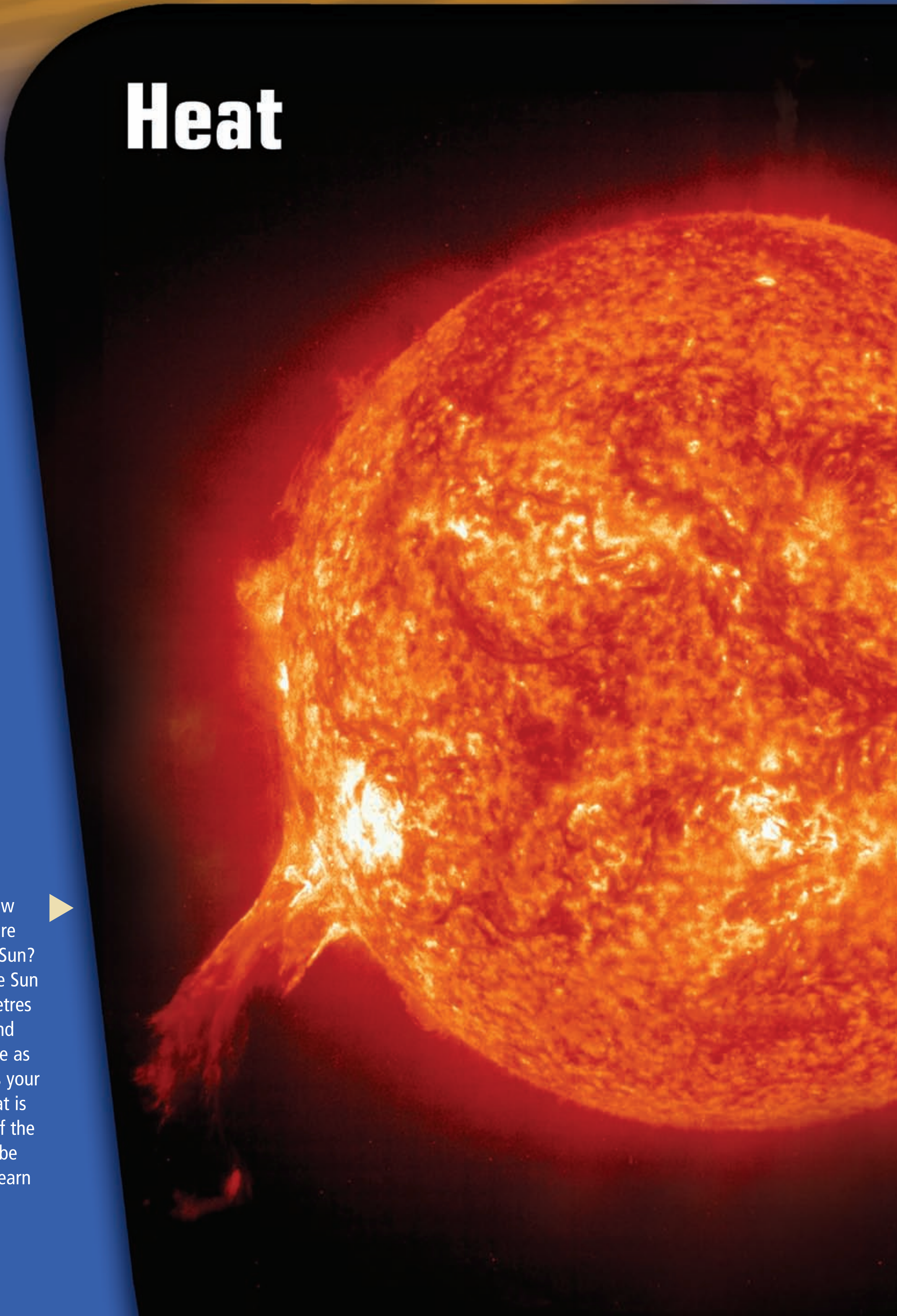
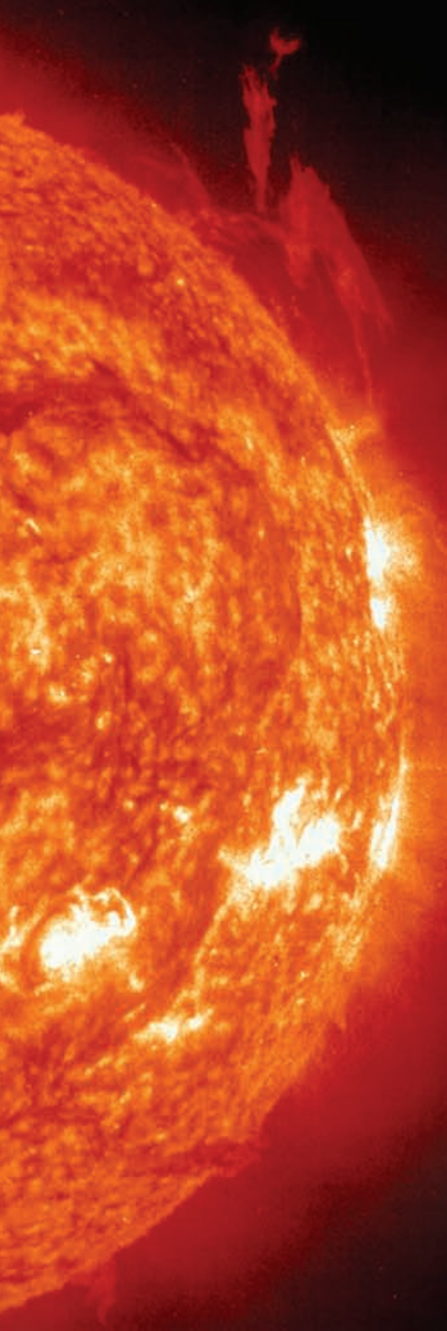
UNIT

2 Heat



How hot is the Sun? How can astronomers measure the temperature of the Sun? How does heat from the Sun travel millions of kilometres through empty space and warm Earth? Is a bonfire as hot as the Sun? What is your body temperature? What is heat? These are some of the questions that you will be able to answer as you learn about heat in this unit.



Key Ideas

4 Temperature describes how hot or cold an object is.

5 Scientists use the particle theory of matter to describe temperature

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

Getting Started

Campfires help campers in many ways. They provide light at night. You can roast marshmallows or cook food over them. They also keep you warm after dark.

internet connect

Nearly all of Earth's heat comes from the Sun. Why are regions near the equator so much warmer than regions, such as Canada, that are farther from the equator? How do average temperatures differ between Canada and Brazil, a country in South America? Start your search at **www.discoveringscience.ca.**

Camping can be a lot of fun, especially when sitting around the campfire at night. A campfire is not only pretty but you might need the fire to keep you warm in the evening. Have you ever noticed that your face and the front of your body can be almost too warm while your back is cool? Just a tiny breeze can cause a chill on your shoulders. How can you feel so warm and cool at the same time?

Suppose you go to your tent to get a jacket. Your hands might feel very chilly so you rub them together. How can rubbing your hands give you a feeling of warmth similar to holding them near the campfire? Now suppose you decide to have some hot chocolate and put a kettle of water on the camp stove. When you pick up the kettle to pour your hot water, you might wonder why the handle got so hot. It wasn't touching the camp stove. Nevertheless, the hot chocolate feels good as it goes down. Finally, the fire is nearly out and it is time to crawl into your sleeping bag and get a good night's sleep. Even though the sleeping bag does not generate any heat like the campfire does, you feel very cozy and warm inside it.

When you go camping, you realize the importance of heat and finding different ways to stay warm. In this unit, you will learn more about heat and temperature. You will learn how scientists through the years developed ways to measure the temperature of different objects. You will learn how scientists explain the difference between hot and cold objects. You will also find out how heat travels from one place to another.

Careful! The handle on the pot might be hot!

Word Connect

Early philosophers believed that a mixture of heat, cold, moisture, and dryness in a person determined their temperament. The word *temperature* comes from the same root as the word temperament.

Baffle Your Skin

Find Out ACTIVITY

In this activity, you will discover whether your skin is a good instrument to determine how hot or cold an object is. You will do this by placing your hands in water of different temperatures.

Materials

- 3 bowls of water large enough to dip your hands into the water
- very warm tap water
- room-temperature water
- cold water (refrigerator temperature)

What to Do

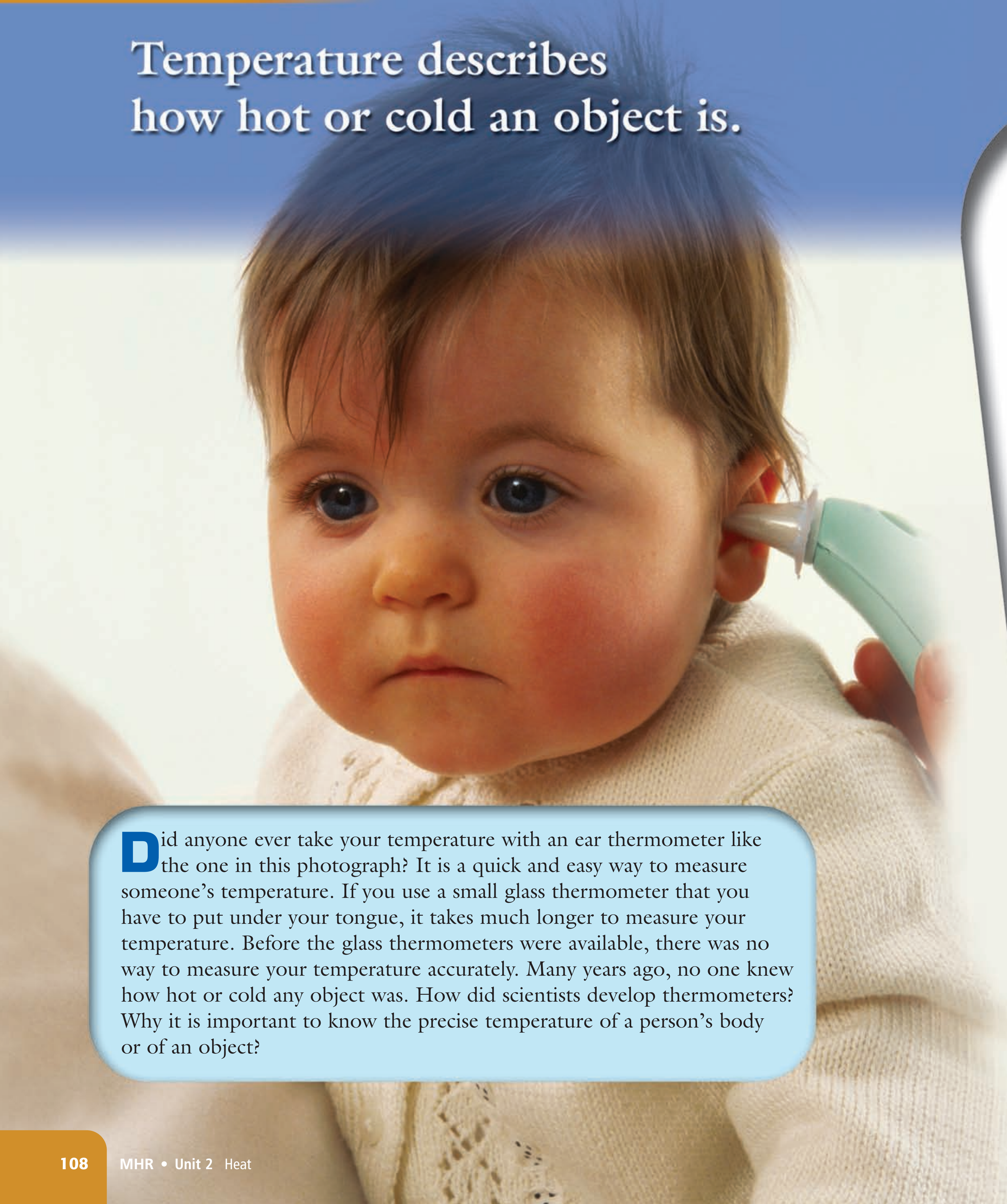
1. Put one hand in the bowl of cold water and the other hand in the bowl of hot water. (If the hot water is too hot to keep your hand in it, cool it with a small amount of room-temperature water.) Hold your hands in the two bowls of water for one minute.
2. Quickly put both hands in the bowl of room-temperature water.
3. Repeat steps 1 and 2 but use the opposite hands that you used in step 1.

What Did You Find Out?

1. Describe how each hand felt in step 2 when you put both hands in the same bowl of water. Give a possible explanation for your observations.
2. Was there any difference in your observations in step 3 compared to step 2? If there was, suggest a possible reason why.
3. Use your observations to explain how the same air temperature can seem warm in the winter and cool in the summer.

Chapter 4

Temperature describes how hot or cold an object is.



Did anyone ever take your temperature with an ear thermometer like the one in this photograph? It is a quick and easy way to measure someone's temperature. If you use a small glass thermometer that you have to put under your tongue, it takes much longer to measure your temperature. Before the glass thermometers were available, there was no way to measure your temperature accurately. Many years ago, no one knew how hot or cold any object was. How did scientists develop thermometers? Why it is important to know the precise temperature of a person's body or of an object?

What You Will Learn

In this chapter, you will
- **describe** the temperatures of a variety of common objects and substances
- **explain** the difference among the temperature scales
- **demonstrate** the use of a thermometer
- **explain** how different thermometers work

Why It Is Important

Understanding the differences among temperature scales is important for interpreting weather reports and for cooking food in an oven. Being able to read and interpret a thermometer helps you plan your activities and know how to dress appropriately for the weather.

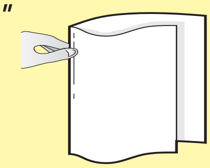
Skills You Will Use

In this chapter, you will
- **observe** how well your skin can determine temperature
- **predict** the temperature of a variety of objects
- **measure** temperature with a thermometer that you constructed

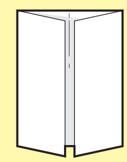
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 4.

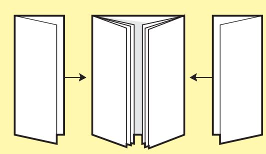
STEP 1 **Using** an 11″ × 17″ sheet of paper, begin as if you were going to fold the paper in half along the long axis, but instead of creasing the paper, **pinch** it in to show the midpoint.



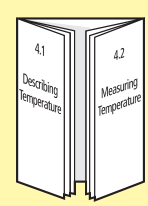
STEP 2 **Fold** the outer edges of the paper in to meet at the midpoint, forming a shutter fold.



STEP 3 **Staple** one sheet of 8.5″ × 11″ paper, folded along its length, into each side of the shutter fold to create a notebook on each side.



STEP 4 **Label** the left side of the notebook "4.1 Describing Temperature" and the right side of the notebook "4.2 Measuring Temperature".



Organize Record information, define terms, and solve problems from the chapter in the pages of the notebook you have created. In the middle section of the Foldable, create a chart comparing average temperatures in Newfoundland and Labrador to other places in the world.

4.1 Describing Temperature

Knowing the temperature of common things, such as room and body temperatures, helps you better understand temperatures of less common things. Maintaining a constant body temperature is critical to your health. A person might not be able to recover if hypothermia is prolonged. Temperature scales are based on reference points such as the freezing and boiling points of water. To construct a thermometer, you need something that changes visibly as the temperature changes.

Key Terms

body temperature
hypothermia
room temperature

Figure 4.1 shows one way that temperature affects your life. Every day, you and many other Canadians check the weather forecast to decide what to wear. "What is the temperature? Do I need a heavy coat and gloves or will I be comfortable in a light jacket?" Temperature affects your life in other ways too. Perhaps you take a lunch to school. You might take soup in a Thermos® to keep it warm but you eat your sandwich at room temperature. You might buy cold milk at school. Do you know what comfortable room temperature is? What is normal body temperature? Find out how well you can match a temperature to a description by completing the Find Out Activity on the next page.

Did You Know?

The highest temperature ever recorded anywhere in the world is 57.7°C. This temperature was recorded in El Azizia, Libya, a country in Africa. The lowest temperature ever recorded is –89.2°C. This temperature was recorded in Vostok in Antarctica.

Figure 4.1 How you dress and the activities you participate in depend on the weather.

4-1A Boiling Hot, Freezing Cold

Find Out ACTIVITY

In this activity, you will try to match temperatures to descriptions of places or things. You will probably be able to guess many of the temperatures of common things. Other temperatures might surprise you. Read the directions and then see how well you can match the temperatures to the descriptions.

What to Do

1. In your notebook, make a table with three columns. Write the following headings at the top of the columns: Very Cold, Everyday, and Very Hot.
2. Read each of the descriptions in the list below. As you read a description, decide which heading in your table fits the description. Write the description under that heading in your table.
3. For each description, choose the temperature from the list that you believe is the correct temperature. Write the temperature beside the description in your table. Discuss your answers with your partner until you agree on each one.
4. Check your answers against the list that your teacher has. Correct any mistakes that you might have made.

Description
Temperature of lava from Hawaiian volcanoes
Temperature of ocean currents off Canada's east coast
Temperature of ocean currents off Canada's west coast
World record coldest air temperature
Comfortable room temperature
Body temperature of a budgie bird
Temperature outside the Space shuttle while it orbits Earth
Temperature of a candle flame
Comfortable temperature for heat-loving bacteria
Normal human body temperature
Temperature of ice cream
Oven temperature for baking bread
Temperature of food in a freezer
Temperature of the interior of the Sun
Temperature of hot tea or coffee
Temperature of boiling water at sea level
Temperature of a slush of pure water and ice
Temperature of the surface of the Sun

Temperatures (°C)
4 to 10
–5
–87
–121 to –156
92
15 000 000
–10 to –15
200
20 to 25
37
40
1
100
6000
1150
55
800
0

This "Morning Glory Pool" is heated by energy from deep within Earth. The water remains at about 95°C even if there is snow on the ground nearby.

What Did You Find Out?

1. How many temperatures were you able to guess correctly?
2. Which temperature surprised you the most?
3. What was the most important thing you learned from this exercise?

Temperatures of Common Things

You have probably heard the phrase "comfortable room temperature" many times. What is "comfortable room temperature?" Some people are comfortable at temperatures that other people might consider too cool or too hot. Most people, however, are comfortable when the **room temperature** is somewhere between 20°C and 23°C. Many people, like the person in Figure 4.2, feel that it is more comfortable to sleep when the temperature is lower such as 18°C.

Figure 4.2 A temperature of 18°C is considered comfortable for sleeping.

Figure 4.3 Be sure to check the recipe to find the right temperature for the food that you are baking.

Have you ever baked cookies? What was the temperature of the oven? Oven temperatures vary for different foods. For cookies, you usually set the temperature at 175°C. To cook a roast or poultry, as in Figure 4.3, the oven temperature is usually set at 160°C. You need a very hot oven—about 250°C—to bake pizza.

It is important to keep a refrigerator and freezer at the right temperatures so that food will not spoil. The temperature of the refrigerator should be 4°C and the freezer should have a temperature of –18°C.

Body Temperatures

Your **body temperature** is an important indicator of your health. Your normal body temperature is 37°C. A temperature above 37°C indicates that you have an infection or an illness. The increased temperature is your body's way of fighting an infection. Bacteria (germs) can be destroyed by an increase in temperature. However, if your temperature rises above 40°C, the heat can also harm your own tissues, especially your brain.

If skiers or hikers do not dress properly, or if a person falls into cold water, as shown in Figure 4.4, their body temperatures can drop dangerously low. The condition is called **hypothermia.** When the body temperature decreases a few degrees, the heart begins to slow down and body organs do not function correctly. If a person's body temperature drops below 32°C, it is very difficult to revive the person.

Figure 4.4 If someone falls into icy cold water, it is very important to get them out of the water and give them warm dry clothing very soon. Hypothermia is very dangerous.

Did You Know?

The temperature of the filament of an incandescent light bulb is 2500°C. Although these bulbs waste a lot of energy, they have been used for more than a hundred years. However, the federal government plans to ban inefficient incandescent light bulbs by the year 2012.

internet connect

Learn more about preventing and treating hypothermia by doing research on the Internet. Start your search at **www.discoveringscience.ca.**

A temperature of 37°C is normal for humans but not for all animals. Figure 4.5 shows an extreme example of body temperature for one animal. Table 4.1 shows you the normal body temperature for several different birds and mammals. Look for trends in the table. For example, how does the normal body temperature of birds compare to the body temperatures of the mammals in the list?

Table 4.1 Temperatures of Some Birds and Mammals

Animal	Body Temperature (°C)
Dog	38.5
Horse	37.7
Pig	39.5
Sparrow	41.0
Chickadee	42.0
Gray Jay	40.4
Kangaroo	35.9
Hedgehog	34.0

Did You Know?

Arctic cod, relatives of the more familiar Atlantic cod, swim in waters that are so cold that the bodies of other fish would freeze. The arctic cod do not freeze because their bodies make a chemical that acts like antifreeze and prevents their tissues from freezing.

Figure 4.5 An oryx is a type of antelope that lives in hot dry regions of Africa. The body temperature of an oryx can get as high as 43°C in the daytime. However, the temperature of the oryx brain does not get higher than 39°C.

Animals other than birds and mammals cannot generate enough heat in their bodies to keep their temperatures constant. The body temperature of these animals is affected by their surroundings. Lizards often stretch out in the Sun so that the sunlight will warm their bodies. Animals that live in cold climates have many ways to adapt to the low temperatures.

Reading Check

1. If you were asked what room temperature is, why would it not be possible to give a specific temperature?
2. What is the typical temperature in a refrigerator?
3. What is your normal body temperature?
4. What is hypothermia?

Did You Know?

The coldest temperature ever recorded in Newfoundland and Labrador is –51.1°C (Esker Station). The highest temperature recorded in Newfoundland and Labrador is 41.7°C (Northwest River).

Air Temperatures

When you hear the word *temperature*, the first thing you probably think of is weather. Nearly every day, you hear a weather report. The reporter tells you how high and how low the temperature will be for the next few days. Sometimes the weather report will include average temperatures for the month. Figure 4.6 shows the monthly highs and lows in your province.

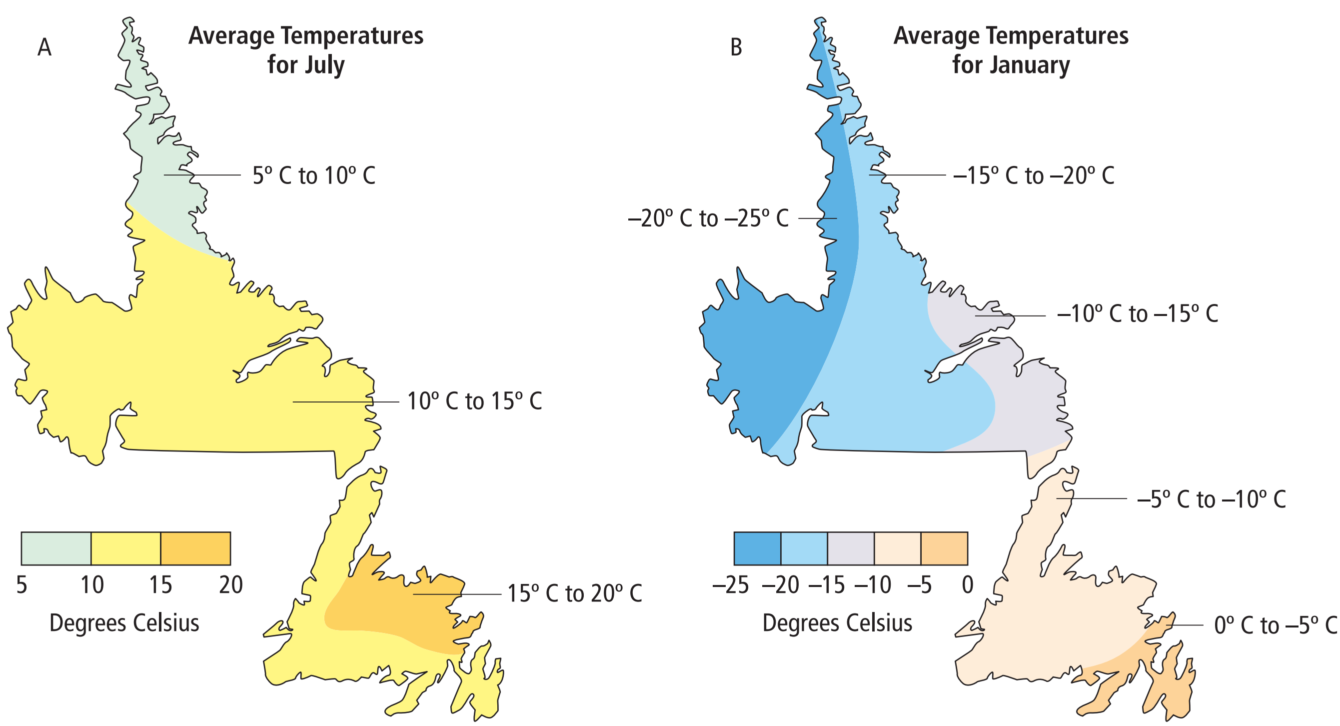


Figure 4.6 Map A shows average temperatures for July and map B shows average temperatures for January. Locate the place where you live on the map and find the average temperatures in July and January.

How do the average temperatures in Newfoundland and Labrador compare to other places in Canada? Table 4.2 lists data of average temperatures for the months of January and July in several cities across Canada.

When you look at the average temperatures, remember that the highs can be much higher and the lows can be much lower than the average temperatures. For example, the all-time record high temperature in Saskatoon, Saskatchewan is 40.6°C and the record low temperature is –50.0°C.

Table 4.2 Average Temperatures for January and July in Some Canadian Cities

City	January (Temperature °C)	July (Temperature °C)
Gander, Newfoundland and Labrador	–6	16
Halifax, Nova Scotia	–5	18
Goose Bay, Newfoundland and Labrador	–16	16
Montreal, Québec	–9	21
Toronto, Ontario	–6	21
Resolute, Nunavut	–31	4
Winnipeg, Manitoba	–17	20
Saskatoon, Saskatchewan	–17	19
Edmonton, Alberta	–12	18
Yellowknife, Northwest Territories	–27	17
Vancouver, British Columbia	3	17

Reading Check

1. According to Table 4.2, the average temperature for January in Gander is –6°C and in Goose Bay it is –16°C. On a January day, could it be colder in Gander than it is in Goose Bay? Explain.
2. Which places in Table 4.2 have higher average temperatures in January than Gander? Which places have lower average temperatures in July than Gander?
3. Examine Map B in Figure 4.6 and answer the following questions.
   (a) Is the section of Newfoundland and Labrador that is warmest in January by the ocean or inland?
   (b) Is the section of Newfoundland and Labrador that is coldest in January by the ocean or inland?

Going to (Temperature) Extremes

What are some of the highest of the highs and lowest of the lows in temperature? Some of these values might surprise you.

