temperatures to objects at lower temperatures.

Restaurants use heat lamps to keep food hot. The lamps are hotter than the food beneath them. Electromagnetic waves travel from the lamps to the food. Particles in the food absorb thermal energy from the waves. The food particles begin to move faster. As a result, the kinetic energy and the temperature of the food increase.

**Reading Check**

**8. Contrast** convection and radiation.

## Mini Glossary

**conduction (kuhn DUK shun):** the transfer of thermal energy due to collisions between particles in matter

**convection:** the transfer of thermal energy by the movement of particles from one part of a material to another

**heat:** thermal energy moving from a region of higher temperature to a region of lower temperature

**radiation:** the transfer of thermal energy from one object to another by electromagnetic waves

**thermal conductor:** a material in which thermal energy moves quickly

**thermal insulator:** a material in which thermal energy moves slowly

**1.** Review the terms and their definitions in the Mini Glossary. Write a sentence that explains what conduction, radiation, and convection have in common.

_____

**2.** Use what you have learned about the transfer of thermal energy to complete the table.

| Name | How It Transfers Thermal Energy | Example |
|---|---|---|
| Convection | _____ _____ _____ | _____ |
| Conduction | _____ _____ _____ | _____ |
| Radiation | _____ _____ _____ | _____ |

**3.** How did forming and answering questions help you understand this lesson?

_____

_____

### What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON