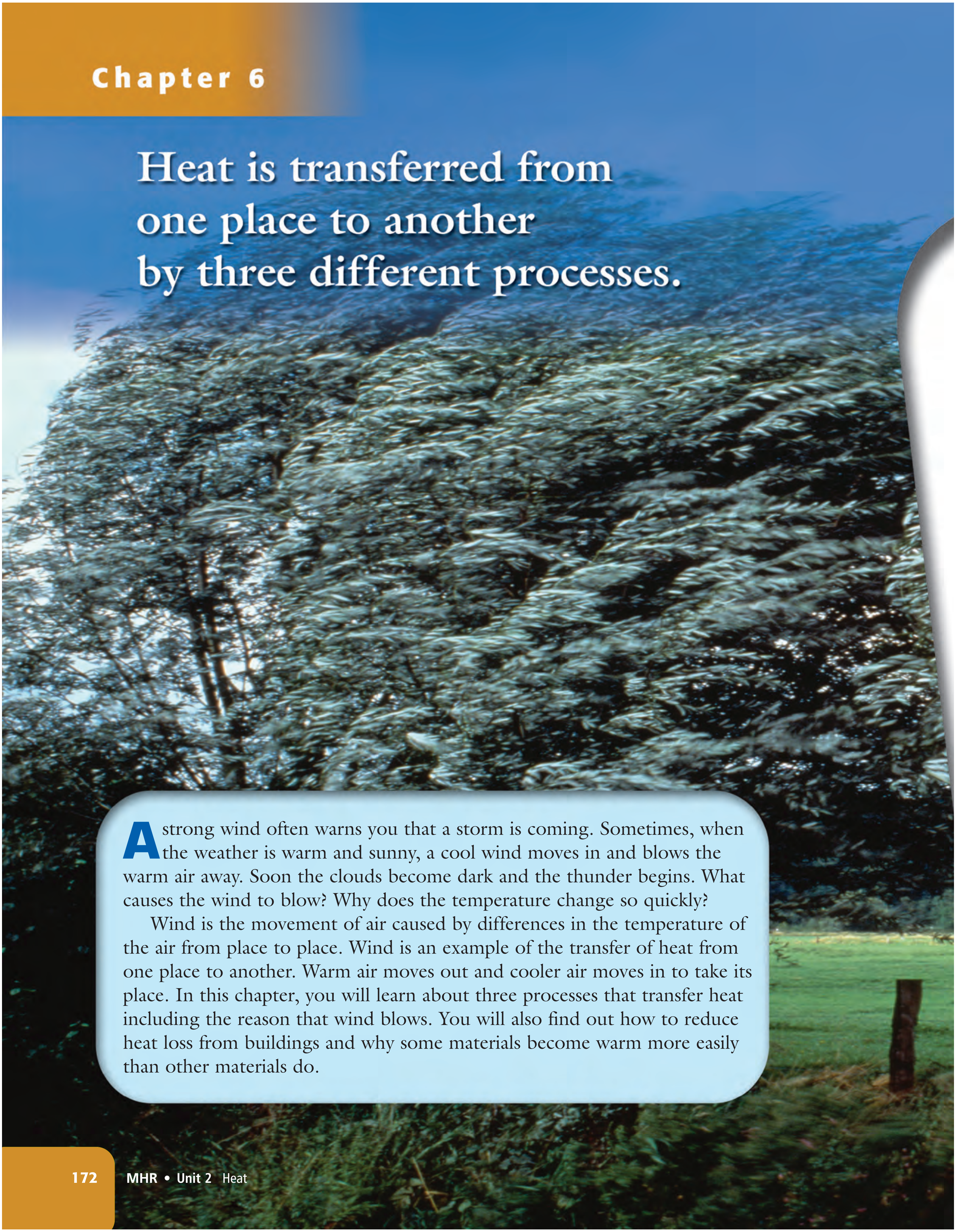


Chapter 6

Heat is transferred from one place to another by three different processes.

A strong wind often warns you that a storm is coming. Sometimes, when the weather is warm and sunny, a cool wind moves in and blows the warm air away. Soon the clouds become dark and the thunder begins. What causes the wind to blow? Why does the temperature change so quickly?

Wind is the movement of air caused by differences in the temperature of the air from place to place. Wind is an example of the transfer of heat from one place to another. Warm air moves out and cooler air moves in to take its place. In this chapter, you will learn about three processes that transfer heat including the reason that wind blows. You will also find out how to reduce heat loss from buildings and why some materials become warm more easily than other materials do.

What You Will Learn

In this chapter, you will
- **explain** the difference between heat and temperature
- **describe** the three mechanisms of heat transfer which are conduction, convection, and radiation
- **define** specific heat capacity
- **compare** the specific heat capacities of some common materials

Why It Is Important

Understanding specific heat capacity of substances will help you know which types of hot objects are more likely to burn your skin. You will also know why water is best for treating burns. Specific heat capacities will also help you understand weather conditions.

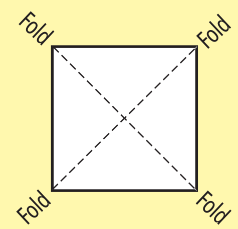
Skills You Will Use

In this chapter, you will:
- **observe** the rate at which different liquids warm
- **control** variables that will may affect experimental results
- **explain** some weather systems

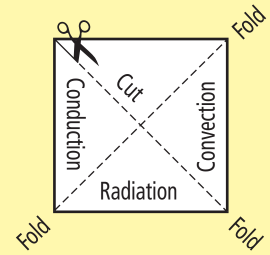
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 6.

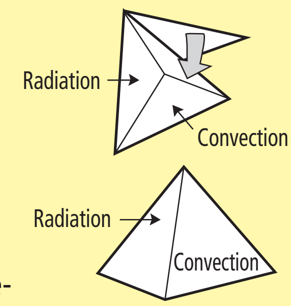
STEP 1 **Fold** a large square of paper diagonally to form an X.



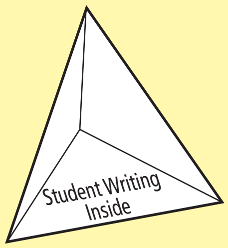
STEP 2 **Cut** along one of the fold lines, stopping at the centre intersection point. This cut will form two triangular sections. **Label** the Foldable as shown.



STEP 3 **Fold** and glue the blank triangular section under the one labelled "Conduction" to form a three-sided pyramid.



STEP 4 **Lay** the pyramid on its side to write notes inside the triangular sections.



Organize As you progress through the chapter, take notes and record new terms related to radiation, conduction, and convection on the inside of the pyramid. Additional notes can hang from the sides of the pyramid to make a mobile.

6.1 Processes of Transferring Heat

Conduction occurs when particles in an object vibrate in place but collide with neighbouring particles passing kinetic energy to them. Convection occurs when warm fluids move from one place to another. Radiation occurs when electromagnetic waves carry energy from a source to another object. The object then absorbs the energy of the electromagnetic wave.

Key Terms

conduction
convection
convection currents
radiation

Figure 6.1 Lizards often bask in the Sun to absorb the radiant energy, which increases their body temperature.

Lizards belong to the class of animals called reptiles. Reptiles do not generate enough heat to keep their bodies at a constant temperature. For many years, biologists thought that the body temperature of reptiles was always the same as the temperature of the air around them. However, more research showed that reptiles have some clever ways to warm their bodies to temperatures higher than the temperature of the surrounding air. The lizard shown in Figure 6.1 is basking in the Sun. The lizard's body absorbs the radiant energy of the Sun and becomes warmer. If its body becomes too warm, the lizard might take a dip in a nearby pond to cool off.

Radiation is one of the three processes that transfer heat from one place to another. In this section, you will learn about all three processes: conduction, convection, and radiation.

Did You Know?

One type of lizard that lives high in the Andes Mountains in South America is especially efficient at absorbing radiant energy from the Sun. The lizard will crawl out of its burrow in the morning when the air temperature is as low as –5°C. It will climb up on some vegetation and orient its body so that its back is directly toward the Sun. After two hours of basking, the lizard's body can reach temperatures higher than 30°C even though the air temperature is near the freezing point.

6-1A Currents in a Pie Pan

Find Out ACTIVITY

When you heat a pan of water, how does all of the water get hot instead of just the water on the bottom of the pan? In this activity, you will observe the movement of water, or currents, when the water is heated.

Safety

- Use care when handling hot items.
- Do not touch an electric plug if your hands are wet.

Materials

- aluminum pie pan
- hot plate
- stirring rod
- liquid hand soap or shampoo (that appears pearly, not transparent)
- food colouring (any colour)
- water

What to Do

1. Fill the pie pan about half full of water.
2. Add about two tablespoons of hand soap or shampoo.
3. Stir gently to mix the soap and water but do not make bubbles.
4. Place the pie pan on a hot plate.
5. Wait until the solution is motionless then turn the hot plate on the lowest setting.
6. Observe the movement of the solution as it begins to heat.
7. When you see movement, add a drop of food colouring and watch the pattern in which it moves. Repeat this process several times.

What Did You Find Out?

1. Describe the motion of the water solution as it was heating.
2. Suggest a possible reason why the water followed the pattern of movement that you observed.
3. Suggest a way in which the movement of air (wind) might be similar to the movement of the water that you observed.

Did You Know?

If you completed the activity above, you might have seen circular motion in several small areas of the solution. These units are called convection cells. The process that caused these convection cells to form also causes the formation of certain types of clouds such as the tall cumulus clouds in the photograph on the right. A similar process occurs on the surface of the Sun causing visible cells (see page 104).

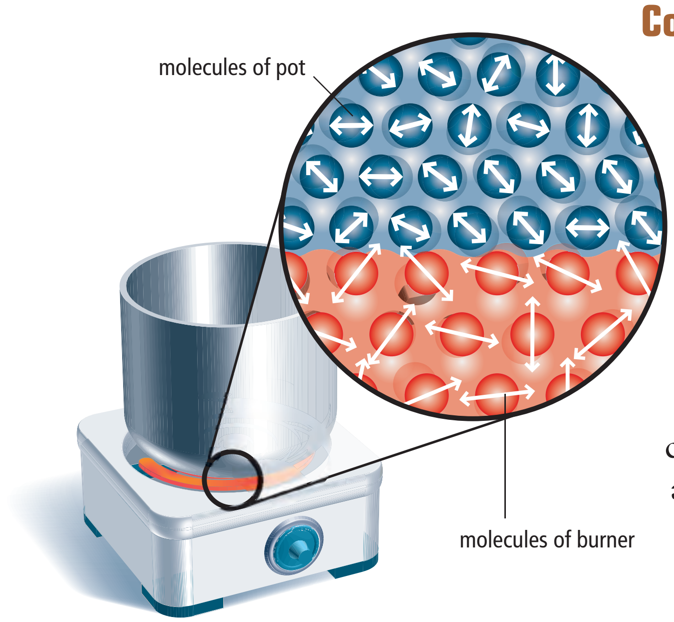


Figure 6.2 The length of the arrows on the particles in the stove burner and the bottom of the pan indicate the relative amount of kinetic energy that they have. The burner heats the pan by conduction caused by the collisions between particles in the burner and particles in the pan.

Conduction

Conduction is the transfer of thermal energy that occurs when warmer particles come in contact with cooler particles and transfer energy to the cooler particles. An example is shown in Figure 6.2. When you put a pan on a hot burner on the stove, the particles in the burner are hot and the particles in the bottom of the pan are cool. The hot particles in the burner collide with the cooler particles in the pan and transfer some kinetic energy to them. As a result, the particles in the pan become warmer.

When particles on the surface of an object are heated by any type of heat source, they begin to vibrate with more kinetic energy. They then collide with the nearby particles and transfer kinetic energy to them as shown in Figure 6.3. This process continues with each particle colliding with other nearby particles until additional kinetic energy has been transferred to all of the particles in the object. Heat has been conducted throughout the entire object or substance.

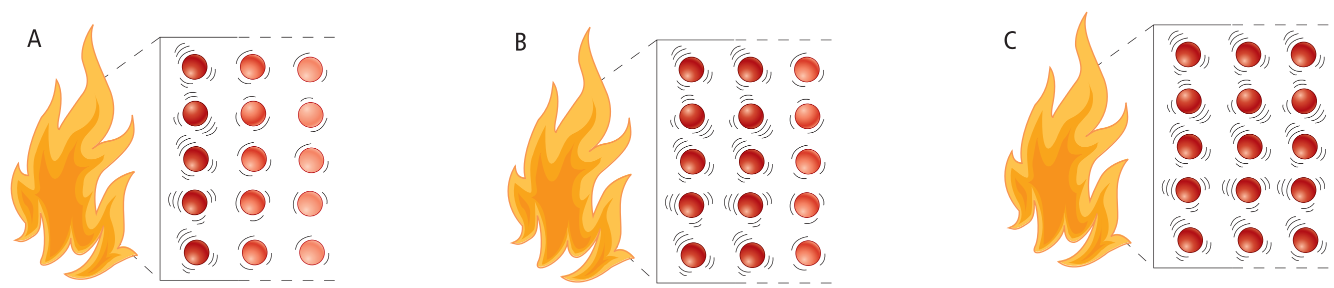


Figure 6.3 (A) Particles near a heat source absorb energy from the source and begin to move faster and, therefore, have more kinetic energy. (B) When the hot molecules on the surface collide with the neighbouring particles, they give some of their own kinetic energy to the nearby particles. (C) The collisions continue and heat is transferred throughout the object.

The important thing to remember about conduction is that the individual particles in a substance remain in place. The energy is passed from one particle to the next by collisions. Therefore, the energy is transferred through the substance but particles do not leave their original position. Conduction occurs mostly in solids.

Reading Check

1. What is necessary in order for conduction of heat to occur between two objects?
2. Does conduction occur in objects that are solids, liquids, or gases? Explain why.
3. How is heat transferred from one side of a solid object, such as the bottom of a skillet, to the other side of the object, such as the inside of the skillet?

Convection

Convection is the process in which a warm liquid or gas moves from one place to another, carrying heat with it. Figure 6.4 shows you how convection occurs. The candle flame heats the air around it. As you know, when a gas such as air is warmed, it expands. In the warm air, the particles are farther apart. Therefore, each small volume of warm air has fewer particles and is lighter than it was when it was cool. Therefore, the warm air rises. If nothing else happened, the rising air would leave an empty space below it. However, the heavier, cool air moves in to fill the place that the warm air left. As the warm air rises, it cools and, once again, becomes heavier. Eventually the cooled air drops back down again. These patterns of movement are called **convection currents.**

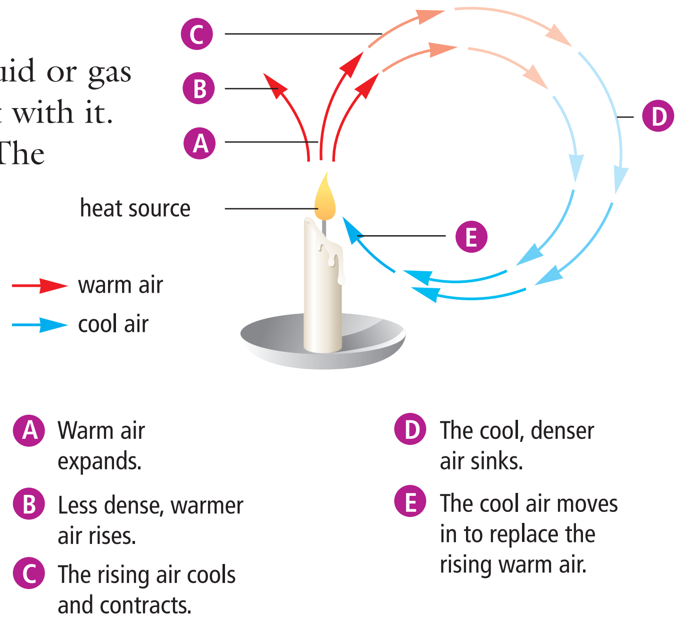
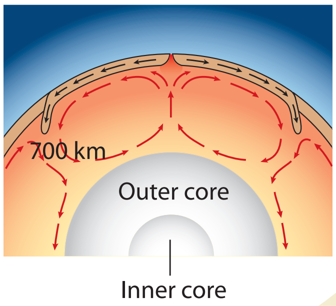


Figure 6.4 As the air near the flame becomes warmer, it rises, cools, and then drops back down again.

Wind is a form of convection current. The Sun heats Earth's surface unevenly and the air above the warmer parts of the surface rises. Cooler air moves in to replace it. Figure 6.5 summarizes the process that causes wind. The Sun warms part of Earth's surface more than another for many reasons. For example, near the equator the Sun's rays strike the surface more directly, and therefore, Earth's surface becomes warmer than it does farther from the equator. As you know, the nature of some surfaces causes them to absorb solar energy more readily. Bare ground becomes much warmer than water or a ground surface covered with vegetation. Snow covered ground reflects most of the sunlight away. Regardless of the cause of heating Earth's surface, the air above the warmer surface becomes warm by conduction. When the bottom layer of air warms, it expands and then rises. Cooler air, which is more dense and heavier,

Did You Know?

Geologists have evidence that shows that the continents and large oceanic plates have moved great distances over Earth's surface over millions of years. They believe that the motion is caused by convection currents in the molten fluid in the centre of Earth. In the diagram below, the red arrows show convection currents in the molten magma, the liquid layer below Earth's crust. The smaller black arrows show the movement of Earth's crust, which includes the continents.



Suggested Activity

Investigation 6-1E on page 188.

internet connect

There are animations on the Internet that illustrate convection currents. To find an animation, start your search at **www.discoveringscience.ca.**

moves in to replace the air that rose. At the same time, the rising air expands and cools. If the air was moist, the cooling causes the moisture to condense and results in rain. The cool air eventually begins to drop back to Earth. The result is a very large, circular convection current.

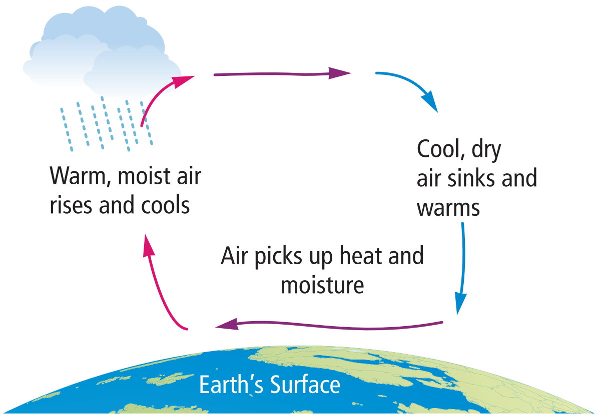


Figure 6.5 Wind is a type of convection current. You only feel the wind that is blowing along the surface of Earth. It appears to be blowing in one direction. However, the surface wind is part of a circular movement of air in the atmosphere.

Convections currents also occur in liquids. For example, when you heat water over a Bunsen burner, the water on the bottom of the beaker is heated by conduction because it is in contact with the hot beaker. As soon as the water begins to warm up, it expands and rises to the top. Cooler water moves down and becomes heated. The water circulates up and down in the beaker, as shown in Figure 6.6. If you continue to heat the water after it has all been heated to 100°C, it will begin to boil.

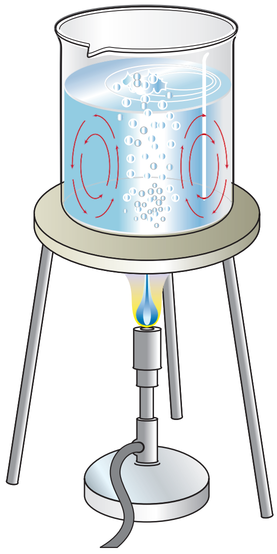


Figure 6.6 The arrows show the pattern followed by convection currents in the water.

6-1B Displaced Drops

Find Out ACTIVITY

You can create a small-scale model of convection. You will use water of different temperatures and food colouring to follow the movement of the water.

Materials

- 250 mL beaker
- 2 100 mL beakers
- stirring rod
- dropper
- room-temperature water
- ice water
- very hot water
- food colouring (two different colours)

Safety

- Handle the hot water with care.

What to Do

1. Add room-temperature water to the 250 mL beaker until it is about three quarters full.
2. Put some ice water in one 100 mL beaker and put some hot water in the other 100 mL beaker.
3. Add one colour of food colouring to the ice water and the other colour to the hot water. Mix thoroughly with the stirring rod.
4. Predict what will happen when you drop cold water into the room-temperature water and when you drop hot water into the room-temperature water. Record your predictions.
5. Fill the dropper with ice water. Hold the dropper just above the surface of the room-temperature water and gently squeeze out one drop of cold water.
6. Observe the movement of the cold water.
7. Repeat steps 5 and 6 several times. Draw a diagram showing the pattern of movement of the cold water.
8. Repeat steps 5 through 7 with the hot water.

What Did You Find Out?

1. Explain your reasoning for your prediction about the motion of the cold water in the room-temperature water. Was the observed motion the same as your prediction? If not, suggest a possible explanation.
2. Explain your reasoning for your prediction about the motion of the hot water in the room-temperature water. Was the observed motion the same as your prediction? If not, suggest a possible explanation.

Reading Check

1. In convection, what carries heat from one place to another?
2. Why can convection *not* occur in a solid?
3. Give an example of a common form of convection current.

Suggested Activities

Investigation 6-1F on page 189.

Radiation

On a bright sunny day, when you turn your face to the Sun, you can feel its warmth on your skin. Did you know that the radiant energy from the Sun travels about 150 million kilometres through empty space to reach Earth and to warm your face?

Figure 6.7 Light and warmth from the Sun always seem to be present. They appear to reach Earth instantaneously. However, it takes about 8 min for the light energy to travel from the Sun to Earth.

Until now, all of the concepts that you have learned about heat have involved the motion of particles. Transferring heat involved collisions between particles or the movement of warm particles from one place to another. How can the Sun's energy heat objects on Earth when there is so much empty space between them? There are no particles to collide with one another. The answer to the question is that radiant energy is carried by waves and not by particles. When matter absorbs radiant energy, the energy carried by the waves is converted into kinetic energy of the particles in the matter that absorbed it.

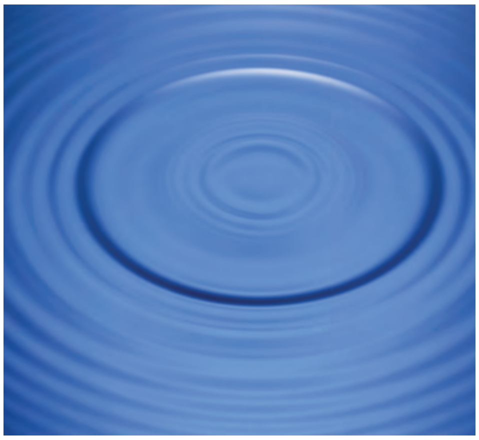


Figure 6.8 When a rock hits the surface of the water, it pushes water particles down and to the side. Each particle of water that is moved pushes on the particles beside it. These motions create the waves that you see on the surface of the water.

Waves

To understand how waves can transmit energy, think about a type of wave that you can see—a water wave. You know that if you drop a stone into a pond, ripples, or water waves, will radiate out from the point at which the stone hit the water. The kinetic energy of the stone was converted into kinetic energy of the water. If something is floating on the water, it will move up and down with the water waves. The floating object will receive kinetic energy from the water. For example, the girl in the

Figure 6.9 You can show that waves transmit energy by making waves in an aquarium and watching a floating object move.

photograph in Figure 6.9 is giving kinetic energy to the rubber ducky without touching it. She is moving her hand up and down in the water. The waves that the girl is creating with her hand are travelling through the water to the rubber ducky causing it to bob up and down. The kinetic energy of the girl's hand is giving kinetic energy to the rubber ducky without touching it.

Light waves and some other forms of waves are called electromagnetic waves. You cannot see electromagnetic waves because they are not made of matter as are water waves. Electromagnetic waves are made of electric and magnetic energy. They can carry energy through empty space or through air. **Radiation** is the transfer of energy carried by electromagnetic waves. Whenever you feel heat from the Sun, from a fire, or from a hot burner on a stove, electromagnetic waves are carrying the energy from the hot object to your skin.

There are many types of electromagnetic waves. They are divided into groups depending on their use or some other characteristic. The main groups are listed here.

- *Radio waves* are used to carry radio and television signals.
- *Microwaves* carry information to and from satellites.
- *Infrared waves* are most responsible for transmitting heat.
- *Visible light* are the electromagnetic waves that your eyes can detect.
- *Ultraviolet waves* are the type of waves that come from the Sun and cause sunburns.
- *X-rays* are used to make images of your bones.
- *Gamma rays* come from the radioactive sources and can do serious damage to living tissues.

Did You Know?

Tsunami waves transmit the energy from earthquakes on the ocean floor to continents that are hundreds of kilometres away. When the tsunami waves reach land, they can do serious damage to buildings and living beings on the land.

Did You Know?

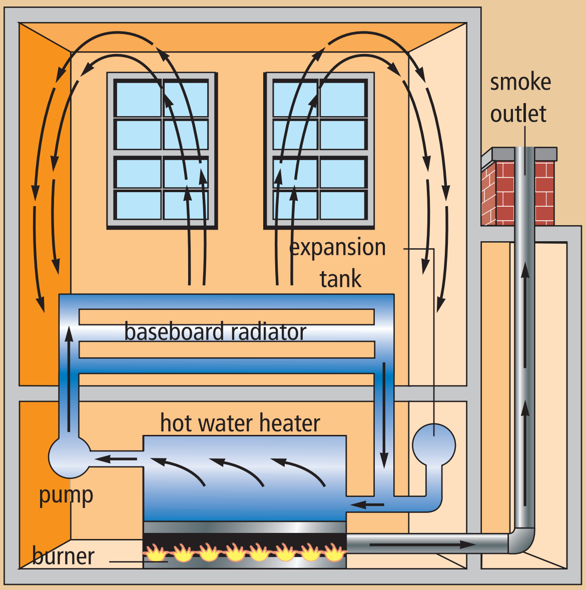
The microwaves that heat food in a microwave oven are a type of electromagnetic wave.

6-1C Energy Transfers and Home Heating Systems

Think About It

Each of the types of energy transfer—conduction, convection, and radiation—occur at one or more places in the process of heating a home. The diagram shown here illustrates the processes that occur in a hot water, home-heating system. The discussion beside the diagram describes the steps in the process. Your job is to identify and describe each step in the process in which a specific type of energy transfer is taking place.

Hot Water Heating System



Oil, gas, or another fuel burns in a furnace, heating water in the boiler. An electric motor drives the pump that circulates the hot water through the system of pipes and baseboard radiators. While the hot water flows through the baseboard radiators, it heats flat metal fins (not shown in the diagram) which, in turn, heat the nearby air. The hot air circulates throughout the room. A thermostat controls the flow of the water through the system of pipes and radiators, turning it off when the room is warm enough.

What to Do

1. Read the description of the home-heating system in detail.
2. Draw a diagram of the system in your notebook.
3. On the diagram, label each step in which an energy transfer is taking place.
4. Describe the process that is taking place at each point where there is a label in your diagram.

What Did You Find Out?

1. How many places in the home-heating system did an energy transfer occur?
2. Why are there fins on the pipes that run through the baseboards?
3. Explain why the radiators are placed along the baseboard instead of near the ceiling.
4. Radiators are often placed below windows. Why do you think that heating systems are designed in this way?
5. Baseboard heaters are usually placed on outside walls and not inside walls of a house. Why do you think that outside walls are the appropriate places for baseboard heaters? (An outside wall is between a room and the outdoors. An inside wall is between two rooms inside the house.)

Absorbing Radiant Energy

Examine the objects in Figure 6.10. What happens when light hits these objects? Light goes right through glass and reflects off of a mirrored surface. These surfaces absorb only a small amount of the light energy. The aluminum foil and the white paper absorb a little more energy but much of the energy is reflected away from the surface. The black paper absorbs more light than any of the other objects.

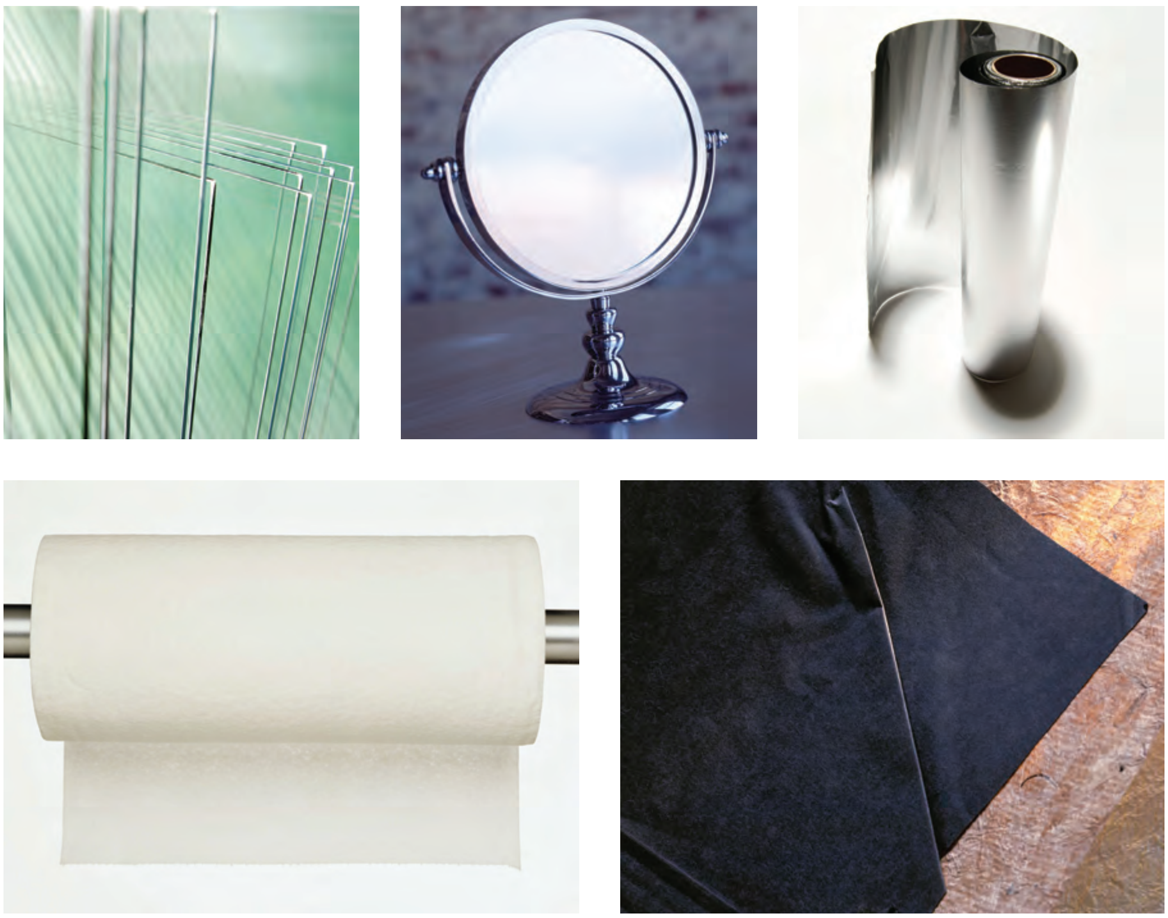


Figure 6.10 Light and other types of electromagnetic radiation interact differently with each of these different types of materials.

Infrared radiation and all other forms of electromagnetic waves react to surfaces in much the same way that visible light reacts. When the surface of an object absorbs the electromagnetic wave energy, it becomes warmer. When the surface reflects the waves or when the waves go right through an object as light goes through glass, the object does not absorb the energy and does not become warmer. An object will receive the energy transmitted by electromagnetic waves only if it absorbs the electromagnetic waves.

Core Lab

6-1D Absorb That Energy

Find Out ACTIVITY

How can you compare surfaces to see which one absorbs radiant energy (electromagnetic waves) the most efficiently? What will you measure?

Safety

- Use care when handling hot items.
- Do not touch the electric plug if your hands are wet.

Materials

- 2 empty, clean soft drink cans
- 2 thermometers
- light (at least 100 W)
- ruler
- dark- and light-coloured cloth or dark- and light-coloured paint
- aluminum foil
- 200 mL cooking oil
- tape or rubber bands

What to Do

1. Think about summer sunlight beating down on different materials. Use your own experience and what you have learned by reading this chapter to make the following predictions. Which type of surface absorbs radiant energy best?

   (a) dark or light

   (b) shiny or dull

2. From the list of materials, choose two materials to compare. Cover soft drink cans with the materials that you chose.
3. Pour 100 mL of cooking oil into each can. Place the cans 10 cm from the light as shown in the photograph.

4. Place a thermometer in each can, and then, read and record the initial temperature of the oil in each can.
5. Turn on the light. Then, read and record the temperature of the oil in each can every 5 min for at least 15 min.

What Did You Find Out?

1. Compare the temperature change of the oil in the two cans. Do your observations support your predictions?
2. If several groups tested the same prediction, how well did their results agree?
3. Combine the results of the entire class and come to an agreement about answers for both comparisons.
4. What factors other than the one that you tested could be affecting the temperature change of the oil in the cans?
5. According to scientific theory, the same materials that absorb radiant energy efficiently should also emit the radiant energy efficiently. Suppose that you have pairs of similar objects with different surfaces as listed below. Which type of surface radiates energy better and therefore, cools down more quickly?

   (a) a light-coloured surface or a dark-coloured surface

   (b) a dull surface or a shiny surface

Knowing which surfaces emit radiant energy the most rapidly is important for aircraft engineers. When flying extremely fast, the air friction rubbing against the surface of an airplane creates a large amount of heat. The airplane that holds the speed record of more than three times the speed of sound is the SR-71 Blackbird shown in Figure 6.11. The surface becomes extremely hot when it is flying at top speed. Engineers knew that the type of surface that absorbs heat most easily also emits heat the most easily. Therefore, the engineers decided to make the surface of the SR-71 Blackbird a dull black so that it would radiate heat away as rapidly as possible.

Figure 6.11 The SR-71 Blackbird has flown as fast as 3500 km/h. Although the black surface of the airplane radiates heat away as fast as possible, the surface gets so hot that the airplane expands several centimetres due to thermal expansion.

Reading Check

1. How can you transfer energy from your hand to an object without touching the object?
2. What can carry energy through empty space?
3. When radiant energy reaches an object, what must happen in order for the object to become warmer?

Heating Homes

One of the earliest forms of home heating was an open fire in a fireplace. Radiant heat from the fire heated objects with a direct line to the fire. Convection currents in the air spread the heat throughout the room. However, fireplaces warm only one room efficiently. Some large homes had fireplaces in several rooms.

Many years ago, homes in Newfoundland and Labrador were often heated with a wood stove similar to the one shown in Figure 6.12A. Stoves were often black which made them efficient radiators of heat. The room in which the stove was located could be very warm on even the coldest days. However, the transfer of heat to other parts of the house was very poor. Just before bedtime, people would put coals in a bed warmer like the one in Figure 6.12B. They would slide the bed warmer between the sheets and warm the bed.

Figure 6.12 (A) On cold winter evenings, families would sometimes gather around the wood stove and talk about the day. (B) When it was time for bed, they would put hot coals from the stove into a bed warmer like this. They closed the lid and took the bed warmer to the bedrooms and slid it between the covers. When the bed covers were toasty warm, they would hop right into bed.

Did You Know?

A man in Colliers, Newfoundland and Labrador invented and manufactures the solar panels that are shown in the photograph. A fan draws cool air from an inside room and sends it into the 15 cylindrical columns. The curved plastic covering focuses the Sun's rays on the dark-coloured columns. As the air passes through the columns, it is warmed by the solar radiation. Warm filtered air is then directed back into the room.

During the first half of the 1900s, people began to install furnaces in basements with ducts running to all of the rooms. Coal was burned in most of the early furnaces. In the mid 1900s, many furnaces were converted to oil or gas. Air was drawn into the furnace and heated and fans would blow the warm air through the ducts and into the rooms. This system is sometimes called forced air heating. In some houses, water was used to transfer water from the furnace to the rooms. A system of pipes carried water into the furnace where it was heated. Pipes passed through all of the rooms where the heat was transferred to the room air. These two systems — forced air and hot water heating — are still used in most homes.

As the cost of fuel increases and pollution from the burning of fuel threatens the environment, people are looking for new technologies. One of these technologies, called an air-to-air heat pump, works very much like a refrigerator. A fluid is contained inside a system of pipes as shown in Figure 6.13. In the summer, the fluid absorbs heat from the inside of the house and pumps it to the outdoors. In the winter, the heat pump is reversed. It absorbs heat from the outside air and pumps it into the house. You are probably wondering how a fluid can remove heat from cold air. The fluid and the system of pipes have some very special characteristics. When a fluid is allowed to expand rapidly and evaporate from a liquid to a gas, it absorbs heat from the surroundings. To remove the heat, the gas is compressed and converted back into a liquid. This process causes the heat to be released.

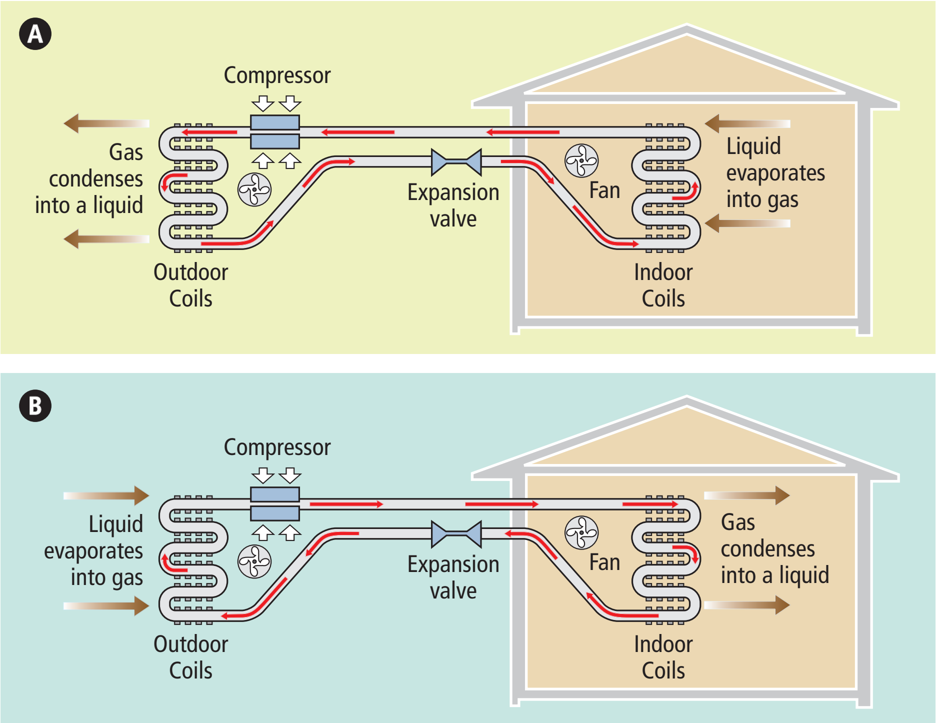


Figure 6.13 (A) In the summer, the coolant goes from the expansion valve into the house. When the coolant expands, it evaporates and draws heat from the room air. It then goes outside and through the compressor. When the coolant is compressed, it releases heat to the outdoors. (B) In the winter, the system is reversed. It absorbs heat from the outside air and releases it inside the house.

A geothermal heat pump is similar to an air-to-air heat pump. Instead of exchanging heat with the outside air, it exchanges heat with the ground. Although it is much more expensive to install, it is more efficient. Just a few metres below the surface of the ground, the temperature stays the same throughout the year. The temperature underground is cooler than the air in the summer and warmer than the air in the winter. As shown in Figure 6.14, a series of pipes are buried in the ground near a house or other building. In the summer, heat is pumped from the house to the ground. In the winter, heat is pumped from the ground to the house. Geothermal heat pumps have been installed in more than 30 000 buildings in Canada. The new Forest Centre building (see Figure 6.15) at Sir Wilfred Grenfell College in Corner Brook is the first building in Canada, other than a residential house, to use geothermal heat pump for heating and cooling.

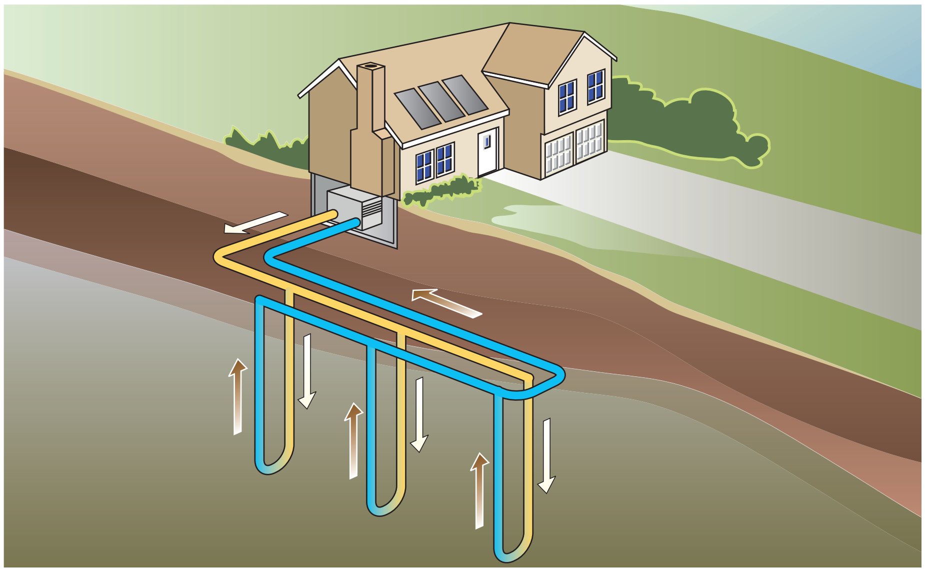


Figure 6.14 Pipes buried deep in the ground remove heat from the ground in the winter and pump it to the house. In summer, the heat pump takes heat from the house and deposits it in the ground.

Figure 6.15 The Forest Centre is on the Campus of Grenfell College, a college of Memorial University. The Centre uses cutting-edge technology of a geothermal heat pump for its heating and cooling

6-1E Blowing in the Wind

Conduct an INVESTIGATION

Inquiry Focus

Skill Check

- Observing
- Modelling
- Explaining systems
- Communicating

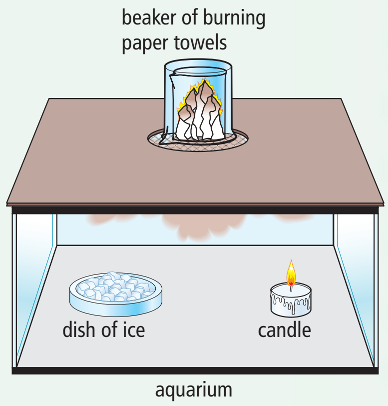
Safety

- Handle matches carefully.
- Wear thermal gloves when handling the beakers with the burning paper.
- Keep loose clothing away from flames and long hair tied back.

Materials

- aquarium with a screen top
- 100 mL beaker
- 1000 mL beaker
- Petri dish
- scissors
- piece of cardboard larger than the aquarium lid
- ice
- short, fat candle
- matches
- paper towels
- tape

Wind is caused by the uneven heating of Earth's surface. You can imitate those conditions in an aquarium. By creating smoke, you can observe the pattern of motion of the air. Your teacher might choose to do all or part of this investigation as a demonstration.



Question

How does a temperature difference on the Earth's surface cause a convection current in the air?

Procedure

1. Cut the cardboard so that it is just a little larger than the aquarium lid. In the centre of the cardboard, cut a hole that is slightly larger than the 1000 mL beaker.
2. Put ice in the Petri dish and place it at one end of the aquarium.
3. Place the candle at the other end of the aquarium.
4. Light the candle.
5. Put the screened lid on the aquarium and put the cardboard on top of the lid.
6. Fold up a small piece of paper towel and put it in the 100 mL beaker. Place the beaker on the screened lid in the centre of the hole in the cardboard.
7. Light the paper towel. Turn the 1000 mL beaker upside down and place it over the beaker with the lighted paper towel to cause the smoke to go into the aquarium.
8. For several minutes, observe and record what happens inside the aquarium.

Analyze

1. Draw a labelled diagram showing the motion of the smoke in the aquarium.
2. How does the ice affect the air around it?
3. How does the candle affect the air around it?
4. Based on the condition of the air near the ice and the air near the candle, explain the overall motion of the air.

Conclude and Apply

5. How does the motion of the air in the aquarium model wind?
6. Describe the conditions in nature that are similar to the conditions in the aquarium.

6-1F Convection in Water

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck
- Observing
- Controlling variables
- Modelling
- Explaining systems

Safety

- Handle the hot tray with oven mitts.
- Do not touch the electrical plugs if your hands are wet.

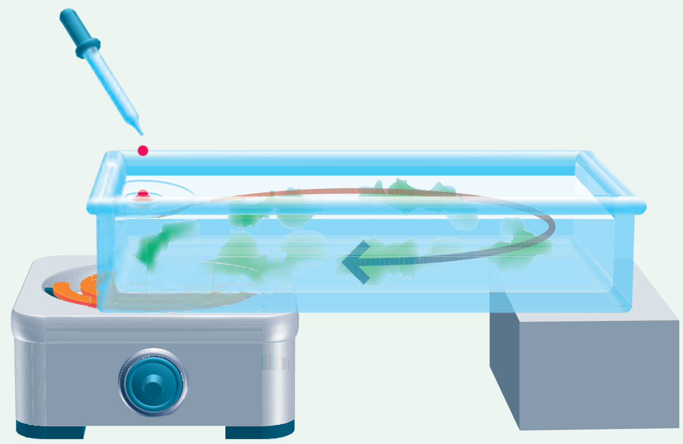
Materials

- hot plate
- block of wood (same height as hot plate)
- large glass baking pan
- water
- food colouring

Uneven heating of water can cause convection currents just as uneven heating does in gases. In this investigation, you will heat water unevenly and observe the movement of water by adding drops of food colouring. Your teacher might choose to do this investigation as a demonstration.

Question

When water is heated in one place, how is the heat distributed throughout the entire volume of water?



Procedure

1. Place one end of the glass baking pan on the hot plate and the other end on the block of wood as shown in the figure.
2. Pour water into the baking pan until it is almost full.
3. Turn the hot plate on low and let the water begin to warm.
4. Add a drop of food colouring to the water above the hot plate as shown in the figure.
5. Observe the motion of the colouring and record your observations.
6. Repeat step 5 several times until you can determine a pattern of motion of the water.
7. Wipe up any spills and wash your hands thoroughly.

Analyze

1. What happened to the drop of food colouring that was dropped into the water above the hot plate?
2. Describe the overall motion of the water in the baking pan.

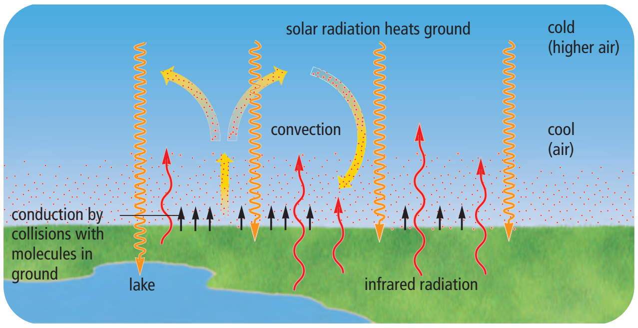
Conclude and Apply

3. Use your knowledge of convection to explain why the water moved as you described it in Analyze step 2.

Science Watch

Earth's Energy Budget

The three types of energy transfer—conduction, convection, and radiation—are all important in keeping temperatures around the world close to the average temperatures that support life. The first diagram shows the basic processes. Solar radiation (wavy orange arrows going down), which is mostly visible light, passes through the atmosphere and is absorbed by land, water, and anything on Earth's surface. The land and water are heated by the solar radiation. The land and water heat the layer of air in contact with the ground and water by conduction (short straight black arrows). The heat is spread through the lower atmosphere by convection (wide yellow arrows). Because they are warm, the land and water also emit infrared radiation. Specific gases in the air such as carbon dioxide absorb some of this radiation. The absorption of the infrared radiation warms the air.



If all of the heat that came to Earth by solar radiation stayed on Earth, the temperature would soon rise to such high temperatures that no life could survive. In order for Earth's average temperatures to remain the same, Earth must loose the same amount of heat that it gains. This energy is lost by emitting infrared radiation back out into space.

Before all of the energy in solar radiation returns to space, it is used for many purposes. The next diagram shows a few of the uses of this energy. Sunlight is absorbed by trees, grass, and other plants. The energy is used to help them grow and store nutrients. Animals eat the plants to gain energy to grow and carry out life processes. Trees and plants are also used to build houses. The coal, oil, and gas that humans take from the ground and use for fuel were once living organisms that used energy from the Sun. After all of these processes have been completed, the energy is eventually radiated back out into space.

Currently, humans are releasing more and more carbon dioxide into the atmosphere by several means including burning fuels in cars and in furnaces, and in the generation of electric energy. The levels of carbon dioxide in the atmosphere are increasing. As a result, the carbon dioxide is capturing more of the infrared radiation and preventing it from escaping back out into space. This process is one of the reasons why global warming is happening. Understanding global warming should help people to prevent it from continuing.

Questions

1. What is the source of the radiation that heats the air?
2. Why is it critical for Earth to emit as much heat by radiation as it receives from the Sun?
3. The levels of carbon dioxide in the atmosphere are increasing. How will this affect the atmosphere? Explain why it will have this effect.

Check Your Understanding

Checking Concepts

1. When one part of a solid object is heated, how is the heat transferred to the rest of the object?
2. How is convection different from conduction?
3. Use the particle theory to explain conduction.
4. What causes the wind to blow? Use the terms "conduction," "convection," and "radiation" in your explanation.
5. Explain how energy can be transferred through empty space where no particles are colliding.
6. Visible light and infrared rays are two types of what form of energy?
7. When a solid object absorbs infrared rays, what happens to the particles in that object?

Understanding Key Ideas

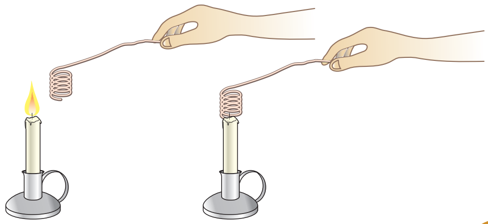
8. The apparatus shown here is used to demonstrate convection. A closed container has glass sides and two glass chimneys. A candle is placed right below one of the chimneys and is lighted. A piece of burning paper is held over the other chimney. Describe the pattern of smoke from the burning paper that you would expect to see. Explain why the smoke would follow the pattern that you described.

9. This diagram shows heat being transferred by conduction, convection, and radiation. Explain how and where each of the types of heat transfer is occurring.

10. Imagine that you are holding one end of a long rope and the other end is tied to a wall. A bell is tied to the middle of the rope. How could you demonstrate the transfer of energy to the bell without touching it? A rope such as this is often used as a model of radiant energy waves. Explain how waving the rope can be a model for transferring radiant energy.

Pause and Reflect

In the following diagram, a candle is burning. Someone is holding a coil made of copper wire. When the coil is placed around the candlewick, the flame goes out. Based on what you know about heat transfer, suggest a possible explanation for the reason that the flame goes out.



6.2 Conductors and Insulators

Although all solids can conduct heat, some do so much faster than others. They are called conductors. Substances that conduct heat very poorly are called insulators. For some applications, such as cooking, you need good conductors. When you want to keep hot things hot or cold things cold, you need to insulate them. Good insulation that is properly applied when a house is being built can save a lot of fuel and expense.

Key Terms

thermal conductivity
insulators

Some cooks feel that a cast iron skillet like the one in Figure 6.16A is the best type of skillet for frying. Some people even use them in the oven for baking corn bread. Most people, however, use a steel or aluminum skillet similar to the one in Figure 6.16B. If both of these skillets were on a stove burner and something delicious was cooking in each, which one would you have to be especially careful with when handling it?

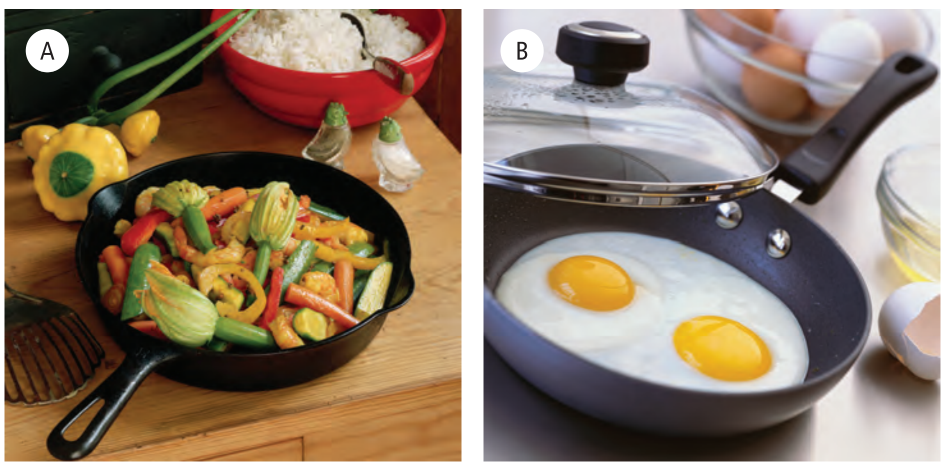


Figure 6.16 If you cook with a cast iron skillet (A), do not touch the handle without using an oven mitt or a hot pad. Most other skillets (B) have insulated handles.

In the last section, you learned that solids transfer heat when hot particles collide with particles beside them. Skillets conduct heat from the burner to the food that is cooking in them. They also conduct heat to the handle. However, some materials conduct heat more readily than others. The handle of the cast iron skillet becomes very hot because cast iron conducts heat fairly well. The handle of the other skillet, however, is not metal. Plastic and other non-metal materials are often used for handles on cookware because they do not conduct heat as well as metals do. In this section, you will learn about materials that conduct heat efficiently and those that do not.

Did You Know?

The bottom of the Space Shuttle is covered with special tiles that conduct heat extremely slowly. These tiles are critical because the friction between the tiles and the air when the shuttle re-enters the atmosphere makes the tiles extremely hot—as high as 1650°C. The astronauts inside of the shuttle are protected from the heat because the tiles radiate heat and conduct it back to the air faster than they conduct heat to other parts of the shuttle.

6-2A The Super Stirrer

For some uses, you would want an object that conducts heat very well. For other uses, you would want an object that does not conduct heat well. If you wanted a stir stick for a hot drink, what type of material would you choose?

Safety

- Handle the hot water with care.

Materials

- plastic (from a pen)
- copper wire
- long iron nails
- wooden craft sticks or wooden pencil

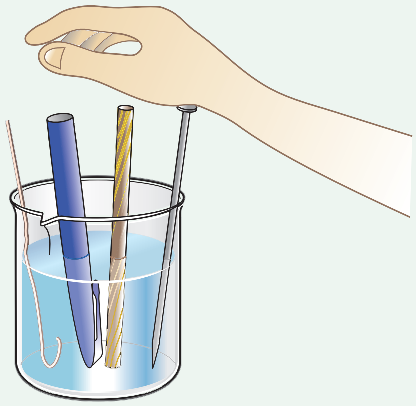
  (Each of the above items should be nearly equal in length.)
- cup or beaker of very hot water

What to Do

1. The items you are going to test for their ability to conduct heat are made of plastic, copper, iron, and wood. Predict which of the categories each material will fit in.

   a) good conductor of heat

   b) poor conductor of heat



2. Your teacher will pour a cup of very hot water for you. Place one end of each sample in the hot water. Wait for one minute.
3. The inside of your wrist is sensitive to heat. Touch the inside of your wrist to the top of each sample to determine which one is the warmest. This one is the best conductor of heat. Remove it from the cup and record which material is the best conductor of heat. Leave the other samples in the hot water for one more minute.
4. Repeat step 3 to find the second-best conductor of heat.
5. Continue to repeat step 3 until you have ranked all of the samples in order from the best conductor to the poorest.

What Did You Find Out?

1. Explain which of your samples would be the best for making:

   a) a stir stick

   b) the bottom of a frying pan

   c) the handle of a frying pan

   d) a container for delivering hot pizza
2. How might the particles in your best conductor differ from the particles in the poorest conductor of heat?

Suggested Activity

Investigation 6-2B on page 199.

Figure 6.17 The copper bottom on some types of cookware is not just for appearance. Copper is an excellent conductor of heat.

internet connect

Glass, stoneware, and ceramic cookware are poor conductors of heat. Why do you think that people cook with these products? You can find some important information about cookware on the Internet. Start your search at **www.discoveringscience.ca.**

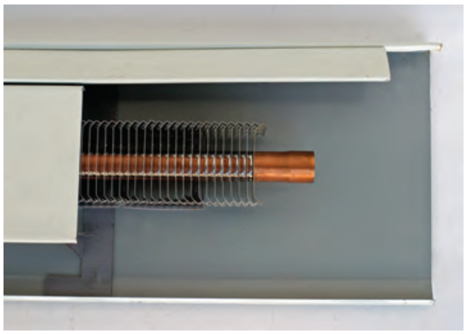


Figure 6.18 Baseboard heaters and radiators heat air by conduction with the air particles that come in contact with the metal surface. The hot air distributes the heat throughout the room by convection.

Cookware

You have probably noticed that most of the best conductors of heat are metals. However, all metals do not conduct heat at the same rate. The rate at which a substance conducts heat is called its **thermal conductivity.** Some metals are better conductors (have a higher thermal conductivity) than are other metals. This knowledge is important when designing or choosing an item that needs to conduct heat well.

Have you ever seen a pan with a copper bottom like the one in Figure 6.17? Did you wonder why the pan was made of two different metals? Copper is a very good heat conductor so it heats quickly and evenly. However, copper reacts with some foods such as tomatoes. The copper would combine with the food that was being cooked and would make it toxic. Therefore, copper is often used for the bottom of the pan but a non-reactive metal such as stainless steel is used to line the pans. Stainless steel does not conduct heat as well as copper so a pure stainless steel pan is not as good as copper is for some types of cooking.

Aluminum is similar to copper. It is a good conductor of heat but will also react with tomatoes and a few other ingredients that are often used in cooking. Aluminum pans must be either lined with a non-reactive metal or treated in a special way to prevent reactions. Good cooks must understand heat conductivity and know which metals are best to use in cooking.

Radiators

Some homes are heated by hot water running through a system of pipes in the rooms. Some hot water heating systems use baseboard heaters while others use large radiators as shown in Figure 6.18. The purpose of the baseboard heaters and radiators is to transfer the heat from the hot water to the air in the room. Therefore, the devices must be made of materials that are good heat conductors. They are always made of metal. As well, baseboard heaters and radiators need to have large surface areas to provide a lot of contact between the hot metal and the air in the room. The baseboard heaters have fins and radiators have many sections to provide these large areas of contact with the air.

The purpose of car radiators is the opposite of home radiators. A car engine creates a lot of heat. If the engine gets too hot, it will be damaged. Therefore, a coolant circulates from the engine to the radiator and back through the engine. While in the radiator, heat is transferred to the outside air. The coolant then returns to the engine to absorb more heat.

Figure 6.19 shows a diagram of a car radiator. The coolant flows through a very large number of metal tubes. The tubes are all connected to a stack of veins made of a metal alloy. This alloy is chosen because it is a very good heat conductor. When the car is moving, air passes through the veins in the radiator and removes the heat. There is also a fan behind the radiator to blow air through when the car is not moving fast enough and the engine temperature increases.

Did You Know?

Materials that are good conductors of heat are usually also good conductors of electric current.

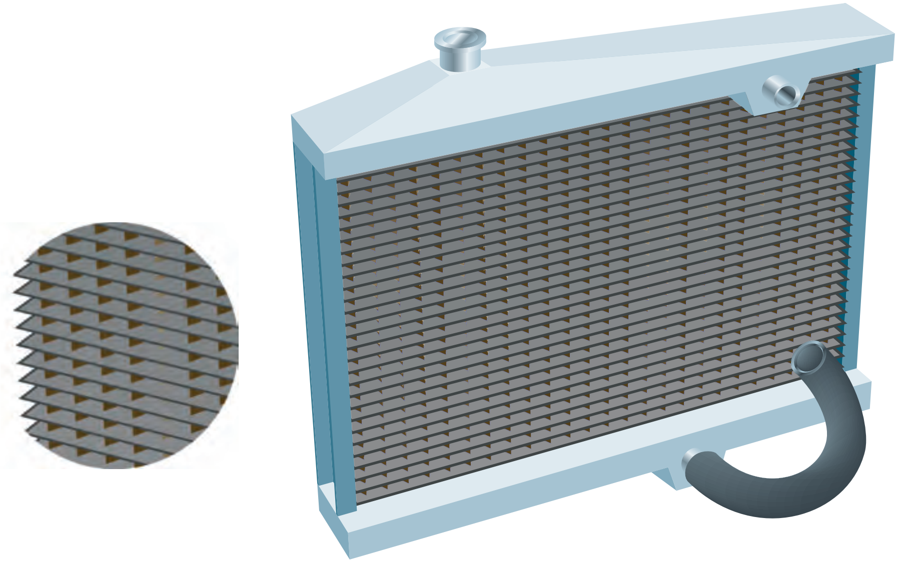


Figure 6.19 The honeycomb shape of the car radiator provides a very large metal surface area so that it can efficiently transfer heat from the engine to the outside air.

Did You Know?

An alloy is a mixture of two or more metals. Some alloys have properties that work better for many applications than the pure metals. For example, stainless steel is an alloy of iron with chromium and some carbon. It is much more resistant to rust than pure iron. Bronze is an alloy of copper and tin. Bronze is harder and more durable than pure copper or pure tin.

Reading Check

1. Why might you choose to purchase cookware with copper bottoms?
2. What class of substances are usually the best conductors of heat?
3. State two important features of radiators that are used in home heating.
4. List some similarities and differences between car radiators and household radiators.

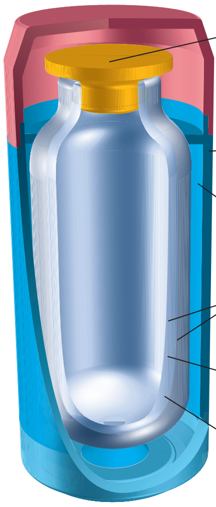


Figure 6.20 You can keep a cold drink cold or some hot soup hot for many hours in a Thermos® bottle.

Insulators

Materials that are very poor conductors of heat are called insulators. You have already seen one important use of an insulator—the handles of cookware. One of the very best insulators is "nothing." In this case, "nothing" means a vacuum. When no particles are present, neither conduction nor convection can occur. It is not possible to create a perfect vacuum in which all particles are removed. However, you can create a partial vacuum in which most particles of gas are removed. A Thermos® bottle as shown in Figure 6.20, is a good example of an insulator that uses a vacuum to prevent heat transfer. The inside of a Thermos® bottle is made of a double glass wall from which most air was removed and then the glass was sealed. The surfaces of the glass walls usually are silvered like a mirror to reduce radiation.

Suggested Activity

Investigation 6-2C on page 200.

Insulating Your Home

Humans have lived in the far North for thousands of years. They used clever methods for keeping the heat in and the cold out of their homes during the long, cold winters. The first European settlers in North America were the Vikings who sailed from Greenland and settled on the island of Newfoundland in about 1000 C.E. In 1960, a Norwegian explorer discovered the remains of one of these settlements. Some of the structures in this settlement were restored. A sod hut from the settlement called L'Anse aux Meadows is shown in Figure 6.21. The aboriginal peoples also built sod huts and supported the structures with whale bones. The thick layers of sod kept the heat inside and the cold outside in the winter.

Figure 6.21 For several years, the Norse settlers lived in these sod huts that are located on the northern tip of the island of Newfoundland. When these huts were discovered in 1960, they were restored, as nearly as possible, to their original condition.

Although sod was a very effective insulator for homes and was used for hundreds of years, great progress had been made in the technology of insulating buildings over the past thousand years. The cost of fuel makes heating modern homes very expensive. All houses leak some heat and it must be replaced. Keeping heat loss as small as possible will save fuel and save money. Home builders and contractors need to understand how and where heat leaks from buildings and the best ways to reduce the heat loss.

The largest surfaces of any house are the walls. There is always a space between the outer wall and the inner wall. If that space contained only air, the air would form convection currents as shown in Figure 6.22. Warm air would rise and cool air would fall. If the outside temperature is cool, the warm air that is in contact with the outer wall would lose heat to the outdoors by conduction through the wall. The air would begin to cool and drop and continue to lose heat to the outside. The cool air near the bottom of the space would receive heat by conduction through the inner wall. As the air warmed, it would begin to rise and continue to receive heat from the inner wall. As the warm air rises, the process would begin again.

As you know, when air can move, the convection currents it forms transfer heat from the inside to the outside of a house when the outside temperature is cool. However, if air is not allowed to move, it becomes a good insulator. The insulation that is built into walls of houses and other buildings, traps air and prevents it from moving. The material from which insulation is made is also a good insulator. Several types of materials, such as fibreglass and polystyrene, are used to make insulation. Figure 6.23 shows a variety of forms of insulation that are available. Builders and contractors must decide which type is best for each situation.

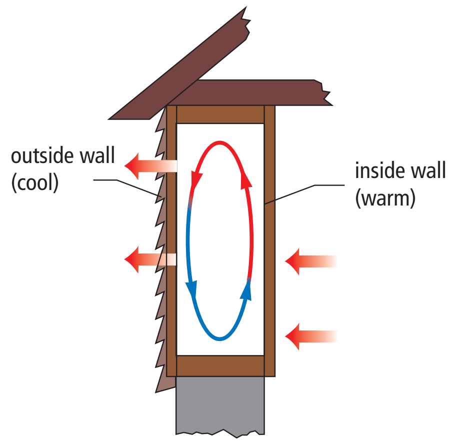


Figure 6.22 In the winter, if there was nothing but air between the inner and outer sections of a wall, convection of air would cause rapid heat loss from the house.

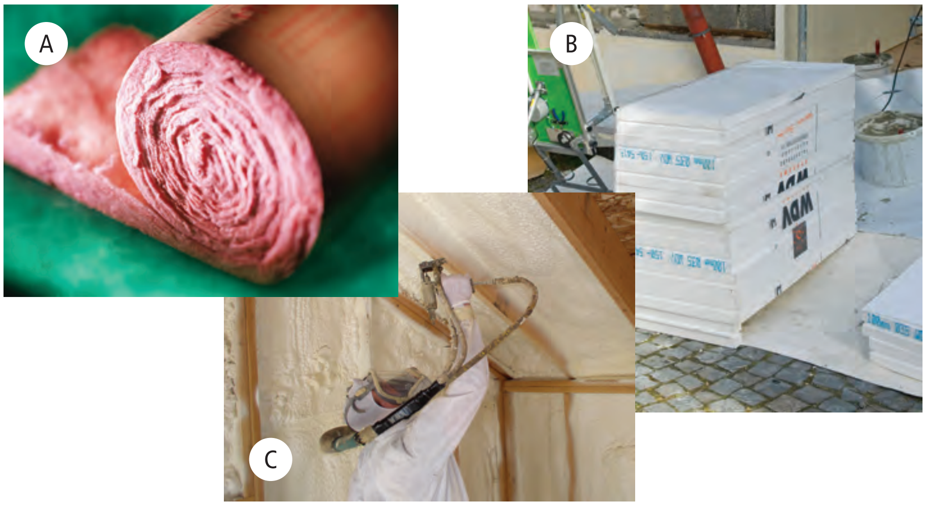


Figure 6.23 (A) Insulation often comes in rolls of a soft material called batt that is placed between the wooden beams in a wall. (B) Solid foam sheets of insulation are used for some situations. (C) Some builders prefer a spray foam that is applied directly to the structure of the building.

All types of insulation are rated according to their "resistance to heat transfer" or R-value. Table 6.1 lists the R-value of some common types of insulation. Materials with higher R-values are better insulators. In a wall, there will be several layers of different types of material. The total R-value is the sum of the R-values of each layer. For example, if you had plywood, fibreglass batt, and drywall, the total R-value would be 1.26 + 0.90 + 3.14 = 5.30.

Suggested Activities

Investigation 6-2D on page 202.

Table 6.1 R-Values of Building Materials

Type and Thickness of Material	Approximate R-Value
25 mm concrete	0.19
25 mm drywall	0.90
25 mm plywood	1.26
25 mm vermiculite	2.13
25 mm fibreglass batt	3.14
25 mm expanded polystyrene	3.86
25mm polyurethane (foamed-in-place)	6.25
25mm polyisocyanurate (foil-faced)	7.20

Windows are the places where the greatest heat loss occurs in a house. A single thickness of glass has an R-value of 0.91. Some new windows have two pieces of glass with an air space sealed between the layers of glass as shown in Figure 6.24. Sometimes a gas called argon is added to the air between the layers of glass. The total R-value of these windows can be as high as 2.04.

You can probably think of many more places that insulation is used. For example, the sides of a refrigerator or a freezer need to be insulated. Although you may not think of them as insulators, your own sweaters, jackets, mittens, and coats are forms of insulation for your body.

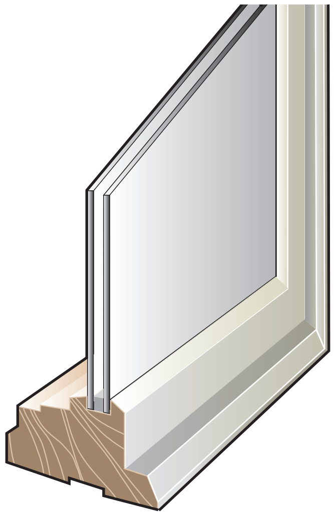


Figure 6.24 Air is sealed between the two pieces of glass to form some insulation in the window. If the seal is broken, however, moisture can get between the panes and condense creating water droplets between the pieces of glass.

Reading Check

1. Why is a vacuum a good insulator?
2. Air is a poor conductor of heat. Why would heat leak out through the double wall of a house if there was only air between the inner and outer walls?
3. Polyurethane foam, which is sprayed directly onto walls, is very expensive. Why might a builder or contractor choose to use an insulator that is more expensive than others that are available?
4. A single pane of glass has an R-value similar to that of one layer of drywall. Why, then, does so much heat escape through windows?

6-2B Heat Conductivity Rate

Conduct an INVESTIGATION

Inquiry Focus

Skill Check

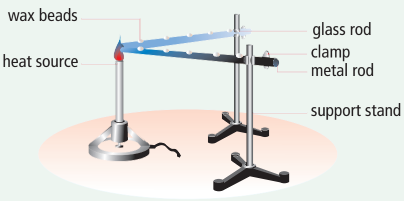
- Predicting
- Measuring
- Classifying
- Evaluating information

Safety

- Clean the equipment and wash your hands thoroughly at the end of the investigation.

Materials

- matches
- candle
- Bunsen burner
- 2 clamps
- glass rod and metal rods of equal diameter and length
- heat conductivity apparatus
- 2 support stands
- timing device
- ruler



Although all solids conduct heat, some conduct it much more rapidly than others. Some materials conduct heat extremely slowly. These materials are called insulators. In this investigation, you are going to test the rate of heat conduction in several materials.

Question

What is the rate of conduction of heat in various substances?

Prediction

Predict the order of the materials, copper, glass, iron, and aluminum, in the order of their ability to conduct heat from fastest to slowest rate of heat transfer.

Procedure

1. Light the candle. Let it burn until there is some melted wax at the top. Tilt the candle carefully and place drops of wax along the metal and the glass rods, one drop every 4 cm.
2. Use clamps to attach one end of each rod to a support stand.
3. Arrange the rods so that the free ends come together over the Bunsen burner flame.
4. As the rods heat, observe the melting of the wax beads. Record your observations.
5. To compare the thermal conductivity of different metals, use a conductivity apparatus (not shown). Place a drop of wax on the *end* of each metal rod of the apparatus.
6. Secure the conductivity apparatus hub over the flame.
7. Measure the length of time that it takes for each wax bead to melt. Record your observations.

Analyze

1. What do your results tell you about the transfer of heat through metals and non-metals?
2. List the tested materials according to their ability to transfer heat, from fastest to slowest.

Conclude and Apply

3. Compare your results with your predictions. Explain any differences.
4. Describe three places in your home in which you want a fast transfer of heat. List three situations in which you want a slow transfer of heat.

6-2C Keep it Cool

Skill Check
- Predicting
- Measuring
- Controlling variables
- Evaluating information

Safety

- Use care when handling the coffee cans because they can have sharp edges.

Materials

- scale or balance
- 6 identical, empty, metal coffee cans with plastic lids
- large basin
- thermometer
- ice cubes
- paper towels
- foam pellets about the size of peanuts
- poured insulation
- sheets of plastic bubble wrap
- wood shavings
- aluminum foil
- sealable plastic bags

Imagine that your assignment for a party was to bring a frozen dessert. You have to make it at home and take it to the party. How will you prevent it from melting while you transport it to the party and keep it until after the dinner? In this investigation, you will test the ability of several possible materials to prevent ice cubes from melting.

Question

Which type of insulating material will prevent ice cubes from melting?

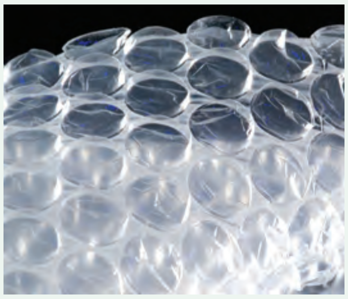
Prediction

Predict the order of the following types of materials, as well as poured insulation, as insulators from best insulator to poorest.

(a) foam pellets

(b) aluminum foil

(c) sheets of plastic bubble wrap



(d) wood shavings

Procedure

1. In the large basin, prepare a warm water bath of about 60°C.
2. Prepare the coffee cans as follows:
   - Half fill one can with wood shavings.
   - Half fill one can with foam pellets.
   - Place the bubble wrap so that it will fit, rolled, in another can.
   - Cover the inside of another can with poured insulation.
   - Line the fifth can with aluminum foil.
   - Leave the sixth can empty.

3. Choose six ice cubes that are approximately the same size.
4. Place each ice cube into a sealed plastic bag. Measure the mass of each one and record this data on a table similar to the one on the next page.
5. Put the ice cubes and bags into the cans as follows:
   - One onto the wood shavings. Add enough shavings to fill the can.
   - One onto the foam pellets. Add enough foam pellets to fill the can.
   - One onto the bubble wrap. Place more bubble wrap on top to fill the can.
   - One onto the poured insulation. Cover it with insulation.
   - One into the can lined with aluminum foil. Wrap aluminum foil around it.
   - One onto the bottom of the empty can.
6. Put the lids on the cans.
7. Place the six coffee cans into a warm water bath for 30 min.
8. While you are waiting, consider and revise your predictions.
9. After 30 min, quickly remove all of the ice cubes from their cans. Take each ice cube out of its bag. Pour out the water.
10. Place the cubes back into the plastic bags. Record the mass of each ice cube.
11. Clean up all materials and wash your hands thoroughly.

Insulation Material	Ice Cube Initial Mass (g)	Ice Cube Final Mass (g)	Ice Cube Lost Mass (g)
Wood shavings			
Foam pellets			
Bubble wrap			
Poured insulation			
Aluminum foil			
Empty can			

Analyze

1. In which container did the ice melt most? least?
2. Which container had the best insulation?
3. Which container had the poorest insulation?

Conclude and Apply

4. Which would be the best material(s) to use to get the frozen dessert to the party?
5. Are there any other factors that you would have to consider when you are planning a way to carry your dessert to the party? Explain.

6-2D When You're Hot....

Problem-Solving Focus

Skill Check
- Predicting
- Controlling variables
- Evaluating information
- Working co-operatively

Safety

- Be careful when working with hot liquids.

Materials

- 2 glass jars with metal lids
- wood chips
- thermometer
- plastic bags
- wool blankets or scarves
- aluminum foil
- newspapers
- foam pellets
- duct or electrician's tape
- string

A Thermos® bottle is just what you need if you want to keep your soup hot or your drink cold. The Thermos® bottle does have one big fault. If you drop it once, the vacuum bottle inside will break and you will have to buy another one. Perhaps you can improve on that design.

Problem

How can you construct a container that will keep water hot?

Design Criteria

A. You may choose from the materials in the list on the left.

B. Insulate one jar. Use another as a control. Compare the results of the two jars to see how well your insulation works.

C. Even with the insulation in place, the top of the insulated jar must be easy to reach and easy to unscrew.

Design and Construct

1. With a group, consider and record the advantages and disadvantages of each available insulating material. Record your conclusions in a table similar to the unfinished table below.

Insulation Material	Advantages	Disadvantages

2. Decide which insulator would be best for this job. Sketch and label the design using these materials. Get your teacher's approval.
3. Build your insulated jar.
4. Fill both jars with hot water from the tap. Measure and record the temperature of the water in each container. Put tops on the jars. Set them aside for four hours.
5. Arrange for someone in your group or your teacher to open both jars after four hours. The assigned person will measure and record the temperature of the water in each jar.

Evaluate

1. Would you be able to keep hot chocolate warm with your insulated jar?
2. How might you improve your plan? Make a list of things to consider including the following:

   (a) ability to insulate

   (b) ease of carrying

   Write a paragraph describing your improved plan.

Career Connect

Ask an Expert

Mario Patry is a salesman at a camping equipment store. He knows a lot about outdoor equipment. He can help campers decide which of the store's 30 different sleeping bags they will need for their camping trips. Mario knows a lot about insulation and energy transfer—the same topics that you have been studying. Here is what Mario tells his customers.

When a customer is choosing a sleeping bag, the first question I ask is where and when do they intend to use the bag. If you are backpacking in southern Canada in July, you will want a very different bag than if you are backpacking on Baffin Island in April. The right kind of sleeping bag can keep you warm on Baffin Island. Our warmest bag has a temperature rating of –40°C. It can keep you warm on a very cold night, if you use it in a tent that acts as protection from the wind. Also, you should put a pad under it for insulation from the cold ground.

Many factors affect how well a sleeping bag can keep the camper warm. Probably the biggest factor is the kind of insulation it uses. By that I mean what the filling in the bag is made of. There are two main types of sleeping bags: those filled with down (the fluffy layer under the feathers of water birds) and those that have synthetic fills (fibres made by machine). If you compare a down sleeping bag with a synthetic sleeping bag of the same thickness, the down bag is warmer.