Temperatures	Comments
2 billion °C	highest temperature generated in a laboratory
15 million °C	temperature at the centre of the Sun
4000°C	temperature at the centre of Earth
3550°C	highest melting point of any chemical element (carbon, in the form of diamond)
100°C	boiling point of water
58°C	highest temperature recorded on Earth
46.5°C	highest body temperature a person has had and survived
45°C	highest temperature recorded in Canada
37°C	average human body temperature
14.2°C	lowest body temperature a person (a two-year old child) has had and survived
0°C	freezing point of water
–3°C	lowest body temperature for a mammal (in a hibernating arctic ground squirrel)
–63°C	lowest temperature recorded in Canada
–89.2°C	lowest temperature recorded on Earth
–273.14°C	lowest temperature generated in a laboratory
–273.15°C	lowest temperature possible

Science Watch

Wind Chill

What does a weather report mean when it says that the temperature is –15°C but it "feels like" –24? The "low" number tells you how cold it feels. A low temperature is not the only thing that makes you feel cold. You have probably noticed that a gentle breeze on a cold day can make you feel much colder. Have you ever wondered why quiet air does not feel as cold as moving air?

The heat in your body heats the air in contact with your skin. That thin layer of warmed air insulates your skin from the colder air. When the wind blows, it moves that warmed layer of air away from your skin and replaces it with colder air. The colder air draws more heat from your skin making it feel even colder. As the wind speed increases, it removes the warm layer of air away faster until there is no longer a layer of warm air protecting your skin from the cold.

The "feels like" number in the weather report is called the wind chill. The wind chill number is the temperature of still air that would have the same effect on exposed skin as the combination of the actual temperature and wind. For example, a temperature of –15°C and a wind speed of 20 km/h would have the same effect on your skin as a temperature of –24°C with no wind.

Wind chill is as dangerous to your skin as low temperatures. Environment Canada provides the following guidelines to help people avoid the dangers of wind chill.

Wind Chill Hazards

Wind Chill	Description	Hazard
0 to –9	Low	• Slight increase in discomfort
–10 to –24	Moderate	• Uncomfortable • Exposed skin feels cold • Risk of hypothermia if outside for long periods
–25 to –44	Cold	• Risk of frostbite • Check face, fingers, toes, ears, and nose for numbness or whiteness • Risk of hypothermia if outside for long periods
–45 to –59	Extreme	• Exposed skin may get frostbite in minutes • Check face, fingers, toes, ears, and nose for numbness or whiteness • Serious risk of hypothermia if outside for long periods • Be ready to cut short or cancel outdoor activities
–60 and colder	Extreme	**DANGER** • Outdoor conditions are hazardous • Exposed skin will get frostbite in less than 2 min

Source: Environment Canada, Wind Chill Information Site: *www.windchill.ec.gc.ca*

Questions

1. What is wind chill?
2. How can you protect yourself from frostbite if you have to go out when the wind chill is very low?

Check Your Understanding

Checking Concepts

1. What does it mean when your body temperature is above 37°C?
2. What is hypothermia?
3. What is the typical temperature of the freezer compartment of a refrigerator?
4. What are some common oven temperatures for baking different foods?
5. What is the average temperature in July and in January in the region where you live?

Understanding Key Ideas

6. If you were told that something had a temperature of 4°C, where would you expect to find that object?
7. Why might you put a thermometer in the refrigerator?

8. Estimate the temperatures of the following items.
   (a) a cup of soup
   (b) the flame of a candle
   (c) the record cold temperature in Québec
   (d) an ice cream cone
   (e) a person who has the flu
   (f) a carton of ice cream in a freezer
   (g) a container of juice in a refrigerator
   (h) a container of juice on a kitchen table
9. The thermometers in the following picture are called meat thermometers.
   (a) Describe how you think meat thermometers might be used.
   (b) Suggest a reason why meat thermometers are used.

Pause and Reflect

Imagine that you saw someone fall through the ice on a frozen lake. Describe the steps that you would take to prevent the rescued person from getting hypothermia.

4.2 Measuring Temperature

To measure temperature precisely, you need something to change visibly as the temperature changes. Galileo used the change in the volume of air trapped in a glass tube to measure temperature. Other instruments used the change in the volume of a liquid to measure temperature. Some temperature measuring devices use the difference in the expansion of metals as the temperature of the metals increases. Other devices use an electric current in different metals to measure temperature. The Fahrenheit temperature scale was the first widely used scale. The Celsius scale is based on 0°C as the freezing point of water and 100°C as the boiling point of water. The Kelvin scale is based on 0 K as the coldest possible temperature.

Key Terms

bimetallic strip
calibrate
Celsius scale
Fahrenheit scale
Kelvin scale
thermocouple
thermogram
thermometer
thermoscope

Several of your senses can tell you that someone is cooking something in an oven, as in Figure 4.7. When the oven heats up, often you can smell the odour of something cooking. You can also see the glow of the coils in the oven. As you approach the oven, you can feel the heat. Your senses of sight, smell, and touch tell you that the temperature of the burner is high.

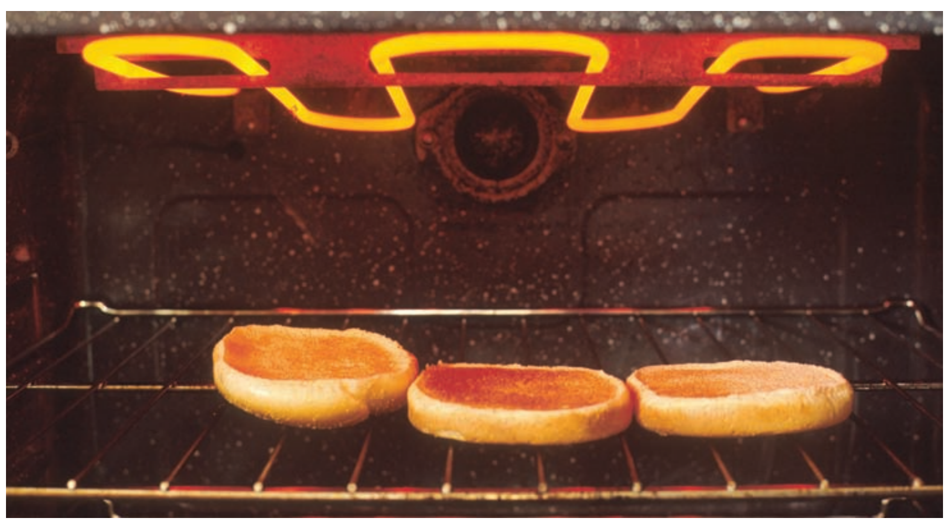


Figure 4.7 The glow of the coils in the oven tells you that the coils are very hot.

You can often easily sense a change in the temperature of an object or a substance using several of your senses. However, it is usually quite difficult to sense the precise temperature. You need a special instrument to measure the precise temperature of an object or a substance such as the air around you. In this section, you will learn how scientists developed instruments that measure temperature. You will also learn about different temperature scales.

Did You Know?

Pottery makers bake their clay pots in extremely hot kilns. They use cones that bend at different temperatures to estimate the temperatures in the kilns.

4-2A Building a Thermoscope

Find Out ACTIVITY

Teacher Demonstration

An instrument that measures temperature must contain a substance that changes visibly as the temperature changes. In this activity you will observe a change in the volume of air as the temperature of the air changes.

Safety

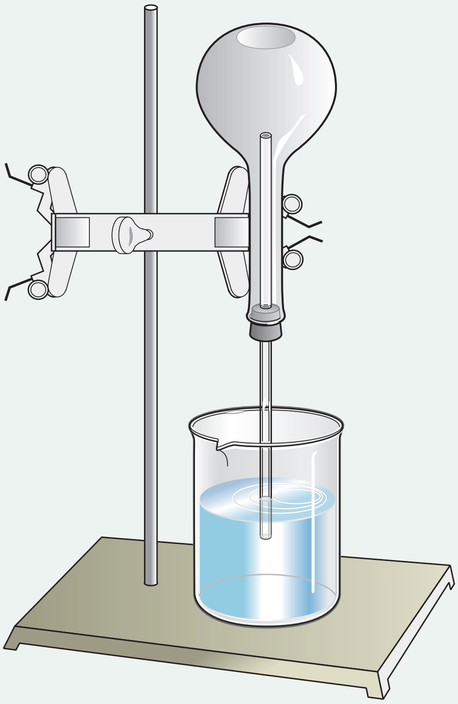
Handle the glass tubing carefully to avoid breakage.

Materials

- glass tube
- rubber stopper with hole
- spherical flask
- modelling clay
- beaker
- coloured water
- clamp
- retort stand
- cloth
- ice water

What to Do

1. Push the glass tube through the hole in the rubber stopper.
2. Put the stopper in the opening of the flask. Use modelling clay to help ensure that the apparatus is airtight.
3. Rub your hands together briskly and then grasp the flask in the upside down position.
4. Hold for a moment while the flask becomes warm from your hands.
5. Insert the end of the glass tube into the beaker of coloured water.
6. Release your hands from the flask and secure the flask with the clamp on the retort stand as shown in the diagram. (A volunteer from the class might be asked to assist for this step.)
7. Observe the coloured water in the glass tube while the air in the flask returns to room temperature.
8. Wet a cloth with ice water and place it on the flask. Observe the position of the coloured water.



What Did You Find Out?

1. What happened to the coloured water when the flask cooled to room temperature?
2. What happened to the coloured water when the cold cloth was placed on the flask?
3. Give a possible explanation for what you observed.

