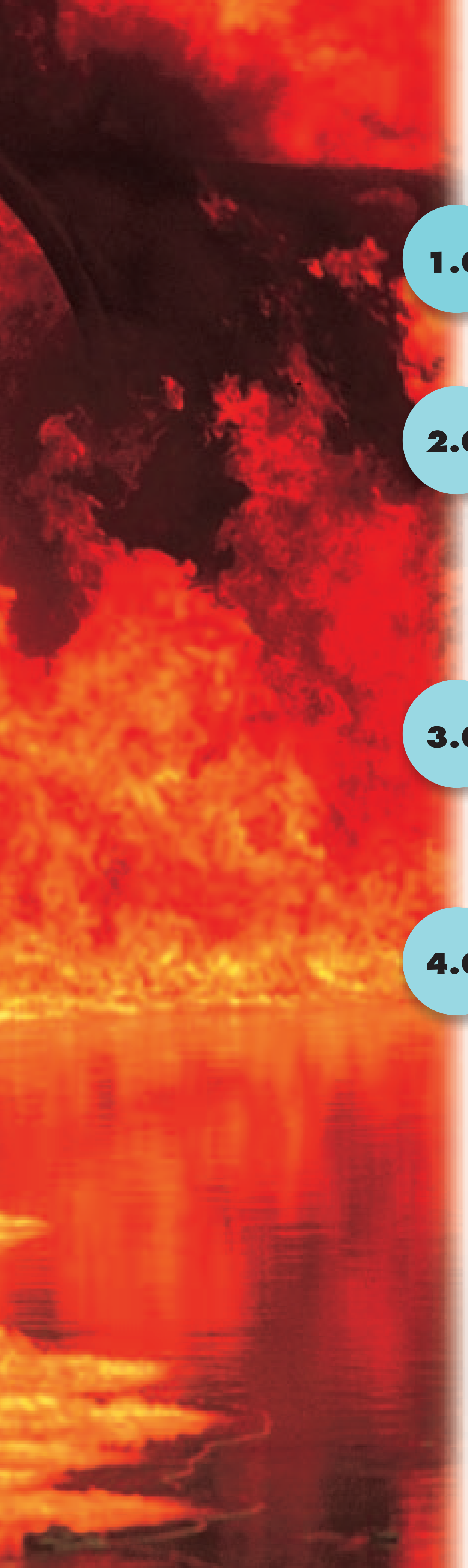
UNIT C

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.

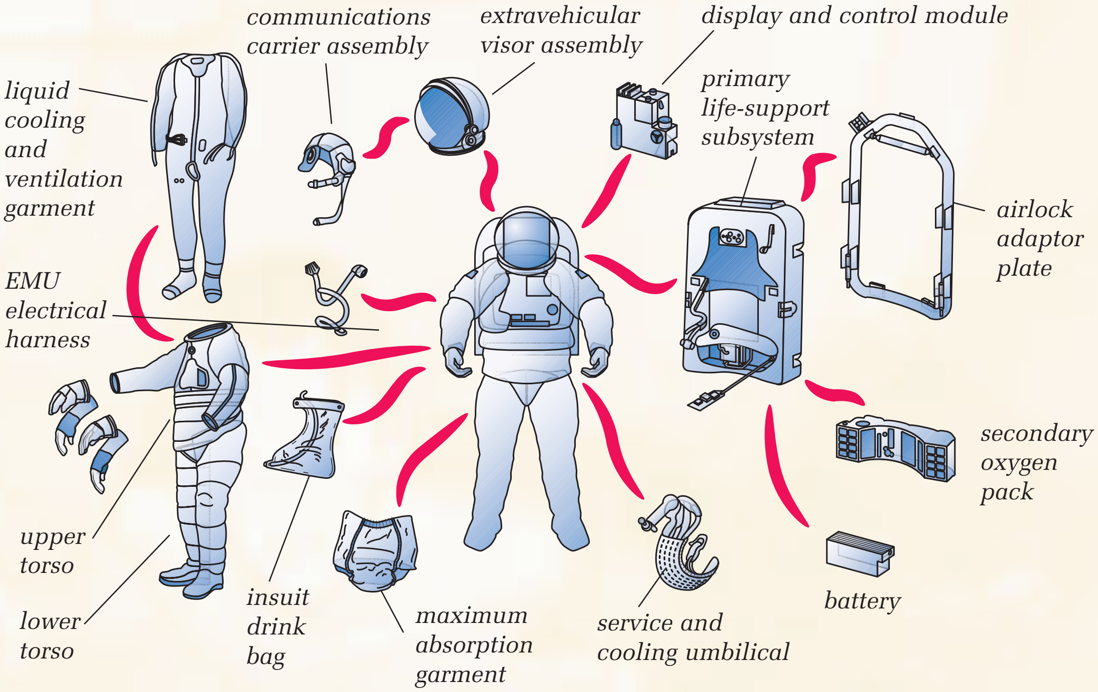
When we venture into space, we must take our environment with us. We need to control the air, pressure, and temperature within a safe range, so that we can live and carry out the work that is needed. Our heat needs must be met whether we are living with others inside the shuttle or the space station,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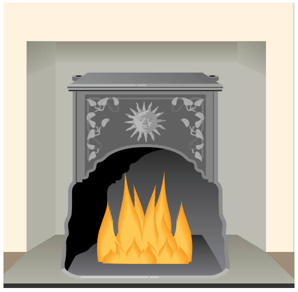
Two Heating Systems in One

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

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.

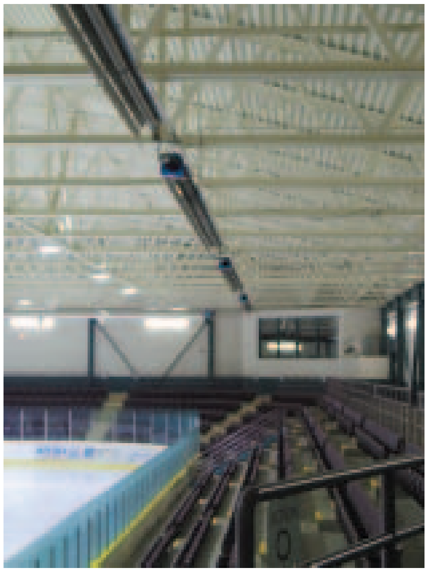


Figure 1.1 These heating units help keep hockey and figure skating fans warm.

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.

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*

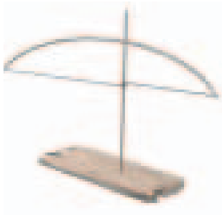


Figure 1.4

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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.

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

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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.

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.

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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.

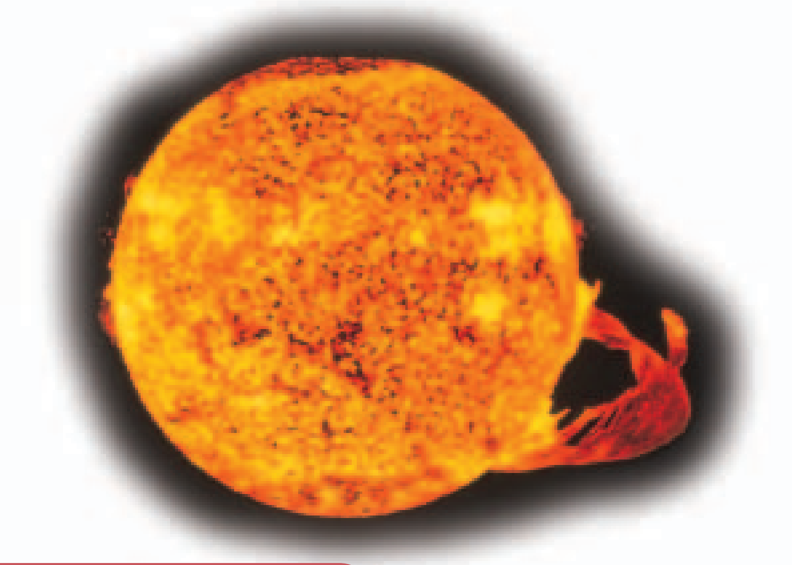


Figure 1.7 Energy from the sun can be used for heating buildings and water, and for producing electricity.

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!"