Down puffs up very high—we call this effect "loft"—because of the many, many tiny air pockets between the bits of down. These air pockets are excellent insulators. They warm up with heat from the body and hold on to this warmth instead of letting it seep out of the sleeping bag. If you unroll your sleeping bag when you first set up camp, it has a chance to puff up with as many air pockets as possible before you sleep in it. Synthetic fill doesn't have as much puffiness, or loft, as down has. Fewer air pockets mean less trapped heat.

Down is very expensive. It is sometimes twice the price of a comparable synthetic bag, so some customers would not buy a down bag. Also, synthetic is a better choice if there is a chance your sleeping bag will get wet. A down bag takes much longer to dry out than a synthetic bag. While it is wet, the feathers stick together and, as a result, it will not insulate as well.

A lot of what I know about equipment I've learned from reading backpacking books and magazines and from trying out the equipment myself. I have been cycling, skiing, and winter camping for years. When I began working here, I completed two weeks of training to learn about the specific products the store offers.

Wild, Weird, Wonderful

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Animal Insulation

Animals that live in the Arctic have many different ways to insulate their bodies from the extreme cold.

The polar bear has a very thick fur that traps air making it a good insulation. Also, the individual hairs are hollow. They act like light pipes collecting sunlight and guiding it to the skin. Although their coat is white, polar bear skin is black, and therefore, absorbs radiant energy very well. In addition, polar bears have a layer of fat just below the skin. Fat is a good insulator. If a polar bear runs across the ice for a while, it gets too warm. It then lies flat on the ice to cool off.

Arctic seals swim in icy water. Water is a much better heat conductor than air so water can remove heat from a body very rapidly. Seals are insulated with a thick layer of blubber under the skin. The blubber can be as much as 7 cm thick. If a seal moves across land for too long, even at freezing temperatures, they become extremely hot because the blubber is such a good insulator.

The coat of the arctic fox is so thick that it needs no other insulation. In addition, the pads of the fox's feet have fur to prevent them from freezing. The fur also helps prevent them from slipping on ice. When the fox sleeps, it curls its long fluffy tail around its nose and face to protect them from the cold.

The musk ox has a very thick coat with a very soft, thick fur under the longer, stiffer hairs. A herd of musk ox huddle together, not only to protect each other from predators but also to keep warm. You might say that musk ox use each other as insulators.

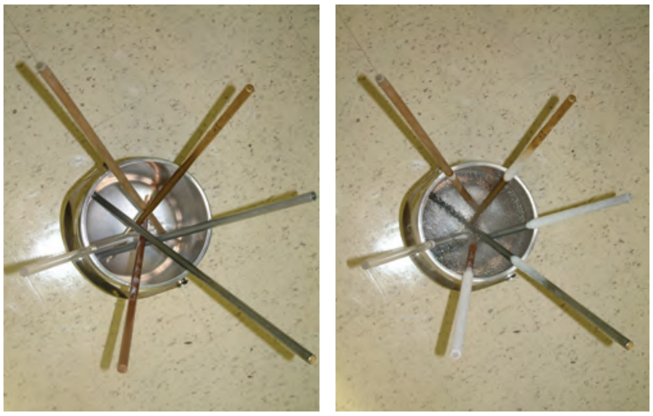
Check Your Understanding

Checking Concepts

1. Why are handles on cookware often made of plastic?
2. Copper and aluminum are good thermal conductors. Why is stainless steel often used for the lining of cookware?
3. Why are household radiators made of metal?
4. What is the purpose of a car radiator?
5. Describe the parts of a Thermos® jug. How can they keep cold drinks cold and hot foods hot for such a long time?
6. There are many types of insulation used in homes and other buildings. What is one feature that they all have?
7. Glass is a poor insulator but all homes have many windows. What is one way to reduce the loss of heat through windows?
8. What does the R-value of a type of insulation tell you?

Understanding Key Ideas

9. In the picture below, on the left, the rods made of different types of metals had just been placed in a thermos containing liquid nitrogen, which is extremely cold. The picture on the right shows the rods after they sat in the liquid nitrogen for several minutes. Explain how you can determine the order of the abilities of the metals to conduct heat. Which one is the best conductor and which is the poorest?



10. Use Table 6.1 on page 198. What would be the R-value of a wall that had 50 mm of concrete, 50 mm of expanded polystyrene, and 25 mm of plywood?
11. While baking a cake, you want to avoid burning the bottom of the cake. Should you use a glass or a metal baking pan? Explain why.

Pause and Reflect

Imagine that you are going on a picnic and taking a lunch for four people. You do not have a cooler so you are going to construct one from materials that you can find around your home. List items that you would use that are likely to be available in your home. Make a sketch of the cooler and explain why you chose the different parts.

6.3 Temperature versus Heat

Heat and temperature are related but different quantities. Heat is related to the total kinetic energy of all of the particles in a substance. Temperature is related to the average kinetic energy of the particles in a substance.

Key Terms

thermal energy
specific heat capacity

St. John's sits on the east coast of Newfoundland and Labrador, looking out on the Atlantic Ocean. The average temperature in January is –3°C and in July it is 15°C. As you read in Table 4.1 in Chapter 4, the average temperature in January in Winnipeg, Manitoba is –17°C and in July it is 20°C. Winnipeg is located in the central plains of Canada. Notice that St. John's is not as cold as Winnipeg in the winter and not as hot as Winnipeg in the summer. The main difference between St. John's and Winnipeg is that Winnipeg is surrounded by land and St. John's is nearly surrounded by water. Could water prevent St. John's from having the temperature extremes that Winnipeg has?

Figure 6.25 The Atlantic Ocean prevents the temperature from being extremely high or extremely low in St. John's.

If you made many more comparisons of temperatures in cities that are surrounded by land and cities located near large bodies of water, you would find patterns that are similar to those found in St. John's and Winnipeg. The presence of large bodies of water has a major effect on the climate. In this section, you will learn how the temperature of substances responds when heat is added or removed. This information will help you to understand the effect of large bodies of water on the local climate.

Did You Know?

The Gulf Stream is part of a group of currents in the Atlantic Ocean. It starts in the Gulf of Mexico and flows north along the east coast of the United States. Just before it reaches Newfoundland and Labrador, it goes east across the Atlantic Ocean. When it reaches Europe, it is called the North Atlantic Drift. The current carries enough heat from near the equator to northern Europe to significantly affect the climate.

6-3A Mix It Up

Find Out ACTIVITY

When you combine liquids that are at different temperatures, what determines the final temperature of the mixture? In this activity, you will combine 10 mL of room-temperature water, alcohol, and vegetable oil to separate 20 mL samples of ice water. Predict whether the final temperatures will be the same.

Safety

- Use care when handling the alcohol.

Materials

- 3 50 mL beakers
- 25 mL graduated cylinder
- laboratory thermometer
- stirring rod
- ice water
- room-temperature water
- room-temperature alcohol
- room-temperature vegetable oil

What to Do

1. Measure and pour 20 mL of ice water into each of the three 50 mL beakers. Do not allow any ice to get into the water in the beakers.
2. Measure and record the temperature of the water in each beaker.
3. Measure 10 mL of room-temperature water and pour it into one of the 50 mL beakers. Stir with a stirring rod and measure the temperature of the water.
4. Measure 10 mL of room-temperature alcohol and pour it into the second 50 mL beaker. Stir with a stirring rod to thoroughly mix the water and alcohol. Measure and record the temperature of the mixture.
5. Measure 10 mL of room-temperature vegetable oil and pour it into the third 50 mL beaker. The oil and water will not mix but by stirring thoroughly, you can create enough contact for the oil and water to exchange heat. Measure the temperature of the water after mixing.

What Did You Find Out?

1. To separate samples of 20 mL of ice water, you added equal amounts of water, alcohol, and oil that were all at the same temperature. List the mixtures in order of final temperature from highest to lowest.
2. Provide a possible explanation for any temperature differences that you observed.

Average and Sum of Kinetic Energies

To understand the difference between heat and temperature, you need to analyze the meaning of the average kinetic energy of the particles and the sum of the kinetic energies of the particles in a substance. You have learned that the average kinetic energy of the particles in a substance is directly related to the temperature of the substance. You will now find out how heat is related to the sum of the kinetic energies of the particles of a substance. Consider the following example.

Suppose that you had a beaker with 100 mL of water in it. You measured the temperature as shown in Figure 6.26A and found that it was 40°C. Then, imagine that you poured half of the water into another identical beaker and measured the temperature in both beakers as shown in Figure 6.26B. What would be the temperatures of the water in each of the two beakers? You are probably thinking, “Of course, the temperatures would both be 40°C.” This is correct. The temperature does not depend on the amount of water. In Chapter 4, you read that temperature is a measure of the average kinetic energy of the particles in a substance. There might be 1000 particles, 1 000 000 000 particles or 1 with a hundred zeros following it. The temperature of a substance does not depend on the number of particles present.

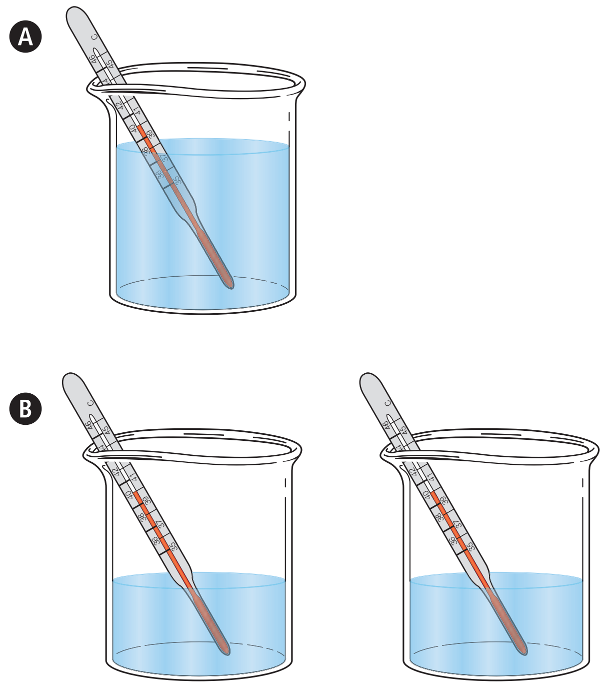


Figure 6.26 When you divide water into several different parts, the temperature is not affected. What is affected?

Now analyze the total amount of kinetic energy of the particles in the beakers in Figure 6.28. The total kinetic energy of all of the particles in a substance is the *sum* of the kinetic energies of each of the particles. Therefore, when you pour half of the water in one beaker into another beaker, the total kinetic energy in each beaker is half of the original. The *average* kinetic energy of the particles is still the same even though there are only half as many particles in each beaker. Since the average kinetic energy is the same, the temperature is still the same. Although, the *total* kinetic energy in each beaker is only half of the original, the temperature in each beaker is the same as the original.

Scientists usually call this total kinetic energy of the particles the **thermal energy** of the substance. People who are not scientists usually think of thermal energy as heat. So, the amount of thermal energy, or heat, is reduced when you pour some of the water out of the beaker but the temperature does not change. Heat and temperature are *not* the same. They are related but clearly different quantities.

Did You Know?

Scientists reserve the word *heat* to mean thermal energy that is transferred from one object to another or from one place to another. Technically, heat is the transfer of thermal energy.

Absorbing and Losing Heat

You know that adding heat to a substance will increase its temperature. However, do you know how much the temperature will increase when you add, for example, 1000 J of heat to 100 mL of a substance? Examine Figure 6.27 to find an answer to that question.

When you add 1000 J of heat to 100 g of water and to 100 g of alcohol, the increase in the temperature is not the same. When you add the same amount of heat to the same mass of two different substances, the size of the temperature increase depends on the type of substance. Scientists call this property of substances the specific heat capacity of the substance.

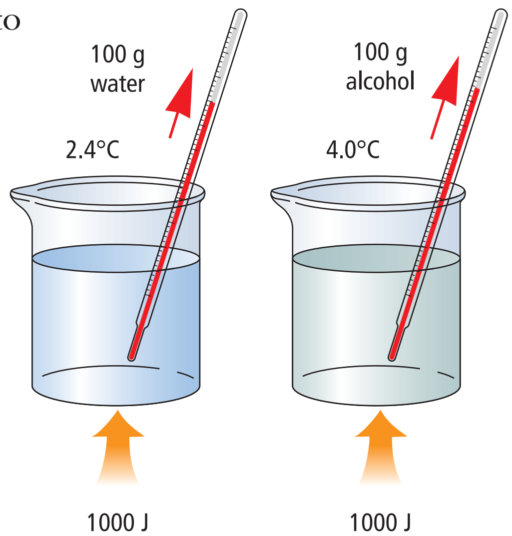


Figure 6.27 When you add 1000 J of heat to 100 g of water, the temperature of the water increases by 2.4°C. When you add 1000 J of heat to 100 g of alcohol, the temperature of the alcohol increases by 4.0°C.

The **specific heat capacity** of a substance is the amount of heat needed to raise the temperature of 1.00 g of the substance by 1.00°C.

For example, it takes 4.18 J of heat to increase the temperature of 1.00 g of water by 1.00°C. You would say that the specific heat capacity of water is 4.18 J/g ·°C (4.18 joules per gram per degree). It takes 2.43 J of heat to increase the temperature of 1.00 g of alcohol by 1.00°C. You would say that the specific heat capacity of alcohol is 2.43 J/g ·°C. (2.43 joules per gram per degree).

Suggested Activity

Investigation 6-3B on page 212.

Sun, Water, and Solid Ground

As you can see in the example of the water and the alcohol, it takes much more heat (4.18 J) to raise the temperature of 1.00 g of water by 1.00°C than it does to raise the temperature of 1.00 g of alcohol by 1.00°C (2.43 J). In fact, the specific heat capacity of water is higher than the specific heat capacity of most other substances. This difference in specific heat capacity is one reason why the temperature of water does not increase as much as the temperature of the ground when the Sun shines on them. Figure 6.28 shows you more reasons why the temperature of water does not change as readily as the temperature of the ground.

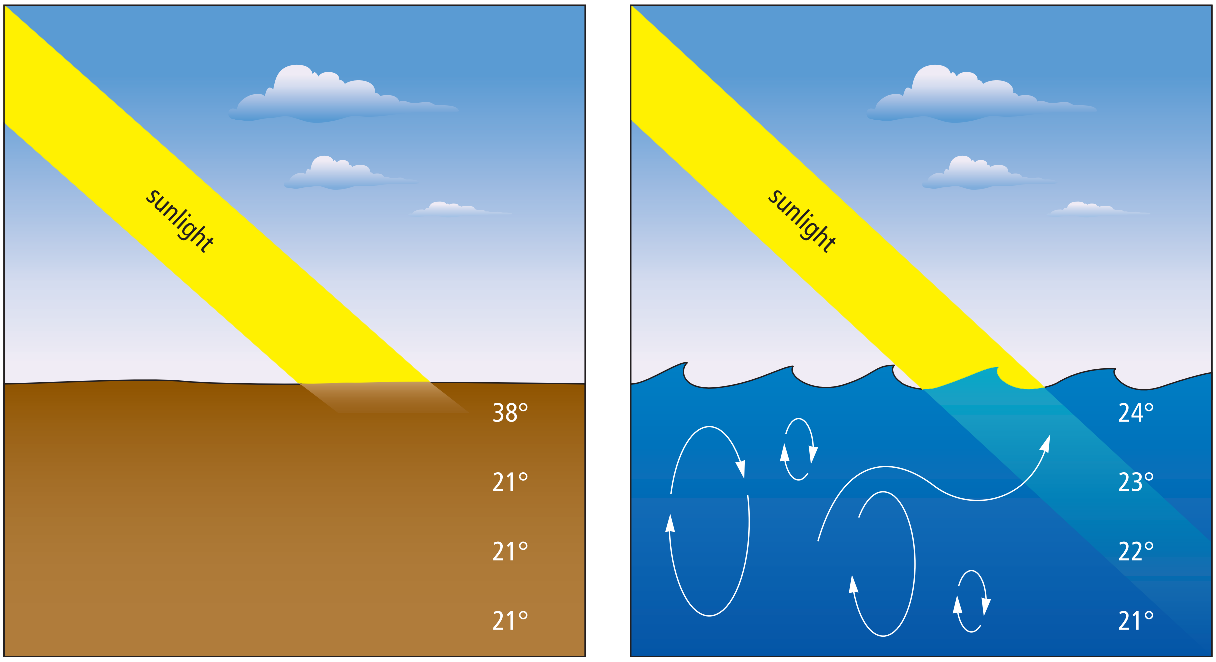


Figure 6.28 When the same amount of sunlight hits ground and water, the temperature of the ground increases more than the temperature of the water.

