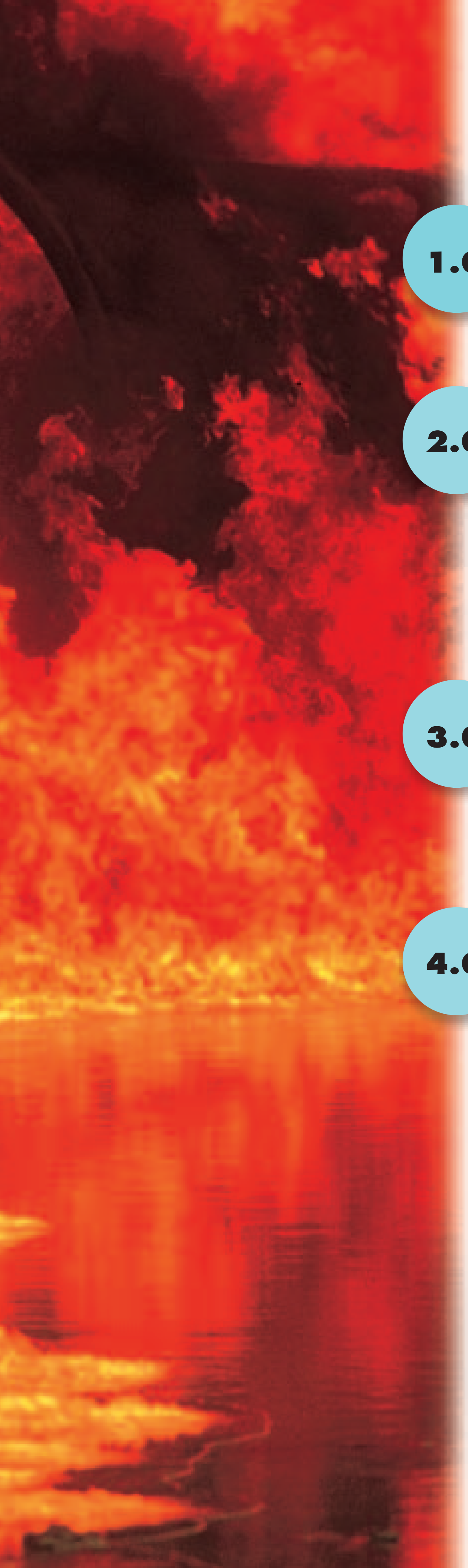
UNIT C

# Heat and Temperature



**In this unit, you will cover the following sections:**

## 1.0

**Human needs have led to technologies for obtaining and controlling heat.**

**1.1** History of Heat Technologies

**1.2** Heat Technologies in Everyday Life

## 2.0

**Heat affects matter in different ways.**

**2.1** States of Matter and the Particle Model of Matter

**2.2** Heat and Temperature

**2.3** Heat Affects the Volume of Solids, Liquids, and Gases

**2.4** Heat Transfers by Conduction

**2.5** Heat Transfers by Convection and Radiation

## 3.0

**Understanding heat and temperature helps explain natural phenomena and technological devices.**

**3.1** Natural Sources of Thermal Energy

**3.2** Heating System Technologies

**3.3** Heat Loss and Insulation

## 4.0

**Technologies that use heat have benefits and costs to society and to the environment.**

**4.1** Looking at Different Sources of Heat

**4.2** Energy Consumption

# Exploring

Imagine being in outer space. Far from Earth's surface, we don't have the protection of its atmosphere to filter and reflect the sun's energy. Orbiting our own planet, we face temperature ranges of –118°C to 132°C. Travelling through our solar system, we find average surface temperatures of 464°C on Venus to –229°C on Pluto. Unprotected, we can't survive any of these temperature extremes.

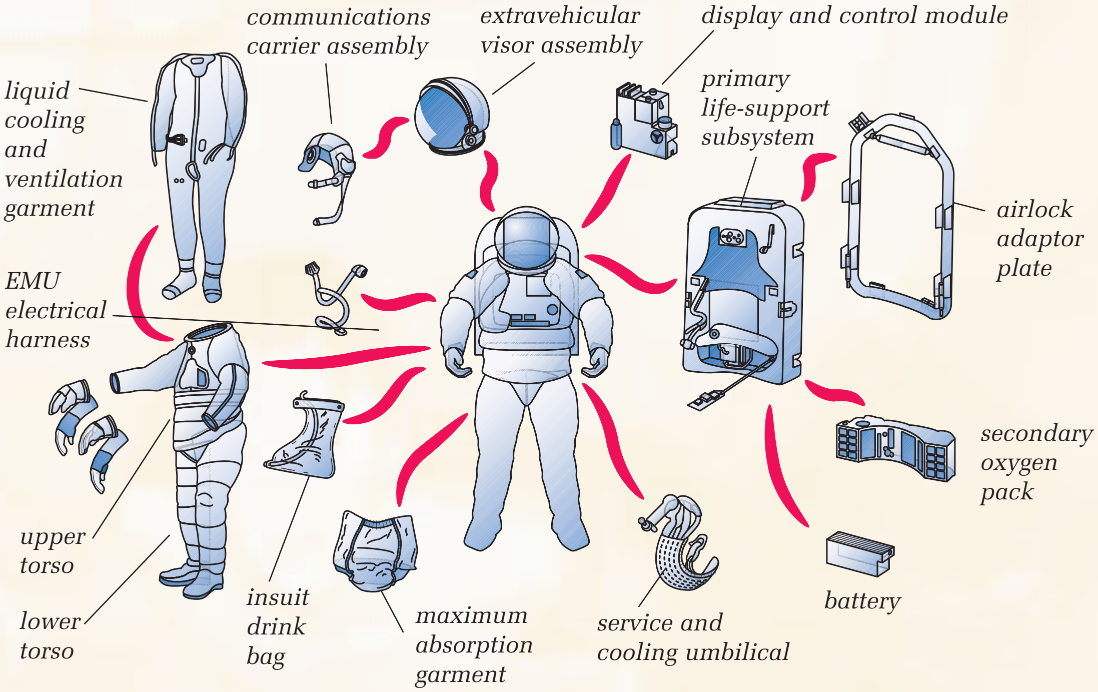
When we venture into space, we must take our environment with us. We need to control the air, pressure, and temperature within a safe range, so that we can live and carry out the work that is needed. Our heat needs must be met whether we are living with others inside the shuttle or the space station, or working all alone outside these protective environments.

The International Space Station (ISS) is the most complex space environment ever created and represents the work of 16 countries. In an area the same size as a large airplane, the ISS contains six laboratories and living space for seven humans. Solar power—energy from the sun—is the main source of energy to run the station 366 km above Earth.

## Survival in a Space Suit

Constructing the ISS in the harsh climate of space requires special failure-proof protection for the astronauts working on it. More than 50 years of research have gone into developing the special space suit known as the Extravehicular Mobility Unit (EMU). "Extra" means "outside of" and "vehicular" refers to the space vehicle. Astronauts wear the EMU when they must work outside the controlled environment of the shuttle or the space station.

**The Parts of the EMU**




The EMU is the astronaut's personal controlled environment, with temperature control being a key component. The temperature control technology of the EMU is designed to cope with temperatures from about –150°C to 120°C.

The outside of the EMU is a combination of a hard fibreglass "shell" and a special fabric that stops tiny meteorites from piercing the suit. Under this, a spandex mesh suit laced with water-cooling tubes is worn next to the skin. This helps keep astronauts cool as they work in the 48.5-kg suits. However, the frigid temperatures of space are a danger to the astronauts' hands and feet. To protect their hands, they have heated gloves with little heaters in the fingertips that they can activate. They also have thermal booties to go over their toes to help keep their feet warm. If necessary, they can turn off the cooling system in the suit.

## Connecting Space and Earth

The scientists who work on space suit technology need to have a strong understanding of heat and temperature. Such an understanding is also important in developing and using heat technologies responsibly down here on Earth. You may not need gloves with heaters in every finger, but you do need warm clothes to survive in our winter climate. And we need heating systems to keep our homes warm.

The heat energy that we use to supply our basic heat needs is essential to our survival. But what about the heat energy that we use for other non-essential activities such as drying our hair and using our dishwashers? How can we use our understanding of heat and temperature to make sure we use our energy resources in a sustainable way?

Give it a **TRY** ACTIVITY

### Is It Hot? Is It Cold?

Today's scientists have a variety of technologies to measure and study heat energy. The earliest researchers of heat energy had no technology that could help them measure temperature accurately. They often relied on their bodies to detect temperature differences. If you hold your hand near a pizza, you can tell if it's hot. But how reliable are your hands as temperature measuring devices? Test them with the following experiment. You will need three buckets. Half-fill one with cold water, one with warm water, and the third one with room temperature water.

- Put one hand in the bucket of cold water and the other one in the bucket of warm water. Keep both hands in water for one minute. While you are waiting, predict how you think your hands will feel when you place them in the bucket of room temperature water.
- Take both hands out of the buckets of cold and warm water and place them together in the bucket of room temperature water. Describe to your classmates how each hand feels.
- Was your prediction correct? Can you explain what happened?

How does the room temperature water feel?

## Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

As you work through this unit, you will learn about the scientific principles related to heat. As your understanding of the nature of heat increases, you will be exploring its uses and effects in everyday life. You will be able to explain the difference between heat and temperature. As well, you will have opportunities to learn more about how human needs for heat impact natural resources and the environment, and to practise your decision-making skills.

Think about the following questions as you perform activities and answer questions throughout this unit.

1. **What technologies do we use to meet human needs for heat?**
2. **What are the scientific principles that make these technologies work?**
3. **What impact do these technologies have on natural resources and the environment?**

The answers to these and other questions about heat and temperature will guide your learning about the nature of heat and help you to understand the role that science plays in allowing people to meet their need for heat.

The project at the end of this unit will allow you to apply your knowledge of how to determine the most likely sources of heat energy loss in an old house. You will use the research, inquiry, and decision-making skills that you practise throughout the unit.

# 1.0 Human needs have led to technologies for obtaining and controlling heat.

## Key Concepts

In this section, you will learn about the following key concepts:

- heat energy needs and technologies
- energy conservation

## Learning Outcomes

When you have completed this section, you will be able to:

- describe technologies that have been developed over time to meet human needs for heat
- trace the connections between heat technologies and why they were developed
- give examples of personal choices and society's choices about using heat-related technologies

Have you ever looked over the open prairie in midwinter? The sound of the wind howling across the empty fields, the vivid colour of the sky at sunset, and the biting cold all combine to make a unique picture. Imagine being an early settler arriving from Europe in the middle of an Alberta blizzard, armed mostly with hopes of making a fortune in the fur trade. What would you have thought as you settled into your blankets at night, trying to keep from freezing to death in your sleep?



For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

# 1.1 History of Heat Technologies

The weather report says it's –30°C outside, and you're sitting inside in front of a window with the sun pouring in. The heat from the sun is so strong that you're comfortable in a T-shirt. But when it's time to go out, you don't just walk outside the way you are. You put on warm clothes. You know that at that temperature outside, going out in a T-shirt could be dangerous. Understanding heat in our climate can be a matter of survival. But understanding heat is also important in everyday life—whenever you cook something, dry your hair, or do anything that uses or produces heat.

## Early Theories of Heat

Human beings have always had to make sure they were warm enough or cool enough. But through much of human history, people were unsure of what heat actually was. Until about 1600, people thought that heat was a combination of fire and air. Then, scientists began doing experiments to find out more about heat. From their observations, they decided that heat must be an invisible fluid called *caloric*. They assumed it was a fluid because it seemed to flow from a hotter object to a colder one. This explanation of heat was called the caloric theory.

The caloric theory would explain what happens when you put a spoon in a bowl of soup. If you leave your spoon sitting there, it will eventually become warm all the way to the end of the handle.

However, some scientists soon questioned this theory. They wondered why, in the example, the mass of the soup and the spoon didn't change. If caloric was a fluid like water, it should have mass. If it flowed out of the soup and into the spoon, shouldn't the mass of the soup decrease and the mass of the spoon increase? But the measured masses of the soup and the spoon were the same before and after.

## Heat Is Energy

Further experimentation and study led scientists to realize that heat is not a substance. They eventually determined that heat is a form of energy. This energy comes from the movement of the tiny particles that make up all matter. You will learn more about heat energy and the particle model as you work through this unit.

The investigation of heat has led to a greater understanding of the difference between heat and temperature. With this increased understanding, the technology linked to how we use heat has changed.

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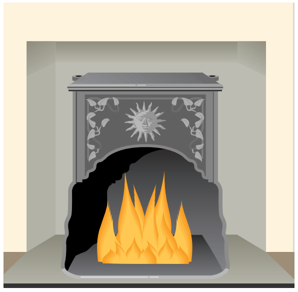
**Two Heating Systems in One**

Fireplaces are one of our oldest heating technologies. The Franklin stove is a dual-purpose heating system designed by the American inventor and politician, Benjamin Franklin (1706–1790). With the front opened, it served as a fireplace. With the door closed, it served as a cooking stove.



## Humans Using Heat

**math Link**

The official unit of heat energy is the **joule** (J). Power is defined in terms of energy per unit of time. The official unit of power is the watt (W), and 1 W = 1 J/s. There are 1000 W in 1 kW. How many joules are in one kilowatt-hour? There are $10^9$ joules in a gigajoule. How many kilowatt-hours are in a gigajoule? Both kilowatt-hours and gigajoules may be used on household heating bills.

Culture is a learned way of life that is shared by a group of people. This includes how they meet their basic needs. Food, clothing, shelter, family life, recreation, education, language, and values and beliefs are all part of what makes up this learned way of life. The tools and technology that the group develops to help meet these needs are also part of their culture. As the technology changes, so too, does the culture. As the culture shifts in response to the new technology, there are often more demands for even higher levels of technology. The inventions of clothes dryers and protective clothing such as ski suits are examples.

The environment in which people live shapes their culture. In Canada, the way of life is influenced by the climate. Heat and the science and technology linked to how we create and use heat to meet our needs are very important to us. Our homes and other buildings, clothing, food, and recreational activities give us daily examples of why we need to understand the concept of heat.

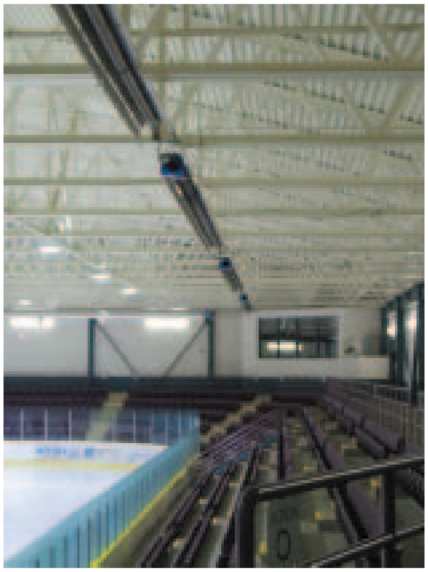


**Figure 1.1** These heating units help keep hockey and figure skating fans warm.

**Give it a TRY** ACTIVITY

### No More Heat

Imagine what would happen if you and your family were without heat for one full week in the middle of January.

- What would happen if natural gas, oil, and electricity were cut off?
- What impact would it have on how you dress, what you eat, or what activities you did?
- How would your way of life change for that one week? Think about what changes you would make.

Write a short story about what you predict would happen in this situation.

## HEAT AND HUMAN NEEDS

*Needs* are the basic, required conditions that we must meet in order to live. It is necessary to our survival that we fulfill these needs. *Wants* stem from needs and include ways in which needs could be met. However, unlike needs, it is not vital to our survival that all of our wants be satisfied.

In Canada, the importance of heat is linked to shelter, clothing, food, water, and physical activity. Because human life can exist only within a certain temperature range (just below 0°C to about 45°C), humans build shelters to keep the temperature of the environment within these limits.

**Figure 1.2** How do you think these children are staying warm?

## HEAT-RELATED MATERIALS AND TECHNOLOGIES

Furnaces and air conditioners are examples of technologies that help to keep our shelters livable and comfortable. When we cannot control the temperature of the environment in this way, we dress in specific clothing. How we store and prepare food and water also relates to heat. When the temperature is too cold, freezing occurs. Temperatures that are too warm can cause food to spoil. Some foods, such as chicken, need to be cooked at high temperatures in order to be safe to eat. The kinds of physical activities that people take part in also depend on the temperature of the environment.

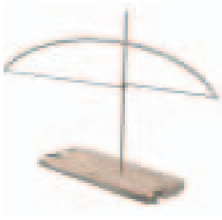
**Figure 1.3** How do you think these children are staying cool?

## Heating Technology through Time

Heat-related technology has changed over time. As people evolved, so did the technology. Look at Figure 1.4 to investigate how heat technology was used in the past.

**Early Heating Technology Timeline**

| 7000 B.C. | 100 B.C. | A.D. 1200 | 1300s | 1700s | late 1700s | 1800s | 1906 |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Humans create fire.* | *Romans develop central heating—heat travels from one source to different areas of a building.* | *Chimneys first appear in Europe.* | *Fireplaces with chimneys are built into the walls of buildings.* | *Cast-iron stoves heat rooms evenly; heat does not escape up the chimney.* | *Central heating reappears—using coal.* | *Forced-air heating* | *Electric heaters* |



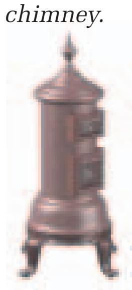


**Figure 1.4**

### reSEARCH

**Using Heat**

List three heat-related objects or materials (examples may include a hair dryer, a dishwasher, or a ski suit) that you use. Research when and why they were invented.

## Check and Reflect

1. In the past, many people used wood stoves or fireplaces to heat their homes. Today, most people use oil or gas furnaces, or electric heating. Why do you think this change occurred?
2. a) Has our climate affected the types of houses we live in or the clothes we wear? Explain your answer.
   b) Do you think our climate has affected the way we live in other ways? Explain your answer. (Hint: Think about entertainment, sports, transportation.)
3. Today, many devices in your home will maintain a constant temperature. List three such devices and give reasons why you think this is important.

# 1.2 Heat Technologies in Everyday Life

In addition to being able to produce heat to meet human needs and wants, it is important also to control that heat. Imagine what would happen if your furnace came on at random times rather than when you needed heat. What if you could not keep the temperature of your oven stable? What if the temperature of your clothes dryer was so high that it started a fire?

**Give it a TRY** ACTIVITY

### HOUSEHOLD TOUR

Close your eyes and take a mental tour of your home. As you travel from room to room, think about household items that make or use heat. Brainstorm a list.

Of all of the examples of heat that you wrote about, which ones were related to needs and which were related to wants? Put together a chart, listing your examples under the headings Needs and Wants. Share your work with a partner.

As technologies have been developed to generate heat, people have also invented ways to direct and manage that heat. But such technologies have come with a cost to the environment. This has led to the need for choices.

**infoBIT**

**Fighting Cancer with Heat**

While not a traditional treatment for cancer, hyperthermia—the use of heat to kill cancer cells—may be an option to help some people in their battle against cancer.

## PERSONAL AND SOCIETAL CHOICES

As you learned earlier, making effective choices begins with separating what you *need* from what you *want*. This is true whether you are making a decision as an individual, or as a group or society.

North Americans have a fairly high *standard of living*. This is a measure of how well we live, including the level of technology that we use in daily life. Because of this, there are many tools that we take for granted and have come to think of as being necessary for living. Microwave ovens, for example, make cooking easier and faster. However, we could survive without them, and many people do.

**Figure 1.5** A microwave oven

**Problem Solving Activity**

# DISSECTING AN ELECTRICAL DEVICE

***Materials & Equipment***

- used electrical device such as hair dryer, toaster, flashlight, or curling iron
- tools such as a screwdriver and pliers

**Figure 1.6** Try to determine what parts of the device are responsible for producing or controlling heat.

**Caution!**
Remove all cords and make sure all capacitors or other devices are discharged before you begin the activity. Have your teacher check your device to make sure it's safe to dismantle before you begin.

## Recognize a Need

Every day, you use devices that require the use of heat. You dry your hair with a hair dryer, press your clothes with an iron, or use a toaster to make a toasted sandwich. Do you know how these devices create heat to help you perform a task?

## The Problem

Dissect an electrical device that generates heat to determine how it functions.

## Criteria for Success

For your dissection to be successful, you must meet the following criteria:

- Your dissection must show the components that you think are responsible for its operation and for producing or controlling heat.
- You must complete a diagram and explanation of your dissection that identifies the parts of the device responsible for producing and controlling heat.

## Brainstorm Ideas

1 Working with a partner, describe how you think the device works.

2 Brainstorm ways to dissect your device. Begin by determining the best way to remove any covers from it.

## Dismantle the Device

3 Before beginning your dissection, make sure all cords are removed and capacitors or other devices that hold an electrical charge are discharged. Do not continue until your teacher has checked that this step has been completed.

4 Using appropriate tools, remove the cover of the device.

5 Draw what you see inside the device.

6 Dissect any parts that you think will help you understand how the device operates and how it produces and controls heat.

## Analyze and Evaluate

7 Make two or more drawings of your dissected device. Each drawing should illustrate a different part of it. Identify those parts that you think produce or control heat.

## Communicate

8 Summarize your findings by writing an illustrated description of how your device operates and how it produces and controls heat.

9 Share your ideas with your classmates.

## Making Sustainable Choices

Both the personal and societal choices we make in using heat energy are important. They are important because they affect our ability to live in a sustainable way. In earlier studies, you may have learned about sustainable use of resources. **Sustainable** means that something can be maintained or continued. When we talk about sustainable use of resources, we mean that we are trying to use our resources wisely and do as little damage as possible to the environment when we use them.

Later in this unit, you'll learn about the different sources of our heat energy. Some of these sources may run out in the future. Others, such as the sun, will not run out for millions of years. However, the sun's energy cannot completely replace the fuels we use for heat energy. A variety of sources of heat energy will be needed. As you learn more about heat energy in this unit, think about how our use of heat energy and heat technologies can contribute to a sustainable use of our resources.

### reSEARCH

**Heating Your House**

Which natural resources does your family use to meet their needs for heat? Check your family's heating bill for this past month for clues. What energy units does the bill use? What effect do you think your family's use of those resources has on the environment? Which form of energy is cheaper? Gas or electricity? What else do people use for heat? Research any additional data and information using print or electronic sources.

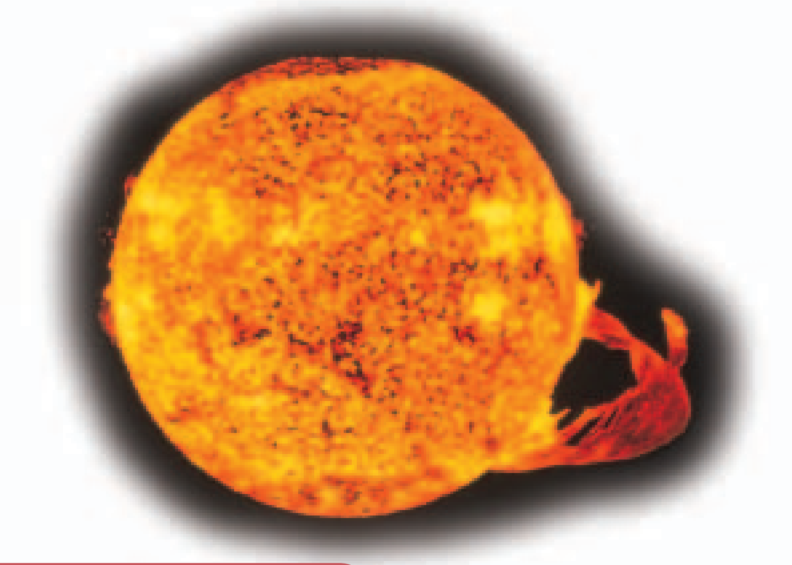


**Figure 1.7** Energy from the sun can be used for heating buildings and water, and for producing electricity.

## Check and Reflect

1. For each heat technology listed below, explain why you think it's a "need" or a "want." If the heat technology is a "want," what could be used if it were not available?
   a) hand-held hair dryer
   b) air-conditioning
   c) household furnace
   d) polar fleece clothing
2. a) Explain what is meant by *standard of living.*
   b) How has most people's standard of living changed over time? Use examples related to heat in your answer.

## Careers and Profiles

# Winter Sportswear Designer

Sally Neal designs sportswear for active Albertans. Her employer, Blue Skys, is an Edmonton-based company that specializes in creating clothing for skaters, skiers, and other people who enjoy winter activities. Some of their clients include Canadian Olympians and world champions.

"There is a lot of technology involved in creating fabrics that are lightweight, move with the person, allow them to stay dry, and also keep them warm. A great deal of research is involved in creating human-made fabrics. You also need to know about the structure of the human body, and how the skeleton and muscles work in movement. Years ago, many Aboriginal people used hides and furs to keep them warm. Today, most people don't want that heavy bulk. Some of our customers are Canada's top winter athletes, and they need their sportswear to become almost a part of them, like a second skin. That's a big challenge!"

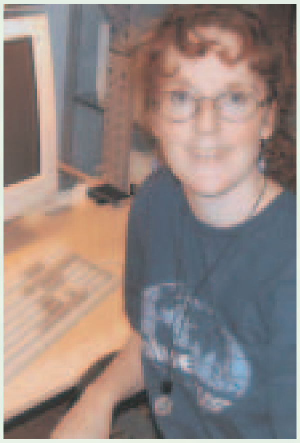


**Figure 1.8** Sally Neal

Layering is an important feature in Sally's designs. Many of the jackets include a removable lining or a vest. Body warmth becomes trapped between the layers of material, creating a kind of insulation. If a person becomes too warm, they can remove a layer. If more warmth is needed, another layer can be added. Many of the fabrics that she works with allow sweat to escape but at the same time block wind and rain from penetrating the material.

"People want more than to meet just their basic need for warmth. They also want style and comfort. They want to look good. Part of what I do is to create unique looks."

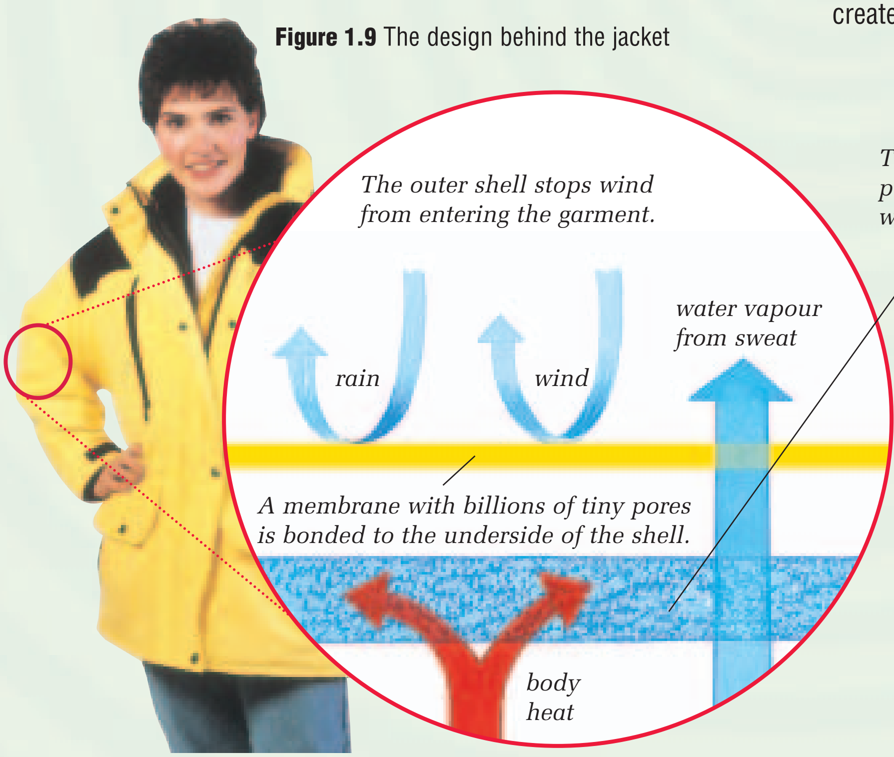



**Figure 1.9** The design behind the jacket

1. How does your own winter wear compare with that of 100 years ago?
2. What do you consider when choosing clothing for the outdoors? How does the design industry shape your choices? How do people influence what designers create?
3. If you could design the ultimate winter wear, what would it look like? Why?

## Assess Your Learning

1. Describe two technologies that use or control heat that were invented in the past. In your description, explain what effect you think each technology had on people's lives at the time it was invented.
2. Identify two examples of heat technologies that have changed over time. Describe how they have changed.
3. Do you agree or disagree with the following statement? Explain your answer. *A hot water heater is both a want and a need.*
4. Think about how the Canadian climate has affected how we use and control heat. Below is a list of other areas in the world. Do you think people who live in each area would use and control heat differently from the way we do? Explain your answers.
   a) a rain forest at the equator
   b) Canada's far north
   c) a desert
5. To help organize your learning about heat and temperature, construct a mind map. As you come across new ideas, use the mind map as a frame to record your notes. Compare your work with a partner to be sure that you have captured all of the main ideas and important details for this section. You will update your mind map throughout the unit.

## Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Science and technology are developed to meet human needs. Over time, heat-related technologies have become more advanced, allowing people to do more in cold conditions and to live more comfortably all year round. Think about what you learned in this section.

1. Identify two human needs and describe how heat technologies help to meet those needs.
2. In what ways have heat-related technologies allowed people to be outdoors any time of the year?
3. Why is it important to consider the idea of sustainability when using heat technologies?

# 2.0 Heat affects matter in different ways.

## Key Concepts

In this section, you will learn about the following key concepts:

- change of state
- particle model
- thermal energy
- heat transfer
- thermal expansion
- temperature
- insulation and thermal conductivity

## Learning Outcomes

When you have completed this section, you will be able to:

- identify technologies that use heat energy
- compare how different materials will conduct, absorb, or insulate against heat energy
- describe how the particle model of matter works
- explain how conduction, convection, and radiation work
- use the particle model and kinetic energy to describe the relationship between heat and temperature

Firefighters are challenged by heat every time they are called to deal with a fire. Special gear helps to protect them from the intense heat. But they also need to know what to expect from the fire. How will it travel? What is it likely to do next? How did it start? What type of fire is it? They need to understand the nature of heat.

In this section, you will learn about the science of heat: how heat can change the state of matter, how it can affect the particles that make up matter, and how it transfers from a hotter object to a colder one. You will also learn the difference between heat and temperature.

 For Web links relating to 2.0, visit **www.pearsoned.ca/scienceinaction**

# 2.1 States of Matter and the Particle Model of Matter

Solid Liquid Gas

**Figure 2.1** Three states of matter

Everything in the universe is made up of matter. Matter exists in three states: solid, liquid, and gas. One way that heat can affect matter is by causing a change of state. This happens by adding or taking away **heat energy**. Heat energy is a form of energy that transfers from matter at higher temperatures to matter at lower temperatures.

Think of what would happen if you were to take an ice cube from the freezer and place it in a hot frying pan. Very quickly, you would see the ice cube melt to a pool of water. After a few moments, that water would begin to bubble, and steam would rise. You would have seen matter change from a solid to a liquid, and then to a gas.

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### Floating Ice

Water, unlike other liquids on Earth, expands when it freezes. And solid ice is less dense than liquid water. The result? Floating ice! Think of ice cubes in a glass of water, or you may have seen ice chunks floating in a lake or pond. What do you think our world would be like if solid ice were more dense than water?

Give it a **TRY** ACTIVITY

## A "Cool" Heat Challenge

Melt an ice cube as fast as you can. But wait! Before you start, here are three rules you must follow.

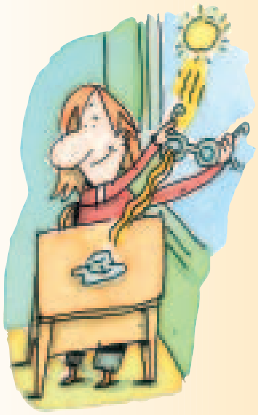
1. You can use only whatever is on or at your desk right now.
2. You must keep and collect as much of the melted ice as possible. Decide how you will collect the water before the ice melts.
3. You may not put the ice cube in your mouth!

Use the stopwatch. Record your time in seconds. When you have finished, answer these questions.

- What strategies did you use to melt the ice cube?
- How did you decide on your strategies?
- Which strategies worked better than others? Why might that be?
- If you could do this activity again, what would you do differently? Why?
- If the rules changed to allow you to use anything to melt the ice cube, what would you use? How do you think that might change your results? Why?

***Materials & Equipment***

- ice cube
- stopwatch



## Water's Changing State

In most of Canada, water goes through changes of state through the four seasons. A glass of water left outside will evaporate in the summer heat. That same glass of water will develop a thin crust of ice as the first autumn frosts come. During the coldest days of winter, the water will freeze to a solid. As the warming days of spring follow, melting will occur, and the water will once again become a liquid. Examples of this can be found in rivers, ponds, lakes, and streams.

### Fact File on Water

- Ice is water in the solid state. The **freezing point,** when water changes from a liquid to a solid state, is 0°C.
- Transferring heat energy to ice causes it to melt. The **melting point**, when water changes from a solid to a liquid state, is also 0°C.
- Continuing to transfer heat energy to liquid water causes the water to boil and change to a gas state. The **boiling point** of water is 100°C.
- Transferring heat energy from water in a gas state causes it to change to a liquid state. This cooling process is called **condensation**. It also occurs at 100°C.

## Particle Model of Matter

Matter can change state when heat energy is added or taken away. A solid can melt to liquid, and a liquid can boil and become a gas. As a gas cools, it returns to its liquid state. When enough heat energy is removed from a liquid, it will become solid again. How does science explain these changes of state?

Scientists who have studied this have developed the **particle model of matter**.

**Figure 2.2** Butter changing state

### All matter is made up of extremely tiny particles.

They are much too small to see except with powerful, magnifying instruments, called electron microscopes.

### The tiny particles of matter are always moving.

This movement involves a form of energy known as kinetic energy. Each particle of matter has **kinetic energy**—energy of movement.

### The particles have space between them.

Different states of matter have different amounts of space between the particles.

### Adding heat to matter makes the particles move around faster.

Faster-moving things have more kinetic energy. So adding heat increases the kinetic energy of the particles.

## Heat and the Particle Model of Matter

Imagine being shrunk to one billionth of your size. Your classmates would need a microscope to find you! But you would be able to see the particles that make up all matter and how they move. These particles are moving because they have kinetic energy. **Kinetic energy** is the energy of movement.

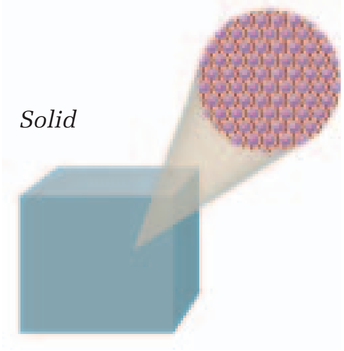



**Figure 2.3a)**

### Solid State

According to the particle model, matter in its solid state has particles that are attached to each other in all directions. This results in the solid having a definite shape and **volume**. Volume is the amount of space that matter occupies. Because they are attached in all directions, particles in a solid are very limited in their movement. They move back and forth only around a fixed position. This means that the particles in a solid have less kinetic energy than the particles in a liquid or a gas.

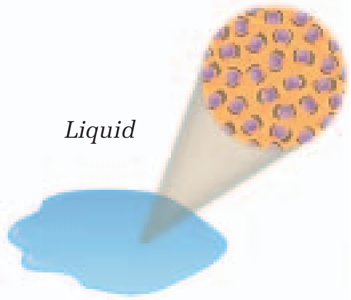



**Figure 2.3b)**

### Liquid State

The particles in the liquid state are only loosely attached to each other and they can easily slip past each other. Because of this, a liquid takes the shape of its container. However, a liquid does have a definite volume. Empty spaces between particles in a liquid are usually larger than those in a solid. This allows for a greater range of movement so the particles in a liquid have more kinetic energy than the particles in a solid.

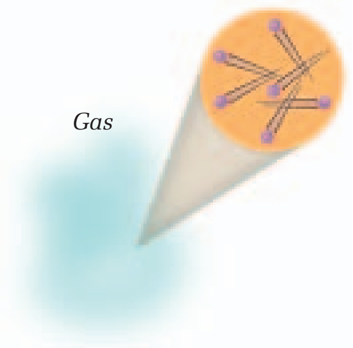



**Figure 2.3c)**

### Gas State

The particles of matter in a gas state are not connected to one another. This allows a gas to fill the empty space of a container. A gas has no set shape. The spaces between particles in a gas state are much larger than those in either a solid or a liquid. This means that the particles in a gas have the greatest freedom of movement and the highest levels of kinetic energy.

## The Effect of Heat on Particles

Heat changes the speed of moving particles of matter. Transferring heat to a substance increases the movement or kinetic energy of the particles in that substance. Transferring heat from a substance slows down the movement of the particles in that substance. That is, the kinetic energy of the particles decreases.

**Inquiry** Activity

# ACTING OUT THE PARTICLE MODEL

## The Question

How can you and your classmates move and arrange yourselves to act like the particles that make up solids, liquids, and gases?

## The Procedure

1. You will work in groups. Each group will work in a separate area. Treat each separate area as if it is a large container.
2. With your group, develop a way to represent a solid state of matter. Decide how to arrange yourselves and how to move to be particles of a solid.
3. Imagine that heat is being added to you. Your solid group is becoming a liquid.
4. Now add more heat and change your positions and movements to represent gas particles.
5. Keep working together until your group is satisfied with the way you represent particles in the three states of matter. Then present one of these states to the rest of the class without saying what it is. Show yourselves changing from that state to another state.

**Figure 2.4a)** Solid

**Figure 2.4b)** Liquid

**Figure 2.4c)** Gas

## Collecting Data

6. Draw two rectangles on a sheet of paper. The rectangles represent "containers." Use them to sketch the two states of matter your group represented. Draw arrows to show your movement. Include other information about the way and the speed that you (as particles) were moving.

## Analyzing and Interpreting

7. As a class, judge each group's presentation based on the following criteria.
   - How easy was it to infer the state of matter being represented? What were the best clues? How accurately did the group represent the state of matter?
   - How well did the group's actions represent the level of kinetic energy of the particles? How accurate was this action?
   - How well did the group's actions show changes in volume?

## Forming Conclusions

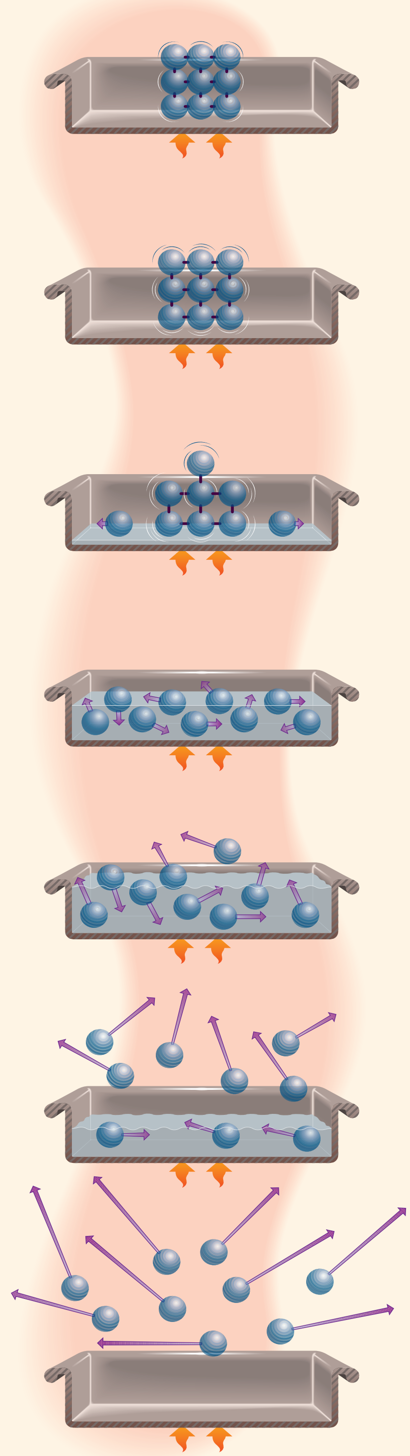
8. Review the scores that you gave your classmates' presentations. Write three paragraphs that describe the best presentation for each state of matter: solid, liquid, and gas.

## Applying and Connecting

Sketch three diagrams that illustrate how adding heat affects the motion of particles. Use one real-life example for each of the three states.

## How the Particle Model Explains Changes in State

The following chart shows what happens to the particles in a solid when heat is transferred to them. As the solid substance melts, becomes a liquid, and then a gas, the activity level of the particles and the amount of space between them changes.



**1 Solid**

- *Solid particles are packed closely together.*
- *Strong attractions, or bonds, hold the particles together.*
- *Solids have a fixed shape.*
- *The particles vibrate, or shake back and forth, in a fixed position.*

**2 Heating a Solid**

- *Transferring heat to a solid makes the particles vibrate more energetically.*
- *Some of the particles move farther away from one another.*
- *The solid expands—its volume increases.*

**3 Melting a Solid**

- *As more heat is transferred to a solid, the particles vibrate even more.*
- *The particles bump against one another.*
- *Some of the particles break loose.*
- *The solid structure begins to break down—the solid melts.*

**4 Liquid**

- *The particles have more kinetic energy to move about.*
- *The bonds that hold the particles together are weak.*
- *Liquids take on the shape of their containers.*

**5 Heating a Liquid**

- *Transferring heat to a liquid makes the particles move more vigorously.*
- *The particles move farther apart.*
- *The liquid expands—its volume increases.*

**6 Boiling a Liquid**

- *As more and more heat is transferred to a liquid, the particles bump and bounce around even more.*
- *Some of the particles are "kicked" out of the liquid.*
- *The liquid boils—it changes to a gas.*

**7 Gas**

- *Gas particles move about very quickly in all directions.*
- *Bumping and bouncing keep them far apart.*
- *Gas particles will fill up the space of any container.*
- *On heating, gas particles spread out even more—the gas expands.*

## Check and Reflect

1. a) Below are pictures of three pure substances; one solid, one liquid, and one gas. Their melting and boiling points are also listed. Use the data to answer the questions below each picture.

