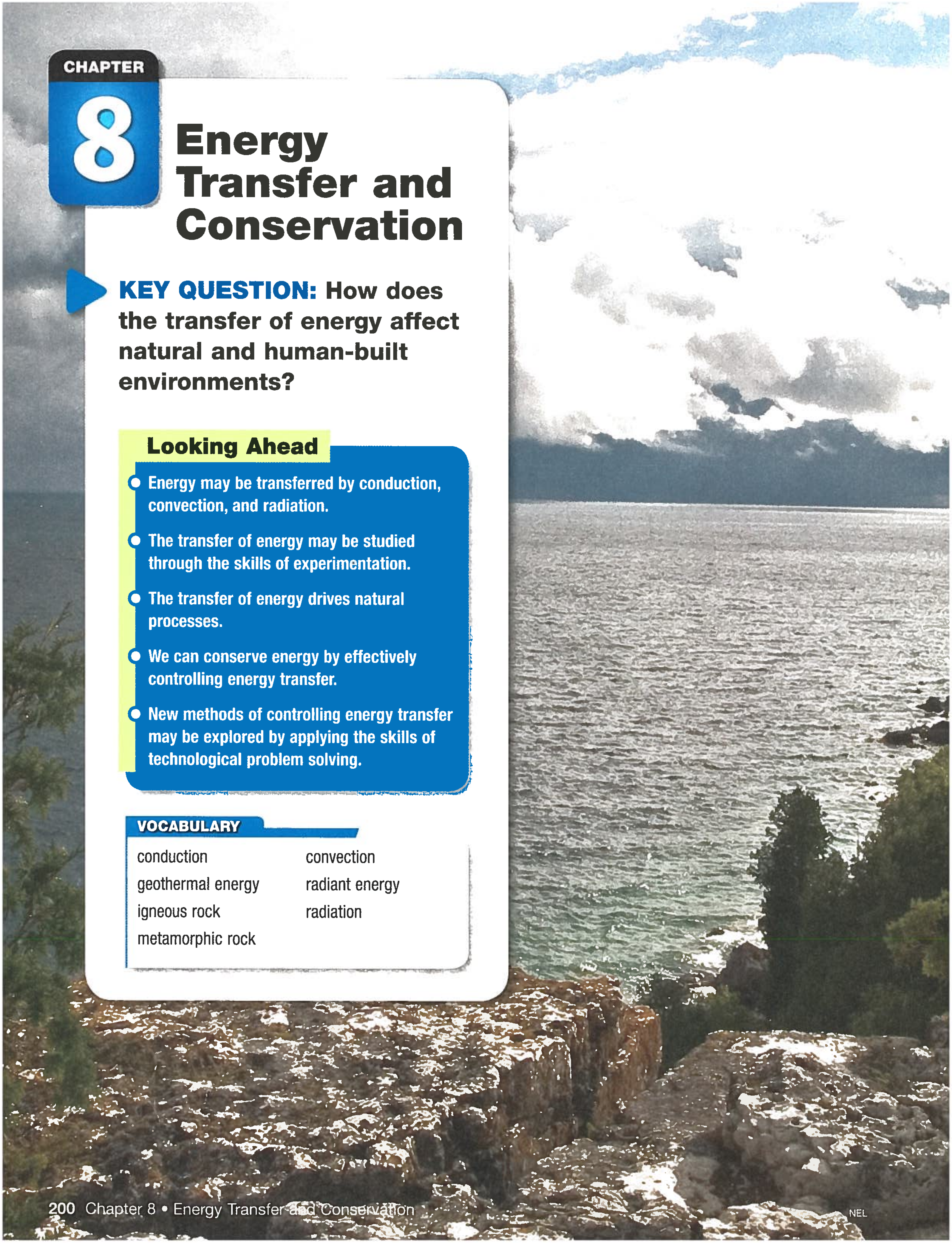


CHAPTER 8

Energy Transfer and Conservation

KEY QUESTION: How does the transfer of energy affect natural and human-built environments?

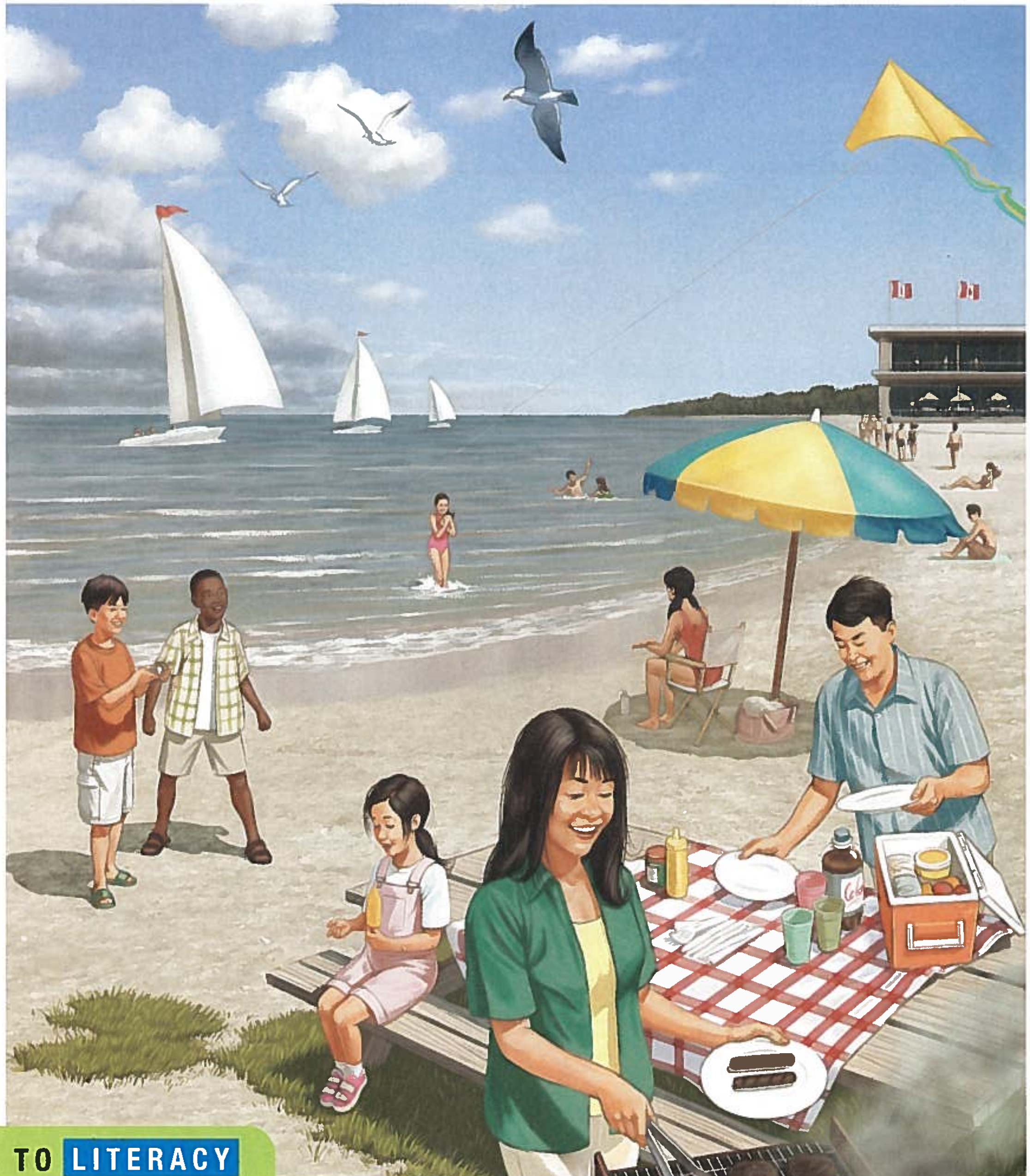
Looking Ahead

- Energy may be transferred by conduction, convection, and radiation.
- The transfer of energy may be studied through the skills of experimentation.
- The transfer of energy drives natural processes.
- We can conserve energy by effectively controlling energy transfer.
- New methods of controlling energy transfer may be explored by applying the skills of technological problem solving.

VOCABULARY

conduction
geothermal energy
igneous rock
metamorphic rock
convection
radiant energy
radiation

A SUMMER DAY AT THE BEACH



LINKING TO LITERACY

Getting Ready to Read

When good readers start to read about a subject that is new to them, they use a number of strategies to get ready to read. They make connections to their prior knowledge of the subject, they use pictures, layout, and titles to make predictions, and they identify the questions they might already have.

1 Look carefully at the beach scene on this page. What does the title make you think of? How many different sources and effects of heat can you identify? What questions do you have? When you make a list, work with a partner to compare your findings and questions.

8.1 Thermal Energy Transfer

TRY THIS: Make a Mini Windmill

SKILLS HANDBOOK 2.B.

SKILLS MENU: questioning, predicting, planning, observing, analyzing, evaluating, communicating

In this activity, you will create a simple device similar to a windmill. You will make this windmill turn without touching it.

Equipment and Materials: scissors; large paper clip; 5 cm × 5 cm piece of paper

1. Bend a large paper clip so that it forms a stand (Figure 1).

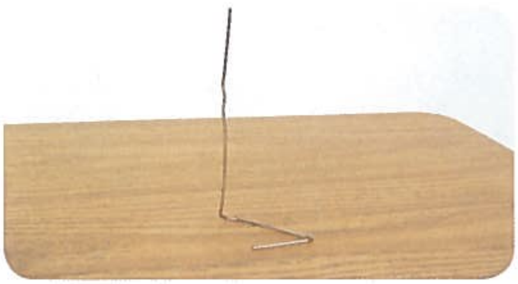


Figure 1 Bend the paper clip to form a stand.

2. Prepare a paper windmill by cutting and folding the piece of paper as in Figure 2.

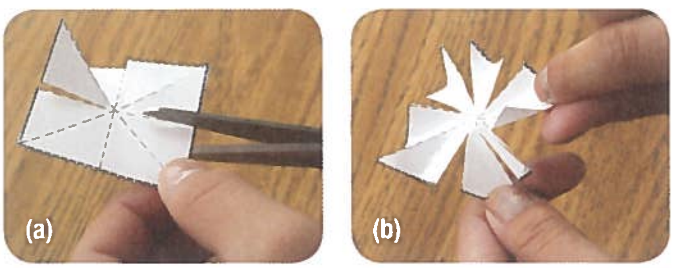


Figure 2 (a) Make eight cuts, but do not cut all the way to the centre. (b) Fold each triangle the same way to make angled fan blades.

3. Choose a place in your home or classroom where the air is still. Place the paper clip stand on a tabletop, and balance the paper windmill on top of the paper clip (Figure 3).

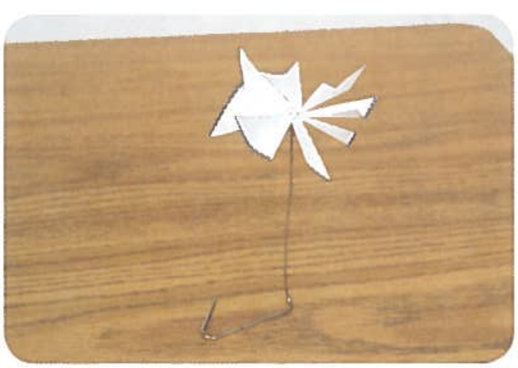


Figure 3 It may take a few tries to get the paper balanced on the paper clip.

4. Keep your hands away from the windmill apparatus and stay very still until the paper part stops moving.
5. Gently cup your hands around the paper clip stand as in Figure 4. Watch what happens. Record your observations in your notebook.

Figure 4 Do not touch the stand or the paper.

6. Predict what happens to the fan when you change the positions of your hands. Test your predictions and record your observations.
7. Analyze your observations. Can you identify any patterns in the results of your tests? Provide a possible explanation for your observations.
8. Write a testable question about this phenomenon that you could explore further.
9. Make a prediction related to your testable question. Your prediction should involve new variables that are different from those that you have already tested.
10. Plan a procedure for testing your prediction. Ask your teacher to approve your procedure, and then perform your procedure. Record and analyze your observations. Compare your prediction to your observations.

A. What do you think is responsible for your observations in step 5?

B. Explain your results using the particle theory.

Humans have invented many technologies that transfer energy from one object to another, or from one place to another. We commonly use central heating furnaces to warm the air throughout our homes during the winter. We use refrigerators and freezers to keep foods cold for long periods of time (Figure 5). How would your life be affected if your home had no furnace or refrigerator?

Figure 5 Refrigerators keep food cool in our homes.

LINKING TO LITERACY

Making Connections

When you make connections, you use personal experiences to help you identify with or understand what you read. Think about your home and all of the ways in which technology helps you with heating and cooling.

Thermal energy naturally moves from a substance with a higher temperature to a substance with a lower temperature. This energy will continue to move until the temperatures of the two substances are the same. When you put a frozen juice box into your lunch bag, it eventually melts as energy is transmitted from less cold items in your lunch to the drink. Technology allows us to control the rate of heating and cooling. If you want the drink to melt faster, you could put it near a hot radiator in your classroom. If you want it to melt more slowly, you could put it into a refrigerator. What other devices allow you to control the processes of heating and cooling?

Thermal energy can be transmitted in several ways. When you understand each of these ways, you will be able to understand, and even control, the transfer of thermal energy more effectively.

CHECK YOUR LEARNING

1. In what direction does thermal energy flow naturally?
2. Give an example of thermal energy being transferred from one material to another.
3. Suggest one way to slow down the transfer of thermal energy into or out of a substance with the aid of technology.

8.2 CONDUCT AN INVESTIGATION

The Transfer of Energy through a Substance

SKILLS MENU

- ☐ Questioning
- ☑ Hypothesizing
- ☑ Predicting
- ☐ Planning
- ☑ Controlling Variables
- ☑ Performing
- ☑ Observing
- ☑ Analyzing
- ☐ Evaluating
- ☑ Communicating

Imagine that your first few steps in bare feet in the morning are on a rug. Then, you walk onto a wooden floor. Which do you think would feel cooler, the rug or the wooden floor? The wooden floor feels cooler. Can you suggest a reason? When your feet first touch the floor, they are warmer than the floor. Thermal energy is transferred from your feet to the floor. The area of floor under your feet gets warmer, and your feet get cooler. Some substances transfer energy more effectively than other substances. The wooden floor feels cooler than the rug even though both are at the same temperature. This is because wood has a better ability than a rug to transfer energy away from your body. You can notice a similar effect when you touch objects in your environment. For example, a metal doorknob transfers energy away from your fingers more quickly than does a book. That is why doorknobs often feel cold.

Testable Question

What kind of material transmits thermal energy most effectively: glass, metal, wood, or plastic?

Hypothesis/Prediction

SKILLS HANDBOOK 2.B.3.

Read the Experimental Design and Procedure. Then, hold the four rods provided in your hands, one at a time. Note the sensation of each rod. Write a hypothesis based on the Testable Question. Your hypothesis should include both a prediction and reasons for your prediction. Base your reasons on the sensations you felt when you held the rods in your hands.

Experimental Design

You will compare the effectiveness of heating rods of various materials in transmitting thermal energy along their lengths. You will use drops of wax to indicate the transfer of thermal energy. The rods will be heated equally, two at a time.

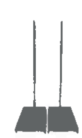
Equipment and Materials

- eye protection
- apron
- glass rod, metal rod, wooden rod, plastic rod (of equal length and diameter)
- 2 support stands
- 2 clamps
- hot plate
- timing device
- candle
- matches


eye protection


apron


glass rod, metal rod, wooden rod, and plastic rod (of equal length and diameter)


2 support stands


2 clamps


hot plate


timing device


candle


matches

Procedure

SKILLS HANDBOOK 5.B.

1. Clamp the metal rod and the wooden rod to separate support stands so that the rods are horizontal.
2. Use a lit candle to drip small beads of wax, equally spaced, along the rods.

Use care with an open flame. Do not touch wax while it is liquid. Hot wax can burn you. Do not allow the glass or metal rod to touch the hot plate.

3. When the wax on the rods has solidified, arrange the rods so that each rod has one end above the hot plate (Figure 1).

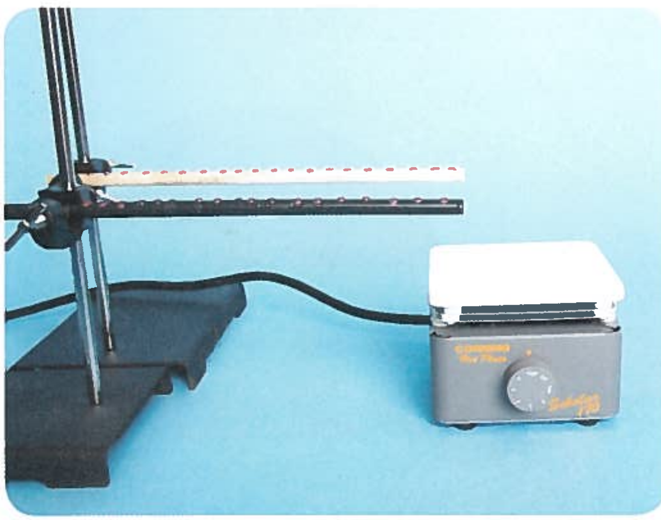


Figure 1 Step 3

4. Turn on the hot plate and time how long it takes each wax bead to melt. Record your observations.
5. Turn off the hot plate after it appears that melting has come to a stop.
6. Test the glass and plastic rods the same way you tested the metal and wood rods. Compare them with each other, and with the metal and wood rods. Record your observations.

Be careful when using a hot plate. Do not touch the top of the hot plate at any time. When unplugging the hot plate, pull the plug, not the cord.

Analyze and Evaluate

SKILLS HANDBOOK 2.B.2., 2.B.7.

(a) Did the evidence you obtained in this experiment support your hypothesis? Explain

(b) Answer the Testable Question.

(c) Rank the materials in order, from slowest to fastest transmission of thermal energy.

(d) Is there an additional test that you could carry out to help you answer the Testable Question? Explain.

(e) When conducting the test in (d), what would the independent and dependent variables be? List the controls that you would use.

Apply and Extend

(f) The particle theory can be used to explain many of the behaviours of substances. Which part(s) of the particle theory may apply to your observations in this investigation? Explain your findings using the particle theory.

(g) Imagine that you have the job of selecting materials for making cookware (pots and pans) (Figure 2). Which materials would you choose for the base of a pot or pan? Which materials would you choose for the handles? Explain why.

Figure 2 What kinds of materials should you use when making cookware?

Unit Task How can you apply what you have learned about energy transfer through different materials to your doghouse design?

8.3 Conduction

When you cook an egg sunny side up in a pan on a hot stove, there is a transfer of thermal energy. The thermal energy transfers from the hot stove burner and through the pan. The energy then moves from the pan and into the cold egg (Figure 1).

LINKING TO LITERACY

Note Taking and Summarizing

Note taking and summarizing are related strategies that help us capture important ideas and details in what we are reading. You start by recording key information as jot notes; then you can use these notes to write a summary that uses the main ideas to create a shorter, but accurate version of the section.

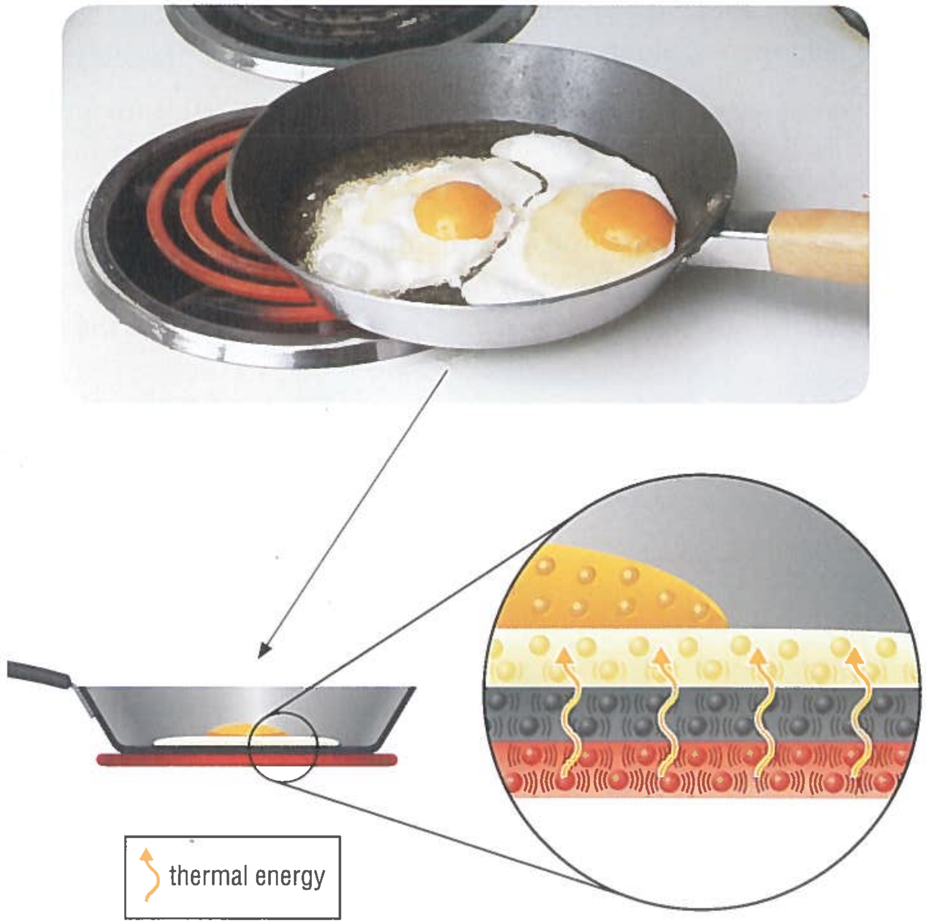


Figure 1 Energy from the burner travels through the pan and into the egg. The particles of the pan collide with the particles of the egg, causing the egg's particles to move faster. This faster motion causes the temperature of the egg to rise.