As you can see in Figure 6.28, the sunlight is absorbed by the top few centimetres of ground, or soil, so it increases in temperature a lot. The only way that heat can be carried deeper into the ground is by conduction, which is quite slow. Sunlight penetrates much deeper into the water so the energy is spread through a larger amount of water. As well, any motion of the water mixes the warmer and cooler water and spreads the heat around more. For these reasons and because water has a much higher specific heat capacity, the water temperature does not rise nearly as much as the temperature of the top layer of ground. If you have ever gone to the beach on a sunny day in the summer, you might have experienced these temperature differences. If you walk on a sandy beach in bare feet, the sand can feel extremely hot. As soon as you step into the water, the water feels cool. Now you can understand why.

Figure 6.29 The sand at the beach can be so hot that you want to run to get to the water. Once in the water, your feet feel cool.

Reading Check

1. Define "specific heat capacity".
2. If you combined four samples of water that each had a temperature of 4°C, would the final temperature be 16°C? Why or why not?
3. What property of a substance influences both heat and temperature?
4. How are heat and temperature different?

6-3B Keeping it Cool

Skill Check

- Observing
- Measuring
- Controlling variables
- Evaluating information

Safety

- Handle containers of hot materials with care.
- If hot oil or water touches your skin, hold the burned skin under a stream of cold water for several minutes. Have a classmate inform your teacher at once.
- Wash your hands thoroughly at the end of the investigation.

Materials

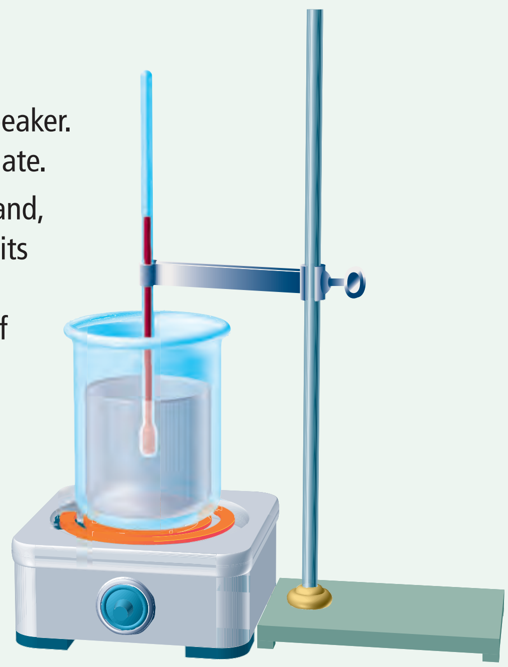
- hot plate
- 500 mL beaker
- graduated cylinder
- thermometer
- retort stand with thermometer clamp
- oven mitts
- stopwatch
- stirring stick
- balance and masses
- water
- oil such as paraffin oil, mineral oil, or motor oil
- vegetable oil
- glass marbles
- sand
- steel shot

In the summer, people often want to go to the beach, to a swimming pool, or just run through the sprinkler. You know that water will make you feel cooler but do you know why? This investigation will help you understand more about why water helps you stay cool.

Question

Part 1: Do all liquids absorb heat at the same rate?

Part 2: Do all solids absorb heat at the same rate?



To get an accurate reading, the thermometer should be held away from the side of the beaker.

Procedure

Part 1 Liquids

1. Pour 200 mL of water into a beaker. Place the beaker on the hot plate.
2. Using the clamp and retort stand, fasten a thermometer so that its bulb is in the water but not touching the side or bottom of the beaker.
3. (a) Record the initial water temperature.

   (b) You want to raise the water temperature by 30°C. Calculate what the temperature will be then.
4. Turn the hot plate to medium high. Time how long it takes to reach the temperature that you calculated in 3(b). Record the time.

5. Turn off the hot plate. Use oven mitts to remove the beaker from the hot plate. Allow time for the hot plate to cool.
6. Repeat steps 1 through 5 using vegetable oil and the other oil. **CAUTION:** If droplets of oil fall on the hot plate, they can ignite.

Part 2 Solids

7. Pour 100 mL of water into a beaker.
8. Add about 100 g of glass marbles to the water in the beaker. Place the beaker on the hot plate.
9. Using the clamp and retort stand, fasten a thermometer so that its bulb is in the water.
10. (a) Record the initial water temperature.
    (b) You want to raise the temperature by 30°C. Calculate what the temperature will be then.
11. Turn on the hot plate to medium high. Time how long it takes to reach the temperature that you calculated in 10(b). Record the time.
12. Use oven mitts to remove the beaker from the hot plate. Turn off the hot plate and allow it to cool.
13. Repeat steps 7 through 12 using approximately 100 g of sand and then using 100 g of steel shot. (**Hint:** To be sure that the sand is heated evenly, you need to stir it with the stirring stick.)
14. Clean up and put away the equipment you have used.

Analyze

Part 1

1. Which liquid(s) took the longest time to increase in temperature by 30°C?
2. Which liquids took about the same amount of time to warm by 30°C? Can you suggest a reason for this result?

Part 2

3. Which solid(s) took the longest time to raise its temperature by 30°C?
4. Which solids took about the same amount of time to warm by 30°C? Can you suggest a reason for this result?

Conclude and Apply

5. Compare the time it takes to heat the materials in Part 1 and Part 2.
   (a) Does the kind of material being heated affect the amount of heat needed to change its temperature?
   (b) What piece of information shows you the answer to 5(a)?

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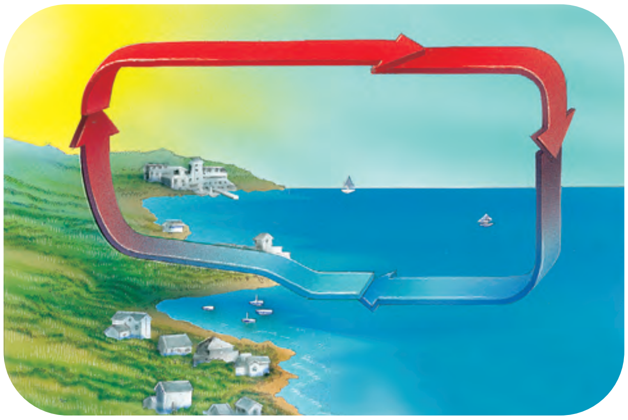
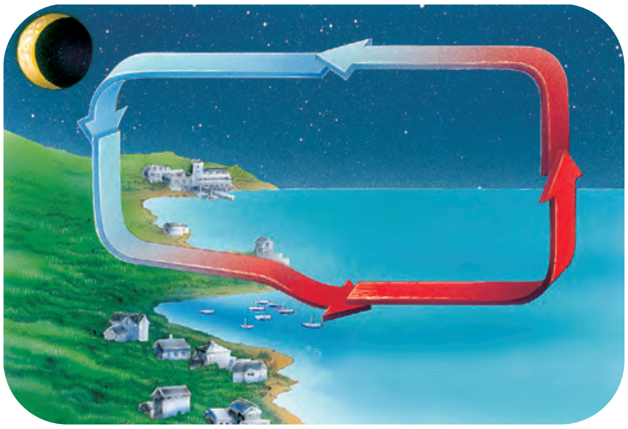
Sea and Land Breezes

Have you ever spent a few days by a large lake or by the sea? If you have, you might have experienced a sea breeze. On a hot summer day, you can depend on a gentle breeze blowing onto land from the water to help you feel cool. Why is a sea breeze so dependable on a hot day? What happens when the air cools down at night? An understanding of specific heat capacities and of convection currents will help you understand sea and land breezes.



On a hot summer day, the Sun beats down on the land and on the water. The low specific heat capacity of soil causes the ground to heat up quickly. Conduction in the soil does not carry the heat away very quickly so the top few centimetres of the soil get very hot. At the same time, the high specific heat capacity of water prevents the water from heating rapidly. The mixing of the water spreads any heat throughout the water. As a result, the water temperature is much cooler than the temperature of the ground. Heat is transferred from the ground to the air and the air begins to rise over the land. The air over the water is about the same temperature as the water so it is cooler than the air above the land. As the air above the land rises, it creates convection currents that draw the cool air in from above the water. The cycle continues as long as the day is hot.



When the Sun goes down, the low specific heat capacity of the soil allows the temperature to drop quickly when the heat leaves the ground by conduction with the air above. The high specific heat capacity of water prevents a rapid change in temperature because a large amount of heat would have to leave the water. Soon after the Sun goes down, the water is warmer than the land. The air above the water is, therefore, warmer than the air over the land. The air above the water begins to rise and the cooler air over the land flows out over the water forming another convection current. This time, however, the breeze is blowing out toward the sea. It is called a land breeze. The sea and land breezes make sitting on the shore comfortable on a summer day or evening.

Notice that wind direction is described as the direction *from* which the wind is blowing. A sea breeze is a wind blowing from the sea to the land. This method of reporting is always used in weather reports. For example, a westerly wind is a wind blowing *from* the west and not toward the west. A land breeze is a wind blowing from land to the sea.

Check Your Understanding

Checking Concepts

1. Vancouver, British Columbia is on the Pacific Ocean while Regina, Saskatchewan is in the prairie. Which city would you expect to be colder in the winter? Which city would you expect to be warmer in the summer? Explain why.
2. The average kinetic energy of the particles in a substance is related to what quantity?
3. The sum of the kinetic energies of the particles in a substance is related to what quantity?
4. Does heat or temperature depend on the amount of substance?
5. The specific heat capacity of aluminum is 0.900 J/g ·°C and the specific heat capacity of iron is 0.444 J/g ·°C. If you added 1000 J of heat to 100 g of each metal, which one would have the greatest temperature increase? Explain why.
6. List two reasons why water stays cooler than soil if the same amount of sunlight falls on both of them.

Pause and Reflect

Fire-walkers are people who walk on hot coals with their bare feet. One of their secrets is a knowledge of specific heat capacity. Before they walk on hot coals, fire-walkers wear a thick pair of socks. The socks make their feet sweat. How might having a layer of water (sweat) on the soles of their feet protect the fire-walker from burns?

CAUTION: This is a very dangerous stunt. Even if you have wet feet, *do not* try this yourself.

Understanding Key Ideas

7. Which beaker, in each of the following pairs, requires more heat to achieve the stated results? Explain each answer.
   (a) Beaker A with 250 mL of water and Beaker B with 500 mL of water are warmed from 10°C to 20°C.
   (b) Beaker A with 250 mL of water is heated from 10°C to 20°C. Beaker B with 250 mL of water is heated from 10°C to 30°C.
   (c) Beaker A with 250 mL of water and Beaker B with 250 mL of vegetable oil are heated from 10°C to 20°C.
8. Use your knowledge of specific heat capacity to explain why water is a better coolant than vegetable oil.
9. Why does water at a beach feel cooler than the beach sand during the day and warmer at night?
10. (a) Write a sentence using the word "capacity" in its everyday sense.
    (b) Write a sentence using the term "specific heat capacity." Your sentence must show that you understand its meaning.
    (c) How is the word "capacity" in its everyday sense different from the word "capacity" when used in the term, "specific heat capacity"?

Chapter 6

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated the methods of heat transfer, insulators, and specific heat capacity. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Conduction, Convection, and Radiation
2. Wind and Convection
3. Waves and Radiation
4. Thermal Conductivity
5. Insulators
6. Specific Heat Capacity

Checking Concepts

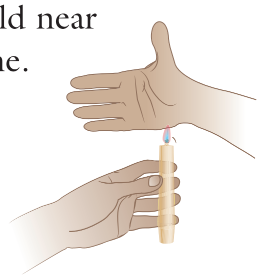
1. Each of the situations described below can be used to model a type of heat transfer. Indicate which type of heat transfer can be modeled by each of the following and explain why.
   (a) At a sports event, the spectators do "the wave." Starting at one end of the stadium, they stand up and then sit down as the next person stands. A rippling motion appears to travel through the crowd.
   (b) Several dominoes are standing close together on edge. You give the end domino a small push, increasing its kinetic energy. It falls onto the next one, which falls onto its neighbour, and so on. Soon all of the dominoes have fallen.
   (c) On a ski hill, people line up at the bottom of the hill, take the lift to the top, and then ski down again to join the crowd waiting for the lift.
2. What type of heat transfer is most important to a lizard that is basking in the Sun? Explain why?
3. Suppose you are given two cups of hot chocolate. One cup is made of shiny metal, and the other cup is made of a metal that has been painted black. Which cup will keep your hot chocolate warm longer? Explain.
4. Why are the handles of pots and pans usually made of non-metals?
5. (a) Why does so much heat escape from windows and doors?
   (b) How can heat transfer from windows and doors be slowed?
6. When boiling fruit and sugar to make jam, the mixture can easily reach a temperature of 105°C.
   (a) Which type of spoon could be used to stir the mixture without becoming soft or burning your fingers: wooden, metal, or plastic?
   (b) Which method of heat transfer must be prevented from happening in the spoon?
7. What is the difference between heat and temperature?
8. The R-value of 25 mm of solid wood is 1.25. The R-value of 25 mm of wood shavings is 2.42. Explain why there is such a large difference.
9. You heat a copper pot and an iron pot using the same method. Which pot heats more quickly? Explain your answer.

Understanding Key Ideas

10. When discussing conduction, you usually think of the process occurring in solids.
(a) Could convection occur in solids? Explain.
(b) Could conduction occur in liquids? Explain.

11. You have been asked to explain to a third grade class why the wind blows. Design an exhibit that you could use to demonstrate and explain wind to third graders. Make a sketch of your exhibit and explain how it works.

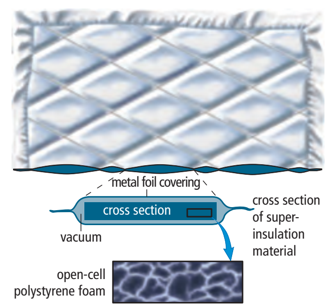
12. You hold a burning candle in one hand. Which of the processes of heat transfer causes your other hand to feel the heat in each of the following situations?
(a) Your other hand is held high above the burning candle and feels the heat.
(b) Your other hand is held near to the side of the flame. The palm of your hand feels the heat.
(c) A drop of wax falls on your hand and you feel the heat.



13. Edmonton, Alberta and Amsterdam, the Netherlands (Holland) are about the same distance north of the equator. Their climates are very different. What might account for this difference?

14. Why do builders put more insulation in an attic than in the walls?

15. A new "super insulation" is made from plastic foam with a shiny, metal foil covering (see diagram below). All the air is pumped out of the holes in the plastic foam. The foil prevents air from entering the foam again. Experts estimate that widespread use of this new material could save as much as one billion dollars' worth of fuel for heating buildings each year.
(a) Explain how the super insulation prevents heat transfer by conduction, convection, and radiation
(b) Suggest one problem that might occur with the new insulation?



16. In an experiment, a student observed that when 1000 J of heat was added to 50 g of granite, the temperature increased by 25.3°C. When 1000 J of heat was added to 50 g of limestone, the temperature increased by 21.7°C. Which type of rock, limestone or granite, has the largest specific heat capacity? Explain your reasoning.