**Sulfur**
- changes from the solid state to the liquid state at a temperature of 113°C
- changes from the liquid state to the gas state at a temperature of 445°C

**Mercury**
- changes from the solid state to the liquid state at a temperature of −39°C
- changes from the liquid state to the gas state at a temperature of 357°C

**Chlorine**
- changes from the solid state to the liquid state at a temperature of −101°C
- changes from the liquid state to the gas state at a temperature of −35°C

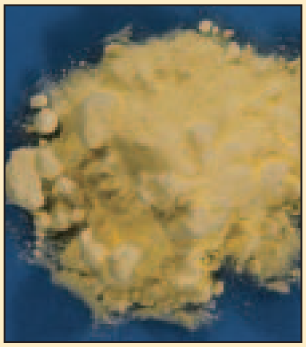


**Figure 2.5a)**
Sulfur is most often found in the solid state. What happens to the state of sulfur when the temperature changes from 20°C to 100°C? from 100°C to 120°C?

**Figure 2.5b)**
Mercury is most often found in the liquid state. It is the only metal existing in the liquid state at room temperature. In what state is mercury at −50°C? −20°C? 200°C? 400°C?

**Figure 2.5c)**
Chlorine is most often found in the gas state. What would you have to do to make chlorine gas change into a liquid? to make solid chlorine change into a liquid?

b) Make a table or a graph that illustrates the melting and boiling points of the three substances shown above.

2. Create a cartoon strip with captions that illustrates the changes in particles from a solid state to a gas. Be sure to represent changes to both the kinetic energy and volume.

3. Design a chart that highlights the main ideas in the particle model. You may wish to use the one shown here, or create your own.

| State of Matter | Distance between Particles | Volume and Shape | Particle Movement |
|---|---|---|---|
| Solid | | | |
| Liquid | | | |
| Gas | | | |

**Figure 2.6** Question 3

### reSEARCH

**Chugging Along**

The *Dorchester* was the first ever steam-powered locomotive built for travel on Canadian railways. Its first trip was on July 31, 1836, along an 80-km track in eastern Canada. It travelled at about 23 km/h. Find out what happened to this locomotive and what technology replaced it.

**info BIT**

**All-Time Low**
In theory, the lowest possible temperature is "absolute zero" or −273.15°C. Scientists have come close to reaching "absolute zero" in a lab, but it has never actually been achieved.

# 2.2 Heat and Temperature

Temperature is a term we're all familiar with. When you get up in the morning, you might listen for the temperature on the radio so you know whether you have to wear a sweatshirt or a warm jacket to school. When you want to heat up some leftovers in the oven, you have to set the temperature so you don't burn them.

**Temperature** is a measure of how hot or cold matter is. Recall that heat energy transfers from hotter substances to colder ones. If you put a pot of soup on a hot stove burner, the soup will slowly heat up. Heat is transferring from the burner to the soup. Suppose you measured the temperature of the soup before you heated it and then again after it had been on the burner for a while. What do you think you would find?

If your soup came out of a can stored in the cupboard, it was probably at room temperature, about 20°C. After a few minutes of heating, its temperature would be several degrees higher. Heat energy has transferred from the burner to the soup. The soup now has more heat energy, and its temperature went up. Does that mean that heat energy and temperature are the same?

## Total Kinetic Energy

So far in this unit, we have been using the term *heat energy* to describe the kinetic energy of particles in matter. However, to understand better how matter changes temperature and what this change means, we should use the scientific meanings of the terms *thermal energy*, *heat*, and *temperature*.

The **thermal energy** of a substance is the total kinetic energy of all the particles the substance contains. If you measured the thermal energy of a cup of water, for example, you would be measuring the total amount of kinetic energy of all the water particles in the cup.

Think about your soup example again. You heat the soup in a pot, and then pour a small amount of it into a cup. The temperature of the soup is the same in the pot and in the cup. But the soup in the pot has more thermal energy than the soup in the cup. This is because the amount of soup in the pot is greater than the amount of soup in the cup. A larger amount of soup contains more particles. If you added up the kinetic energy of all soup particles in the pot, you would find that it was greater than the total kinetic energy of the soup particles in the cup.

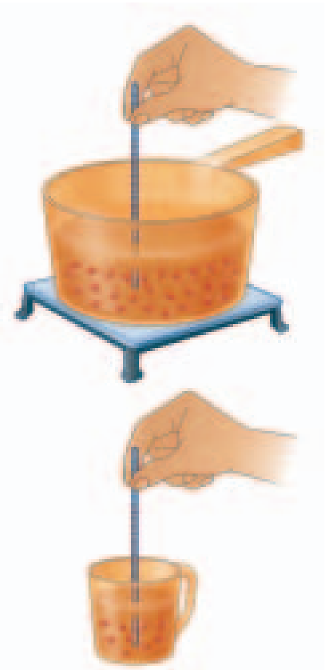


**Figure 2.7** The soup in the pot has more thermal energy than the soup in the cup. But both are the same temperature.

## Energy Transfers

Scientists use the word **heat** to mean the energy that transfers from one substance to another because of differences in kinetic energy. So, in our soup example, the soup became hot because kinetic energy transferred from the particles in the hot stove burner to the cooler soup. A scientist would say that heat transfer had occurred.

## The Difference between Heat and Temperature

Earlier in this unit, you learned how the particle model explains changes in state. The particle model also explains changes in temperature. Look at Figure 2.8. The kinetic energy of the water particles in the spoon increases as energy transfers from the flame to the water. The temperature of the water increases. Then, the spoon is placed in the freezer. Heat energy transfers from areas where particles have greater kinetic energy to areas where particles have less kinetic energy. In this case, kinetic energy transfers from the water particles in the spoon to the particles of the cold air in the freezer. The kinetic energy of the water particles in the spoon has decreased, and so the temperature has gone down.

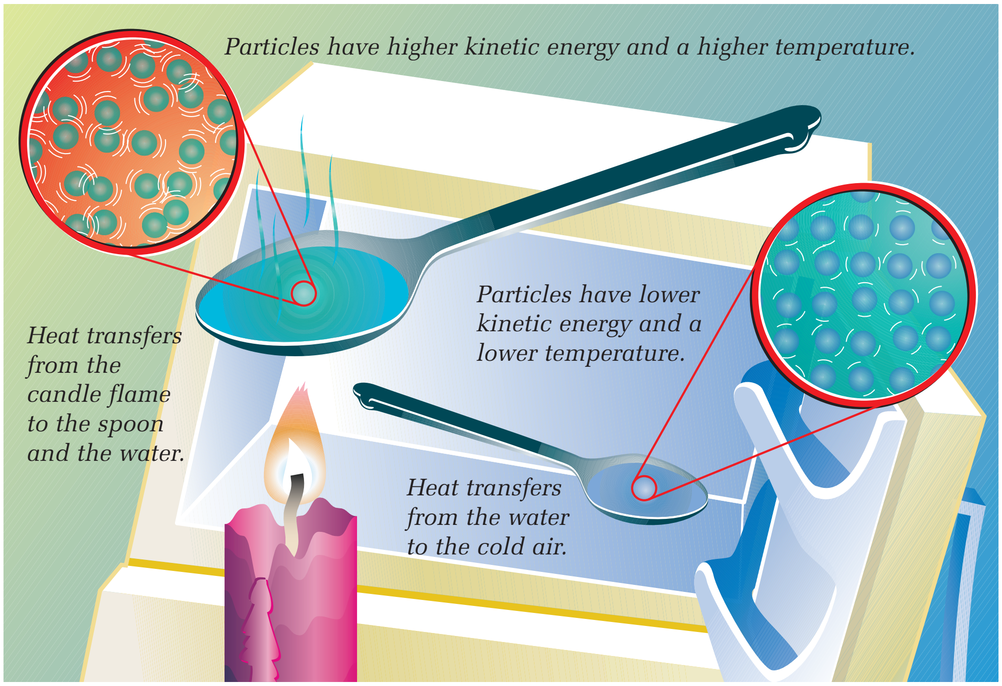



**Figure 2.8** The temperature of the water in the spoon changes when heat transfers to it or from it.

Earlier, we said that temperature is a measure of how hot or cold a substance is. From the particle model, you know that the coldness or "hotness" of an object represents the kinetic energy of the particles it contains. Temperature then is more than simply a measure of how hot or how cold a substance is. It is a measure of the average kinetic energy of the particles in a substance.

## Understanding the Difference

So thermal energy, heat, and temperature are different.

- Thermal energy is the total kinetic energy of all the particles in a substance.
- Heat is the energy that transfers from a substance whose particles have a higher kinetic energy to one whose particles have lower kinetic energy.
- Temperature is a measure of the average kinetic energy of the particles in the substance.

**Figure 2.9** John Locke performing experiment

## Measuring Temperature with Thermometers

More than 300 years ago, an English scientist, John Locke, did an experiment to try to prove that our sense of touch was not a very accurate way to measure temperature. He filled three pans with water: one with water that was as hot as he could stand to touch, one with very cold water, and one with lukewarm water. He placed his left hand in the hot water, and his right hand in the cold water for one full minute. He then set both hands into the lukewarm water. To his left hand, the lukewarm water felt cool. To his right hand, the same lukewarm water felt warm. This proved to Locke that we needed a more reliable way to measure temperature. Such thinking led to the invention of the modern-day thermometer.

**math Link**

In Canada, we report temperatures in degrees Celsius. In the United States, temperature is reported in degrees Fahrenheit. The conversion equation is: $^{\circ}C = 5/9(^{\circ}F - 32)$. If you were watching an American weather forecast, and the temperature was 75°F, what would the temperature be in degrees Celsius? How would you convert 30°C to degrees Fahrenheit?

### Thermometer Scales

Galileo Galilei, an Italian scientist, invented the first device for measuring temperature in the 1590s. But it was not until the early 1700s that an accurate way to measure temperature was developed by a German physicist, Gabriel Daniel Fahrenheit. The scale that he created became known as degrees Fahrenheit, and this is still used in many countries today—including the United States.

In 1742, Swedish astronomer Anders Celsius came up with a different scale for measuring temperature. This is the one that we now use in Canada, measuring temperature in degrees Celsius.

**Inquiry Activity**

# Investigating Temperature Measurement

### Materials & Equipment

- 400-mL beaker
- ice
- water
- unmarked alcohol thermometer
- stirring rod
- felt pen
- hot plate
- oven mitts
- ruler

**Caution!**
Use oven mitts to remove the beaker from the hot plate. Be careful not to splash any hot water.

## The Question

How can you make a thermometer to measure temperature?

## Procedure

1. Fill the beaker with ice and water. Place the unmarked alcohol thermometer into the ice and water. Use a stirring rod to stir the mixture. Mark the level of the alcohol on the thermometer with a felt pen. Remove the thermometer from the beaker.
2. Place the water on a hot plate and bring it to a boil. Carefully place the thermometer in the water. Once the level of the alcohol stops changing, mark the stable level on the thermometer. Remove the thermometer from the water. Turn off the hot plate and use the oven mitts to remove the beaker.
3. Using the ruler, measure the distance between the two farthest marks on the thermometer. Divide this distance into 10 equal sections and mark these divisions on the thermometer. Mark another point in the middle of each division.
4. Your teacher will give you a "mystery" liquid at an unknown temperature. Place your thermometer into the solution and record the level.

**Figure 2.10** Step 1 and step 2

## Collecting Data

5. Make a table or chart in your notebook to record the temperatures that you measure for the water and for the unknown liquid.

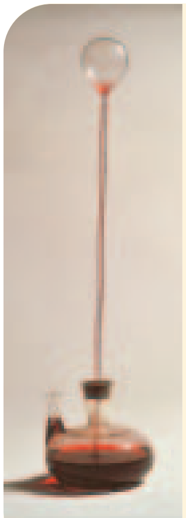
## Analyzing and Interpreting

6. Knowing that water freezes at about 0°C and boils at 100°C, determine how many degrees each division on your thermometer represents.
7. How close was your measurement of the temperature of the unknown liquid to the reading that your teacher had recorded? If there was a difference, why do you think this occurred?

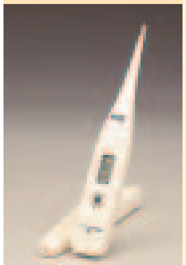
## Forming Conclusions

8. Describe how you constructed a thermometer and how it can be used to measure a range of temperatures. Explain any limitations to this device.

## History of the Thermometer

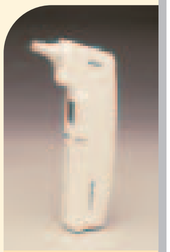


Galileo's thermoscope



Digital thermometer

| | |
|---|---|
| **200 B.C.** | A device, now generally known as a thermoscope, was used to show the expansion of air with an increase of temperature. Although the device did not have a scale, it is the oldest form of thermometer known. |
| **1590s** | Air thermometers, which used trapped air to measure temperature, were invented. These were, in fact, a form of thermoscope. One such thermometer, Galileo's thermoscope, is shown at left. |
| **1630s** | Use of water expansion thermometers was recorded. |
| **1650s** | The first sealed liquid thermometer was perfected. It was more accurate than the thermoscope. |
| **1714** | Gabriel Daniel Fahrenheit developed the first widely used measuring scale for temperature. He also perfected the use of mercury in liquid thermometers. |
| **1742** | Anders Celsius developed the centigrade scale. It was later renamed the Celsius scale. |
| **1852** | The modern form of the mercury-in-glass clinical thermometer was patented. |
| **1861** | The electrical-resistance thermometer was invented in Germany. It uses an electrical current to measure temperature. |
| **1970s** | The digital thermometer was introduced to consumers for home use. This instrument works in the same way as the electrical-resistance thermometer but has a digital scale. |
| **1990s** | The infrared thermometer was introduced to consumers for home use. It uses an infrared sensor to measure temperature. A small tip at one end of the thermometer inserted into a human ear measures the body temperature within seconds; this instrument is particularly useful with infants. |



Infrared thermometer

## Check and Reflect

1. Use Figure 2.11 to help you explain the difference between heat and temperature.

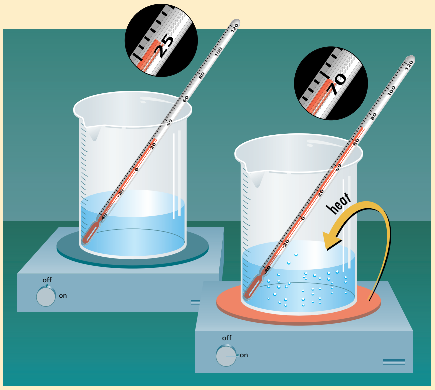



**Figure 2.11** Question 1

2. According to its definition, temperature is a measurement of the average kinetic energy of the particles in a substance.
   a) Explain "average kinetic energy" in your own words.
   b) Why is the word "average" important?
3. Describe three major changes to thermometers during the history of their development.

### reSEARCH

**Canadian Contributions**

How have Canadians added to our understanding of heat and temperature? What inventions or ideas have Canadians thought of to share with the rest of the world?

# 2.3 Heat Affects the Volume of Solids, Liquids, and Gases

When heat transfers from one object to another, the volume of each object is affected. If only a small amount of heat is transferred, you may not notice the difference. But if the difference is great enough, it can affect everyday life. This change in volume caused by heat transfer is an example of the particle model at work.

*info*BIT

**Balloon Brothers**

Thermal energy can be converted into flight. In 1783, Joseph and Jacques Montgolfier lit a fire under a large balloon made of paper and silk. The fire heated the air inside the balloon, causing it to expand. Since the heated air was less dense than the surrounding air, the balloon was able to rise into the sky.

## Observing the Effect of Heat

Think about the following examples. Work with a partner to develop a scientific explanation for what happened in each situation.

1. A large area of concrete is poured as a single slab to create a new outdoor basketball court for your school. The work is done in August before the new school year starts. A very cold winter follows. When spring comes and you and your friends want to use the court, you notice several large cracks in the concrete. It looks like the concrete will need replacing.

**Figure 2.12** The concrete cracks after a cold winter.

2. You are working on your bike on a hot summer afternoon. You need to replace a metal bolt, and you find that it fits inside a metal nut. Leaving most of your tools and the bike sitting in the sun, you take a break for an hour. When you come back, you pick up the bolt and find that it's hot to the touch. You grab the right size of metal nut that has been sitting in the shade. It doesn't fit. You use an identical nut that had been sitting in the sun, and it fits!

**Figure 2.13** Fitting the nut to the bolt

3. After getting caught in a summer thunderstorm, you decide to make yourself a mug of hot chocolate. The biggest mugs are in your kitchen freezer, chilled and ready for lemonade on the next hot day. You take one, noticing that the thick glass is covered with a light layer of frost. As you pour the boiling water into the mug, you hear and see it crack.

**Figure 2.14** Boiling water cracks the chilled mug.

**Inquiry Activity**

# Heating and Cooling a Copper Wire

## The Question

What will happen to copper wire when it is heated and cooled?

## The Hypothesis

Form a hypothesis based on the question. (See Toolbox 2 if you need help with this.)

**Caution!**
Always use caution around an open flame.

### Materials & Equipment

- 2 retort stands
- about 130 cm of thin copper wire
- metre-stick
- aluminum foil
- paper clip
- steel nut (not galvanized) or any mass of 20–25 g
- candle
- candleholder
- matches

**Figure 2.15** Step 3. Adjusting the paper clip and nut

**Figure 2.16** Step 7. Heating the copper wire

## Procedure

1. Wind and tie the copper wire around the two retort stands. Set the stands about 1 m apart so that the copper wire is taut.
2. Place a sheet of aluminum foil on a tabletop so that it is under the wire.
3. Carefully bend part of the paper clip into a hook shape. Hang the hook from the middle of the copper wire. Hang the nut on the open end of the paper clip.
4. Measure the distance from the bottom of the nut to the aluminum foil on the table. Record this distance.
5. Place the candle in the candleholder, and place the candle and candleholder on the aluminum foil below the wire. Carefully light the candle.
6. Write your prediction of what will happen when you heat part of the wire with the candle. Let the lighted candle heat part of the wire for about 2 min.
7. After 2 min of heating, carefully blow out the candle. Measure and record the distance from the bottom of the nut to the aluminum foil. Let the wire cool. Do not touch it as it will be very hot.
8. After about 10 min, measure and record the distance again from the nut to the aluminum foil.

## Collecting Data

9 Make a chart like the one shown below to record your data.

| Distance of Nut from Tabletop (mm) | | |
|---|---|---|
| Step 4 | Step 7 | Step 8 |
| | | |

## Analyzing and Interpreting

10 How did the distance from the nut to the aluminum foil change as heat transferred to the wire? How did it change as heat transferred from the wire?

## Forming Conclusions

11 Use the particle model to explain what happens to a copper wire when it is heated and cooled. Include a diagram to help make your explanation clear.

## Expansion and Contraction of Solids

The particle model of matter tells us that when the thermal energy of a solid increases, so does its volume. We say that the solid **expands**. This occurs when heat transfers to a solid. When the thermal energy of a solid decreases, its volume decreases, and the solid **contracts**. This occurs when heat transfers from the warmer solid to cooler matter.

This is critical information for people who work in a variety of professions. Engineers designing bridges and buildings need to consider this information in their plans. Steel beams will bend or even break if the plans do not allow for expansion and contraction. This process of expansion of a substance caused by an increase in thermal energy is called **thermal expansion**. Expansion joints were invented to deal with this and are used on bridges, highways, and between railroad tracks.

**Figure 2.17a)** When temperatures are low the space between metal joints is large. When temperatures rise the space between the metal joints closes up.

**Figure 2.17b)** Workers installing a gas pipeline

People who lay pipes for the gas pipelines, construction workers, and steelworkers are only a few examples of people who use the science of expansion and contraction in their jobs.

## Heat Affects the Volume of Liquids and Gases

Like solids, matter in the liquid and gas states will also expand when their thermal energy increases. That is, when heat transfers to them from warmer matter. And they will contract when their thermal energy decreases. That is, when heat transfers from them to cooler matter. Liquids usually expand more than solids do, but not as much as gases do.

## Expansion and Contraction in Liquids and Gases

We can see a simple example of expansion and contraction of a liquid in the thermometer. Liquid, usually alcohol, is placed in a narrow glass tube. As the liquid becomes warmer, it expands and rises in the glass tube. As it cools, contraction takes place and the liquid drops down.

Similar principles are at work when there is a change in the heat energy of a gas. Imagine that you are invited to a party in the month of January. At the end of the celebration, you take home a cluster of helium balloons tied to ribbons. It is a very cold night, and you walk quickly. The farther you go, the more the balloons seem to be "wilting." They no longer pull at the ribbons, but now bob near your shoulders. By the time you reach home, the balloons are noticeably smaller and look a bit wrinkled. However, after they have been in your bedroom for an hour, the balloons are in the same condition as when you left the party. Both contraction and expansion have been at work!

**Figure 2.18** Why are the balloons wilting?

*re*SEARCH

### Full Steam Ahead!

Steam-powered automobiles were popular in the late 1800s. Some cars could go very fast. In 1906, one car was clocked at 205 km/h! However, by the 1930s, because the internal combustion engine had become popular, steam cars had all but disappeared. How did the steam car work? What was the science behind this invention?

## Check and Reflect

1. You and your family give your grandmother a ring for her birthday. Unfortunately, it is too small to fit her finger. How can the concepts of heat and temperature help make the ring her proper size?
2. Write a hypothesis to explain how the particle model of matter explains expansion and contraction. Write your ideas in a paragraph and include a diagram to illustrate your explanation.
3. Use Figures 2.19a)–d) and your understanding of thermal energy, heat, and thermal expansion to answer each question.

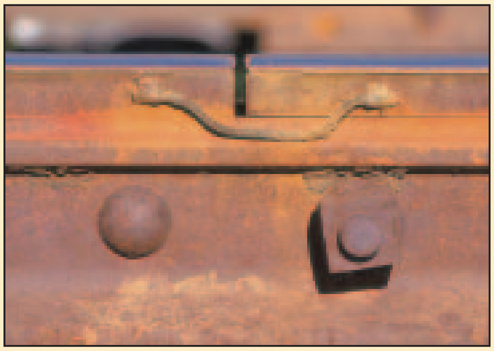


**Figure 2.19a)** Train tracks span great distances. Spaced many metres apart are small gaps between the rails. What's the purpose of these gaps? What might happen if the gaps weren't there?

**Figure 2.19b)** Workers set up these electrical cables during the summer. You'll notice that the cables are not stretched tightly. They sag. What is the advantage of leaving some slack when installing electrical cables like these? What might happen if the cables were installed tightly with no slack?

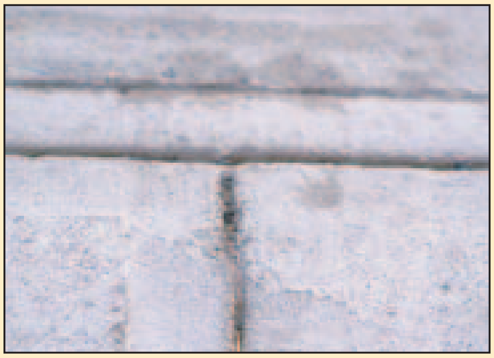


**Figure 2.19c)** Did you ever notice that sidewalks are made of slabs with gaps between them? What is the advantage of leaving these gaps? What might happen if the slabs were placed right up against each other?

**Figure 2.19d)** Pop and juice bottles are never filled all the way to the top. What is the advantage of leaving some space in these bottles? What might happen if the bottles were filled completely?

TRY This at Home

ACTIVITY

## HOMEMADE HOT-AIR BALLOON

Have you ever watched a hot-air balloon drift across the horizon on a warm evening? You can create your own balloon with a friend or family member by following these steps.

- Find a plastic bag, such as a large garbage bag.
- Check for and seal any holes in the bag.
- Using paper clips, gather parts of the open edge of the bag to make the opening smaller, about 10 cm in diameter. Spread the paper clips evenly around the opening.
- Ask your friend to hold the hair dryer so that the hot-air nozzle is pointed upward. Make sure that the air intake vent of the hair dryer is not blocked. This will prevent the hair dryer from overheating.
- Turn the hair dryer on to its highest heat setting. Be very careful when handling the hair dryer to avoid a burn.
- Gently bring the open end of your bag over the hair dryer, keeping it at least 10 cm away from the nozzle. Hold the bag in place until it appears to be full of hot air. Turn off the hair dryer. Release the bag and watch what happens!

**Caution!**
Be careful when using plastic bags, especially around younger children.

### *Materials & Equipment*

- large plastic garbage bag
- paper clips
- hair dryer (blow dryer)

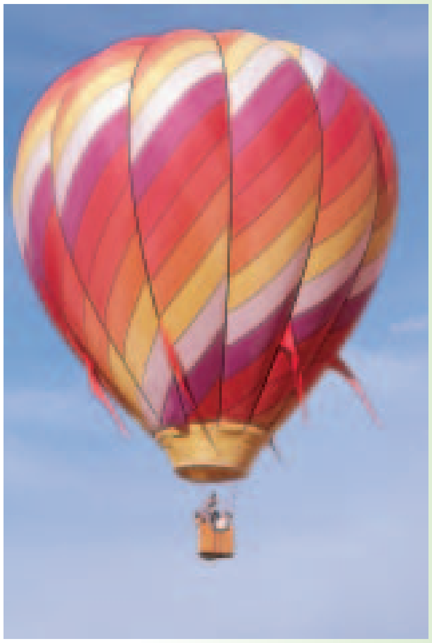


**Figure 2.20** A hot-air balloon

### Things to Think About

- Did your balloon go straight up or did it have a crooked flight?
- What could you add to your balloon to give you more control over its flight?
- Would using different types of bags make any difference to the results? Why or why not?
- Could you use more than one hair dryer?
- Would using different heat settings on the hair dryer make a difference to the flight of your balloon?
- How could you redesign your hot-air balloon so that it could carry an object like a pen or small toy into the air?

# 2.4 Heat Transfers by Conduction

If you have ever had the experience of roasting hot dogs or marshmallows over a fire using a wire coat hanger, you have probably noticed that the metal will heat up very quickly and burn your hand if you are not careful. When taking a metal tray from the oven, you need to use oven mitts to avoid a burn. In each of these cases, heat has transferred from the source to another substance.

**Figure 2.21** Oven mitts help prevent this person's hands from getting burned.

**infoBIT**

**Space Insulation**

A special thermal protection system prevents space shuttles from burning up on re-entering Earth's atmosphere. The shuttle's high speed compresses the air, which creates intense heat. NASA designers developed a special ceramic tile that can withstand temperatures of nearly 1400°C. Approximately 33 000 of these special tiles are attached to the underside of a shuttle.

## Conduction

One way that heat transfers through matter is by **conduction**. Conduction is the transfer of heat energy between substances that are in contact with each other. Here's how it works. Figure 2.22 shows a metal spoon in a cup of hot chocolate. The particles in the hot chocolate are moving rapidly, and they bombard the particles in the parts of the spoon that are in the hot liquid. The spoon's particles that are being pushed around start to move faster, vibrating back and forth. The faster they move, the greater the thermal energy in that part of the spoon. The spoon begins to warm up.

The parts of the spoon that are not in the hot chocolate become warm because of the movement of other particles within the spoon. The fast moving particles in the part of the spoon that had been warmed by the hot chocolate now bump into their neighbours in the spoon's handle. These particles speed up and bump into those next to them. And so on, until all the particles in the spoon are moving faster. Think of it as a chain reaction. None of the particles move from one end of the spoon to the other. The particles stay in the same part of the spoon. They simply transfer the energy by bumping into each other.

**Figure 2.22** A metal spoon in a mug of hot chocolate. Heat is transferred from the hot liquid to the spoon. The particles in the spoon speed up and the spoon becomes hot.

**Problem Solving Activity**

# The Butter Test

**Materials & Equipment**

- beaker or other suitable container for hot water
- butter or margarine
- assorted materials for testing
- paper towels

## Recognize a Need

You are doing research for a company that makes electrical appliances. These appliances generate a lot of heat, so designers want to use materials that will enable the heat to be removed. At the same time, they have to consider the cost of the materials. You have been asked to recommend the best conductor based on performance and cost. You will make your recommendation using data from the "butter test" and the cost information provided. The butter test involves placing a small amount of butter at one end of a piece of each material. You then place the other end of the material in hot water. The faster the butter melts, the better conductor the material is.

## The Problem

What material will be best to use in the appliances based on cost and conducting ability?

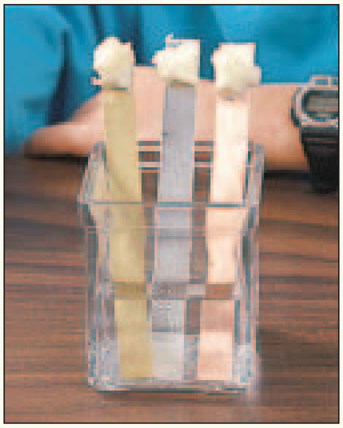


**Figure 2.23**

## Criteria for Success

For your recommendation to succeed, you must meet the following criteria:

- You must design a butter test for the materials provided to determine which material will melt the butter the fastest.
- You must base your recommendation on the butter test and the information you are given about the cost of each material.
- You must communicate your results using diagrams, charts, or graphs.

## Brainstorm Ideas

1. Your teacher will tell you what materials are available and the cost of each.
2. Working with your group, determine which variable is the manipulated variable and which one is the responding variable in your test. What variables will you be controlling (or keeping constant)? Record your ideas.
3. Determine how you will set up your butter test to ensure your variables are all controlled.
4. Create a plan and have it approved by your teacher before continuing.

## Test and Evaluate

5. Perform your test based on your plan.
6. Record your results.

## Communicate

7. Based on cost, what is the cheapest material to use for the appliances?
8. Based on conducting ability, what is the best material?
9. Based on a combination of cost and conducting ability, what is the best material to use?
10. Illustrate your results using diagrams, charts, or graphs.

## Conductors

One of the key characteristics of conduction is that heat transfers in only one direction—from areas of greater kinetic energy to areas of less kinetic energy. That is, heat transfers from areas having more thermal energy to areas having less thermal energy. One example is placing a hot water bottle next to cold skin. The hot water bottle contains more thermal energy than the skin does. So heat transfers from the hot water bottle to the skin. Although the temperature of the skin rises as conduction takes place, none of the matter from the hot water bottle moves to the skin. The skin becomes warm because of energy transfer between particles.

Conduction is most common in solids. It is less common in liquids, and it is rare in gases. Materials that allow easy transfer of heat are called **conductors**. Metals are examples of good conductors of energy.

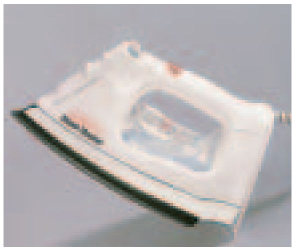


**Figure 2.24** An iron

**Figure 2.25** A metal pot and lid

**Figure 2.26** A curling iron

## Insulators

**Insulators** are materials that do not allow easy transfer of heat. They reduce the amount of heat that can transfer from a hotter object to a colder one. Plastic, cork, and wood are good insulators. This means that they are poor conductors of heat.

In household products that use heat, we often combine insulators with conductors to create safe tools. Look at Figures 2.24 to 2.26. Identify which parts of each device are conductors and which parts are insulators.

## Check and Reflect

1. What are the three types of changes that may happen when heat transfers into or out of matter?
2. Explain the difference between a conductor and an insulator, and give at least three examples of each.
3. The sun heats a wooden door and a metal knob on the outside of the door. What happens to the metal knob on the other side of the door? Write a paragraph using the words *heat energy*, *kinetic energy*, *conduction*, and *insulation* to explain the situation.

### reSEARCH

**A Good Idea?**

Use print or electronic resources to research what material is the best conductor, and list two of its uses. Prepare a diagram showing how it works in each situation, and a written summary of your results.

# 2.5 Heat Transfers by Convection and Radiation

*info***BIT**

**Burning Hot!**

The average surface temperature of the sun is 5500°C. The temperature at the centre of the sun is thought to be 15 000 000°C. Less than one billionth of the sun's total energy output reaches Earth.

**Caution!**
Use care with an open flame. Ensure there are no flammable materials close to the flame.

**Figure 2.27** Sitting around a campfire

If you have ever sat by a campfire on an evening when there was little wind, you may have noticed that the sparks from the fire did not simply go straight up into the air. Rather, they seemed to swirl and travel in an almost circular motion. If you added paper to the fire, you would have seen a similar motion as the embers (pieces of paper that are still glowing with fire) moved above the fire.

*Give it a* **TRY** — ACTIVITY

## CANDLE MAGIC

Work with a partner. Predict what the smoke will look like when you blow out a candle. Then, light a candle and let it burn for about 15 s. Gently blow out the flame. Notice what happens to the thin ribbon of smoke as it moves above the candle. Was your prediction correct?

## UNDERSTANDING CONVECTION

Another way that heat transfers through matter is by convection. In convection, heat is transferred when liquid or gas particles move from one area to another. Recall that in conduction, the particles do not move—only the heat does. In convection, the particles themselves move. For this reason, convection occurs only in liquids and gases.

### Convection Currents

Heat transfer by convection occurs when the particles in a liquid or gas move in circular patterns called **convection currents**. Convection currents form when heat transfers to liquids or gases. Figure 2.28 shows how convection currents form in a pot of water on the stove.

Heat first transfers to the bottom of the pot from the hot burner by conduction. In turn, heat transfers from the heated bottom of the pot to the water that is in direct contact with it. The kinetic energy of the water particles increases. They move faster and spread farther apart. In other words, the water at the bottom of the pot expands.

As the water expands, it becomes less dense and rises up to the surface. The particles in the rising warm water push the cooler particles at the top aside. This cooler water sinks toward the bottom of the pot to fill the space left by the rising warm water. When the cooler water reaches the bottom, it too heats up and expands. It rises, leaving space for more water from the top to sink downward.

As the water moves away from the heat source, it cools down slightly. When it reaches the top of the pot, it comes in contact with the air. Energy from the water transfers to the air, and the water cools down even more. This cooler water is pushed to the sides by the warmer water rising underneath it. The cooler water drops down along the sides of the pot. Here, too, energy is lost through heat transfer from the water to the pot and the air outside.

This sets up a circular convection current. As long as heat continues to transfer from the hot burner, this pattern of convection currents continues to transfer heat throughout the water.

**Figure 2.28a)** *Heat from the hot element reaches the water particles at the bottom of the pot by conduction.*

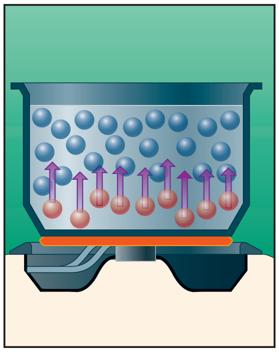


**Figure 2.28b)** *The heated water expands and becomes less dense. Hot particles begin to rise, pushing the cooler particles at the top to the sides.*

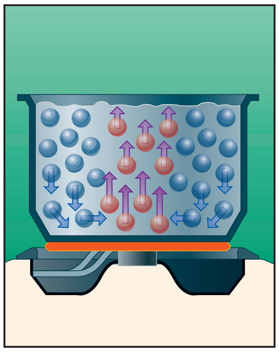


**Figure 2.28c)** *The cooler particles sink from the top to take the place of the rising particles.*

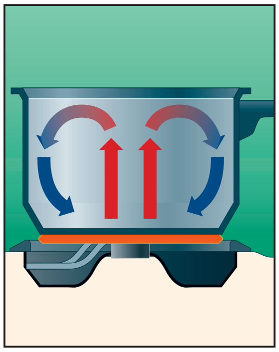


**Figure 2.28d)** *As the particles reach the bottom, they in turn are heated. The processes in Figures 2.28a)–c) repeat continually to result in a convection current.*

**Inquiry** Activity

# INVESTIGATING CONVECTION

## The Question

How does convection transfer heat in fluids?

### Materials & Equipment

*Part 1*

- smoke box
- small candle
- splint or incense stick to produce smoke
- fire safety equipment

*Part 2*

- small jar and lid with small hole in it
- warm water
- food colouring
- 70-cm string
- 2000-mL beaker
- cold water

## Procedure

*Part 1 Convection in a Gas (Teacher Demonstration)*

1. Set up the smoke box as shown in Figure 2.29.
2. Slide open the plastic front cover of the smoke box and light the candle. Slide the plastic cover back into place.
3. Wait for 1 min, and then light the splint or incense stick.
4. When the smoke from the splint or incense stick becomes visible, carefully hold the splint or incense stick at the top of the chimney on the side without the candle. Record your observations.

**Figure 2.29** Set-up of smoke box

*Part 2 Convection in a Liquid*

5. Fill the jar to the top with warm water that has been coloured with food colouring. Screw the lid on tightly. Tie each end of the string around the top of the jar below the lid to create a handle.
6. Fill the beaker two-thirds full of cold water. Lower the jar into the beaker until it is completely submerged but not touching the bottom of the beaker.
7. Record your observations when you first submerge the jar and then at 30 sec, 60 sec, and 120 sec after submerging it.

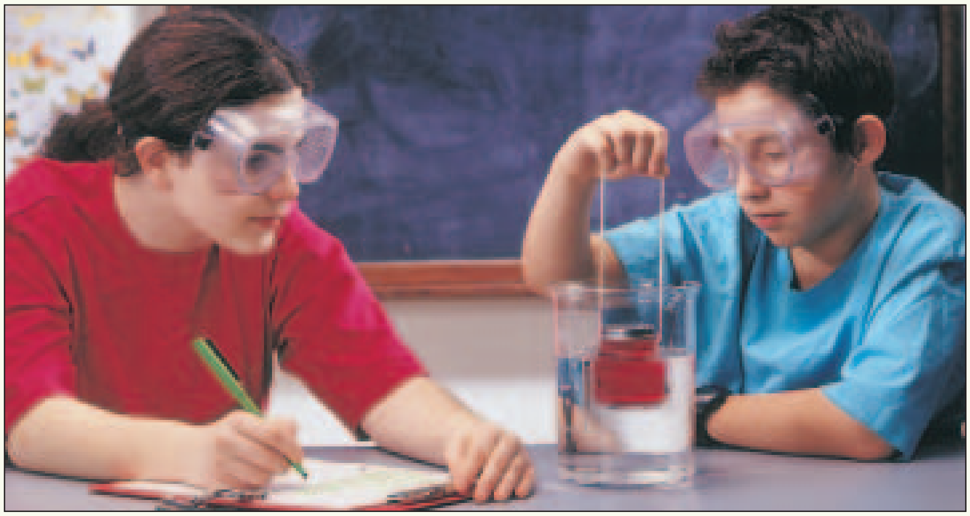


**Figure 2.30** Observe what happens to the coloured water in jar.

### Collecting Data

*Part 1*

**8** Draw the smoke box set-up when the candle is lit.

**9** On your drawing of the smoke box, draw the path of the smoke after the splint or incense stick is lit and held above the smoke box.

*Part 2*

**10** Record your observations in words and diagrams.

### Analyzing and Interpreting

*Part 1*

**11** What path did the smoke from the splint or incense follow? Did you see any evidence that hot air rises? If so, what is this evidence?

**12** What surprised you about the path of the smoke?

**13** What effect do you think the heat from the candle is having on the air inside the smoke box directly above the candle?

**14** As the candle heats up the air above it, what do you think is happening to the rest of the air inside the box? Outside the box?

*Part 2*

**15** What happened to the warm water as it remained submerged in the cold water? Why do you think this happened?

**16** Are there any similarities between your observations in part 2 of this activity and those in part 1? Provide examples to support your answer.

### Forming Conclusions

**17** Using your observations and discussions in class, describe how the process of convection transfers heat in a liquid and a gas.

## Convection Currents in Air

As with conduction, heat transfers by convection move in only one direction. It moves from an area of greater kinetic energy to one of lesser kinetic energy. Think about being in a cold room that has a heater in one corner. When the heater is first turned on, the only part of the room that is warm is the space closest to the heater. As the air near the heater heats up, it expands, becomes less dense, and rises. Cooler air moves in to take its place near the heater. This air is then heated, and it rises. Convection currents form, and eventually the entire room becomes warm.

## Energy Efficient Windows

Heat transfer by convection from a heater or in a cooking pot delivers heat energy where it is needed. However, convection can also cause heat loss. This used to be a problem in windows in houses. In the summer, people needed only one pane of glass in their windows. But our cold winters meant two panes of glass were needed to make houses feel more comfortable. Every fall, people would add another window called a storm window. These helped to keep houses warmer by reducing drafts and providing a bit of extra insulation. The extra insulation came from the air space between the inner and outer windows. Air is a poor conductor of heat.

The problem with the old storm windows was that they weren't very efficient. They still lost a lot of heat because convection currents would form in the air space between the panes of glass. The convection currents would transfer heat from one pane of glass to the other. Energy efficient windows are designed to reduce heat transfer. They do this by preventing convection from occurring between the panes of glass. Some windows contain a gas such as argon or krypton to improve their performance in reducing heat transfer. These gases are better insulators than air. They do not move as easily in convection currents as air does.

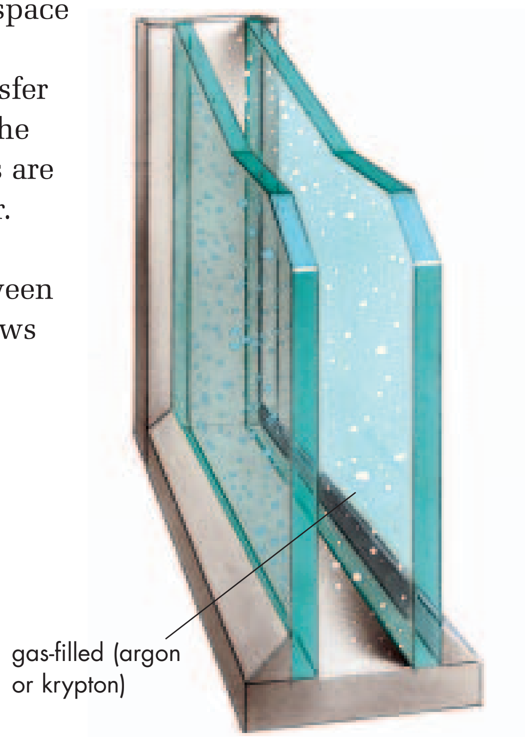



**Figure 2.31** An energy efficient window

## HEAT TRANSFERS BY RADIATION

Conduction and convection are two ways that heat transfer occurs. **Radiation** is the third. Both conduction and convection rely on the movement of particles to transfer heat energy. Radiation does not. Think of all the energy we receive from the sun every day. It reaches us across millions of kilometres of space where there are very few particles. Radiation is the transfer of energy by invisible waves that can travel great distances. Energy transferred from its source by radiation is called **radiant energy**. Heat is only one type of radiant energy. It is transferred by invisible waves called **infrared waves**.