The particles in the hot stove burner vibrate quickly. When the pan comes into contact with the burner, the fast-moving particles of the burner collide and transfer energy to the slow-moving particles of the cold pan. This energy transfer raises the temperature of the pan.

The same process occurs between the hot pan and the cold, raw egg. The egg is in direct contact with the pan, so the fast-moving particles of the hot pan collide and transfer energy to the particles of the cold egg. The temperature of the egg rises, and the egg begins to cook.

Cooking an egg in a pan on a stove is an example of conduction. **Conduction** is the transfer of thermal energy through a substance, or between substances in contact. This energy transfer is caused by the collision of particles.

conduction: the transfer of thermal energy through a substance, or between substances in contact, by the collision of particles

Some devices we use are designed to conduct energy quickly. The pots and pans we use for cooking conduct energy quickly from a hot burner to cold food. Metals, such as copper and aluminum, are called "conductors" because they transfer energy easily (Figure 2). Other devices are designed to prevent conduction. The boots we wear in the winter are designed to prevent energy transfer from our warm feet to the cold snow. The foam, fleece, or felt that lines the boots is called an "insulator" because it reduces the conduction of thermal energy (Figure 3). A chef usually stirs hot soup with a wooden or plastic spoon instead of a metal spoon. Thermal energy is transferred less easily through wood and plastic than through metal. This means that there is less chance of the chef burning his or her hand.

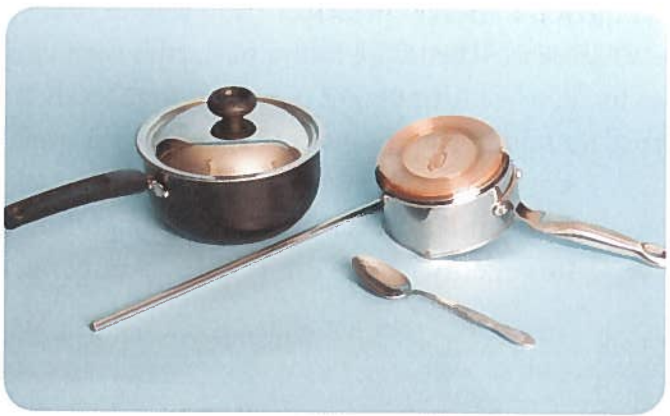


Figure 2 Metals are good conductors of energy and are used in many useful products.

Figure 3 Insulators are used in products to prevent the transfer of energy.

Unit Task How can you apply what you have learned about conductors and insulators when selecting materials for your doghouse?

CHECK YOUR LEARNING

1. How has your understanding of the word "conductor" changed since you read this section?
2. In your own words, explain how thermal energy is transferred by conduction.
3. List one material that is a good conductor and one that is a good insulator. Suggest one use for each material.
4. Sketch a diagram that shows how thermal energy is transferred from a pot of hot soup to a chef's hand, if the chef uses a metal spoon to stir the soup. What advice could you give the chef to help her avoid a painful burn?

8.4

Conduction and Geological Processes

Figure 1 Exposed rock of the Canadian Shield can be seen along many highways in Ontario.

Have you ever seen rock formations like those in Figure 1? The wavy dark and light lines in the rock indicate that the rock may not always have been completely solid. Were these solid rocks once softer and flexible a long time ago? If so, where did the energy that softened the rock come from? Have you ever wondered why the rocks in this area look the way they do?

The Sun is a major source of thermal energy on Earth's surface. Another large hidden source of thermal energy is **geothermal energy** within Earth. We can see the effects of this energy directly during volcanic eruptions (Figure 2). We also see geothermal energy where hot springs bring boiling liquid to the surface of Earth (Figure 3).

geothermal energy: energy contained below Earth's surface

Earth's interior is composed of four layers. The first is a thin layer of solid rock called the crust. The second is a hot, flexible layer of rock called the mantle. Then there is a molten outer core and a solid inner core of iron and nickel (Figure 4). The temperature of Earth's core is estimated to be close to 7000 °C. Although it is not obvious, even Earth's cooler outer crust contains a significant amount of geothermal energy.

Thermal energy from deep within Earth is conducted through the matter in the upper layers. This energy helps form rocks and minerals.

Figure 2 Volcanic eruptions provide evidence of geothermal energy.

Figure 3 Geothermal energy heats the liquid in hot springs.

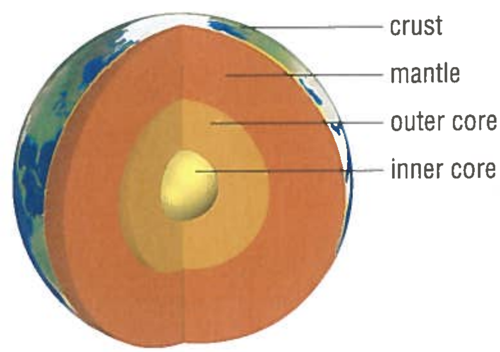


Figure 4 This cross-section shows the four layers that make up Earth's interior.

Heat and Rock Formation

Rocks inside Earth are constantly melting and solidifying. When rock is heated to high temperatures (between 625 °C and 1200 °C), it melts into magma. When hot magma is pushed to the surface in a volcanic eruption, it cools and solidifies into new rock. This new rock is called **igneous rock** (Figure 5). Common igneous rocks include pumice, obsidian, and granite.

igneous rock: rock formed from magma that has cooled and solidified

Figure 5 Pumice is an igneous rock.

Earth's crust, which consists of the continents and ocean floors, is constantly moving very slowly. Movements of Earth's crust have significantly changed our planet. Sometimes two pieces of Earth's crust push against each other. This collision pushes existing rocks deep into Earth, toward the hot core. When the rock is exposed to high pressure and temperatures above 200 °C, the particles of the rock absorb the geothermal energy. The particles are rearranged, resulting in the formation of a new type of rock, called **metamorphic rock** (Figure 6).

The Canadian Shield is made mostly of metamorphic rock, and contains some of the oldest rock on Earth (about 4 billion years old). You can see examples of the Canadian Shield through much of Northern Ontario, especially in the Sudbury area. The Canadian Shield covers about two-thirds of Ontario.

metamorphic rock: rock that is formed when heat and pressure change existing rock

Figure 6 Gneiss (pronounced "nice") is an example of metamorphic rock.

Diamond

Diamond is a mineral composed of pure carbon and is the hardest natural material found on Earth (Figure 7(a)). Diamonds form deep in Earth's crust (about 150 km below the surface). At these depths, heat and pressure may change graphite (another form of carbon) into diamond. Therefore, diamonds are a type of metamorphic rock.

Diamonds are often found near the sites of old volcanoes, where magma from ancient eruptions carried rocks containing diamonds closer to Earth's surface. Diamonds are crystals that can be cut, polished, and used in jewellery (Figure 7(b)). Since they are very hard, diamonds are also used on the tips of saw blades and drill bits to cut through rock and steel (Figure 7(c)).

To learn more about diamonds,
Go to Nelson Science

Figure 7 (a) A rough diamond found in a mine, (b) a cut and polished diamond set in a ring, and (c) an industrial diamond in a saw blade

CHECK YOUR LEARNING

1. Describe the formation of rocks due to conduction of geothermal energy within Earth.
2. Name two types of rocks and one mineral formed by conduction of energy.
3. What are some relationships between moving continents, geothermal energy from within Earth, and metamorphic rock?
4. Why can diamond be considered a type of metamorphic rock?

8.5 Convection

In substances such as water and air, thermal energy can be transferred from one area to another. This transfer of energy relies on the fluid characteristics of such materials. For example, think about a pot of soup cooking on a stove. When the soup is heated, the water particles near the bottom of the pot start to move faster and farther apart. This makes the particles near the bottom less dense (and lighter) than those near the top. Therefore, the colder, denser soup near the top sinks to the bottom of the pot. This causes the less dense soup to move upward and replace the cold soup. This movement creates a current in which colder soup near the top of the pot moves to the bottom and warms up. Then, warmer soup near the bottom of the pot moves to the top and cools down (Figure 1).

LINKING TO LITERACY

Finding the Main Idea

Finding the main idea involves being able to summarize what you read into one or two ideas that tell the most important facts or messages from a long passage of text. The main ideas are usually found at the beginning of paragraphs or sections of text. Can you find a main idea about convection on this page?

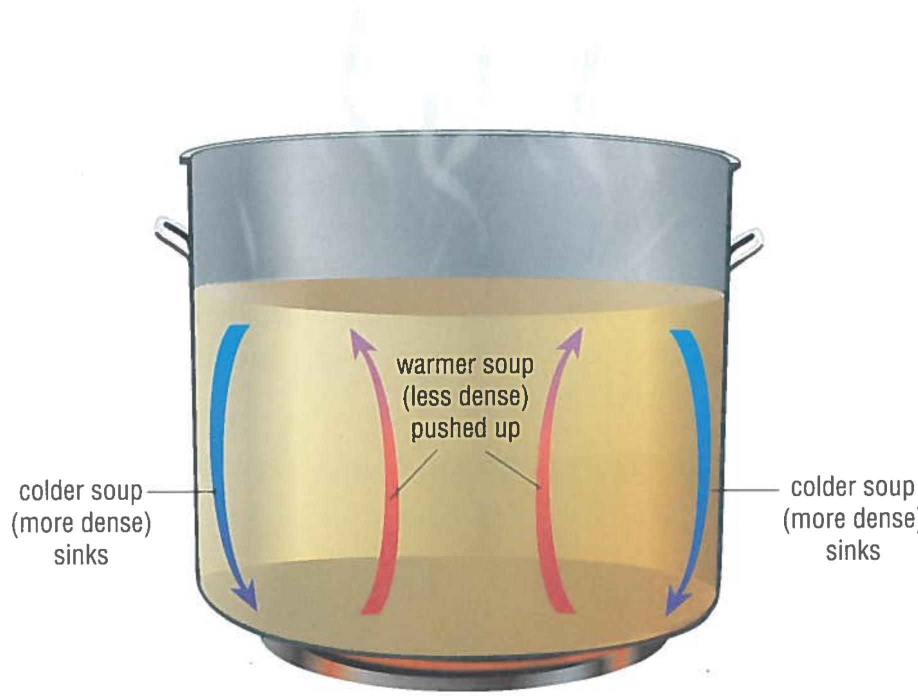


Figure 1 Soup is heated by convection.

The continuous movement of warmer and colder soup in a pot is an example of convection. This process transfers energy from one part of a fluid to another. Thus, **convection** is the transfer of thermal energy caused by the flow of a fluid's particles (a gas or liquid). Convection does not occur in solids because the particles of a solid only vibrate; they cannot flow.

convection: the transfer of thermal energy from one part of a fluid to another by a circulating current of faster-moving and slower-moving particles

TRY THIS: Investigate Convection Currents

SKILLS MENU: observing, analyzing, communicating

SKILLS HANDBOOK 2.B.6., 5.B.

In this activity, you will actually see convection currents in action.

Part A: Convection in a Liquid

Equipment and Materials: 100 mL beaker; retort stand and ring clamp; hot plate; water; food colouring

1. Set up the beaker, stand, and clamp so that only half of the beaker is on the hot plate. This way, one side of the beaker will be heated more than the other side (Figure 2).

Be careful when using a hot plate. Do not touch the top of the hot plate at any time. When unplugging the hot plate, pull the plug, not the cord.

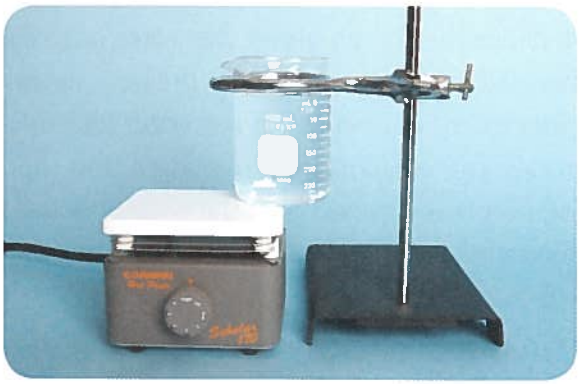


Figure 2 Setup of the beaker on the hot plate

2. Fill the beaker with cold water. Now, add a single drop of food colouring to the beaker on the side over the hot plate.
3. Heat the beaker and observe the motion of the food colouring. Record your observations.

A. Draw a diagram of the motion of the food colouring. Show where you think the water would be warmer and where it would be cooler.

B. What caused the motion of the food colouring? Describe the motion of the water and the food colouring using the particle theory.

Part B: Convection in a Gas—Demonstration

1. Look at the gas convection apparatus shown in Figure 3. Predict what will happen when smoking paper is held above the chimney. Record your prediction.

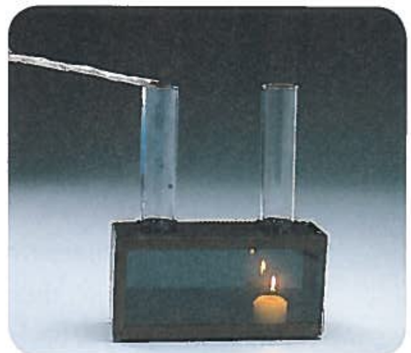


Figure 3 The burning candle is placed beneath one chimney; the smoking paper is held above the other one.

2. Your teacher will set up the apparatus, and hold the smoking paper over one chimney. Record your observations.

A. Draw a diagram of the motion of the smoke. Show where you think the air particles would be moving faster and where they would be moving more slowly.

The circular flow of water particles in a warming pot of soup is called a convection current. Convection currents do not only form in pots of soup. Convection currents also form in lakes, oceans, aquariums, and in the air around you.

Unit Task How can you apply what you have learned about convection to the design of your doghouse?

CHECK YOUR LEARNING

1. Explain how thermal energy is transferred through convection.
2. Use the particle theory to explain how a convection current starts in a fluid.
3. Give two examples of convection currents that you might encounter in everyday life.
4. If you wanted to warm your room using a portable heater, where would you place the heater? Why?

8.6

Convection in the Environment

Uneven heating of liquid on a stove can produce convection currents. Similarly, uneven heating of air at Earth's surface can produce convection currents in the air. Large convection currents in air are called "wind."

The air feels cooler near lakes and oceans in the summer because the energy from the Sun does not heat the air over land and water evenly. Near a lake, the air above the water is colder than the air above the land because land requires much less of the Sun's energy to warm up than does water. The warm air particles above the land are more strongly heated by the warm land surface below. They move faster and spread apart. This makes the air above the land less dense (lighter) than the air over the water. The cool, dense (heavy) air above the water moves down and toward the land. This pushes the warm air over the land upwards (Figure 1). We feel this movement of cool air off the water and toward the land as a cool sea breeze. The warm air that rises high into the atmosphere over the land eventually moves over the water, cools down, sinks, and then moves toward the land again. This daytime movement of air near a body of water is caused by convection.

LINKING TO LITERACY

Synthesizing Information
When you read text that presents new information or ideas, you compare it with what you have read or already know, or compare it with other sources. Use both the text and the diagram on this page, together with what you already know, to help you understand convection in the environment.

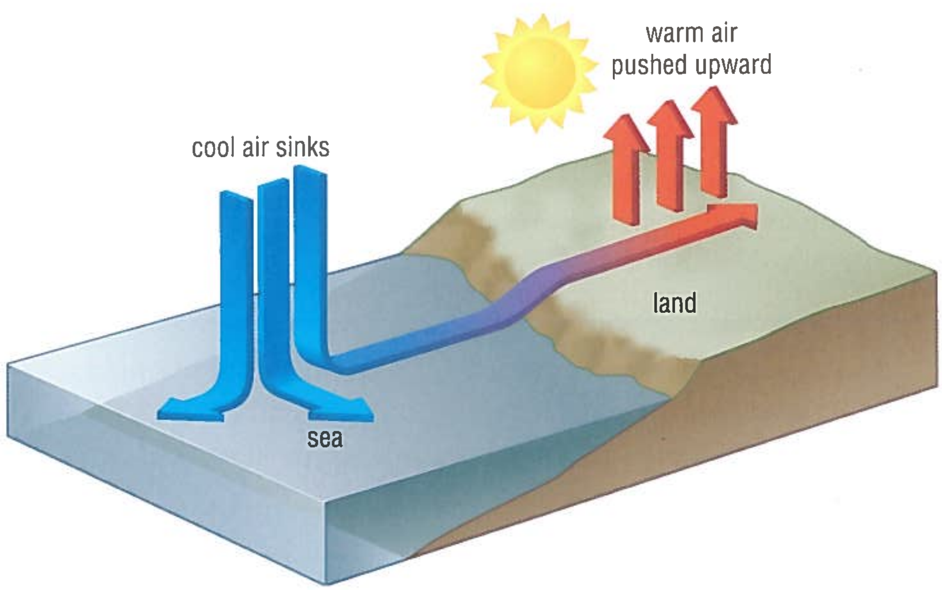


Figure 1 The uneven heating of Earth's surface creates warm and cool air, similar to the convection current in a pot of heated water or soup.

When the Sun goes down in the evening, the land cools more quickly than the water. The warm water heats the air above it, making the air less dense. The cool, dense (heavy) air over the land moves down and out toward the water. This pushes the less dense (lighter) air over the water higher into the atmosphere. A "land breeze" then moves from the land toward the water.

Thunderstorms

Thunderstorms produce lightning and thunder, and are usually associated with strong winds and heavy rains (Figure 2). Thunderstorms create severe weather such as hail, tornadoes, and hurricanes.

Thunderstorms often form on hot, humid days. Earth's surface is warmed by energy from the Sun. The energy is then transferred to the air above the surface of the ground by conduction. This warmed air is less dense than the surrounding cooler air. The warm air is rapidly pushed up higher into the atmosphere by convection, carrying water vapour along with it. As convection pushes the air higher, the water vapour cools and condenses into microscopic droplets of water that appear as large puffy clouds (Figure 3). Large amounts of thermal energy are released as the water vapour condenses. This energy warms the air, so it is pushed even higher into the atmosphere. As the warm, moist air rises higher, it spreads out and the remaining water vapour condenses, forming large clouds called thunderheads (Figure 4). The water droplets in thunderheads eventually become heavy enough to fall as rain.

Figure 2 Lightning is a common sight during thunderstorms.

Figure 3 These puffy white clouds form because of convection currents.

Figure 4 Thunderheads result as air in clouds warms and rises higher.

Convection and Geological Processes

The temperature of Earth's mantle increases as you go deeper. So, the top of the mantle is cooler than the bottom. Over millions of years, cooler mantle rock sinks as warmer mantle rock rises closer to Earth's crust. This creates very slow convection currents (Figure 5). These convection currents transfer energy and may cause volcanic eruptions.

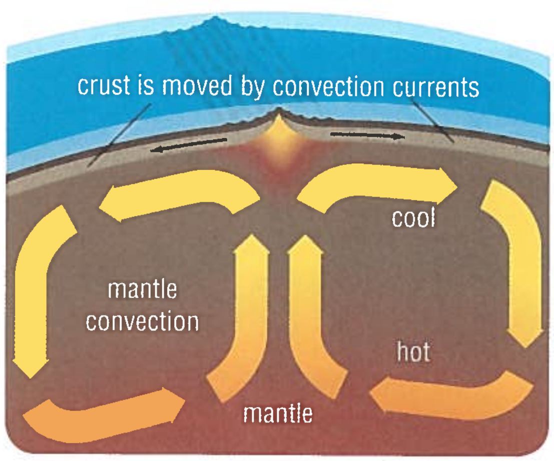


Figure 5 Convection currents below Earth's crust

CHECK YOUR LEARNING

1. List three natural processes that depend on convection.
2. **(a)** Draw two diagrams to explain land and sea breezes.
   (b) Label each diagram "day" or "night," as appropriate.
3. What geological events occur because of convection currents in Earth's mantle?
4. **(a)** For thunderstorms to occur, the air must have two characteristics. What are they?
   (b) Are thunderstorms more likely to form over land or over water? Why?

8.7 Radiation

Figure 1 How is the Sun's energy transferred to Earth?

When you look out into space, you see stars and planets. Did you know that there are almost no particles in the space between Earth and the Sun? How, then, does energy travel from the Sun to Earth? Conduction and convection both require particles to transfer energy. We know that energy reaches Earth from the Sun because our bodies are warmed by the Sun on a sunny day (Figure 1). Without this energy, there would be no life on Earth.

There is a way in which energy can be transferred without the use of particles. A form of energy called **radiant energy** travels outward from the Sun through empty space. Radiant energy travels in the form of electromagnetic waves, or rays. Radiant energy from the Sun includes visible rays (light) and invisible rays (ultraviolet (UV) rays and infrared rays). We use the term **radiation** to describe the transfer of radiant energy in the form of electromagnetic rays. The Sun emits electromagnetic rays in all directions, but only a small portion of them reach Earth.

radiant energy: energy that travels in the form of electromagnetic waves through empty space; includes visible light, ultraviolet rays, and infrared rays

radiation: the transfer of radiant energy by means of electromagnetic waves

Matter can both absorb and emit (give off) radiant energy. Benches at a baseball field get quite hot when the radiant energy from the Sun shines on them (Figure 2). This is because the radiant energy is absorbed by the particles of the benches and converted to thermal energy. When this occurs, the particles of the material move faster. This raises the temperature of the benches. The seats that are in the shade are usually much cooler to the touch.

LINKING TO LITERACY

Asking Questions

Good readers are always questioning before, during, and after they read. Sometimes they find the answers in the text; other times, they do more research. As you read about radiation, think about the different questions you have:

- questions about words or ideas in the text that you do not understand
- questions about something that interests you

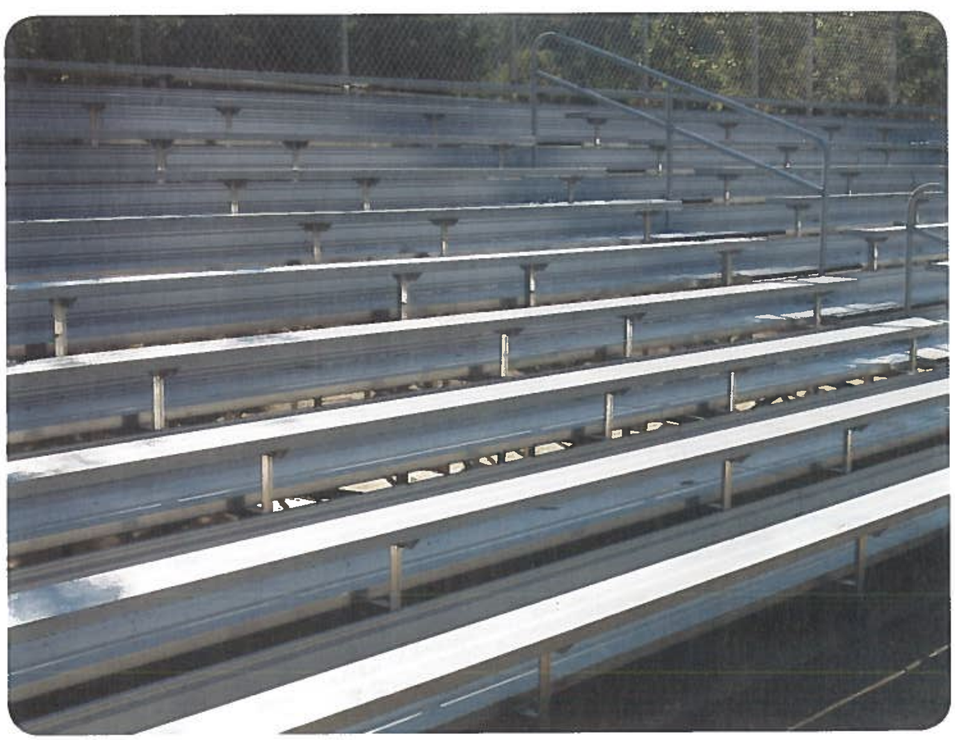


Figure 2 Radiant energy from the Sun makes the benches hot.

There are also sources of radiant energy on Earth. For example, candle flames and incandescent light bulbs glow and feel hot. They glow because they give off visible light. They feel hot because they emit infrared rays. Infrared rays are also emitted by hot objects that do not glow, such as curling irons and hot plates. If you place your hand near (but not on) a curling iron or a hot plate, you can feel that they are giving off a form of energy. The energy given off by objects that emit infrared rays is converted to thermal energy in your skin, which is why they feel hot.

Absorption and Reflection of Radiation from the Sun

Most of the radiant energy from the Sun (also called solar energy) that reaches Earth's surface is in the form of visible light and infrared rays (Figure 3). Other forms of radiant energy from the Sun, including UV rays, X rays, and gamma rays, are mostly absorbed by Earth's atmosphere. Only a small amount of these rays reach the surface of the planet. The amount of UV rays that reaches Earth's surface depends on a number of factors, such as the level of ozone in the atmosphere, the time of day, the season, and the weather. The remaining radiant energy passes through the upper atmosphere and is absorbed or reflected by clouds, water, land, buildings, our bodies, and all other living things.

To learn more about what happens to solar radiation that reaches Earth,
Go to Nelson Science

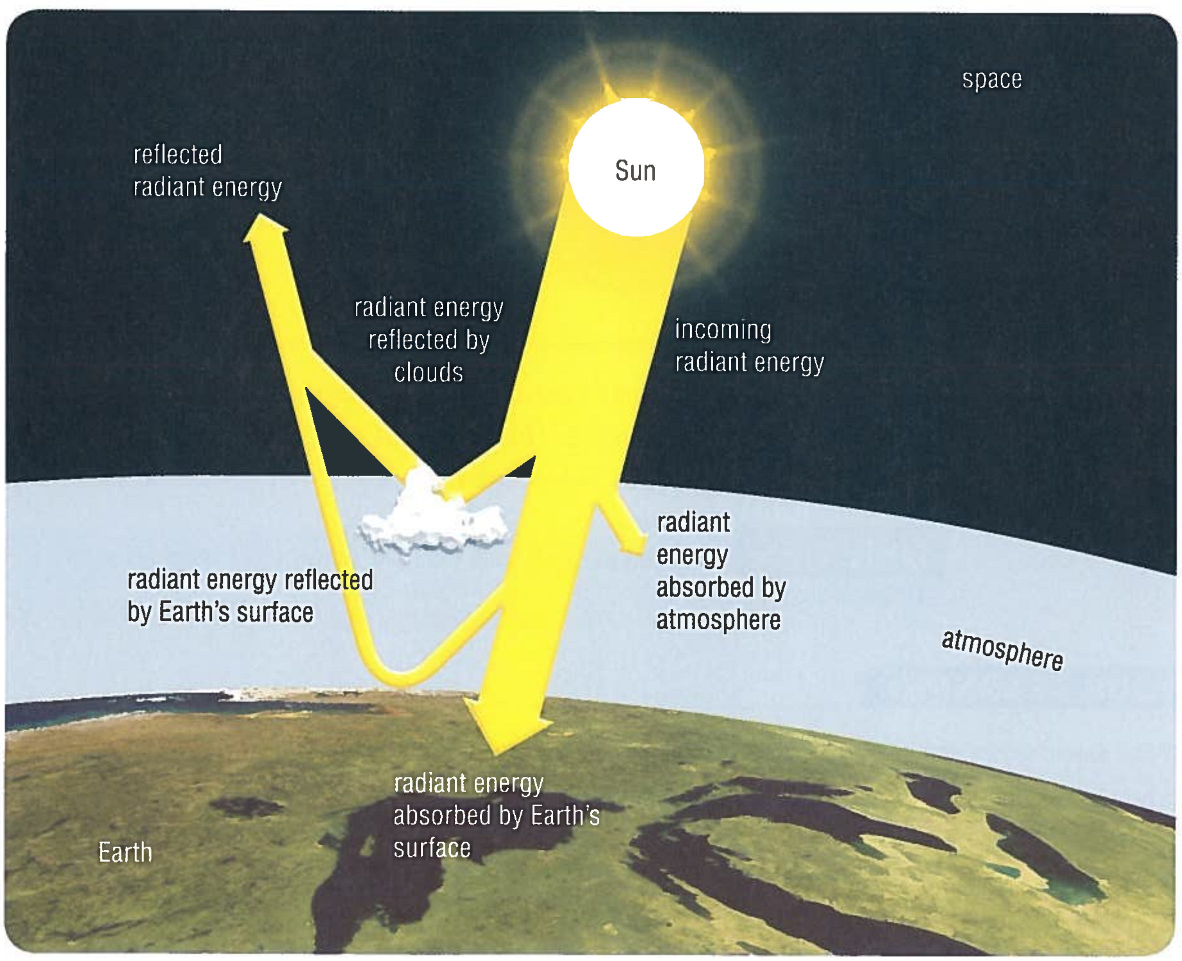


Figure 3 Earth and Earth's atmosphere both absorb and reflect radiant energy from the Sun.

Figure 4 Rock exposed as glaciers melt absorbs more energy than it reflects.

During the day, when radiant energy from the Sun strikes an object, the energy may be reflected or absorbed. Energy that is absorbed warms the object. The colour and texture of objects affect how much energy is absorbed. For example, snow and ice reflect much of the Sun's radiant energy back into space. They do so because they are white and smooth. However, when snow melts, it uncovers the darker rock below. When sea ice melts, it exposes the ocean water. The rocks and water are less able to reflect the visible light of the Sun. The exposed rock and water absorb more of the radiant energy (Figure 4). Cities also absorb a lot of radiant energy because many roads and buildings are dark. Darker colours tend to absorb radiant energy better than lighter colours or shiny surfaces.