The Invention of Thermometers

About four hundred years ago, several scientists became interested in precisely measuring temperatures. One person who worked on temperature measuring instruments was the famous Italian scientist, Galileo Galilei (1564–1642). In 1596, Galileo developed an instrument called a **thermoscope** that is similar to the one shown in Figure 4.8. The thermoscope consists of a glass bulb with a very long, narrow tube and a container filled with a coloured liquid. The end of the glass tube sits in the liquid. When the air in the bulb is cooled, it contracts and the liquid rises up higher in the tube. When the air in the bulb is then warmed, the air expands and pushes the liquid down. When you see the coloured liquid in the tube rising or falling, you know that the temperature of the air in the bulb is changing.

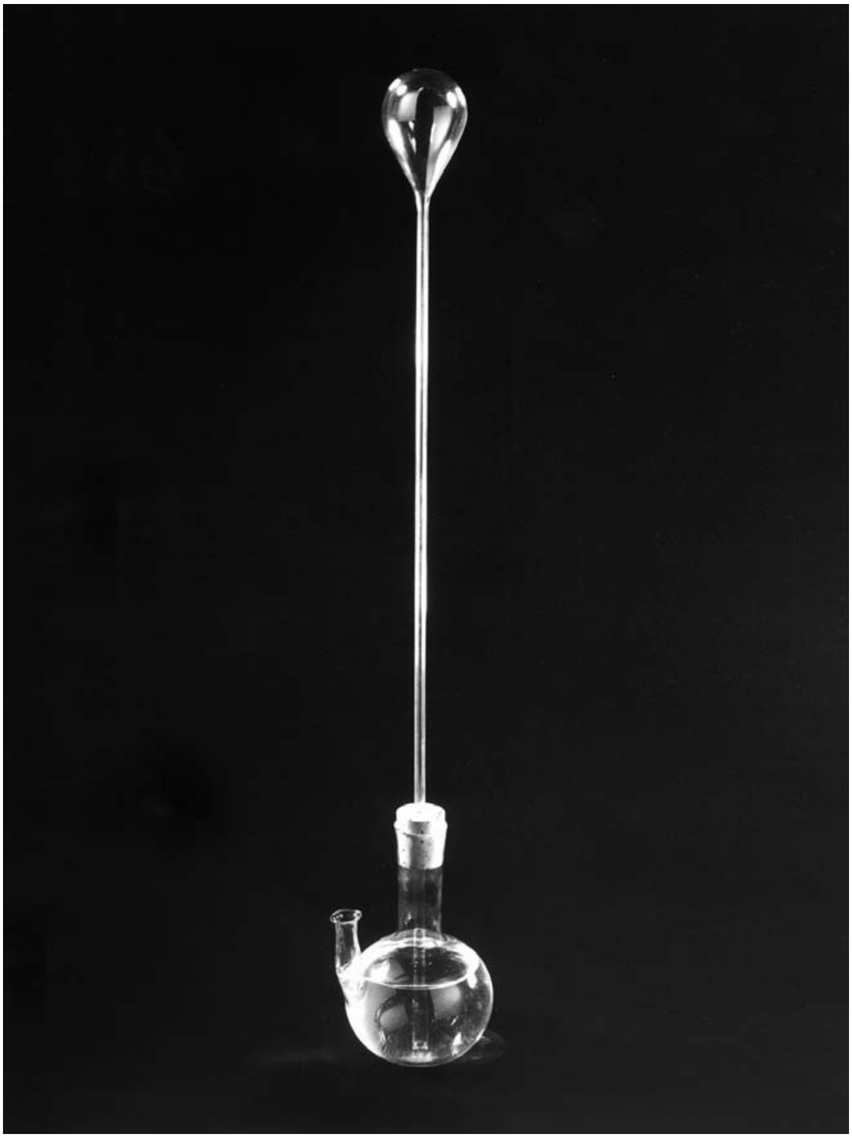


Figure 4.8 Galileo's original thermoscope looked much like this one. As the air warms, the coloured liquid drops down in the tube. As the air cools, the coloured liquid rises.

Galileo's instrument was not called a thermometer because it had no scale (numbers) on it. The thermoscope showed whether the air was hot or cold but did not show a temperature in numbers. Scientists continued to improve the air thermoscope and developed other types of temperature measuring devices such as the liquid thermoscope shown in Figure 4.9. It is the liquid in this thermoscope that expands when it is heated and contracts when cooled.

As scientists continued to develop these instruments, they started adding a number scale on the tubes so they could compare temperatures in different experiments. These instruments can correctly be called **thermometers.** However, the numbers were different on each thermometer and, therefore, had different meanings. Scientists could not compare measurements made with different thermometers. They needed a way to give a specific meaning to the numbers on all thermometers.

The Fahrenheit Scale

Many scientists were developing temperature scales but the scale developed by Gabriel Fahrenheit (1686–1736) was the first to be widely used. Other scientists had tested many different liquids for use in thermometers including alcohol and mercury. Using carefully planned experiments, Fahrenheit made many improvements on these thermometers.

To assign numbers to a scale on his thermometers, Fahrenheit chose two things known to have constant temperatures. The coldest thing that could be generated in the laboratories in Fahrenheit's time was a mixture of salt, ice, and water. The temperature of this mixture was called zero. Since body temperature is also constant, it was used as a second reference point. Body temperature is near 100 on Fahrenheit's scale. The space between zero and 100 on the thermometer was divided into 100 units. The units on Fahrenheit's scale are called degrees Fahrenheit and symbolized, °F. As thermometers were improved and the scale developed, several fixed points on the **Fahrenheit scale** were observed. The freezing point of water is 32°F and the boiling point of water is 212°F. Body temperature is now known to be 98.6°F.

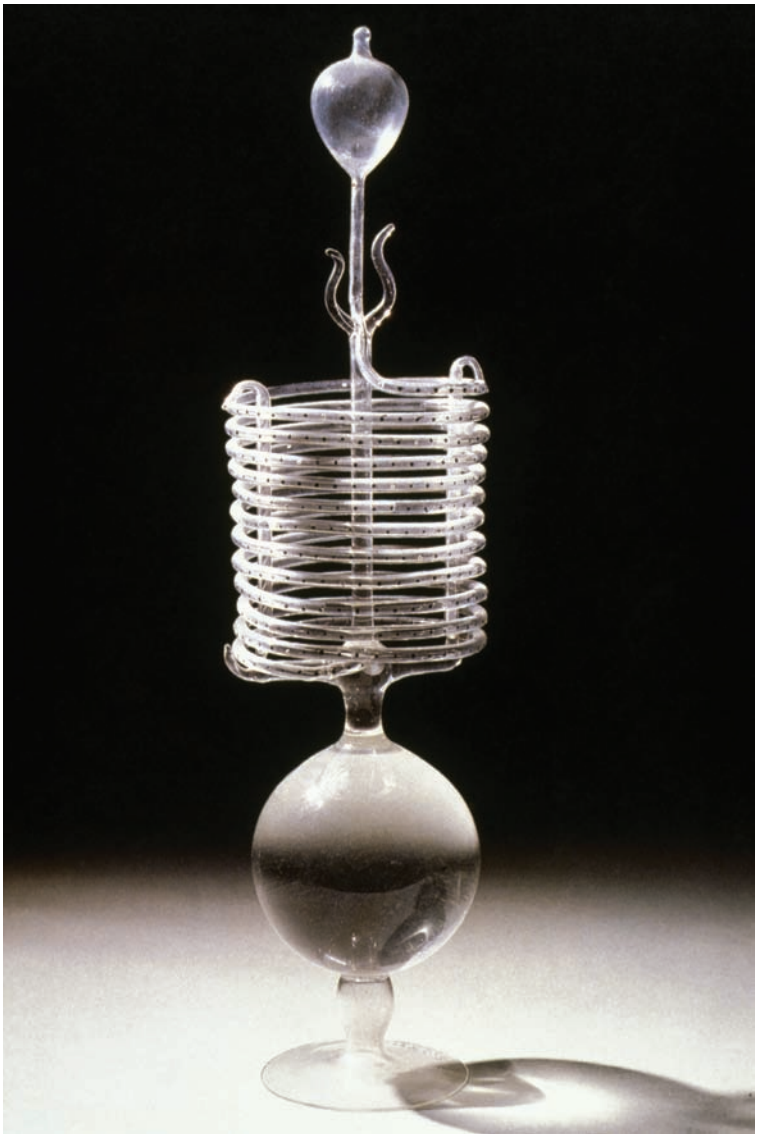


Figure 4.9 The liquid rising up the tube of this thermoscope shows that the temperature is increasing.

Did You Know?

The only countries that still use the Fahrenheit scale are the United States, Burma, South Yemen, and Tonga.

The Celsius and Kelvin Scales

Some scientists felt that it would be more convenient to have a scale with the freezing point of water as zero and the boiling point of water as 100. However, scientists were not sure that the freezing and boiling points of water were the same at different places on Earth, or under different amounts of atmospheric pressure. Anders Celsius (1701–1744), a Swedish astronomer, did detailed studies of the freezing point and boiling point of water. He showed that both are affected by atmospheric pressure. However, he also showed that the freezing and boiling points of water are always the same if they are measured under the same conditions. Therefore, to create a reliable temperature scale, he had to choose the conditions to use. He chose standard atmospheric pressure, which is atmospheric pressure at sea level. The values for the freezing and boiling points of water under these conditions became the standards for the temperature scale. In honour of his detailed work, the temperature scale was named the **Celsius scale.** Today, the Celsius scale is the most commonly used temperature scale.