When the invisible radiant energy waves come in contact with an object, the particles in the object increase in kinetic energy. The particles move faster and the object becomes hotter. Every hot object produces some radiant energy. That's why your hand feels warm when you hold it near a hot object without touching it. The heat you feel is transferred to you by radiation.

**Figure 2.32** Even on a cold day, the sun's radiation can heat the floor.

You get into a car that has been parked in the sun on a hot, sunny day. It is hot inside—the fabric seat feels quite warm. But try touching the dashboard. It's probably so hot that it can almost burn your hand! Part of the reason for this is that the different materials absorb the sun's heat to different extents. Now, think about the clothing you have worn on hot, sunny days. Do you recall how you felt when you wore light-coloured and dark-coloured clothing? How do you think the different colours affect the absorption of the sun's heat?

**Inquiry** Activity

# Heating Different Coloured Surfaces

## The Question

How do different colours of surfaces affect the absorption of heat transferred by radiation?

## The Hypothesis

Restate the above question in the form of a hypothesis.

*Materials & Equipment*

- 2 large test tubes
- test-tube rack
- sand
- white paper
- scissors and tape
- 2 thermometers
- black paper
- 100-W light bulb (optional)
- timer

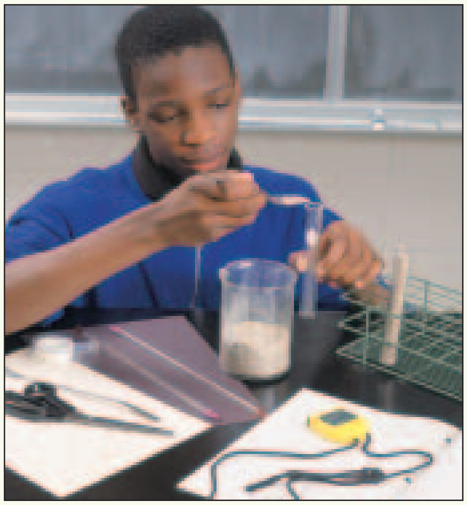


**Figure 2.33a)** Step 1. Filling the test tube with sand

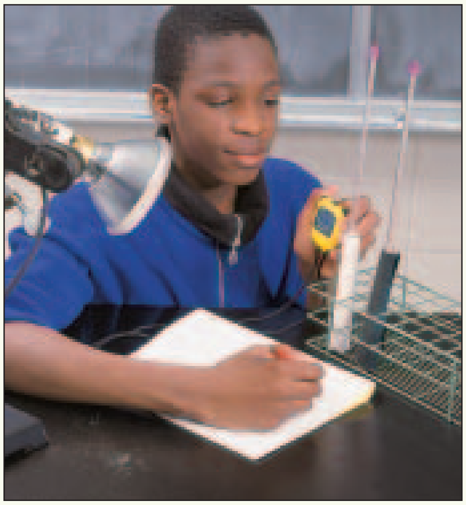


**Figure 2.33b)** Step 8. Using the stopwatch to keep track of time

## Procedure

1. Fill each test tube with sand to the top.
2. Tape white paper around one test tube so that it is fully covered, including the top.
3. Cut a small hole in the top and carefully insert a thermometer about 5 cm into the sand. Gently tap the test tube to pack the sand as you insert the thermometer. Put the test tube back in the test-tube rack.
4. Repeat steps 2 and 3 with the other test tube using black paper. Make sure that the thermometers are inserted to the same depth in the two test tubes. Put the test tube in the same rack next to the white test tube.
5. Read the thermometers and record the temperature of the sand in the test tubes.
6. Place the test tubes in the rack in the sun on a window sill. If there is no sun, use a 100-watt bulb as a heat source and put the rack 20 cm in front of the bulb.
7. Predict which test tube will heat up faster in 15 min.
8. Read and record the temperature in each test tube every 3 min for 15 min.

### Collecting Data

9 Record your temperature readings in a data chart like the one shown here.

| White Tube | | Black Tube | |
|---|---|---|---|
| Time (min) | Temperature (°C) | Time (min) | Temperature (°C) |
| 0 | | 0 | |
| 3 | | 3 | |
| 6 | | 6 | |
| etc. | | etc. | |

### Analyzing and Interpreting

10 Use your data to draw a graph showing how the temperature of the sand changed over time in each test tube.

11 Based on your graphs, which test tube heated up faster?

### Forming Conclusions

12 Present your results in a summary in paragraph form. Your summary should answer the following questions:

- Which of the two test tubes absorbs more heat from the sun?
- What do you think your results would be if you had added a third and a fourth test tube and used orange paper on one and aluminum foil on the other to cover them? Explain your reasoning.

13 How did the results compare with your hypothesis?

### Applying and Connecting

Clothing designers may use certain colours during one season but not the next. Most people wear white or other light colours in the summer to reflect the sun's heat. In winter, black or dark colours are the choice for many people since they absorb heat. Designers know this and keep it in mind when choosing fabrics.

**Figure 2.34** Dressing for the different seasons

## *re*SEARCH

**Planets of the Solar System**

Of the planets in the solar system, Mercury is closest to the sun. However, Venus, its neighbour, has a higher average surface temperature. Why?

## Reflect or Absorb?

Matter can reflect or absorb radiant energy. Objects that are shiny and light coloured are good reflectors of radiant energy. So on a hot, sunny summer day, to stay cool, you would probably choose light-coloured clothing. Dark and dull objects are good at absorbing radiant energy. If you have been on a black sand beach such as those found in parts of Europe, the Caribbean, or the South Pacific, on a sunny day, then you know just how good dark colours are at absorbing radiant energy! At the hottest point in the day, the skin on the soles of people's feet will begin to burn if they run barefoot over a long stretch of sand.

**Figure 2.35** A black sand beach in Spain

## Check and Reflect

1. Explain how convection works to make your bedroom warm.
2. Use what you have learned about convection to explain why the floors in most homes are cold in winter.
3. Tanning studios have become popular in the past few years. How can you get a tan in a tanning studio?
4. If more radiant energy was allowed to reach the surface of Earth, what do you think might happen? Why?

## Assess Your Learning

1. Create a mini poster that shows your understanding of conduction, convection, and radiation.
2. You try, unsuccessfully, to open a brand new jar of pickles. You find that the lid is too tightly sealed. After running the lid under the hot water tap for a short time, you are able to open the lid. Explain what happened.
3. It is a hot day and your family decides to have ice cream with dinner. You walk the 30 min to the store to get 1 L of ice cream. Knowing that it will melt before you get back, you need to make a plan to get the ice cream home in its solid state. What would you do? Why?
4. Teeth are examples of solid matter. When you eat hot food or drink cold water, your teeth will expand or contract depending on the temperature inside of your mouth. What would a dentist need to consider when filling a cavity?
5. Summarize your new learning on the mind map that you started on page 189.

## Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Understanding the science of heat helps us to appreciate how it affects our lives. In this section, you read about examples of how we use heat technology to meet our needs. Think about the information you learned and the activities you did in this section.

1. You have studied how heat moves in three different ways: conduction, convection, and radiation. For each one, describe an example of a technology that uses that method of heat transfer to meet our needs.
2. Describe two examples of heat technology that you use in your daily life. Identify if the device uses conduction, convection, or radiation.

# 3.0

# Understanding heat and temperature helps explain natural phenomena and technological devices.

## Key Concepts

In this section, you will learn about the following key concepts:

- heat energy needs and technologies
- thermal energy
- thermal energy sources
- insulation and thermal conductivity
- energy conservation

## Learning Outcomes

When you have completed this section, you will be able to:

- describe ways in which thermal energy is produced naturally
- describe how solar heating works
- compare and evaluate materials that maximize or limit the transfer of thermal energy
- explain how devices and systems respond to temperature change
- describe how household devices allow us to generate, transfer, control, or remove thermal energy
- explain practical problems in controlling and using thermal energy

The glowing liquid rock, the blasting hot gases, the billowing ash—volcanoes are both frightening and fascinating. Imagine the amount of thermal energy that Earth must contain to melt rock into a flowing liquid. Volcanoes form when heat and pressure force this hot, liquid rock up to Earth's surface. In some volcanoes, like the one shown here, rivers of liquid rock flow from an opening in the ground. Fire and heat from such a river consume everything in its path. A volcano is just one indicator of Earth's thermal energy. Other examples include hot springs and geysers.

# 3.1 Natural Sources of Thermal Energy

What natural sources of thermal energy do you think exist? Look at Figures 3.1–3.4 and read the captions.

**Figure 3.1** The sun is Earth's natural source of thermal energy. Many people refer to the sun's energy as solar energy. "Solar" comes from the Latin word *sol*, which means sun.

**Figure 3.2** Earth is a considerable source of thermal energy. Much of this energy remains deep inside. It is called **geothermal energy**. "Geo" means Earth, and "thermal" means heat. This geothermal energy is being used in Iceland and parts of New Zealand to provide hot water and to grow crops.

**Figure 3.3** All fires consume some type of fuel (wood, oil, coal, or natural gas). Fire converts the chemical energy stored inside the fuel into thermal energy, light energy, and often, sound energy.

**Figure 3.4** Decay is a source of thermal energy. The breakdown of dead plants and animals releases thermal energy. If you have ever done any composting, you have felt the thermal energy produced by the decaying process.

*Give it a* **TRY** ACTIVITY

## APPLICATIONS OF THERMAL ENERGY

So far in this unit, you have discussed and investigated many uses of thermal energy. Work with a group. Brainstorm as many of these applications of thermal energy as you can think of. Record your ideas, in words and pictures, on a sheet of paper that will be your "thermal energy placemat." Share your results with other groups. Change or add to your placemat as you work through the rest of this unit.

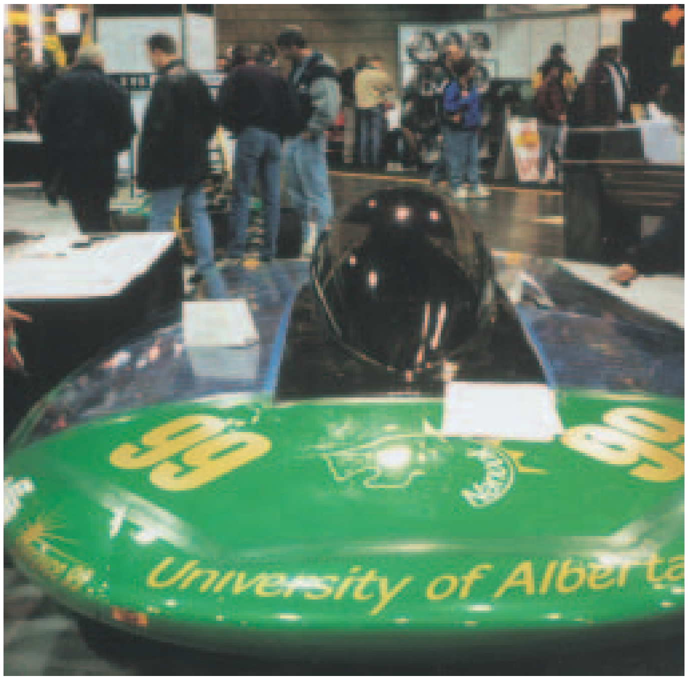
## FOCUS ON SOLAR ENERGY

Solar energy, or energy given off by the sun, is the most important source of thermal energy for life on Earth. This type of thermal energy is produced by the nuclear reactions that happen inside of the star that is our sun. Every 40 min, the level of energy that comes to Earth is equivalent to the energy used by humans over the period of a full year. Imagine being able to store all of that energy!

*info***BIT**

**Nanook**

Question: What do you get when you combine more than 70 students from the University of Alberta and the Northern Alberta Institute of Technology (NAIT) with an exciting dream for an environmentally friendly car? Answer: *Nanook*, Alberta's first ever solar-powered race car! *Nanook* is the product of 21 months of creative work by the student design team. Its ultra-sleek 5.8-m body is almost completely covered by 560 solar cells and weighs only 500 kg, including the driver. The solar cells capture the sun's energy, which becomes the race car's power source. Onboard batteries can store the sun's energy during daylight hours so that *Nanook* can travel up to 90 km/h—even at night—without burning any gasoline!



## Using the Sun's Energy for Solar Heating

Solar heating systems are of two types: **passive** or **active**. A passive system is heated directly by the sun's rays. It is designed to heat a building without fans or pumps to help carry the heat to different parts of the building. An active system will rely on some mechanical device to help transfer that energy.

**Figure 3.5** Windows in a passive solar house. In summer and at night, these windows are covered by special insulated shades.

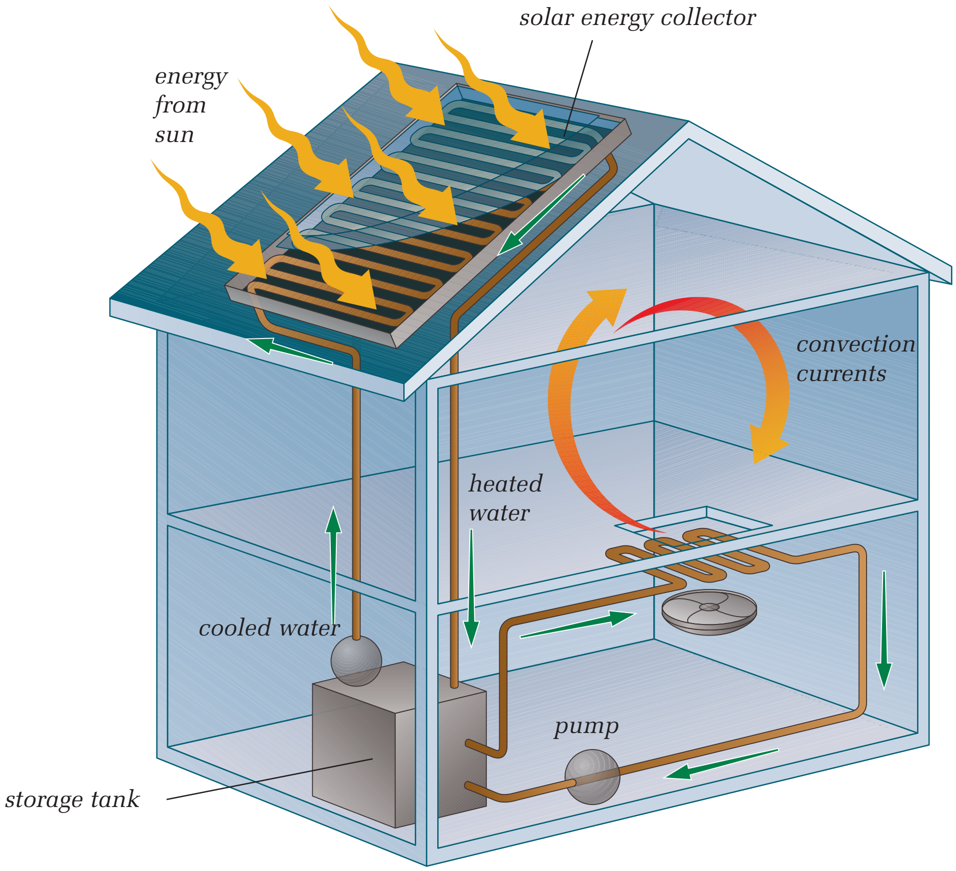
## Passive Solar Heating

The basic approach for passive solar heating is simple: reduce heat loss and increase heat gain from the sun. On the most basic level, this means insulating the building as much as possible and placing most of the windows on the south side. A large overhang above the windows shades them from the summer sun, so the building doesn't become too hot. In the winter, the rays of the low sun bring radiant energy into the rooms. The warmth this produces is carried to the other rooms in the building by convection currents.

The thermal efficiency of a building's design can be measured by how well it prevents heat loss. It can also be measured by how well it maintains an even temperature throughout a 24-hour period. Special materials can increase the thermal efficiency of a passive solar home.

Extra panes of glass and special coatings on windows allow windows to let radiant energy from the sun in, but prevent much of it being reflected back out. Special materials in the house can be used to store thermal energy. For example, a stone or brick wall inside the room is placed where the sun shines on it most of the day. Some of the sun's heat transfers to the stone or brick. The stone or brick stores it as thermal energy. Then, at night, when there is no sun and the room begins to get cold, the stone or brick heat transfers into the air and keeps the room a comfortable temperature.

Figure 3.6 An active solar heating system




## Active Solar Heating

Active solar heating systems usually have three components: a collector, a heat storage unit, and a heat distribution system. Look at Figure 3.6.

Water is used in the collector to trap solar energy. Copper tubing on a black surface is placed under glass panels. As the sun's rays pass through the glass, the area becomes heated. Insulation helps to keep the thermal energy from escaping. The water running through the copper tubing becomes heated and is pumped to the heat storage and distribution units.

In a prairie climate, a combination of passive and active solar systems can usually meet up to 75% of a family's heating needs. In warmer climates, a greater percentage is possible. Landscaping can also add to the effectiveness of a solar design. Trees can block cold winter winds and help to provide a cooling shade in summer.

Depending on your location and the season, a backup heating system is usually needed for both passive solar and active solar heating systems. The backup system is used when sunlight is not available, or when not enough heat is collected during the day to keep a building warm during the night.

**Decision Making Activity**

# Is Solar Energy a Practical Option?

## The Issue

One option for heating our homes is with active or passive solar systems. Is solar heating a practical option for your home?

## Background Information

Solar energy is not just for new homes. New homes provide an opportunity to design a house in the most effective way to use the sun's energy. These designs include the use of special materials and equipment. But it is possible to change existing homes—including apartment buildings—to make some use of solar energy. For example, placing solar collectors on the roof could provide some hot water. Adding or increasing the size of the windows on the south side of a building could provide some of the space heating. These windows would have to be well insulated at night so they would not allow heat loss from the space.

Many companies that sell solar energy products advertise on the Internet. Do a search for these Web sites and make a list of sources. Use these sources to find information about the cost and efficiency of solar heating products and designs. Make a list of solar options that could be used in your home. For each one, list its approximate cost and its advantages and disadvantages.

## Support Your Opinion

Do you think solar energy is a practical option for your home? Write a paragraph summarizing your opinion. Make sure to support your opinion with facts from your research.

**Figure 3.7** Solar panels

**reSEARCH**

**Solar Energy Uses**

Prepare a report on how solar energy is used in scientific experiments.

## Solar Energy and Electricity

In addition to providing heat, solar energy can be converted into electricity. Solar cells are arranged in panels which are connected to form a **solar array**. A series of these solar arrays are then placed so as to capture and store the sun's energy in low voltage batteries. Household appliances needing electricity can use this solar energy during the day. Electricity can also be drawn from the batteries when the sun has gone down. Remote weather stations are often powered in this way because it is both difficult and expensive to deliver regular electricity to these areas.

**Figure 3.8** This photo shows a different kind of solar array. Here, an array of hundreds of mirrors reflect solar energy onto a water-filled tower. This heats up the water to produce steam, which is used to generate electricity. Such arrays are set up in desert areas where there is plenty of sunshine and little rain.

## Costs and Benefits of Solar Energy

Solar energy has many benefits. Unlike fossil fuels, the sun's energy is not limited, and it is available to everyone. Solar energy does not create pollution in the way burning fossil fuels to provide energy does, nor does it carry the radiation risks that nuclear energy does.

However, the cost of setting up a solar system is usually more expensive than conventional fossil fuel or electrical systems. Generally, in Canada, solar energy cannot provide all the space or water heating needed in a home. A backup system is needed using conventional fuels or electricity. Solar cells for electricity are expensive and cannot provide large amounts of electricity economically. Disposal of solar cells when they are no longer operational may be an environmental concern.

Passive solar energy use continues to be a lower cost option. Maximizing solar energy use this way can be costly—special designs and special materials are needed. But as you read earlier, simple changes can be made to existing buildings to increase the use of solar energy.

Research and development continue into ways of improving the efficiency of solar devices and decreasing their costs.

## Check and Reflect

1. Describe four ways in which thermal energy is produced naturally. Give an example of each way not mentioned in this section.
2. What is a passive solar heating system?
3. Predict how important you think solar energy technology will be 100 years from now.
4. Explain how our way of life today affects our thinking about whether or not to use solar heating in our homes.

# 3.2 Heating System Technologies

Think for a moment about what it is like to be cozy in your bed while there is a snowstorm happening outside. In addition to the blankets that you have wrapped around you, the furnace in your home will help to keep you warm—even if it is –30°C outside. But how does the thermal energy from the furnace that is somewhere else in your home travel to your room? How does it know when to come on and when to go off? How is it that the furnace doesn't come on at all during the summer yet it starts up again on chilly fall mornings?