TRY THIS: Radiant Energy and Colour

SKILLS MENU: predicting, observing

SKILLS HANDBOOK 2.B.3., 6.A.4.

How well an object absorbs radiant energy depends on the colour of the object and how much it reflects light. In this activity, you will discover which colours absorb the most radiant energy.

Equipment and Materials: paint brush; 4 thermometers; source of radiant energy (for example, the Sun); 4 containers (small coffee cups with lids or pop cans); 4 different colours of paint

Do not touch the hot lamp. To unplug the lamp, pull the plug and not the cord.

1. Look at the four colours of paint. Using what you have learned about the absorption of radiant energy, write a hypothesis relating the colour of the containers and their relative temperatures after they have been exposed to radiant energy for 20 min.
2. Paint each container a different colour.
3. Place a thermometer into each container and record the temperature of the air in each one.
4. Place all four containers in a source of radiant energy for 20 min. Make sure that each container is receiving the same amount of radiant energy, and that no containers are touching.
5. After 20 min, measure and record the temperature of the air in each container.

A. Compare the temperatures of the containers.

B. Evaluate your hypothesis based on your observations and temperature measurements.

C. Make a conclusion about radiant energy, temperature of an object, and its colour.

Scientists are concerned that the average temperature of Earth's surface is steadily increasing. This problem may get worse as Arctic ice melts and water and rock below are exposed.

Unit Task How can you apply what you have learned about radiation as you design your doghouse?

CHECK YOUR LEARNING

1. List two objects that absorb radiant energy from the Sun.
2. List two objects here on Earth that are sources of radiant energy. How can you tell that they emit radiant energy?
3. Distinguish between the effects of solar radiation on a snow-covered asphalt driveway and a shovelled asphalt driveway.
4. Why do you suppose bee keepers use white paint and use shiny aluminum lids on their bee hives?
5. What form of energy do you think microwave ovens use? Explain your reasoning.

8.8 Managing the Transfer of Thermal Energy

We are all stewards of Earth and its resources. It is every person's responsibility to be less wasteful and to conserve Earth's resources. Using energy efficiently and managing it well are important parts of reducing society's impact on Earth. A major way to conserve energy is to manage the transfer of energy into and out of buildings. By understanding what affects the transfer of energy, a building designer is able to make sure that the building's occupants are comfortable. A designer can also ensure that the building wastes as little energy as possible. Poor materials and planning can result in a building that wastes energy (Figure 1). This makes poor use of Earth's resources.

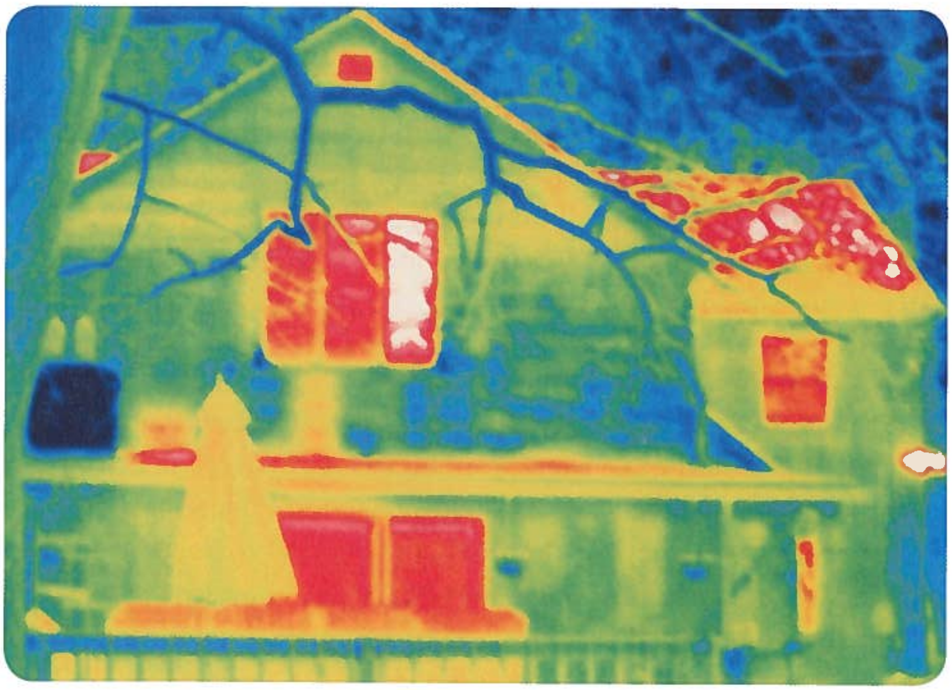


Figure 1 The red, yellow, and white areas in this infrared photo of a house show energy loss. From this photo, can you identify the parts of the house that lose the most energy?

Insulators are materials designed to reduce the flow of energy by limiting conduction, convection, or both. Radiant barriers reduce the loss of energy by radiation. These materials help warm spaces remain warm and cold spaces remain cold.

Architects want to design a house that wastes as little energy as possible. They have to think about everything that separates the house from the outside environment. This is the building's "thermal envelope." The thermal envelope includes walls, the building's roof, insulation, windows, doors, finishes, weather stripping, and air/vapour barriers. The thoughtful design of these parts of the building can reduce conduction, convection, and radiation.

LINKING TO LITERACY

Making a Connection

Good readers often interact with the text by making text-to-self connections. They relate what they read to personal experiences. Think about a time when you directly experienced the loss of energy in a building. How could this energy transfer have been prevented?

Figure 2 Insulation is put into the walls and roof of a house to prevent the transfer of energy.

Table 1 R-Values for Common Insulation Materials

Insulation material (2.5 cm thick)	R-value
wood	0.71–1.41
fibreglass batt	3.2–3.6
cellulose	3.1–3.7
polystyrene foam board	3.6–5.0

Figure 3 Tiny pockets of trapped air prevent energy from being transferred.

Preventing Conduction

Using insulating materials is the best way to prevent heat transfer by conduction and convection. Insulating materials are poor conductors of thermal energy and also limit the movement of air in spaces, reducing convection. Insulation slows the rate at which unwanted energy enters the home in the summer. It also slows the escape of energy in the winter (Figure 2). Thermal energy moves slowly through the insulation and does not readily escape to the outside air.

Insulating materials are tested and given a Thermal Resistance Value (R-value). The higher the R-value, the more difficult it is for energy to move through the material by conduction, convection, or radiation (Table 1). To reduce energy loss, builders should increase the amount of insulation in basement walls, the roof, and exterior walls. Recall that polystyrene blocks are being used to build and insulate the Narangs' new home (Unit Opener, page 176).

Air—An Excellent Insulator

Fur, wool, and down keep animals warm. How do animal fibres keep animals and people warm? They all contain many small air-filled spaces (Figure 3). Air is a gas. Its particles are far apart. Air is not very good at transferring energy by conduction or convection. Relatively thick materials containing small air pockets are good insulators.

Green Roofs

A recent innovation in building design is the green roof (Figure 4(a)). A green roof system has a waterproof barrier, drainage, a lightweight growth medium that acts like soil, and vegetation (Figure 4(b)).

A study in Ottawa in 2001 found that green roofs reduced energy transfer year-round. There was a 10 % reduction in heating costs during the winter. There was also a 25 % saving in air conditioning costs in the summer. Green roofs last a long time, improve air quality, and even provide recreational opportunities.

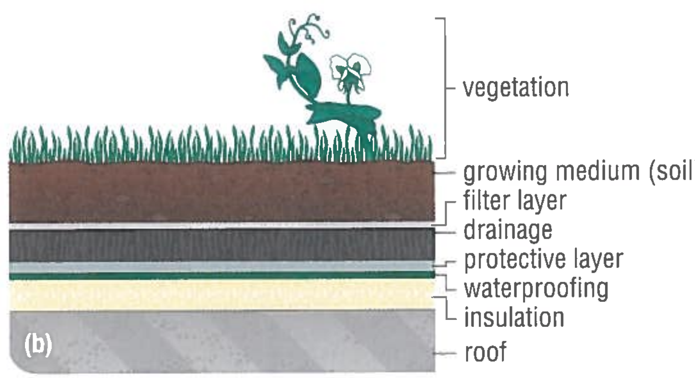


Figure 4 (a) This green roof on the University of Toronto Scarborough campus is one of over 600 that have been installed in Toronto. (b) A typical green roof system

Reducing Energy Transfer by Convection

Energy moves through every house by convection. The second floor of a house is often warmer than the ground floor and basement. Air currents in a house move energy just like winds do outside. Convection also allows energy to escape through gaps around doors and windows.

To prevent energy loss by convection, any gaps in the thermal envelope of a house should be sealed. This stops the flow of air into or out of the house. Moving air is a serious cause of energy loss in a home. In winter, warm indoor air escapes through leaks and is replaced by cold outdoor air. Weather stripping around doors and windows helps keep warm air trapped inside the house (Figure 5). Switches and electrical sockets on outside walls are also common sites of energy loss. Insulating switch plate covers reduces drafts that transfer energy to the outside environment.

Figure 5 Weather stripping reduces drafts and energy loss.

Some homes are tightly sealed to greatly reduce the loss of moisture and energy through the walls. This has both a positive and a negative outcome. On the positive side, moisture from outside cannot get into the house. On the negative side, any moisture inside the house—from people breathing, cooking, and taking showers—is trapped. Here, it may help mould grow and wood rot. Sealing all of the cracks in a home can also trap unhealthy gases produced by certain types of furniture and carpeting. To avoid these problems, all homes need a way to exchange stale indoor air with a good supply of fresh outdoor air. Is there a way to reduce the loss of thermal energy and still bring fresh air in from the outside?

The problem of reducing thermal energy loss and providing proper ventilation has been solved by the air-to-air heat exchanger. This device allows some of the thermal energy in the outgoing warm air to be transferred to the incoming fresh cold air (Figure 6).

LINKING TO LITERACY

Reading a Diagram

Diagrams often illustrate text. Read the legend and scan the diagram. Take a moment to think about how the air-to-air heat exchanger allows thermal energy to be transferred.