In the 1800s, William Thomson, who was given the title of Lord Kelvin, and several other scientists were studying the effects of changing temperatures on gases. While analyzing the results of many experiments, Lord Kelvin developed the idea that there is a coldest possible temperature. He called this temperature *absolute zero*. No substance or object can become colder than absolute zero. Lord Kelvin proposed a new temperature scale that started at absolute zero and had units that were the same size as the units in the Celsius scale. In his honour, this temperature scale is now called the **Kelvin scale.** The units are not called degrees but instead are called kelvins and are symbolized K. Figure 4.10 shows a comparison of the Fahrenheit, Celsius, and Kelvin scales.

Did You Know?

When Celsius first proposed his scale, he assigned 0° to the boiling point of water and 100° to the freezing point. After his death, the numbers were reversed.

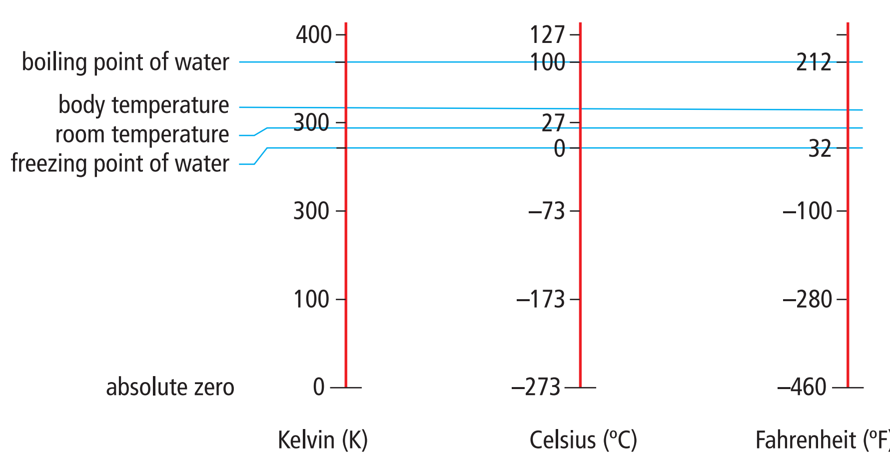


Figure 4.10 Absolute zero is really –273.15°C but it is often rounded to –273°C.

Reading Check

1. What is the difference between a thermoscope and a thermometer?
2. What was the first temperature scale to be widely used?
3. What is the difference between the Celsius and Kelvin temperature scales?
4. Why did Celsius have to choose specific conditions such as standard atmospheric pressure in order to design his temperature scale?

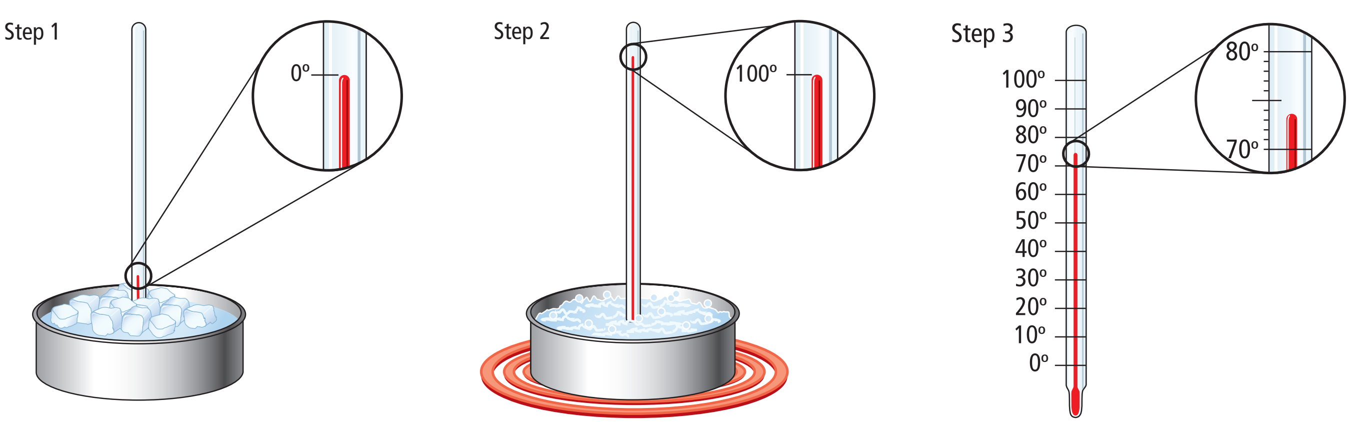
Calibrating a Thermometer

To **calibrate** an instrument means to accurately assign the numbers on a scale. A method for calibrating a thermometer is shown in Figure 4.11. You would start with a thermometer that had no markings on it and follow the steps below.

- Place the bulb of the thermometer in a mixture of pure water and ice.
- Observe the coloured liquid until it no longer moves.
- Mark the point at the top of the coloured liquid and label it 0°C.
- Remove the thermometer from the ice water and place the bulb in boiling water.
- Let the liquid rise until it no longer moves.
- Mark the point at the top of the liquid and label it 100°C.
- Divide the space between 0°C and 100°C into 100 equal spaces. Each space would represent one degree.

Suggested Activities

Investigation 4-2B on page 128.



The liquid level in an ice-water bath is marked as 0°.

The liquid level in boiling water is marked as 100°.

The scale is divided into 100 equal degrees and numbered.

Figure 4.11 The thermometer bulb is put in freezing water and boiling water to mark the positions of the liquid when the temperature is 0°C and 100°C.

The Bimetallic Strip

In recent years, scientists and engineers have developed a variety of devices that can accurately measure temperature. For example, in thermostats that turn a furnace on and off, a **bimetallic strip** is used to measure the temperature. A bimetallic strip is made of two different metals such as copper and iron that expand by different amounts when heated. One side of the strip is made of one of the metals and the other side is made of the other metal. Figure 4.12 shows you what happens when a bimetallic strip is heated. The metal on one side expands more than the other and causes the strip to bend.

For a thermostat, a bimetallic strip is made in the form of a coil. When the coil is heated, the outside expands more than the inside and this causes the strip to coil more tightly. When the coil is cooled, the outside contracts more than the inside, causing it to uncoil. Figure 4.13 shows how this coiling and uncoiling is used to turn the furnace on and off. The end of the coil is attached to a glass capsule containing a drop of mercury. When the coil is cool and loose, the mercury flows toward a pair of wires and makes an electrical connection between them. An electric current can then flow from one wire to the other, turning the furnace on. The heat from the furnace increases the temperature in the house and heats the coil causing it to tighten. When the coil is tight enough, the glass capsule tilts and the mercury flows away from the wires and the electrical connection is broken. Electric current can no longer flow and the furnace turns off.

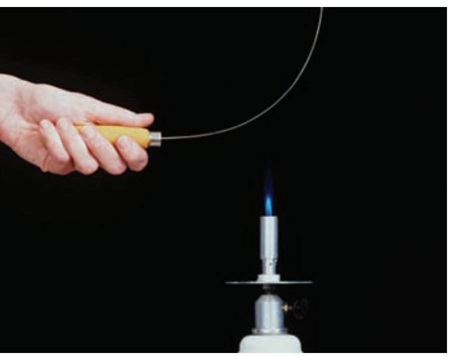


Figure 4.12 When heated, a bimetallic strip bends.

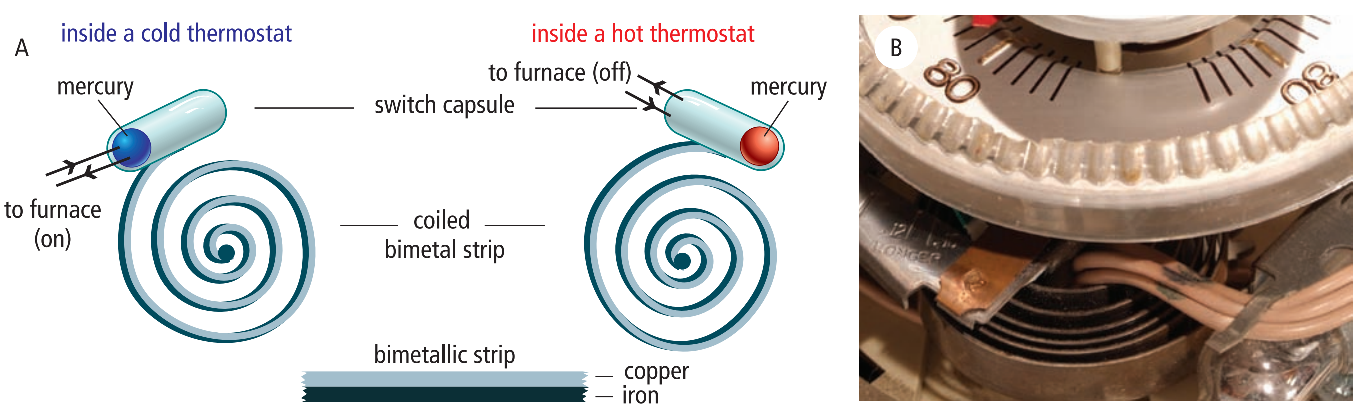


Figure 4.13 The diagram in A shows how the bimetallic strip coil moves the glass capsule with mercury. The photograph in B shows a thermostat with the cover removed. You can see the coil and the glass capsule containing the mercury.