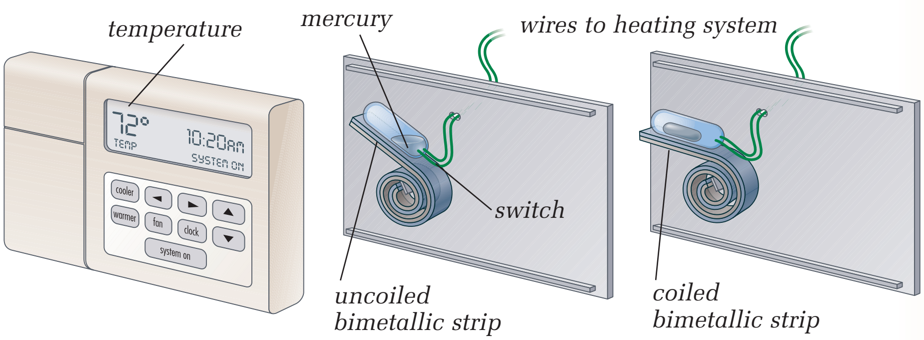
**infoBIT**

**Frosty Fact**

The first transatlantic shipment of frozen meat left Argentina in 1877, bound for France. However, all was not "smooth sailing" when the ship collided with another vessel. The accident caused a long delay and the trip took 6 months to complete. But thanks to a special ammonia compression system, the meat stayed frozen the whole way!

**Give it a TRY** ACTIVITY

## THERMOSTAT: WHAT'S INSIDE?




This diagram shows the inside of a typical thermostat.

Use this diagram to infer and explain how a thermostat works. Here are three tips if you need help.

a) Metals expand when they are heated and contract when they cool.
b) Not all metals expand and contract at the same rate.
c) An electrical conductor allows the passage of an electrical current.

Name five devices in which you would expect to find thermostats.

## Thermostats

In order to live comfortably, we need to be able to control the temperature of our indoor environment. Most people like to keep their homes, offices, and schools at "room temperature," or about 20°C. While this would have been a problem for people in Alberta 100 years ago, we now have **heating systems** that are controlled by **thermostats**. "Thermo" means heat and "stat" means to maintain or to keep the same.

Thermostats are used to control the air temperature in indoor environments. They are also useful in adjusting the temperature of electric appliances such as an oven or an air conditioner.

The switch in a thermostat is a bimetallic strip, which consists of two different metals joined together. When heated, one of the metals expands faster than the other. This causes the strip to bend.

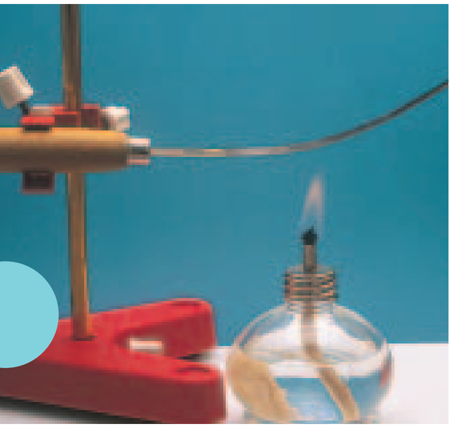


**Figure 3.9** A bimetallic strip bends when heated.

The bending effect of the bimetallic strip is used to measure temperature change. As the strip bends and unbends, it opens and closes an electric circuit that controls a heat-regulating device, such as an electric blanket.

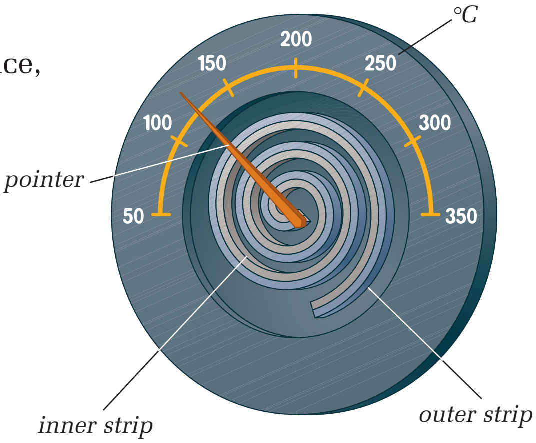



**Figure 3.10** When the coil of the oven thermometer is heated, the inner strip expands more than the outer strip. The coil opens. The more the coil is heated, the wider it opens. At the end of the coil is a pointer that moves over the scale.

## Heating Systems

There are two types of heating systems: **local heating systems** and **central heating systems**.

- Local heating systems provide heat for only one room or a small part of a building. Fireplaces, wood-burning stoves, and space heaters are common examples of local heating systems. Space heaters are small, portable heating systems that run on fuel or electricity.
- Central heating systems provide heat from a single, central source such as a furnace. The heat transfers through a network of pipes, ducts, and vents or openings in different places around the building. You very likely have a vent in your bedroom. Most newer homes with central heating systems use **forced-air heating**. Some older buildings use **hot-water heating**.

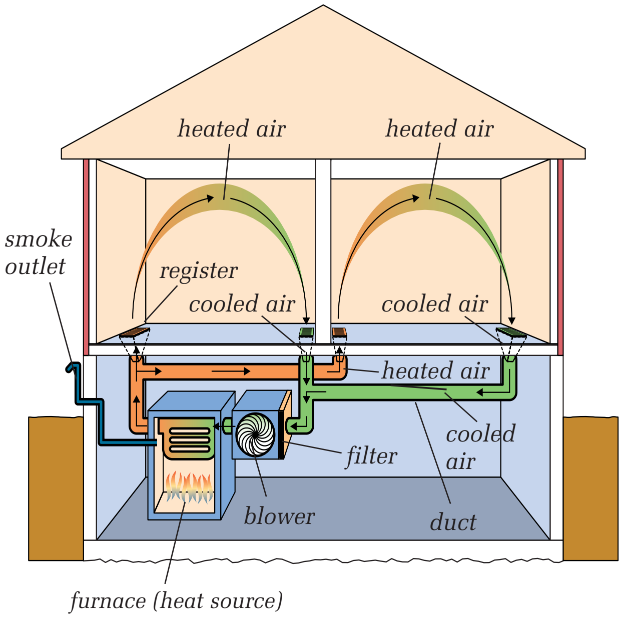



**Figure 3.11** Forced-Air Heating

- *Air is heated by burning fuel in a furnace.*
- *The heated air travels through ducts (pipe-like passageways) to registers in different rooms. (Registers are panels or grates in the wall near the floor or in the floor itself.)*
- *A blower helps pull returning air back to the furnace.*
- *The filter helps trap dust, hairs, and other fine particles before the air returns to the furnace.*

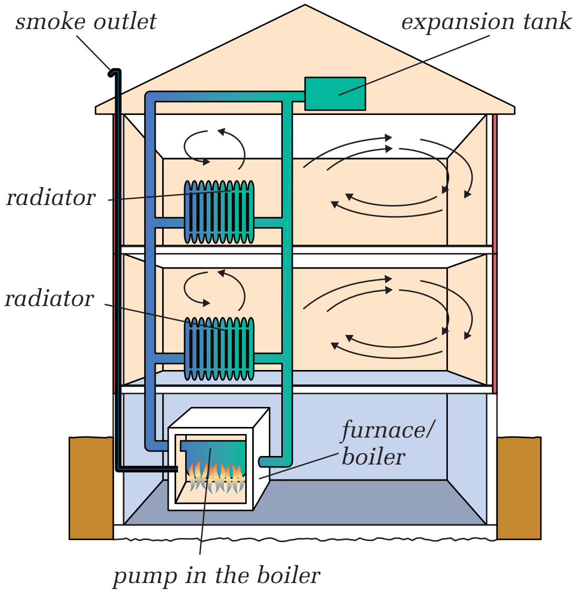



**Figure 3.12** Hot-Water Heating

- *Water is heated by burning fuel in a furnace or boiler.*
- *A pump forces the heated water through a network of pipes that lead to metal radiators.*
- *The hot water heats the radiators, which then warm the air in the room.*
- *As the water cools, it is returned to the boiler and heated up again.*

## Convection at Work

In each of these types of heating systems, the science of convection is at work. Keep in mind that heat travels in only one direction—from areas of higher kinetic energy to areas of lower kinetic energy. The air particles that have greater kinetic energy, and therefore feel warmer, will move faster about the room. As they come into contact with other air particles with less kinetic energy, the particles of cooler air will begin to move more quickly and the spaces between the particles will expand. This means that the volume of the air will increase. This expansion will cause further movement, and a kind of chain reaction will follow until all of the air in the room becomes warmed. But how does the heating system know when to stop providing thermal energy?

When a fireplace becomes too hot, we can adjust the damper. This device is a movable plate that controls the flow of air to the fire. Some space heaters come with an automatic shut-off, but most need people to turn them off when a room has become warm enough.

Most modern central heating systems are controlled by a thermostat. A thermostat makes automatic adjustments to the air temperature in a room by switching a heating system on or off.

## reSEARCH

### Jobs, Jobs, Jobs

In 1995, Canada's natural gas production was valued at $6.8 billion. Make a list of 10 different jobs that are connected with this field and describe how each is connected to the energy industry.

## Keeping Cool

On a hot summer day, nothing tastes better than a slush drink from the convenience store on the corner. As you have watched the coloured drink swirling around in the machine, have you ever wondered how it keeps from melting?

Did you know that thermal energy is needed to create the cold temperatures we link with such technologies as refrigerators, freezers, and air conditioners?

A motor powered by electricity or natural gas (both sources of thermal energy) is at the heart of all of these cooling systems.

Think about it like this. When you put water on your skin, it feels cool. As the water evaporates, it absorbs heat and creates the cool feeling. A cooling system removes heat from a room or other enclosed space. The basic parts of a cooling system are: a storage tank, a compressor, a freezer unit, condenser coils, and a **refrigerant**. The liquid, or refrigerant, used in a refrigerator evaporates at a very low temperature. This creates freezing temperatures inside the refrigerator.

Figure 3.13 shows how a typical refrigerator works. The refrigerant in the storage tank is pumped to the freezer unit. As it passes through the freezer unit, the liquid refrigerant evaporates. It cools as it evaporates so heat transfers from the warmer air inside the refrigerator to the cooler refrigerant. The refrigerator space becomes cooler, while the refrigerant becomes hotter. Now a vapour, it flows through the compressor to the condenser coils. Heat transfers out of the refrigerant, and it cools down and becomes a liquid. Then the cycle repeats.

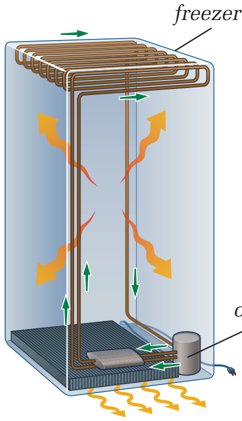



**Figure 3.13** A refrigerator's cooling system

## Check and Reflect

1. Describe some of the possible safety risks involved in not controlling heat and thermal energy in our homes. Include points about household appliances and other everyday devices that generate heat.
2. Explain how a thermostat works.
3. Describe how thermal energy is used to create cool temperatures.
4. Compare the forced-air heating system with the hot-water heating system. Which system would you choose for a house you designed? Why?

# 3.3 Heat Loss and Insulation

One of the challenges for Albertans is keeping the temperature of their buildings comfortable. In the winter, that means keeping the warm air inside and the cold air outside. In summer, it is exactly the opposite. The goal is to keep the cool air inside and the warmer air outside. How can this be done in a climate that has such extreme temperature shifts? Insulation!

*info*BIT

**Natural Insulators**

Fat is one of nature's most effective insulators. In animals like polar bears and seals, fat forms a protective layer to help keep heat from transferring out of an animal's body.

**Figure 3.14** Fibreglass insulation

## Insulation

As you learned earlier, an insulator is the opposite of a conductor. It limits the amount of heat that can be transferred by conduction. In the case of buildings, insulation is used to limit heat loss to the colder outside environment or to limit the amount of heat that is able to enter a cooler building on a hot day. Because heat transfers in only one direction (from areas of higher kinetic energy to areas of lower kinetic energy), insulation is useful in both cases.

The materials used in the construction of a building have a major impact on how heat can be transferred both into and out of a structure. The **thermal conductivity** of a material reflects its ability to transfer heat by conduction. When building a house, you want materials that are good insulators, not conductors. Stone and brick walls are good insulators. However, these can be very expensive, and many people choose to have a layer of Styrofoam panelling between the outer walls and the siding of their homes. Fibreglass insulation can also be packed between inner and outer walls and in the attics of buildings. Doors and windows are another important part of a good insulation plan.

**Figure 3.15** Styrofoam insulation

## Heat Loss

**Figure 3.16**
- white/yellow: the greatest heat loss
- pink/purple: the next greatest heat loss
- green/blue: the least heat loss

Contractors can use infrared photography to "diagnose" the areas of heat loss in a building. This kind of photo is called a *thermogram*. The colour shows the type of heat loss. Look at the thermogram in Figure 3.16. What recommendations would you make to the owners of this home?

The kind of heat loss shown by Figure 3.16 is fairly typical of most homes. Figure 3.17 illustrates this point. Notice that the roof, windows, doors, and walls are all part of the problem of unwanted heat transfer. This means that additional heat will need to be produced in order to keep our homes and other buildings comfortable. This is where the issue of waste comes in. We are wasting electricity and natural gas when the warm air within buildings is transferred to the outside. More resources, particularly the non-renewable resource of natural gas, must be consumed in order to meet our needs and wants for heat.

**Average Heat Loss in a House**

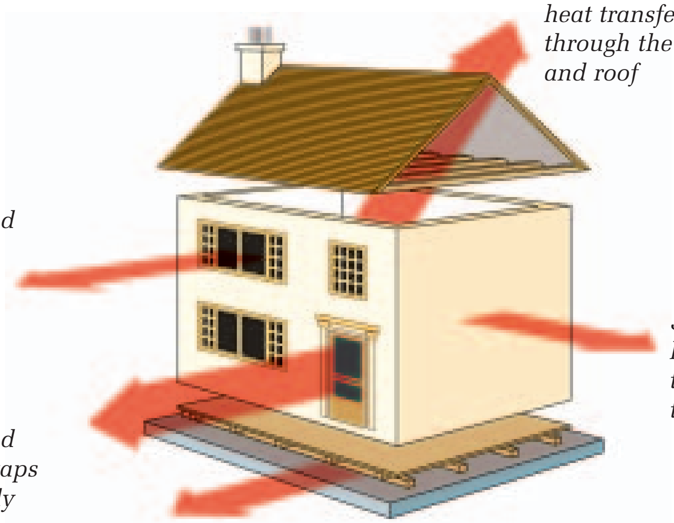



**Figure 3.17** Where does wasteful heat transfer happen in this house? Why does it happen in these places? How would you reduce it?

Many people are involved in developing better insulators to help us keep our indoor environments at a comfortable "room temperature." A lot of research has gone into inventing windows, doors, siding, weather stripping, and insulation that are more efficient at reducing unnecessary heat loss. A system of rating the quality of these insulators has been developed to let consumers know how effective different products are. Every insulator is given a number called an **R-value**. The higher the R-value, the better the product is at providing insulation.

**Problem Solving** Activity

# Mars Mission

## Recognize a Need

It is expected that humans will land on the planet Mars in the first half of this century. The first colonists on Mars will need to deal with temperatures as low as −126°C. As well, they will live through windstorms of up to 300 km/h. How will they stay warm?

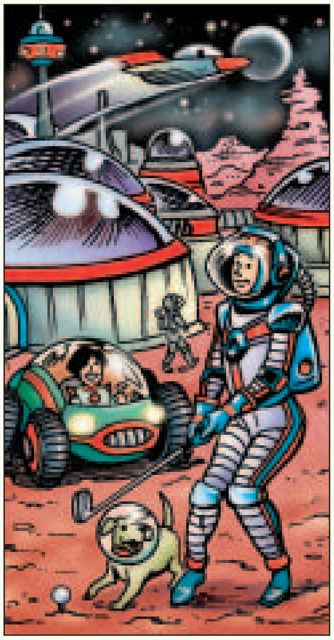


**Figure 3.18** Living on Mars

## The Problem

Use what you have learned so far to design a home for these future colonists. If possible, use a computer-assisted drawing program (CAD) or other graphics program to help give your work a professional finish. Insulation should be a major feature in your design.

## Criteria for Success

Your design should reflect what you have learned to this point in the unit. Your ideas for insulation materials should show your understanding of conductors and insulators. Keep in mind that the colonists will need to transport the building materials from Earth, so weight will need to be considered. Your design will not actually be built, but try to make it as workable as possible.

## Brainstorm Ideas

1 Work with a partner or in a small group. Brainstorm ideas that would fit the criteria. All serious ideas should be considered.

2 Look for ways to blend the best of the group's ideas.

## Design a Model

3 Use the computer to draft your design. If possible, use a three-dimensional design. Include a scale.

## Test and Evaluate

4 How effectively would your design protect the colonists? How well is it insulated? How well does it show your understanding of heat and thermal energy? Make adjustments to improve your design.

5 How practical is your design? That is, could it really be workable on Mars?

## Communicate

6 Share and compare your design with others in the class. You may wish to use a computer and/or a projector to enlarge your work. In your explanation, use your knowledge and the heat-related terms that you have learned to this point in the unit.

## Check and Reflect

1. Describe the role of insulation in keeping the temperature of a building comfortable.
2. Explain the difference between insulators and conductors.
3. Update your mind map. Be sure that you understand the major ideas and the details of this section. Make a list of any questions that you have and share them with a partner. Work together to find the answers.
4. Your neighbour has been complaining about cold drafts coming in under his doors in winter. He wants you to help him minimize his heat loss. What materials do you think might make good insulators? Make a list. Use your list to create a chart comparing which insulator(s) would be best in this situation. What questions would you like to ask your neighbour before you give him your recommendation?

## Experiment on Your Own

## Design Challenge: Insulate It!

### Before You Start ...

Review what you've learned about heat, conductors, and insulators. Now is an opportunity for you to apply that knowledge to stop or slow down an ice cube from melting.

Think about the strategies you would use.

### The Question

How can you design and build a device to prevent an ice cube from melting?

### Design and Conduct Your Experiment

1 Work by yourself or in a small group. What ideas do you have to solve the problem? Brainstorm a list of possibilities and then choose the best idea.

2 Create a plan for how you will build your device. Make sure to include a detailed sketch of your device and a list of the materials and equipment you will need. Have your teacher approve your plan before you start to build it.

3 Build your device. Test it. Do you need to make any changes to your device? Do so now. Retest your device if necessary.

4 Compare your device with those of your classmates. How successful were their devices?

## Assess Your Learning

1. Describe three ways in which thermal energy is found in nature.
2. In your own words, explain how solar energy works. Why do you suppose that it is becoming a more popular choice for consumers?
3. How does a bimetallic strip work? How does it respond to temperature change?
4. Describe the heating system used in your home. Draw a diagram to illustrate your explanation. Identify which natural resources are used to make the heating system work.
5. Explain why we need to control heat and thermal energy in the everyday devices that we use. How do these devices control that heat and thermal energy? What are the dangers of not controlling them ?

## Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

In this section, we looked at how our needs as a society help shape the development of heat-related technology. Think back to the activities you did and what you learned in this section.

1. How have the science of heat and heat-related technologies contributed to our well-being?
2. At the end of this unit, you will work on a project to determine the best options for improving the energy efficiency of an old house. What did you learn in this section that you think could help you with your project?

**Figure 3.19** What direction do you think the windows most likely face?

# 4.0 Technologies that use heat have benefits and costs to society and to the environment.

## Key Concepts

In this section, you will learn about the following key concepts:

- heat energy needs and technologies
- thermal energy sources
- energy conservation

## Learning Outcomes

When you have completed this section, you will be able to:

- identify different sources of heat and evaluate their possible impacts on the environment
- compare how much energy is used by different devices
- identify positive and negative consequences of energy uses
- describe examples of energy conservation

Earth Day is a day for celebrating nature and focussing attention on environmental issues.

Right now Canadians are using non-renewable resources at an increasing rate. In fact, 72% of our energy needs are met by using fossil fuels such as coal, oil, and natural gas. But what will happen when the supply runs out? Should we continue to rely on fossil fuels as such a major source of energy?

Deciding what heat technologies to use is a complicated decision. There are environmental, societal, and economic costs to consider. Achieving a balance among all three costs is not always easy. That's why choosing resources that are renewable is so important. Being able to sustain our energy resources is crucial to the future of the planet.



For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

# 4.1 Looking at Different Sources of Heat

Natural resources come from the environment and are not human-made. There are two types of natural resources: renewable and non-renewable.

Renewable natural resources are those that can be replaced. The sun's energy is an example of a renewable resource. Even though we use it, it is constantly being replaced. Another example is wind energy.

Non-renewable natural resources cannot be replaced. They are limited. For example, minerals such as gold are non-renewable resources. Once they have been used up, no more is available. Fossil fuels—oil, natural gas, and coal—are also non-renewable resources. We rely on them for our heat and thermal energy needs and wants, but once they have been used, no more are available.

*info***BIT**

**Nuclear Power**

The energy stored in 1 kg of nuclear fuel contains nearly 3 000 000 times the energy that is in 1 kg of coal.

**Figure 4.1** Burning fossil fuels pollutes the environment by releasing soot and ashes and gases such as carbon dioxide, carbon monoxide, sulfur dioxide, and nitrogen oxides.

*Give it a* **TRY** ACTIVITY

## LOST!

Imagine being lost while hiking in the woods. You have only one sandwich, two cookies, and an apple to eat. Your only source of water is the juice in your water bottle. Knowing that you will probably be found by this time tomorrow, you sit down to make a plan. How will your food and water last until then? Should you just eat it all now and hope for the best? Or should you try to ration it? Sketch a quick cartoon to show how you would solve this problem. How do you think this story could be linked to the way we use our natural resources? How do you think your solution would change if you had another person lost with you who had no food?