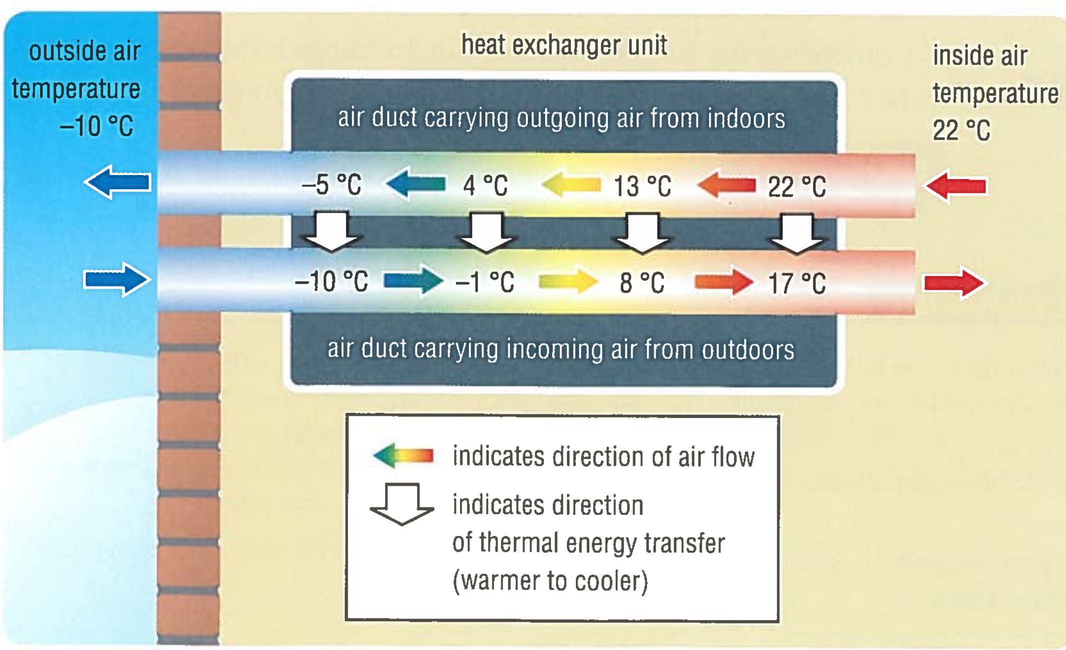


Figure 6 An air-to-air heat exchanger

In a heat exchanger, the air ducts carrying the stale indoor air are in close contact with the ducts carrying the fresh outside air. This allows a continuous transfer of thermal energy from the outgoing warm air to the incoming cool air. By the time the old indoor air leaves the heat exchanger, much of its thermal energy has been transferred to the incoming air. As a result, the fresh air entering the home is already warm.

Reducing Energy Transfer by Radiation

Radiation is the transfer of energy by means of electromagnetic waves. In the winter, if your home is warm, it will radiate energy to the colder outside. In the summer, the strong sunlight warms your house. To prevent this unwanted energy transfer, homebuilders sometimes install a shiny radiant barrier in the attic (Figure 7). The shiny surface reflects radiant energy, preventing it from warming the home. The barrier should be installed with the reflective surface facing up toward the roof. The radiant barrier can then reflect up to 97 % of radiant energy.

Figure 7 Radiant barriers are generally installed in the attic of a house to minimize energy transfer into the home.

Radiant barriers are not used in attics only. Radiant barriers can also be applied to air ducts and water pipes to prevent energy loss as warm air and hot water travel throughout the house.

A lot of radiant energy is lost through windows. Today, most builders install windows that have low-E (low-emissivity) glass. Low-E glass has a special ultra-thin surface layer that reduces the transfer of radiant energy. Like radiant barriers, low-E glass helps keep radiant energy inside during the winter and outside during the summer. One way to reduce heating and cooling costs is to replace older windows with low-E windows.

Controlling the transfer of energy in buildings is important. It helps us to conserve energy resources for future generations.

To learn more about controlling the transfer of energy in homes and buildings,
Go to Nelson Science

Unit Task There are several ideas in this section that you might be able to apply to the design of your doghouse. Make a list of those that you think will be useful.

CHECK YOUR LEARNING

1. Describe an idea in the reading that is new to you. How does this idea add to your understanding of how we can manage energy transfer?
2. Why is it important to consider the transfer of energy when building a house?
3. Explain why the walls and doors of refrigerators and freezers contain thick slabs of polystyrene foam.
4. High-quality modern homes are very well sealed.
   - (a) How does this help conserve energy?
   - (b) What problem may this create?
   - (c) How does an air-to-air heat exchanger overcome this problem and still help conserve energy?
5. Describe one way that builders can reduce each of the types of heat transfer in a building.

Tough Decisions

There is a famous story about three little pigs. The first pig built a straw house because it was cheap and easy; the second pig used sticks because sticks were stronger than straw. The third little pig built a house out of bricks, which took more effort and probably cost a lot more, but it was worth it. The big bad wolf huffed and puffed and blew down the houses made of straw and sticks, but he could not blow down the brick house (Figure 1).

SKILLS MENU

- ☐ Defining the Issue
- ■ Researching
- ■ Identifying Alternatives
- ■ Analyzing the Issue
- ■ Defending a Decision
- ■ Communicating
- ■ Evaluating

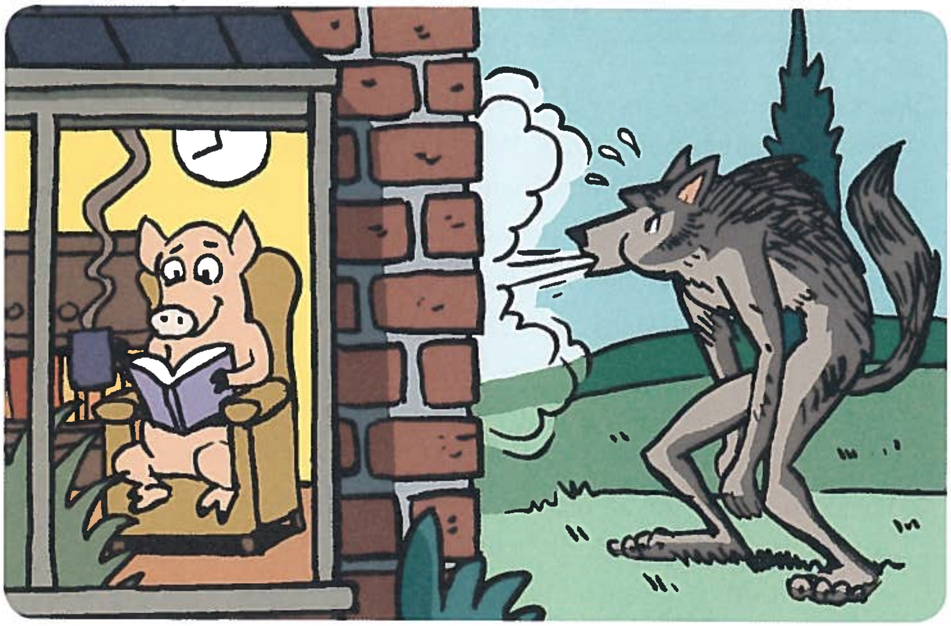


Figure 1 Clearly, the third little pig thoroughly researched building materials!

The moral of the story, of course, is that you should make wise decisions in everything you do, especially when it comes to important things like building a house. The wiser the choices we make, the healthier we will keep the planet for ourselves and future generations.

The Issue

Imagine that your family has decided to buy a brand new home. You offer to help out by researching on the Internet, and then reporting your findings back to your family. Your research reveals that some homebuilders' advertisements focus on the location of the house, others focus on the quality of the building materials (Figure 2), and still others focus on energy conservation. All of these qualities affect the price of the home. Which home will you recommend?

Figure 2 Do the building materials used in new homes help conserve energy?

Goal

Explain to your parents the energy-conserving features of the home you recommend, and try to convince them that the home is worth the price. When everyone in the class has found the home that they would recommend, they will present their choices in a class discussion.

Gather Information

SKILLS HANDBOOK 3.I.

1. Look at information provided by a number of homebuilders on the Internet. Consider the advantages and disadvantages of each home. List any topics that you think need more information.

Go to Nelson Science

2. Learn as much as you can about the different energy-conserving strategies of various homes. What are the advantages and disadvantages of the homes you are considering? The price of the home is important, as is the cost of upkeep.
3. Be sure to consider factors other than the house itself. How long will it take your parents to commute to work? Is there access to public transit? Does the house have a big backyard? Are there any natural areas, such as forests, near the home? These factors also affect how we use Earth's resources and conserve energy.
4. Speak to your friends, relatives, and parents about buying a new home. What would they look for? Ask them about energy conservation.

Identify Solutions

Organize your information into tables and graphs. Select the home that you will recommend, highlighting the energy-conserving features.

Make a Decision

SKILLS HANDBOOK 3.J.6.

Decide which home you would recommend. Be sure to have support for your decision.

Communicate

Present your recommendation to your teacher (who will act as your parents). Prepare a short presentation to the class that includes the three or four main reasons for your selection. Be prepared to justify why you did not choose the other homes.

The Amazing Coffee Keeper

SKILLS MENU

- ☐ Identify a Problem/Need
- ☐ Planning
- ☐ Selecting Materials and Equipment
- ☐ Designing
- ☐ Testing
- ☐ Modifying
- ☐ Communicating

Whether you are designing a building, a winter jacket, or a lunch bag, the choice of materials and their arrangement affect the final function of the product. Understanding how energy transfer works allows you to design a product that efficiently manages the transfer of energy.

Scenario

Every Saturday morning, your dad pours himself a cup of coffee, and then he gets busy around the house. By the time he has a chance to drink his coffee, it is cold. Your dad has asked you to design a device that will keep his coffee warm until he has time to drink it.

Design Brief

You are to build a device that will prevent 300 mL of hot water from cooling more than 10 °C in 30 min. The device must fit on a kitchen table, cannot include any form of heater, and must allow water to be easily poured in and out. Use materials efficiently to keep costs low. All materials must be safe for use in the classroom and home.

Research and Consider

Research similar devices, such as a thermos. Find out how a thermos is constructed. How does each component help to prevent energy transfer?

Go to Nelson Science

With your team, brainstorm possible solutions to this problem, following the design brief. Draw sketches for three different designs.

Plan and Construct

SKILLS HANDBOOK 4.B.3., 4.B.4.