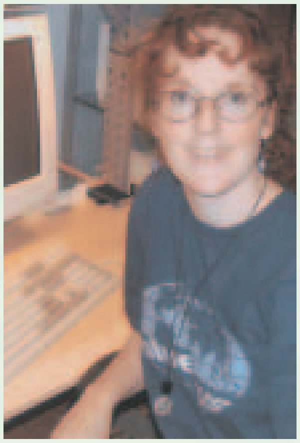
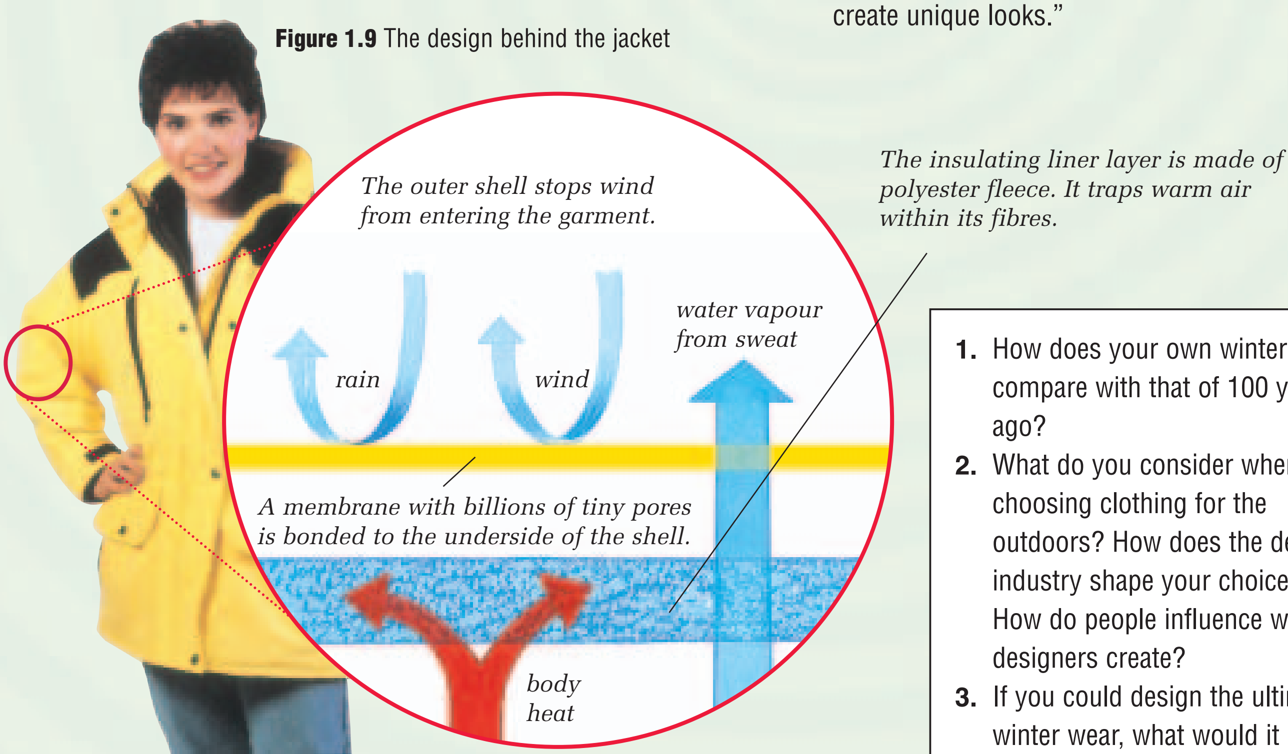


Figure 1.8 Sally Neal

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

Materials & Equipment

- ice cube
- stopwatch

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?

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.

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.

The particles have space between them.

Different states of matter have different amounts of space between 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.

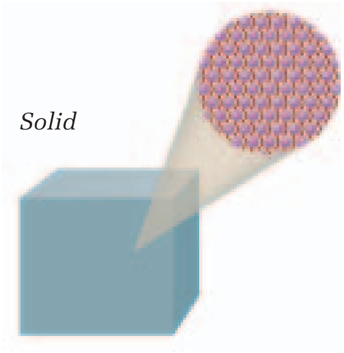

Figure 2.3a)

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.

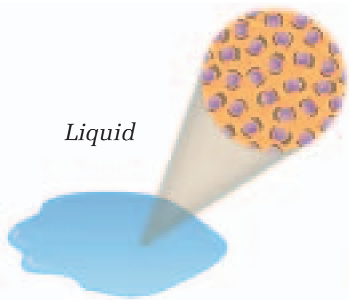

Figure 2.3b)

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.

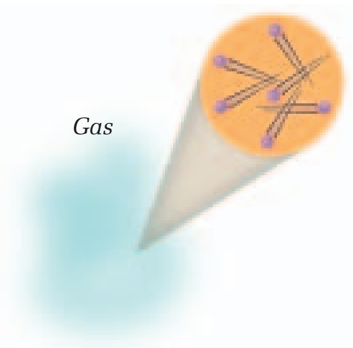

Figure 2.3c)

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.