## Focus on Fossil Fuels

Fossil fuels formed from the remains of plants and animals that lived on Earth millions of years ago. Petroleum (oil) and natural gas are usually extracted from the ground by pumping. Coal is mined. All three are non-renewable resources.

Fossil fuels are used all over the world because they are fairly easy to obtain and transport. They have been available in large quantities and can be used for a variety of purposes. Most of our technology for transportation, heating, and electricity production is designed to use fossil fuels. Because of their widespread availability and technology, fossil fuels are generally cheaper to use than other energy sources.

In 1995, almost 60% of the world's energy needs were met by burning oil and natural gas. Coal provided another 30%. Alberta is rich in all three of these natural resources. Figure 4.2 shows how Canada's use of fossil fuels has increased over time and continues to increase.

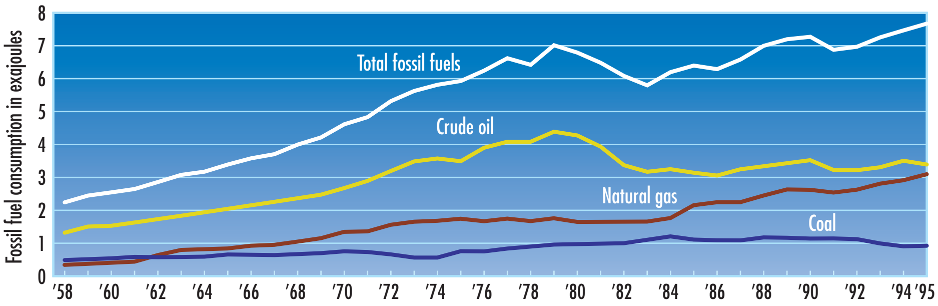



**Figure 4.2** Canadian consumption of fossil fuel

**Figure 4.3** Special technology is needed to drill below the ocean floor and to transport the oil and natural gas to shore.

Although fossil fuels are widely available today, they are non-renewable resources, so eventually they will be used up. As well, there are costs associated with their use today that should be considered when we compare them with other sources of energy.

### Economic Costs

The costs in dollars of using fossil fuels are what we call the economic costs. The most obvious economic cost for you and your family is the cost of buying gasoline to put in your car or natural gas to heat your home. There are other economic costs that you don't see when you pay for your fuel. For example, the companies developing fossil fuel resources must pay the cost of drilling wells for oil and natural gas or mining coal. There are the costs of processing the fuels and transporting them to market (pipelines, trucks).

Some economic costs, such as anti-pollution technology in cars, are associated with the environmental costs you'll learn about below. Economic costs such as these are considered when the costs of developing and using fossil fuels are being analyzed. But there are other costs as well.

### Environmental Costs

The negative effects on the environment of our using these fuels are called the *environmental costs* of fossil fuels. Most of these costs are the result of burning fossil fuels—in cars, trucks, and buses; in furnaces; and in electrical generating plants. When we burn these fuels, chemicals form that pollute the environment and contribute to global warming.

Air pollution caused by the burning of fossil fuels is a major problem in many cities. Gases such as sulfur dioxide and nitrogen oxides in the air are harmful to people's lungs. In earlier studies, you may have learned about acid rain. Rain falling through polluted air dissolves the sulfur dioxide in the air. Acid rain harms lakes and vegetation, as well as stone buildings and statues.

The environmental costs of fossil fuels can be reduced by improving technology. For example, car engines today are much less polluting than those of 20 years ago. Environmental costs can also be reduced by using less fossil fuel.

### Societal Costs

The negative effects on people all together are the *societal costs* of using fossil fuels. Most of these costs are closely linked to environmental costs. For example, pollution in cities causes increased breathing problems for people. The cost to our health care system of treating these problems is a societal cost of using fossil fuels. Similarly, the cost of treating lakes that have been harmed by acid rain is a societal cost because we all have to pay for it. These are societal costs that we deal with right now.

A major concern in the longer term is how we deal with the effects of using up these non-renewable resources. Because fossil fuels are non-renewable, it makes sense to consider other sources of energy that can help us meet our thermal energy demands.

## Alternatives for Thermal Energy

In subsection 3.1, you learned about solar and geothermal energy. These natural sources of thermal energy can provide some of our thermal energy. Other technologies to provide thermal energy are also being used or could be used.

### Wind Energy

Wind energy is the energy of moving air. It can be captured by windmills. In the past, windmills were used mainly to grind flour and pump water. You can still see small windmills on farms being used to pump water out of sloughs or dugouts. These simple windmills are inexpensive and practical. But the windmills used

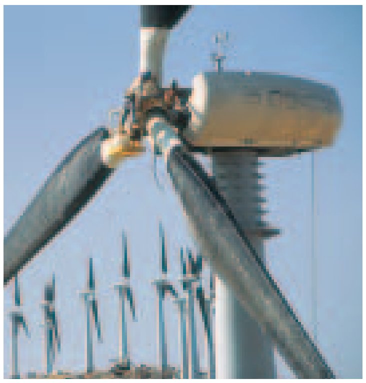


**Figure 4.4** A windmill

for large-scale energy production are high-tech devices specially designed to translate the wind's energy into energy that people can use for electricity. Figure 4.4 shows the kind of windmill used in large "wind farms." A wind farm consists of dozens—sometimes hundreds—of windmills constructed in particularly windy areas to capture the immense energy of the wind. Wind mills are not practical in areas that are not windy.

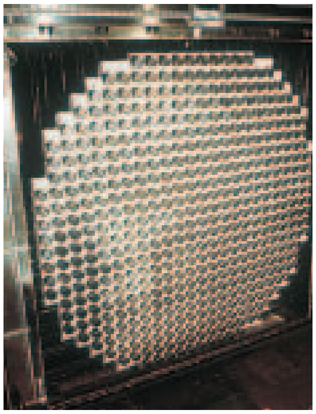


**Figure 4.5** Inside a CANDU reactor

## Nuclear Energy

Most of our electrical energy in Canada is generated from fossil fuel or hydro-electric sources. However, in central Canada, some electricity comes from nuclear energy. Nuclear fission is a process that uses small amounts of radioactive uranium to produce vast amounts of heat. Uranium is a non-renewable natural resource mined in Canada and other countries. Canadian scientists developed the CANDU (Canada Deuterium-Uranium) reactor to provide nuclear energy in parts of Canada and to sell to other countries. These reactors have one of the best safety records in the world.

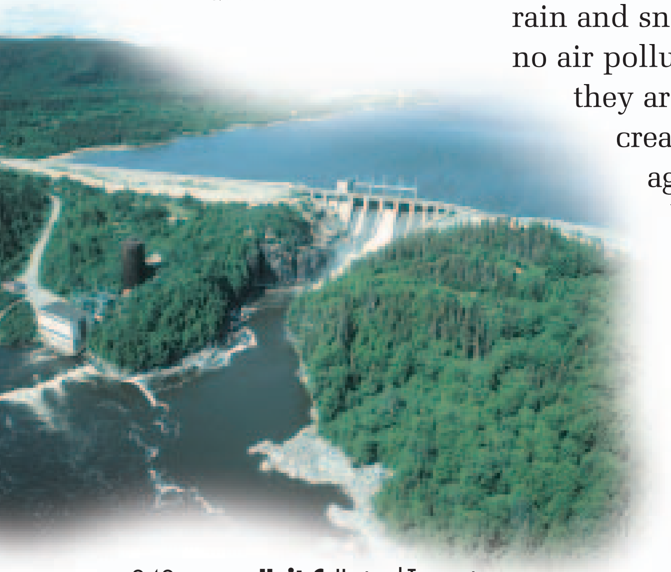
Nuclear power plants can produce large quantities of electricity. However, the fuel source requires special care in handling because it is harmful to living things. This harmful aspect remains after the fuel has been used. A major problem with nuclear energy is the long-term storage of dangerous waste materials.

## Hydro-Electric Power

Energy generated by water moving through a dam is called hydro-electric power. Dams are built across rivers to create large artificial lakes called *reservoirs*. The water from the reservoir flows through the dam where it turns large devices called turbines to generate electricity.

Hydro-electricity is very clean energy, and it's renewable. The reservoir is constantly being refilled by the river, which is fed by rain and snow. Nothing is burned in hydro-electric generation, so no air pollution is produced. Dams are not expensive to operate, but they are expensive to build. Dams and the reservoirs they create can upset or destroy local ecosystems and flood agricultural land. Long-distance transmission lines must be built from dams in remote areas to places where people can use the electricity. These lines are expensive to build. However, the electricity produced is used to produce heat in ovens, toasters, room heaters, and many other appliances.

**Figure 4.6** A hydro-electric dam in Quebec



**Problem Solving** Activity

# What's the Best Choice?

## Recognize a Need

Boiling water is an everyday activity. We do it for cooking, for making hot drinks, and for sterilizing objects. Which heat source will boil 1 L of water the fastest?

### *Materials & Equipment*

- oven mitts
- stopwatch
- large beaker or graduated cylinder
- water
- heatproof container for water
- a variety of sources of thermal energy chosen by you

## The Problem

Design and carry out a test to compare the time it takes for different heat sources to boil 1 L of water.

## Criteria for Success

For your test to be successful, you must meet the following criteria:

- You must safely bring the water to a full boil.
- You must measure the time it takes for the water to come to a boil.

## Brainstorm Ideas

1 Brainstorm a list of available heat sources that could be used to boil water.

2 Brainstorm ways that you can make the experiment fair. What would be some of the variables that you would need to control?

## Test and Record

3 Measure 1 L of cold tap water.

4 Bring the water to a boil.

5 Record the time needed in minutes and seconds.

6 Record the heat source you used.

**Caution!**
This experiment should be done with adult supervision. Use oven mitts and use caution around open flames and other heat sources.

**Figure 4.7** What is the fastest way to boil water?

## Communicate

7 Share and combine your findings with classmates. Construct a chart that will allow you to see everyone's results and to make comparisons.

8 If more than one person worked with a particular source (e.g., an electric stove), compare results. What could account for any differences?

9 Discuss the findings only in terms of the data recorded on the chart. Based on time only, which would be the best choice?

## Comparing the Options

In this unit, you have read about different ways of producing heat and thermal energy. Fossil fuels are the most widely used. But hydro-electric dams and nuclear power stations are also important in certain parts of the country for producing electricity that we can use to produce the heat and thermal energy we need. Solar energy offers a clean, renewable alternative but is not yet widely used. Other energy sources include geothermal and wind energy. Neither of these is widely used in Canada as yet either.

Each energy source has advantages and disadvantages. Some are non-renewable sources; some are renewable. Some can be distributed widely, as hydro-electricity can. Others are usable direct from the source, as solar energy is.

When you are analyzing options for selecting thermal energy sources, remember to consider where the energy will be used. For example, active solar heating may be an attractive option for home heating. But if your home is on the third floor of a 10-storey apartment building, active solar heating probably isn't a practical option.

## Check and Reflect

1. a) Make a chart summarizing the advantages and disadvantages of fossil fuel use.
   b) Why do you think people continue to use fossil fuels in spite of their disadvantages?
2. For each of the following energy sources, explain why it's a renewable or a non-renewable source.
   a) nuclear
   b) hydro-electric
   c) wind
   d) natural gas
3. Do you think all the sources of energy listed in question 2 will be in use 50 years from now? Explain your answer.

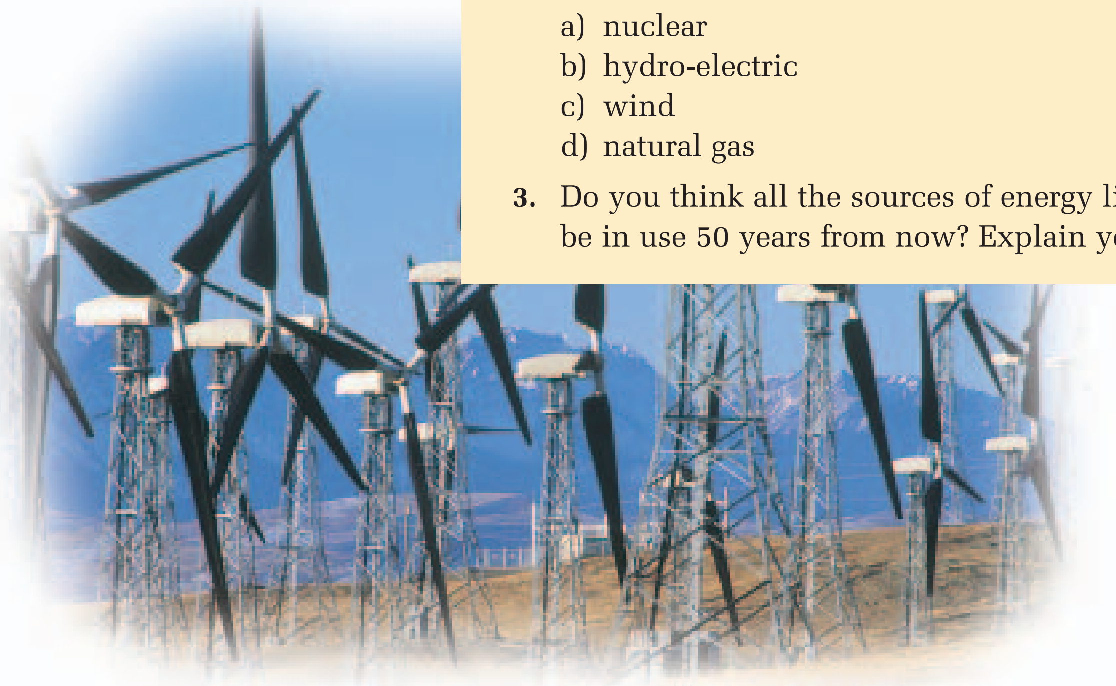


**Figure 4.8** Energy in the wind can be converted into electricity with the help of wind turbines.

# 4.2 Energy Consumption

**Figure 4.9** Hanging clothes on a line to dry conserves energy by not using a clothes dryer.

Have you ever considered how much energy you consume in a day? Do you run the water when you brush your teeth? Do you follow the three Rs—reduce, recycle, and reuse? Do you leave the light on when you are the last to leave a room?

*Give it a* **TRY** ACTIVITY

### ENERGY CONSUMPTION

Make a list of your everyday activities that require energy use. Compare your list with those of your classmates. Make a bar graph of everyone's data. What activity is the most common? the least common? As a class, brainstorm ways you could reduce your energy consumption.

*info*BIT

**Hybrid Power**

In the year 2000, Canadians were introduced to the "hybrid" car—a vehicle that combines an electric motor and a small gasoline engine with a lightweight body and special tires. Much less gasoline is burned (3.5 L/100 km), and the level of harmful gases given off is half that of regular cars. Japan's new laws about the issue of harmful emissions from cars was a major factor in the development of hybrid cars in that country. North American car manufacturers will be selling their own hybrid vehicles by 2003. It is expected that, by 2010, one out of every five cars on the road will be a hybrid.

### Home

The three main energy users are home, transportation, and industry. Energy use in the home is something that you can control. Look at Figure 4.10. Working with a partner, identify as many ways of conserving energy as you can.


**Figure 4.10** What are some ways you can save energy in each scene?

To help people be more energy efficient in their homes, some home renovation stores now carry a line of energy-efficient lighting products and devices that control power consumption by appliances. As well, some stores also stock low-flow shower heads that conserve water.

## Transportation

Most of us rely on cars or trucks for at least some of our transportation needs. In many rural or remote areas, there are no buses or other transit services, so people must use cars and trucks to get around. However, cars and trucks are big energy users and major contributors to air pollution.

Road, rail, air, and marine transportation together account for about 66% of the oil used in Canada. Of that amount, more than three-quarters is used to fuel passenger cars and trucks.

The burning of fossil fuels in car and truck engines produces a variety of harmful chemicals that pollute the air. For example, burning fuels causes nitrogen and oxygen in the air to form gases called nitrogen oxides. People with lung problems have trouble breathing air containing high concentrations of nitrogen oxides. If you live in a city, you may have noticed a brown haze, especially at rush hour. The brown haze is caused by nitrogen oxides in the air.

**Figure 4.11** Public transportation, such as the LRT in Calgary (shown), uses less energy than people driving cars. And there are many other alternatives to cars that should be taken advantage of.

## Actions You Can Take

What can you do to reduce the negative effects of cars? Try walking, riding your bike, roller-blading, or taking public transportation whenever possible. Does a family member drive you to school? Do other students in your neighbourhood go to your school? Maybe you could organize a car pool. Make a list of all the errands that you and your family have to do in a day. See if you can find an efficient way to combine them into one trip.

The size of a car and how it is driven can make a difference to its fuel consumption. Small cars usually consume less fuel, and regular tune-ups can ensure that a car operates more efficiently. Even the way people drive can save energy. Just by driving at 80 km/h instead of 100 km/h, a car owner can increase the number of kilometres travelled per litre by 15%. Reducing the amount of fuel we use conserves a non-renewable resource and reduces pollution.

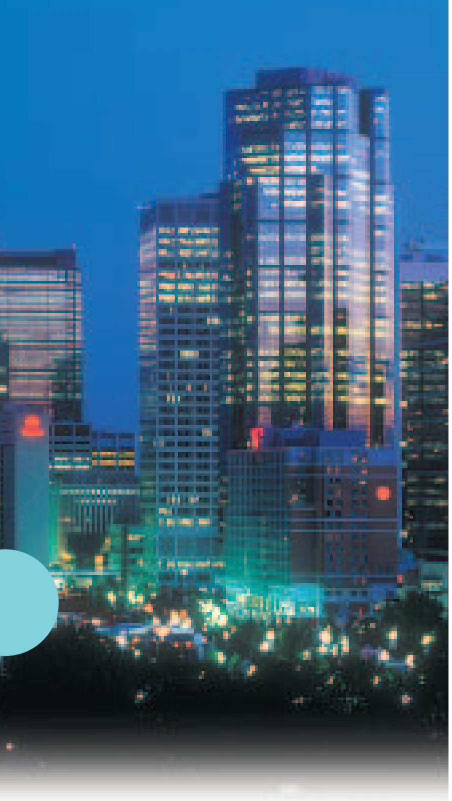


**Figure 4.12** Leaving lights on in empty offices overnight wastes electricity.

## Industry

Industry is the biggest energy user. Think about just one industry whose products you use: shoe manufacturing. Companies who make shoes have offices and factories that must be lighted and heated. They also have computers, photocopiers, and other office machines that need energy. In their factories, they use energy for preparing materials, such as plastic and leather, and for cutting and shaping shoes. Then, they use fuel for the trucks to distribute their products to stores. This is an example from just one industry. But all industries use energy in some way, even if it's simply for light, heat, and office machines.

Sometimes, industry's use of energy can harm the environment. Industry is the major contributor of chemicals called sulfur oxides, which turn to sulfuric acid in the air and form acid rain. Companies must meet a wide range of environmental regulations that are designed to reduce their effect on the environment.

For many companies, energy can be a major cost. In an effort to reduce these costs, they look for ways to reduce their energy consumption. An important tool that companies use is the energy audit. An energy audit focusses on finding places where energy is being wasted and identifying ways to fix the problem. For example, a company finds that they are losing a large amount of heat from leaving the huge doors in the loading area open all the time. By installing an efficient opening and closing system, they can keep the doors closed most of the time. They are only opened when a shipment is being sent out.

## Cogeneration

Some companies use such large amounts of electricity that they have their own small generating plants. However, electricity generation from fuel is not very efficient. Only about one-third of the energy produced from burning fuel such as natural gas, oil, or coal is transformed into electricity. The rest becomes heat that is usually just released to the environment as waste energy. To improve their energy efficiency, many large companies that produce electricity now use a process called **cogeneration**.

Cogeneration is the production of two forms of energy (usually electricity and heat) at the same time from one energy source. Not only large companies but other large organizations use cogeneration. The University of Alberta has its own electricity plant, so it now uses what would have been waste heat to heat the university buildings.

Decision Making Activity

# Conserving Energy in Your Community: Cogeneration

## The Issue

Your community is looking for a way to use energy more efficiently and reduce pollution. You already have an electricity generating station in your area. Some people have suggested that it could be converted to a type of energy production called cogeneration.

Your task is to determine the costs and benefits of cogeneration so that you can make a recommendation on whether cogeneration is a practical choice for your community.

## Background Information

Electricity generation from burning fossil fuels or other fuels, such as wood waste, is an inefficient process. Only about one-third of the energy produced is converted to electricity. The rest is heat, which is usually wasted by being released into the environment. In a cogeneration system, this heat is used to heat hot water, which is then pumped through pipes to heat buildings in the area. A cogeneration system uses one energy source to produce two forms of usable energy. Usually, these are electricity and heat.

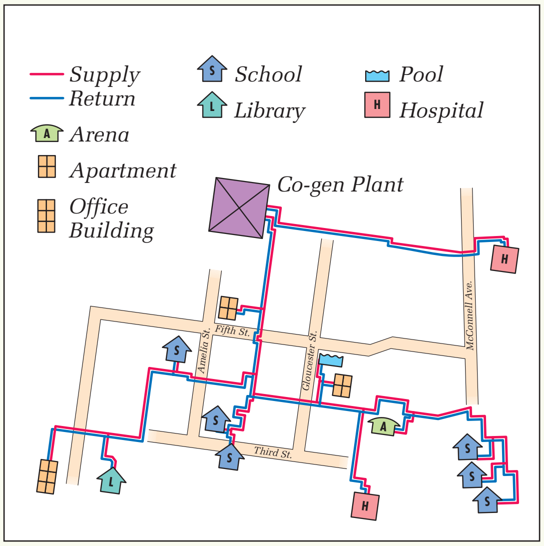



**Figure 4.13** The electricity generating plant in Cornwall, Ontario, uses its waste heat to heat part of the local community. Hot water is pumped through 10 km of underground pipes.