1. Select the best design. Complete a scale drawing of the selected device.
2. Write a list of materials and tools that you will need. (Reduce, reuse, recycle!)
3. Write a step-by-step plan for creating the device. Ask your teacher to approve both the list of materials and the plan.

Use care when cutting materials and when handling hot substances.

4. Once you have approval, build your device.

Test and Modify

SKILLS HANDBOOK 4.B.5., 4.B.6.

Test how well your device keeps just-boiled water hot for 30 min. How much did the temperature of the water change during that time? Note any problems, and then modify your design to correct these problems. Continue correcting your design until it meets the design criteria.

Evaluate

(a) Describe how your device prevented energy loss by (i) conduction, (ii) convection, and/or (iii) radiation.

(b) What were some of the design challenges that you encountered? How did you overcome them?

(c) If you were to do this project again, what would you do differently? Explain.

Communicate

Prepare a short presentation to a potential investor to explain how your device works. Your presentation should demonstrate how your device is used, explain how it prevents heat transfer, and include the results of the testing.

CHAPTER 8

SUMMARY

Energy Transfer and Conservation

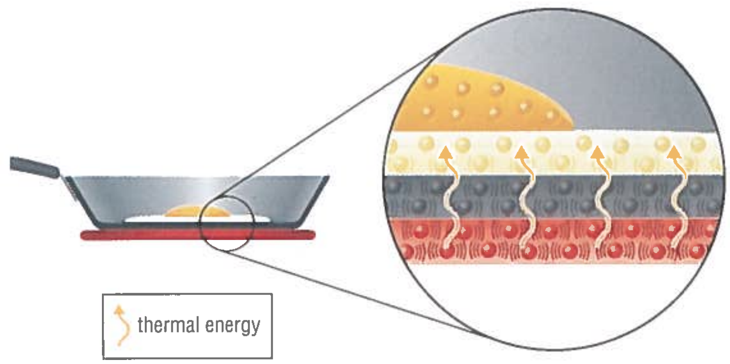
BIG Ideas

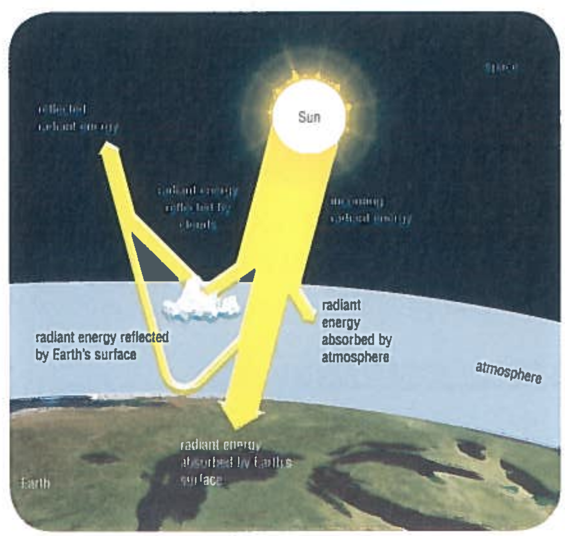
- ☑ Heat is a form of energy that can be transformed and transferred. These processes can be explained using the particle theory of matter.
- ☑ There are many sources of heat.
- ☑ Heat has both positive and negative effects on the environment.

Looking Back

Energy may be transferred by conduction, convection, and radiation.

- Conduction involves the transfer of energy through a material, or from one material to another by direct contact. It involves only the vibration of the particles of the material. Conduction explains why objects feel hot or cold to the touch.
- Convection involves the transfer of energy within liquids and gases. It involves the movement of the particles in convection currents.
- Radiation involves the transfer of energy by electromagnetic waves. Particles are not involved in the transfer of radiant energy, so radiant energy may travel through empty space.





The transfer of energy may be studied through the skills of experimentation.

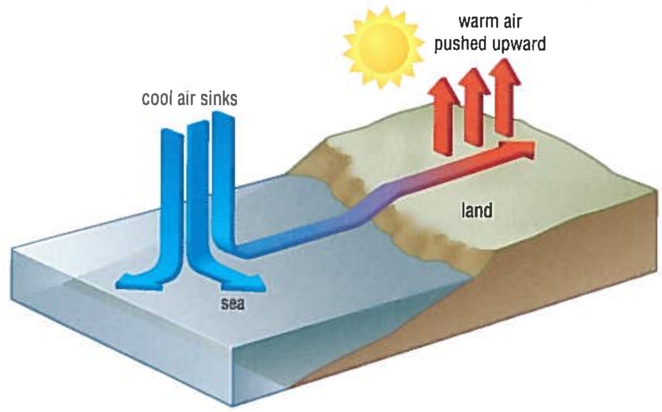
- The transfer of energy by conduction, convection, and radiation may be analyzed by conducting fair tests.

The transfer of energy drives natural processes.

- The formation of igneous and metamorphic rock and diamonds results from conduction.
- Winds, thunderstorms, and the movement of Earth's crust all result from convection.
- Energy reaches Earth from the Sun as a result of radiation. Without this radiant energy there would be no life on Earth.

VOCABULARY

conduction, p. 207
geothermal energy, p. 208
igneous rock, p. 208
metamorphic rock, p. 209
convection, p. 210
radiant energy, p. 214
radiation, p. 214



We can conserve energy by effectively controlling energy transfer.

- Designers can select materials (such as thermal insulators and radiation barriers) that reduce unwanted transfers of energy.
- Limiting unwanted energy transfer conserves energy and reduces the costs (both financial and environmental) of heating and cooling our buildings.

New methods of controlling energy transfer may be explored by applying the skills of technological problem solving.

- Technological problem solving skills may be used to design and construct devices that control the transfer of thermal energy.
- Research skills may be used to explore the technologies that scientists and engineers have devised to control energy transfer.

CHAPTER 8 REVIEW

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding T/I Thinking/Investigation C Communication A Application

What Do You Remember?

1. List the three ways in which energy can be transferred. Briefly describe each way. You may want to use diagrams in your descriptions. K/U

2. Write a paragraph describing the transfer of energy from the Sun to Earth. Use the following terms in your paragraph: "electromagnetic radiation," "space," "light," "infrared radiation," "thermal energy," "absorbed," and "transmitted." K/U C

What Do You Understand?

3. What is unique about the way energy reaches Earth from the Sun? K/U

4. We use a variety of different methods to cook food (Figure 1). For the methods below, list the form(s) of energy transfer involved in the cooking method. Be sure to explain your answer.
   (a) grilling hamburgers on a barbecue
   (b) baking cookies in an oven
   (c) making pancakes in a frying pan K/U A

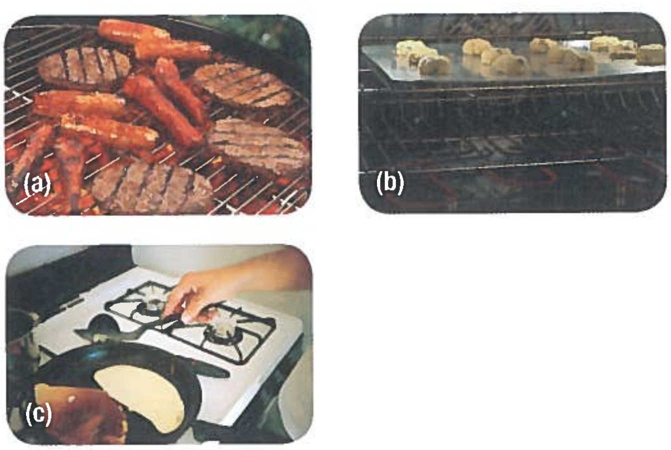


Figure 1

5. Copy Table 1 into your notebook. In each column, list at least three ways that energy transfer affects the natural environment. K/U

Table 1 Methods of Energy Transfer

Conduction	Convection	Radiation

6. How does reducing energy loss from homes demonstrate environmental stewardship? A

7. Explain why a down-filled jacket loses its insulating ability when it gets wet. K/U A

8. Using the Internet and other sources, research what a "thermal" in the atmosphere is. Describe one way in which organisms use thermals to their advantage. A

Go to Nelson Science

9. Using the Internet and other sources, find out what a temperature inversion is. Why do temperature inversions occur? What type of energy transfer do they prevent? What are some of the effects of a temperature inversion? A

Go to Nelson Science

10. Look back at Figure 1 in Section 8.8. This picture is called a "thermogram." What type of energy transfer is important to thermography? Research other uses of thermograms on the Internet. A

Go to Nelson Science

11. Specialized clothing, such as space suits and wet suits, has special properties to keep people warm. Research one type of specialized clothing and explain how energy transfer is taken into account when designing and making the clothing. A

Go to Nelson Science

Solve a Problem!

12. A well-insulated home is more comfortable and costs less to heat.

(a) What are some areas of your home where energy might be lost?

(b) What can be done to reduce this loss?

(c) What are the benefits of reducing energy loss? K/U A

13. Insulated clothing protects our bodies and increases our ability to enjoy outdoor activities in winter. What concepts from this chapter might clothing designers consider when they design cold-weather coats? T/I A

14. Spoons made of different materials sat partially submerged in a container of very hot water for 5 min. The temperatures of the parts sticking out of the water were measured (Table 2). What conclusions can you draw from these findings? T/I

Table 2 Spoon Temperatures

Spoon material	Temperature after 5 min (°C)
stainless steel	80
wood	25
plastic	50
silver	95

15. Name five things that you and your family can do to reduce thermal energy transfer around your home. T/I A

Create and Evaluate!

16. (a) What might be some deterrents to having a green roof?

(b) Suggest how these deterrents might be overcome.

(c) Would you suggest to the government that all government building roofs be converted to green roofs? Why or why not? T/I A

17. (a) What are some of the disadvantages to having airtight buildings?

(b) How can these problems be solved?

(c) How effective are your solutions? T/I A

18. Some older homes and buildings use hot water heating systems (Figure 2). Research what a hot water heating system is (include a diagram). Do you think that hot water heating systems are efficient? Explain your answer. K/U A

Figure 2

Go to Nelson Science

Reflect on Your Learning

19. Think back to the Key Question on the first page of this chapter.

(a) In a brief paragraph, answer the Key Question. You may use diagrams.

(b) Write one or two more questions about the topic of this unit that you would like to explore.

20. Think back to an idea in this chapter that has changed the way you think about thermal energy transfer. Write a brief paragraph describing how your understanding has changed and how this new understanding may affect activities in your everyday life.