Pause and Reflect

Coffee drinkers are sometimes told that if their coffee is too hot, they should let a metal spoon sit in the cup and the coffee will cool faster. Based on what you know about heat transfer, do you think this will work? Explain your reasoning.

UNIT 2

Unit Summary

4 Temperature describes how hot or cold an object is.

- Normal body temperature of humans is 37°C. (4.1)
- Body temperature is an indicator of health. (4.1)
- Hypothermia and hyperthermia can be life threatening. (4.1)
- Average air temperatures in Newfoundland and Labrador vary from –25°C to 20°C. (4.1)
- The first temperature sensing devices were developed in the 1500s. (4.2)
- The commonly used temperature scales are the Fahrenheit scale, the Celsius scale, and the Kelvin scale. (4.2)
- Thermometers must be calibrated by exposing them to substances at known temperatures. (4.2)
- Thermometers must contain a substance that changes as the temperature changes so that the change can be observed. (4.2)

5 Scientists use the particle theory of matter to describe temperature.

- All matter consists of tiny particles that are always moving, have spaces among them, are attracted to each other, and particles of different substances are different. (5.1)
- The average kinetic energy of the particles in a substance is directly related to its temperature. (5.1)
- All pure substances can exist in any of the three states—solid, liquid, or gas—depending on the temperature. (5.2)
- The particle model of matter can explain why particles exist in different states. (5.2)
- Matter in any state expands when the temperature increases and contracts when the temperature decreases. (5.2)
- The changes of state are called melting, freezing, evaporation, condensation, sublimation, and deposition. (5.3)
- Every pure substance has its own melting point and boiling point under conditions of standard pressure. (5.3)
- The particle theory can explain changes of state. (5.3)

6 Heat is transferred from one place to another by three different processes.

- The three mechanisms of heat transfer are conduction, convection, and radiation. (6.1)
- Conduction and convection depend on the motion of particles. Radiation is energy carried by electromagnetic waves. (6.1)
- Absorption of radiant energy by an object depends on its lustre and colour. (6.1)
- Conductors are substances that conduct heat rapidly. (6.2)
- Insulators conduct heat very slowly. (6.2)
- The R-value of building materials describes their effectiveness as insulators. (6.2)
- Heat and temperature are related but are not the same quantity. (6.3)
- The amount of heat required to change the temperature of 1.00 g of a substance by 1.00°C is called its specific heat capacity. (6.3)

Key Terms

- bimetallic strip
- body temperature
- calibrate
- Celsius scale
- Fahrenheit scale
- hypothermia
- Kelvin scale
- room temperature
- thermocouple
- thermogram
- thermometer
- thermoscope
- wind chill

Key Terms

- boiling point
- change of state
- condensation
- deposition
- evaporation
- freezing
- gas
- heating curve
- kinetic energy
- liquid
- matter
- melting
- melting point
- particle theory of matter
- solid
- sublimation
- temperature
- thermal contraction
- thermal expansion

Key Terms

- conduction
- convection
- convection currents
- insulators
- radiation
- specific heat capacity
- thermal conductivity
- thermal energy

Water Heater

In this unit, you have learned a lot about heat, temperature, energy transfers, insulation, and many more concepts involving heat. Can you apply much of this new knowledge in a practical way?

Problem

Design and build a simple but efficient device to harness and transform energy: a candle powered water heater.

Criteria

- Your goal is to raise the temperature of the water as much as possible.
- The water may be heated directly with the candle or indirectly using the candle to heat something else, which will then heat the water.
- Use as many types of heat transfer as possible.
- Your energy transfer device must be non-flammable and movable so that it can be safely placed over the candle after the candle has been lit.
- The candle will be allowed to burn for only 3 min during your demonstration.

Procedure

1. Carefully follow the list of safety precautions below.
   - All non-flammable materials must be approved by your teacher.
   - During and after heating, handle the apparatus with care.
   - Candle flame soot is hard to wash off clothing. Wear a lab coat and wash your hands immediately with soap and hot water if you get soot on them.
   - Have water or a fire extinguisher nearby.
2. You may use any or all of the following materials.
   - thermometer
   - birthday candle
   - 100 mL room-temperature water
   - non-flammable containers, fasteners, reflectors, and insulation
   - matches
3. Brainstorm ideas about how to build the most efficient heater. Think about:
   - energy transfer by convection, conduction, and radiation.
   - prevention of heat loss to the surroundings
   - specific heat capacity (you will need to make sure that the heater itself does not absorb too much energy)
   - possible materials to use (remember that paints, plastics, glues, and tape are flammable, so they do not meet the design criteria)
4. Choose the most practical ideas and write a design proposal that includes:
   - a list of materials
   - a labelled sketch of your device
   - a task list and a time line to show how each group member will contribute
5. Assemble the materials and build your device. You may test and modify it but the candle can be burned for only 3 min during a test. Keep a written record of any design changes you make.
6. For the demonstration, be ready to give a brief explanation of the design features of your device. Then, show how it works!

Report Out

1. Perform a demonstration to the class or present a report that describes your device and your data and results.
2. What was the highest water temperature that you obtained?
3. What was the temperature increase that you achieved during the three-minute burn?

Building Codes and Insulation

Contractors, architects, and builders have to understand heat transfer and insulation. All buildings, residential and commercial, need many different types of insulation to keep the heat inside in the winter and to keep the heat outside in the summer.

Background

Governments make regulations about the amount and type of insulation that buildings must have. The codes are different in different climates. Some types of materials, such as asbestos, were used in the past but have been found to be toxic. They are no longer permitted.

Asbestos insulation can be a hazard for people living or working in a building where it is present. It should be identified and removed.

Find Out More

What does the homeowner need to know about insulation? Whose responsibility is it to ensure that the correct amount and type of insulation is used? What types of insulation are appropriate for walls, attics, crawl spaces, pipes, metal buildings, ceilings, and other places? Use the Internet, encyclopedias, books, or interview contractors to learn more about insulation and the codes. Record and organize your findings.

When is spray foam the appropriate type of insulation to be used?

When must insulation be applied to the outside of a building?

Are all inside walls insulated?

Report Out

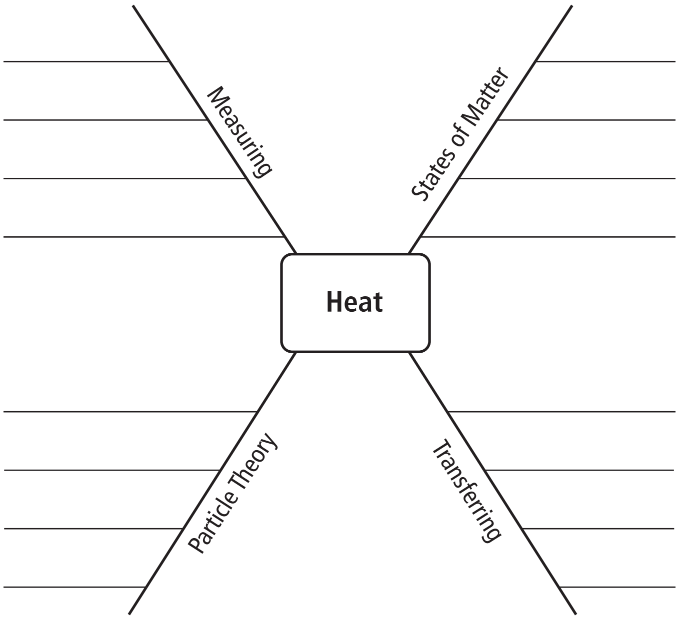
1. Prepare a pamphlet to present the information you have learned about insulation and building codes. Include information about R-values and types of insulation and about who is responsible for following building codes.
2. Prepare a poster and an oral presentation to present with the pamphlet about your findings. Include the items that are listed in the first suggestion.

UNIT 2

Unit Review

Visualizing Key Ideas

1. Copy the spider map on the right into your notebook. Do not look at your textbook. Beside each topic, fill in as many words as you can that are related to that topic. When you have completed the map, go back through this unit and look for other words you could include. Add these words to the map using a different colour pen.



Using Key Terms

2. Decide whether each of the following statements is true or false. If it is false, rewrite it to make it true.
(a) The Celsius scale is defined to make absolute zero equal to 0°C.
(b) Comfortable room temperature is 37°C.
(c) Zero degrees on the Fahrenheit scale is the freezing point of water.
(d) The boiling point of water is 212°F.
(e) Condensation is the reverse process to sublimation.
(f) Thermal contraction occurs when the temperature of an object increases.
(g) Matter is anything that has mass and takes up space.
(h) Wind is a form of conduction.
(i) Liquids are incompressible at a constant temperature.
(j) The specific heat capacity of a substance tells you how much heat is required to melt 1.00 g of a substance from its solid state to its liquid state.

Checking Concepts

4

3. Which of the following temperatures would you *not* expect to find on a recipe for cooking or baking food in a normal oven?
(a) 160°C
(b) 200°C
(c) 240°C
(d) 450°C

4. State a reasonable temperature for each of the following.
(a) summer day in Bonavista
(b) a person with a severe infection
(c) comfortable room temperature
(d) body temperature of a bird

5. How is a thermoscope different from a thermometer?
6. If the temperature of a substance is 273.15 K, what is the temperature on the Celsius scale?
7. What does it mean to calibrate a thermometer?
8. Describe how a bimetallic strip responds to a change in temperature. State one common use for a bimetallic strip.

5

9. What two factors determine the kinetic energy of an object?
10. If the temperature of an object increases, what can you say about the kinetic energy of the particles that make up the object?
11. Compare the shapes of solids, liquids, and gases.
12. How does the particle theory of matter explain the differences between solids and liquids?
13. Use the particle theory to explain why gases expand when they are heated.
14. The amount of thermal expansion of solids is very small. Explain why it is still very important for design engineers to know the exact amount that a solid might expand.
15. Why can pure water *not* be used in a car radiator in the winter?
16. Sublimation is the change from what state of matter to what other state?
17. What does the particle theory tell you about the forces between the particles of a substance that has very high melting and boiling points?

6

18. How does the particle theory explain conduction of heat?
19. Explain why gases and liquids rise when they are heated.
20. Why can convection *not* occur in solids?
21. What carries energy through empty space?
22. What happens to the particles in an object when it absorbs radiant energy?
23. State two applications in which you would want to use a material that is a good heat conductor.
24. What are two important features of radiators that are used in hot-water heating systems in homes?
25. Why does a vacuum make a good insulator?
26. Heat and temperature of an object are both related to the kinetic energy of the particles in a substance. How are the two quantities different relative to the kinetic energy of the particles?
27. State two reasons why the temperature of the ground increases much more than the temperature of water when they absorb the same amount of radiant energy from the Sun.

Understanding Key Ideas

28. Many household appliances, such as irons, are heated electrically. They usually contain a thermostat that switches electric power on and off to keep the appliance at a constant temperature. Think of at least three examples of other appliances that might use thermostats to switch electric power on and off.
29. With a group, create a short skit to show the behaviour of particles of matter in each of the following situations.
    (a) low temperature
    (b) warming up
    (c) high temperature

UNIT 2

Unit Review

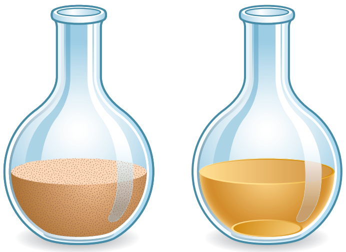
30. Imagine that you can see the moving particles in a drop of liquid on your skin. Describe:
(a) the speed of the particles that are able to escape from the surface of the drop
(b) the speed of the particles that are left behind in the drop
(c) the temperature change of the drop as particles continue to escape
(d) the change of state that is occurring

31. Carbon dioxide gas sublimes at –78.5°C.
(a) If you cool carbon dioxide below –78.5°C, in what state will it be?
(b) Could you produce liquid carbon dioxide by warming the solid?

32. Explain why hot water can float on top of cold water.

Thinking Critically

33. One of the characteristics of a liquid is that it takes the shape of the container. However, the illustration below shows sand, a solid, taking the shape of its container.
(a) Does this mean that sand is a liquid?
(b) Explain why or why not in terms of the particle theory of matter.



34. Choose the most appropriate temperature-measuring instrument to use in each situation below. In each case, explain your choice.
(a) controlling an electric frying pan
(b) making long-term temperature records at a weather station
(c) detecting small forest fires before they spread
(d) monitoring temperatures inside a furnace
(e) checking trains for overheating wheel bearings as they pass by a station
(f) studying temperature changes inside a building over a 24 h period

35. The photograph shown here was taken in the summer. Describe how the position of the transmission lines would change as the temperature dropped in winter. Why would it be a bad idea to stretch the transmission lines more tightly when they were hung between the towers in the summer to save on the amount of line that would be needed?

36. Aerosol spray cans often have a warning on their label to avoid heating them. Explain what would happen if an aerosol can was heated.

37. On a very cold day, a car enters a carwash. As soon as the hot water strikes the windshield, it cracks. Based on what you know about the effect of temperature on solids, explain this event.

38. Reinforced concrete is concrete that has had metal bars added to increase its strength. Without the steel, concrete can tend to be brittle and crack. Engineers are careful to use steel when reinforcing concrete because it has almost the same rate of thermal expansion as concrete.

(a) Why is it so important that the concrete and steel have similar expansion rates?

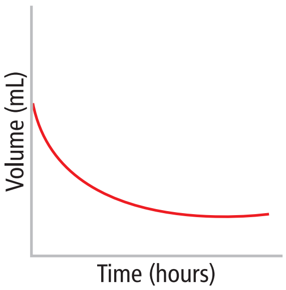
(b) What would happen if metal bars with a different thermal expansion rate were used to reinforce concrete?

Developing Skills

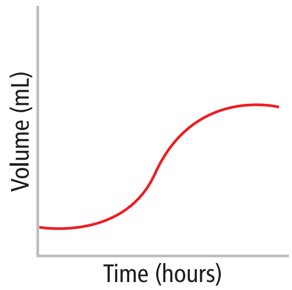
39. The two graphs below show the volume of a liquid in a laboratory thermometer during a temperature measurement.

(a) Which graph shows what happens when the thermometer is placed in water in a pot on the stove and the burner is turned on?

(b) Which graph shows what happens when the thermometer is placed in a jug of water that was just placed in a refrigerator?



Graph A

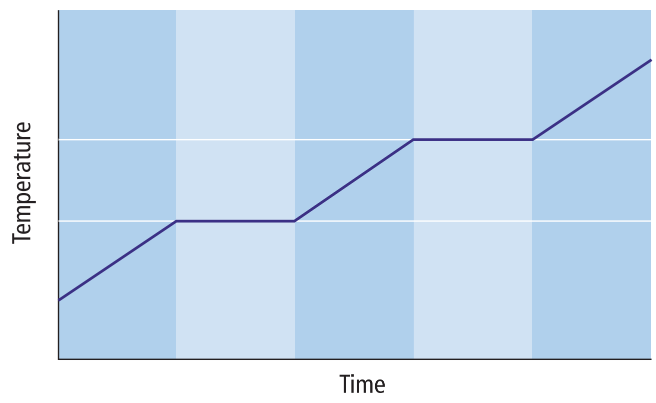


Graph B

40. Copy the following graph. Add the labels listed below to your graph. Explain the meaning of the graph and the labels.

(a) boiling point
(b) melting point
(c) solid
(d) liquid
(e) gas
(f) melting
(g) evaporating

Heating Curve



Pause and Reflect

Astronauts in the Space Shuttle and the International Space Station do experiments and make observations in the weightlessness, or microgravity, of the orbiting spacecraft. They have made observations while heating water with an electrical probe that is inserted into water. When the water near the hot probe becomes warmer, it does not make convection currents. The hot water just stays beside the probe. When it begins to boil, a bubble of water vapour just stays in contact with the hot probe and grows larger. Provide an explanation for these observations made under conditions of weightlessness.