Cogeneration makes sense because:

- it makes good use of heat that would otherwise be wasted
- it reduces air pollution because two forms of energy are generated at the same time
- it reduces thermal pollution of rivers and lakes

Constraints to cogeneration in communities include:

- a large investment in equipment and in setting up the distribution systems, especially in areas that are already built up
- the need for cooperation among many groups: municipal government, the utility that owns the electricity generating plants, developers, and building owners
- problems with municipal and provincial regulations controlling placement of large plants and systems

## Support Your Opinion

Find out how your community meets its electrical and heating needs. Research the costs and benefits of cogeneration. Using the information from your research, explain in your own words why cogeneration would or would not make sense for your community. You may wish to illustrate your written work with a poster, diagram, or chart. In your report, suggest one or more scientific questions that would need to be answered before a final decision on cogeneration could be made.

## Being a Responsible Citizen

When people purchase products that promote a cleaner environment, they are making a responsible decision. As well, they can voice their ideas to government about supporting research that will help to develop new environmentally friendly technologies that use energy wisely.

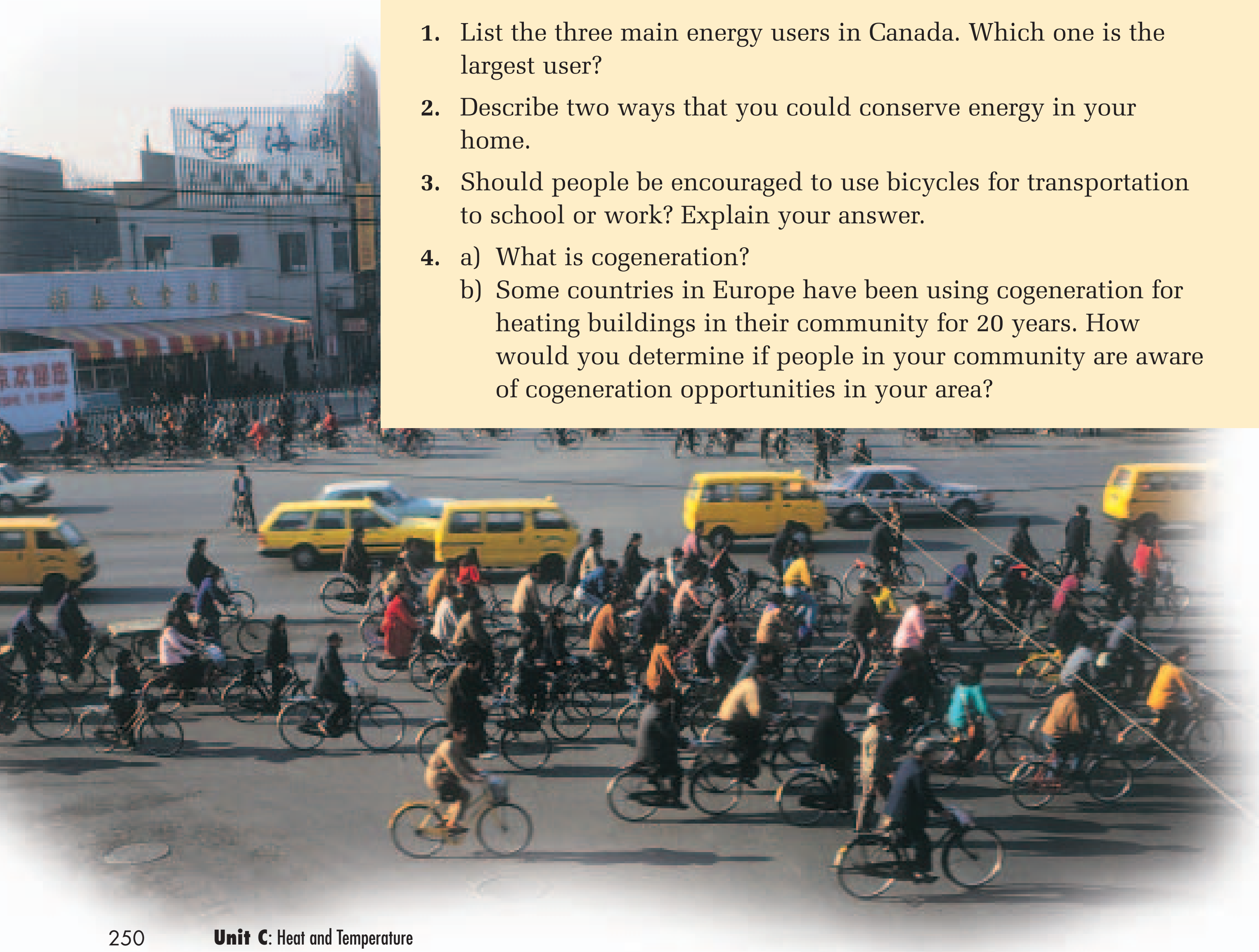
### reSEARCH

**Recycling**

Recycling is a good way to conserve energy and natural resources. Work with a group to prepare a radio announcement encouraging people to recycle. Find information about how much energy and money can be saved by recycling.

## Check and Reflect

1. List the three main energy users in Canada. Which one is the largest user?
2. Describe two ways that you could conserve energy in your home.
3. Should people be encouraged to use bicycles for transportation to school or work? Explain your answer.
4. a) What is cogeneration?
   b) Some countries in Europe have been using cogeneration for heating buildings in their community for 20 years. How would you determine if people in your community are aware of cogeneration opportunities in your area?



## Assess Your Learning

1. a) Make a chart comparing the economic and environmental costs of wind energy, nuclear energy, and hydro-electricity.
   b) Which one do you think would be the best choice for your part of the province? Why?
2. Do you agree or disagree with the following statement? Explain your answer. *We need to look at other sources besides fossil fuels for meeting our thermal energy needs.*
3. Most of British Columbia's electrical energy needs are provided by hydro-electricity. Most of Alberta's are provided by generating stations burning fossil fuels. Why do you think these two neighbouring provinces use such different technology?
4. You have been asked to design an action plan to help conserve energy at your school.
   a) What data would you need to collect before you could prepare your plan?
   b) Make an outline for your plan.
5. Complete the mind map that you started at the beginning of this unit.

## Focus On — SOCIAL AND ENVIRONMENTAL CONTEXT

Every day we use heat-related technologies, but we may not be aware of the effects of our using these technologies. For example, we know that when we turn on the shower, we'll get water the temperature we want. But the water is hot because technology was developed to heat that water using either electricity or fossil fuel. The use of these energy sources can affect the environment. Think back to the information learned and the activities you did in this section.

1. Brainstorm a list of at least five ways that you used heat or thermal energy in the past week. For example, you heated water for drink or you made ice cubes. What effect do you think your actions had on the environment?
2. Think about each action in question 1. Suggest a way that you could have done it differently.
3. What recommendations would you make for yourself and your family members in the future when making decisions about using heat technologies?

# The Ostrowskis: Clean, Green Living

The Ostrowskis' house

## The Issue

Sustainable living. How realistic is the idea? Imagine living in an Alberta home that had no natural gas line, no furnace, did not use city water or sewage systems, and used no city electricity. What century do you think you would be living in? The past? The future? How about today?

Meet Jorg and Helen Ostrowski, a twenty-first-century couple living in suburban Calgary. Their 170-$m^2$ environmentally friendly home reflects their commitment to a way of life that focusses on a minimal use of natural resources. In one year, they save an average of:

- $1800.00 on utilities (gas, water, electricity)
- $500.00 for space and water heating
- 10 000 kWh of electricity
- 5000 kg of coal for generating electricity
- 238 200 L of treated drinking water

Their home has such high-tech features as:

- solar power for electricity
- system for collecting and storing rainwater
- non-flush toilets that compost human waste
- super-efficient wood-burning fireplace for heating and cooking (uses one cord of wood per year—2.4 m long by 1.2 m wide by 1.2 m high. Scrap wood is collected from local companies rather than cutting down trees.)
- solar cookers for cooking and baking food

Making informed and responsible choices that protect the environment is at the heart of the Ostrowskis' lifestyle. They read labels and carefully consider how buying products will impact the environment. "In Alberta, we have an overabundance of natural resources and so we have lost our sense of appreciation. We need to reflect for a moment, to ask ourselves, 'What can we give back to society, to make the world better?' This kind of thinking makes us realize that what you put into the system comes back out," notes Jorg.

## Go Further

Now it's your turn. Follow the Ostrowskis' lead. Look into the following resources to help you form your own opinion about sustainable living.

- Look on the Web: Check out sustainable living or sustainable development on the Internet.
- Ask the Experts: Try to find an expert on sustainable living. Experts can be found in many places: environmental groups, universities, government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about sustainable living.

## In Your Opinion

Create a 3–5-min video, write an article for your school newspaper, or make a poster to share your views on sustainable living. Be sure to highlight key information from your research so that your opinion is backed by facts.

| Key Concepts | Section Summaries |
| --- | --- |
| **1.0**<br>• heat energy needs and technologies<br>• energy conservation | **1.0 Human needs have led to technologies for obtaining and controlling heat.**<br>• Heat technologies have changed and developed over time as people work to meet their needs for heat.<br>• Culture (way of life) includes how people meet their basic needs, and technology is linked to culture.<br>• As people have evolved, so has the development of heat-related materials and technologies.<br>• Choices about the environment are made by individuals and by society. |
| **2.0**<br>• change of state<br>• particle model<br>• thermal energy<br>• heat transfer<br>• thermal expansion<br>• temperature<br>• insulation and thermal conductivity | **2.0 Heat affects matter in different ways.**<br>• Transferring heat to or from matter can cause a change of state.<br>• The particle model of matter explains why matter changes state and changes volume.<br>• Conduction transfers heat between two substances in contact with each other; only the energy is transferred from particle to particle; convection transfers heat by the movement of particles; radiation transfers heat by invisible waves.<br>• Thermal energy is the total kinetic energy of the particles in a substance; heat is the energy transferred between two substances; heat transfers from substances whose particles have a higher kinetic energy to substances whose particles have lower kinetic energy.<br>• Temperature is a measurement of the average kinetic energy of the particles in a substance. |
| **3.0**<br>• heat energy needs and technologies<br>• thermal energy<br>• thermal energy sources<br>• insulation and thermal conductivity<br>• energy conservation | **3.0 Understanding heat and temperature helps explain natural phenomena and technological devices.**<br>• Thermal energy is produced naturally by the sun, decay, fire, and geothermal sources.<br>• Passive and active solar heating systems use the sun's energy and are environmentally friendly.<br>• Thermostats help control temperature in heating systems.<br>• Insulation helps block unwanted heat transfer. |
| **4.0**<br>• heat energy needs and technologies<br>• thermal energy sources<br>• energy conservation | **4.0 Technologies that use heat have benefits and costs to society and to the environment.**<br>• Non-renewable resources such as fossil fuels have a limited supply.<br>• Fossil fuels such as oil, natural gas, and coal are major heat sources but burning them is harmful to the environment.<br>• Three types of costs are involved in using natural resources: economic, environmental, and societal.<br>• Five alternatives for producing thermal energy include solar energy, wind energy, geothermal energy, nuclear energy, and hydro-electric power; each has different costs and benefits. |

# PROJECT

## USING THERMAL ENERGY MORE EFFICIENTLY

### Getting Started

Canadians of this century live fast-paced lives. Change is part of our culture. As technology quickly advances, we often seem to model the saying, "Out with the old, in with the new!" But is that always the best decision?

In this unit, you have learned about making decisions that consider possibilities, facts, values, and priorities. You have a new understanding about the science of thermal energy and how we use that energy to meet our needs and wants for heat. How and why we have developed different heat-related technologies has been explored. You have also learned about different costs linked to the use of natural resources. This project will help you apply your learning to the renovation of a historical building in your community.

### Your Goal

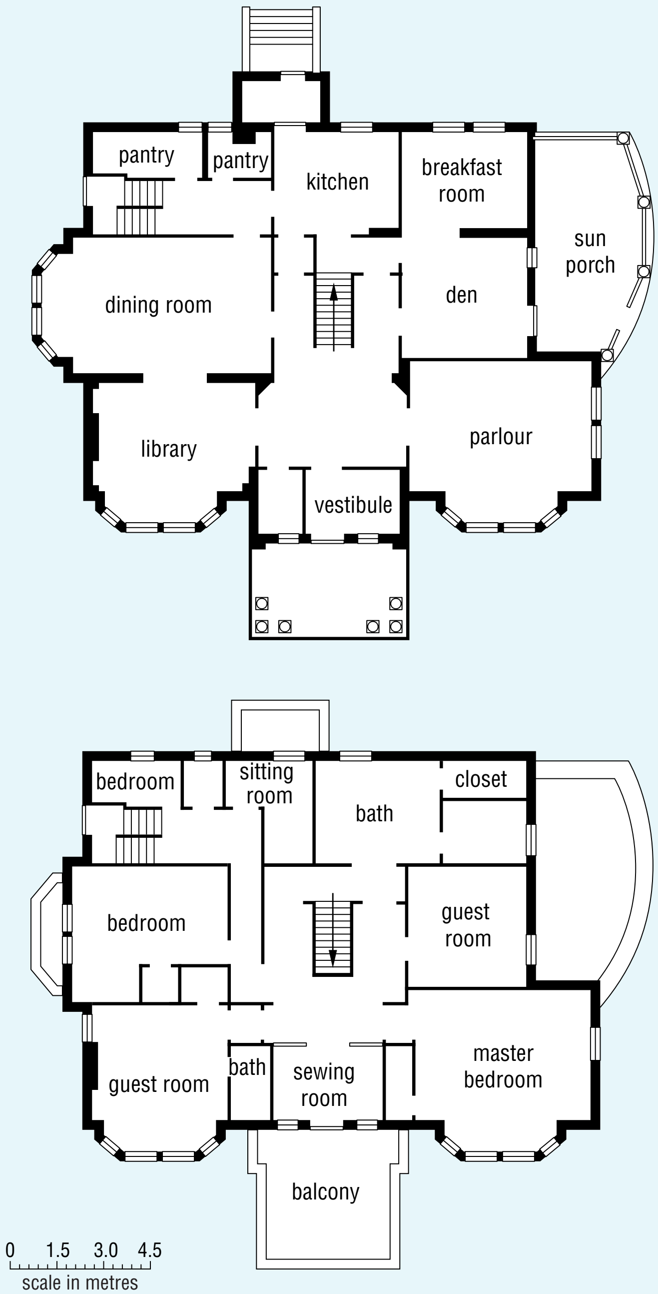
Use the background information to determine the most likely sources of thermal energy loss in this old house. Figure out how thermal energy could be used more efficiently and in a more environmentally friendly way. Develop a plan within a budget of $50 000.

### What You Need to Know

In 1911, the Michaels family, founding members of your community, built a very grand brick mansion in the centre of town. The family's history of generous community service and financial donations made them well loved. The Michaels home became a unique community landmark.

This past summer, the last surviving member of the Michaels family died, and in the will, left the mansion to your community. Some developers would like to tear it down to make a shopping complex because of its prime location. Another group would like to bulldoze the house to put up condominiums. However, a third group wants to preserve the house and turn it into a museum that would celebrate the community's history. They feel that the house's historical value is as important as its economic value. They also believe that it is very worthwhile to conserve the high-quality materials that were used in constructing the house.

At a town hall meeting, it is decided that the third group should have a chance to make the house into a museum. School programs and other activities could be run from such a place, giving the people of the community and visitors a chance to learn more about local history. Most people feel that it is important to save the building if some of the operating costs can be lowered. The outside of the building is still in very good shape, needing only some minor repairs to the brickwork. However, there is a major concern about the large monthly heating bill.




A real estate report provides clues to solving the problem:

- inside of house in excellent condition—has many special features including hardwood flooring, oak panelling, variety of ceiling mouldings, sliding doors, carved staircase, south-facing sun porch (glass enclosed), stained-glass windows, four large fireplaces, 3-m-high ceilings
- original heating system (hot-water heating)
- original single-pane windows
- original insulation in attic
- has new electrical wiring
- landscaping consists of large lawn area, small shrubs, and flowering plants

## Steps to Success

1 Work in teams of 3 to 5. Brainstorm what you would do to reduce the heating bill. Make a list of all possible options. Then collect information about the costs of making changes to the house. Writing letters, making phone inquiries, reading catalogues, visiting home improvement stores, using e-mail, and checking Web sites on the Internet are some ways to gather the needed information.

2 Prepare a written proposal that clearly explains what changes you would make and why. Remember that you need to stick to your $50,000 budget. Using diagrams, CAD drawings, three-dimensional models, or other visual aids will add to your written work.

3 Present your team's plan to the class.

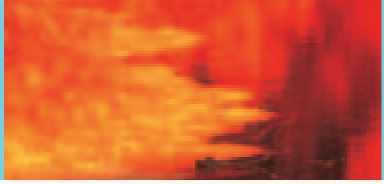
## How Did It Go?

4 Describe how you decided on the changes to make to the house.

5 Describe your research process. How was it similar or different from other teams' research?

6 How well did your team work together? How effectively did you make your decisions?

7 What would you do differently another time?



# Unit Review: Heat and Temperature

## Unit Vocabulary

1. Write a short story about heat and temperature using the following terms.

   thermometer
   particle model of matter
   expand
   contract
   conduction
   convection
   radiation
   insulator
   conductor
   convection current
   radiant energy
   temperature
   kinetic energy
   thermal energy
   fossil fuels
   solar energy
   sustainable use of resources

## Check Your Knowledge

### 1.0

2. Is heat a substance or a form of energy? Explain your answer.
3. Describe one example of heat technology from the past and one example from the present day.
4. a) Give one example of a personal choice related to the use of heat as an energy source or technology.
   b) Give one example of a societal choice related to the use of heat as an energy source or technology.
5. Identify one technological device that produces heat and explain how it does that.

### 2.0

6. List the four main ideas of the particle model of matter.
7. How does the particle model explain a change of state of matter?
8. A metal bolt heated to a high temperature will be slightly larger than if it was in a freezer. Why?
9. Define *conduction*, *convection*, and *radiation*.
10. Define *temperature*. Include the words "kinetic energy" and "particle model of matter" in your definition.
11. Explain how heat and temperature are related yet different concepts.

### 3.0

12. Give three examples of natural thermal energy.
13. Describe how passive and active solar heating systems differ.
14. Explain how a thermostat works and why it is important for safety.
15. Describe and give examples of local and central heating systems.
16. Explain how insulation works in a building and why we use it.

### 4.0

17. Describe three alternative forms of energy that can be used to produce thermal energy.
18. Describe three non-renewable resources.
19. Describe two examples of energy conservation in your home or community.

## Connect Your Understanding

**20.** Create a chart or picture that illustrates the three ways heat can be transferred. Your chart should include a description of the method of heat transfer and an example of a device that uses it.

**21.** Humans have gone from burning wood as their main heat source to using alternative energy sources such as solar energy. Describe how and why this has happened. Include illustrations in your answer.

**22.** List some of the costs and benefits to using fossil fuels. For each point in your list, describe the consequences to the environment and society.

## Practise Your Skills

**23.** A student poured hot water into a plastic cup, a Styrofoam cup, and a Styrofoam cup with newspaper wrapped around it. Each had a thermometer in it. The student recorded the water temperature for each cup for 10 min (see table below). Graph the results for each cup, and determine which results go with which cup. Briefly explain your choices.

| Time (Minutes) | Container 1 (Temp °C) | Container 2 (Temp °C) | Container 3 (Temp °C) |
|---|---|---|---|
| 1 | 75 | 75 | 75 |
| 2 | 73 | 72 | 73 |
| 3 | 70 | 66 | 69 |
| 4 | 68 | 63 | 67 |
| 5 | 67 | 59 | 63 |
| 6 | 65 | 55 | 60 |
| 7 | 64 | 53 | 58 |
| 8 | 63 | 50 | 55 |
| 9 | 61 | 46 | 53 |
| 10 | 60 | 44 | 49 |

**24.** Sketch a diagram of your home. In that same diagram, show how passive and active solar heating could be used where you live.

## Self Assessment

**25.** Describe the fact or concept that you found most interesting or most surprising in this unit.

**26.** What unanswered questions do you still have about heat and temperature?

**27.** Has your thinking about sustainable living changed now that you have finished this unit? Why or why not?

**28.** What do you now see as your own personal responsibility to the environment?

### Focus On — Social and Environmental Context

In this unit, you have learned about the social and environmental context of heat and temperature. Think about what you learned as you answer the following questions.

**29.** In a paragraph, describe the relationship between these terms: human needs, thermal energy technologies, fossil fuels, and conservation.

**30.** What are three major issues related to how we generate and use heat?

**31.** Reread the three questions on page 179 about the social and environmental context of heat and temperature. Use a creative way to demonstrate your understanding of one of the questions.