The Thermocouple

A **thermocouple** has two wires made of different metals. The two metals are connected at both ends. A temperature difference between the two ends causes a small electric current to flow through the wires. One end, called the reference junction, is held at a known temperature. The other end, called the measuring junction, is used to measure an unknown temperature. The thermocouple can be calibrated so that the amount of current indicates the temperature. Thermocouples are more durable than most other instruments for measuring temperature. In addition, they can measure much higher temperatures than typical thermometers. Figure 4.14 shows a diagram of a thermocouple.

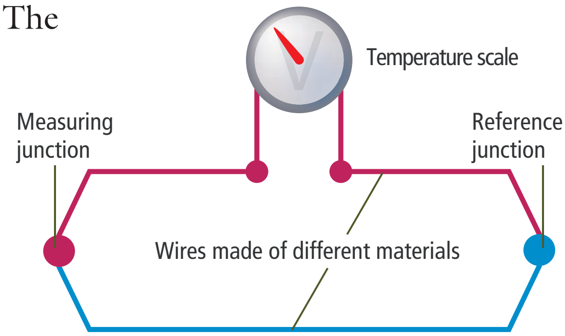


Figure 4.14 The amount of electric current that flows in a thermocouple depends on the difference in the temperature between the points where the two different types of metal wires are connected.

Infrared Thermograms

All objects give off infrared radiation. Your eyes cannot see infrared radiation but some special types of film and some electronic detectors can sense it. Film and electronic devices convert the infrared radiation into colours that can be interpreted as temperature differences. This is called a **thermogram.** Figure 4.15 shows a thermogram of a building and a photograph of the same building beside it. You can see where heat is escaping from the building by the red and yellow areas of the thermogram.

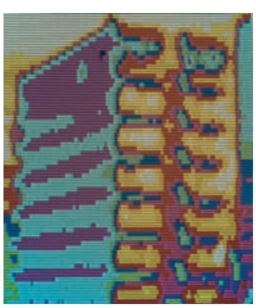


Figure 4.15 Building contractors and structural engineers can tell where a building is losing heat by studying thermograms. They can then plan ways to improve the buildings to reduce heat loss.

Reading Check

1. What does it mean when you say that you are going to calibrate a thermometer?
2. What happens when you place a bimetallic strip in the flame of a burner? Explain why this happens.
3. Name and explain the purpose of two important parts of a thermocouple.
4. If you cannot see infrared radiation, how can it be used to detect temperature differences?

internet connect

All living bodies give off a lot of infrared radiation. Doctors can use thermograms of body parts to help with the diagnosis of a medical problem. Learn more about body thermograms by starting at **www.discoveringscience.ca.**

4-2B Make Your Own Thermometer

Skill Check

- Measuring
- Controlling variables
- Evaluating information
- Working co-operatively

Materials

- small glass bottle with a narrow neck
- drinking straw or tubing
- one-hole stopper
- stand and ring clamp
- dishcloth
- ruler
- bowl of coloured water
- modelling clay
- ice-cold water
- two calibration devices

Today thermometers and other scientific instruments are mass-produced in factories. Early scientists, however, had to build their own measuring devices. Their clever designs used everyday materials, yet produced accurate measurements. Can you use modern materials to build a working model of one of the earliest thermometer designs?

Safety

Problem

Use everyday materials to build a thermometer that accurately measures temperatures in your classroom.

Criteria

A. Thermometers built in part 1 should detect increases in temperature when your teacher warms them gently with a hair dryer, and decreases in temperature when they are cooled with a cold washcloth.

B. At the end of part 2, the thermometer will have a properly constructed scale with evenly spaced degree markings and suitable numbering.

C. The thermometer must measure the temperature of the classroom accurately. The reading should be within 2°C of the temperature measured by a standard laboratory thermometer.

Part 1

Assembling the Thermometer

Design and Construct

1. Using the materials your teacher provides, your group will design and assemble a thermometer like the one illustrated the diagram. Notice that the cloth over the bottle is not part of the thermometer. It illustrates the method for cooling the air in the bottle as described in Criteria part A. The straw or tubing needs to have an airtight seal against the bottle's neck. You could use modelling clay to make a good seal.
2. Warm the bottle with your hands. Record what happens in the dish at the end of the straw. *Troubleshooting:* If nothing happens, your hands are probably about the same temperature as the bottle. Try wetting a washcloth with warm water, wringing it out, and draping it over the top of the bottle.
3. Wet a washcloth with cold water, wring it out, and drape it over the bottle. What happens to the level of the water inside the straw?

4. When you are sure that your thermometer is working correctly, have your teacher certify that it meets Criterion A.

Evaluate

1. Which part of your thermometer responds to changes in temperature? Describe how it responds when the air in the bottle (a) warms up (b) cools down.
2. Why might you add marks and numbers to your thermometer? Where would you put them?

Part 2

Calibrating the Thermometer

Design and Construct

1. Plan a method for creating a scale for your thermometer so that it can measure temperatures accurately. Here are some hints:
   (a) You must have a way to fasten your scale to the thermometer, take it off for measuring and marking, and then replace it on the thermometer in its original position.
   (b) Start by marking the scale at two known temperatures at least 10 degrees apart. You could use two wet washcloths. Soak one in water with a known cool temperature. Wrap it around the top of your thermometer and watch the liquid level rise. Mark the highest level.
   (c) Repeat step (b) using a washcloth soaked in water with a known warm temperature. Mark the lowest level the liquid in your thermometer reaches.
   (d) You now have two markings on your scale, for two different temperatures. Leaving the straw in place, remove the scale from the thermometer. Mark the proper temperatures beside each mark.
   (e) Measure and record the distance between the two marks in millimetres.
   (f) Determine the temperature difference between the two marks. Do this by subtracting the lower temperature from the higher temperature.
   (g) Divide the distance measured by the temperature difference. The answer gives you the number of millimetres that represent one degree.
2. Use your calculations to finish making your thermometer scale. Number the scale every 5 or 10 degrees.
3. Show your teacher or another lab group that your calibrated thermometer meets Criteria B and C.

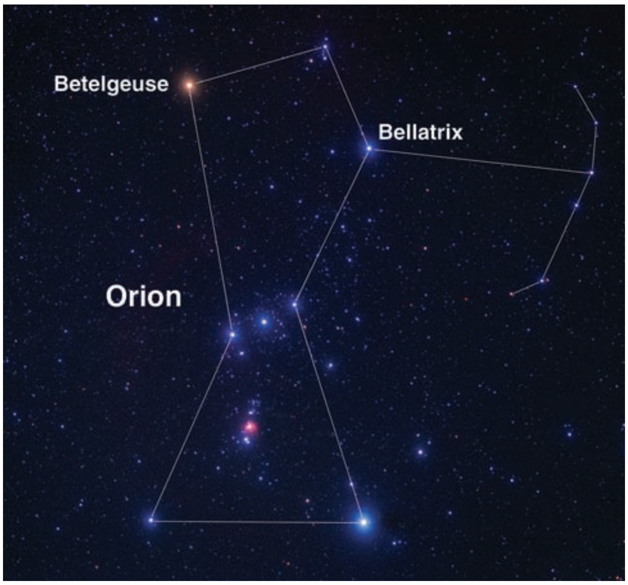
Evaluate

1. Did your thermometer meet the design specifications? How could you improve it?
2. What main problems did you have building your thermometer. How did you overcome them?
3. Why are the thermometers constructed in this activity not very useful in everyday life?

Wild, Weird, Wonderful

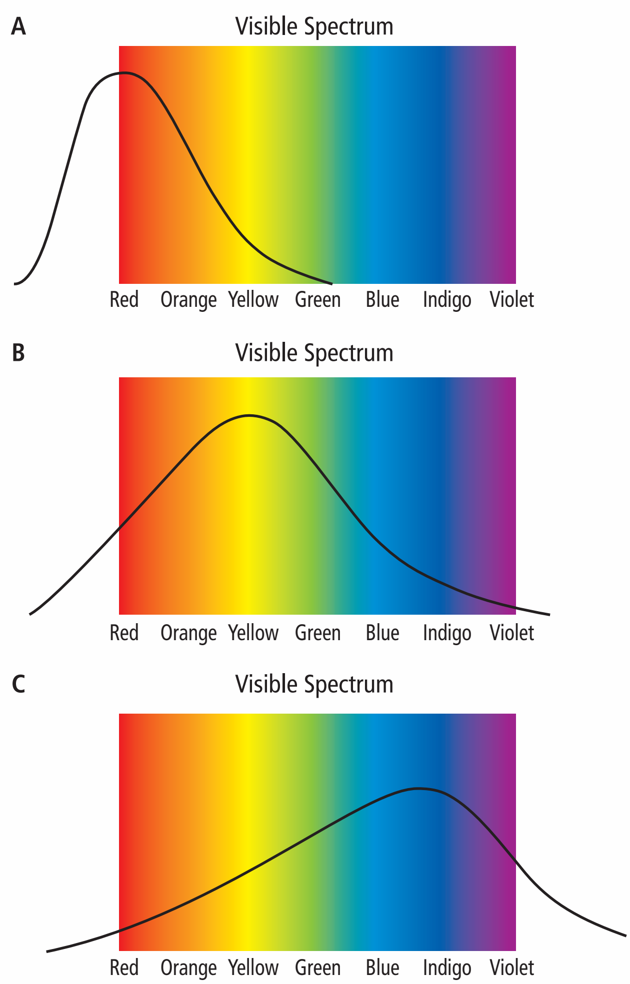
www Science

Measuring the Temperatures of Stars



The photograph shows the constellation Orion. Astronomers tell us that the temperature on the surface of the star Betelgeuse is 3100 K and the temperature on the surface of Bellatrix is 21 500 K. Do you wonder how astronomers can "take the temperatures" of the stars? Astronomers determine the temperature of the stars by their colour. All stars might look white to your eyes, but astronomers use telescopes with special instruments to determine their colours.

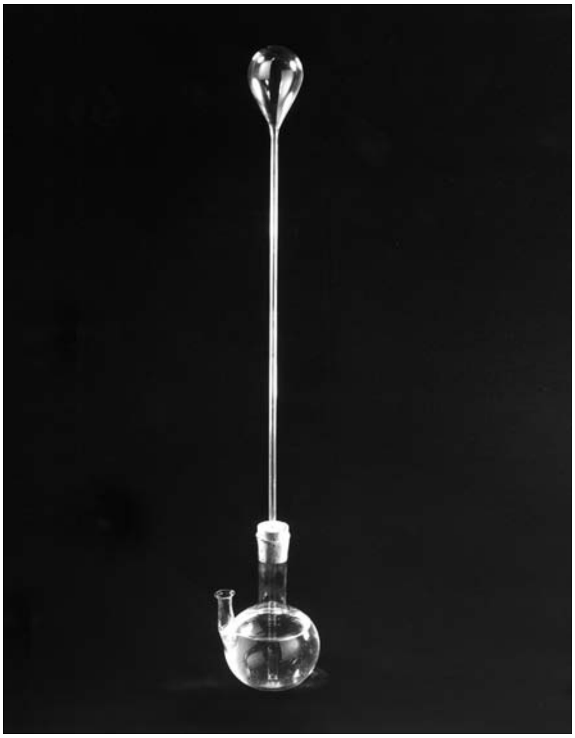
How is colour related to temperature? Think about turning on a burner on an electric stove. As it begins to heat up, it turns red. Other objects that are hotter than a burner will have other colours. As the temperature goes up, the colours go through the colours of the rainbow. The diagram on the right shows you the colours of the rainbow, called the visible spectrum, and why stars appear to be different colours. There are more "colours" on each side of the visible colours but human eyes cannot see them. However, special instruments can detect these "colours." Each section of the diagram has a curved line that shows you how much of each colour is given off by certain groups of stars. In part A, only red and a tiny bit of yellow is given off so the stars look red. These stars would have temperatures around 3000 K. In part B, more yellow is given off than any other colour so the star would look orange to yellow. These stars are around 4000 K to 5000 K. In part C, there is more blue and purple than any another colour. These blue stars are around 20 000 K. What do you think are the colours of Betelgeuse and Bellatrix?



Check Your Understanding

Checking Concepts

1. What type of information about temperature does a thermoscope provide?
2. Explain how Galileo's air thermometer showed a change in the temperature.
3. What was the first temperature scale to be widely used?
4. How does the Celsius scale differ from the Fahrenheit scale?
5. How is the Kelvin temperature scale similar to the Celsius temperature scale? How is it different?
6. Explain what it means to calibrate a thermometer.
7. Why does heat cause a bimetallic strip to bend?



Understanding Key Ideas

8. Explain the properties that a device must have in order to measure temperature.
9. Some early scientists used wine as the liquid in their thermometers. Suggest a reason for choosing to use wine.
10. Why did the scientists need to pick two things with constant temperatures in order to put scales on their thermometers?
11. Why do you think that the Celsius scale is more practical than the Fahrenheit scale?
12. What does "absolute zero" mean?
13. Explain how a thermostat can turn a furnace on and off.
14. What might be the advantages of using a thermocouple instead of a laboratory thermometer?

Pause and Reflect

A man was driving down the street and when he came to a red traffic light, he stopped. While sitting at the light, he noticed a temperature sign outside of a bank. The sign was flashing between 11° and –11°. Can you explain why the sign was showing these two numbers?

Chapter Review

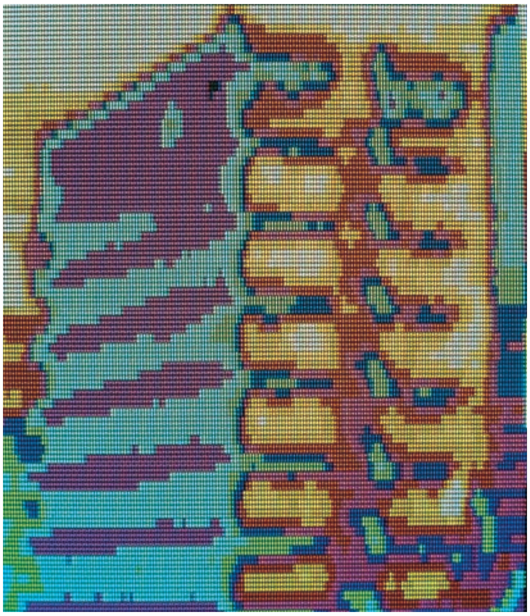
Prepare Your Own Summary

In this chapter, you investigated the temperatures of common things and ways to measure temperatures. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes.

1. Temperatures of Everyday Items and Places
2. Thermoscopes and Thermometers
3. Temperature Scales
4. Modern Temperature Measuring Devices

Checking Concepts

1. Choose five items that have different temperatures. What are the approximate temperatures of these items?
2. If the temperature of a freezer in a refrigerator was –6°C, what might happen to the food stored in it?
3. Which of the following animals would you expect to have a body temperature higher than your body temperature?
   (a) kangaroo
   (b) horse
   (c) elephant
   (d) robin
4. Why is your skin a poor instrument for measuring temperature?
5. Describe Galileo's first thermoscope.
6. In addition to developing a temperature scale, what other accomplishments did Fahrenheit make related to measuring temperatures?
7. What is the difference between the Celsius scale and the Kelvin scale of temperatures?
8. What was Lord Kelvin's major contribution to the concept of temperatures?
9. Explain how a thermogram is made.



Understanding Key Ideas

10. If you were told that an object had a temperature of –14°C, would you pick it up with your bare hands? Why or why not?

11. Explain why one person might touch an object and say it was cool while another person touches the same object and says that it is warm?

12. If a classmate told you that the coldest temperature ever recorded in Newfoundland and Labrador was –21°C, what would you tell your classmate?

13. Suppose that you were present on the hottest day that was ever reported in Canada. What would your body temperature have been? Explain your answer.

14. Many appliances in the home are heated electrically. They usually contain a thermostat that switches electricity on and off to keep the appliance at a constant temperature. Identify two examples of this use for thermostats.

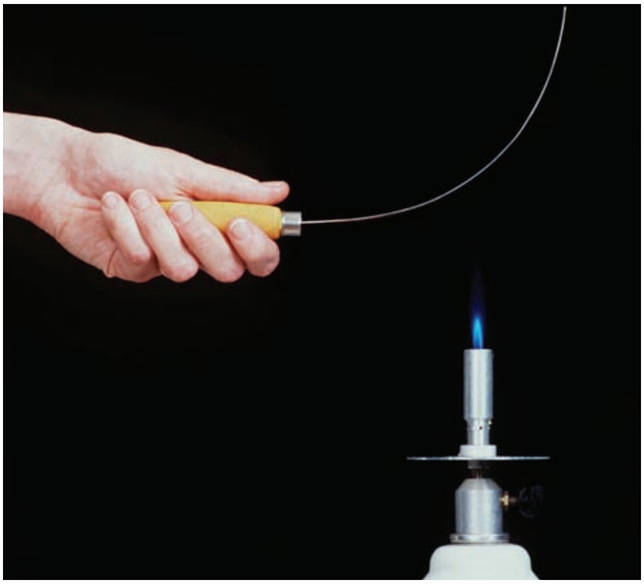
15. Erin and Val go to a swimming pool on a warm summer day. Val spreads her towel in the Sun and lies down, while Erin decides to lie in the shade. After about twenty minutes, they decide to jump into the pool. Predict how warm the water will feel to each person. Explain how you arrived at your prediction.

16. Why do you think that scientists used coloured liquids in their thermometers?

17. Many people worked on the development of a temperature scale that set 0° as the freezing point of water and 100° as the boiling point of water. Why was the scale named after Celsius?

18. Why was –273.15°C on the Celsius temperature scale chosen for 0 K on the Kelvin temperature scale?

19. Bimetallic strips and thermocouples are both made from two different metals. What properties of the metals allow these devices to measure temperatures?



Pause and Reflect

Before the temperature scale that was designed using 0° for the freezing point of water and at 100° for the boiling point of water was named the Celsius scale, it was called the Centigrade scale. The prefix "centi-" means a hundredth part of something. Explain why this was an appropriate name for the temperature scale.