Topic 4.1 What is light and how is it produced?

Key Concepts

- Many technologies produce light by converting other forms of energy.
- Light is energy and travels like a wave.

Key Skills

Inquiry

Key Terms

incandescence
luminescence
electromagnetic waves
wavelength
electromagnetic spectrum

You want to get a message to a friend. In the blink of an eye, by phone, instant messaging, or e-mail, your message can be sent and received—all thanks to the energy of light and other energy that is very similar to light.

Communication was not always this simple and speedy, however. Even communicating a message over fairly short distances can be tricky without today's technology. For instance, in the past, sailors sent messages in the form of coded pulses of light between ships as they passed each other. Series of long and short pulses of light were created by opening and closing the shutters over a bright light. Communicating in this way carried messages at a rate of about two or three pulses per second.

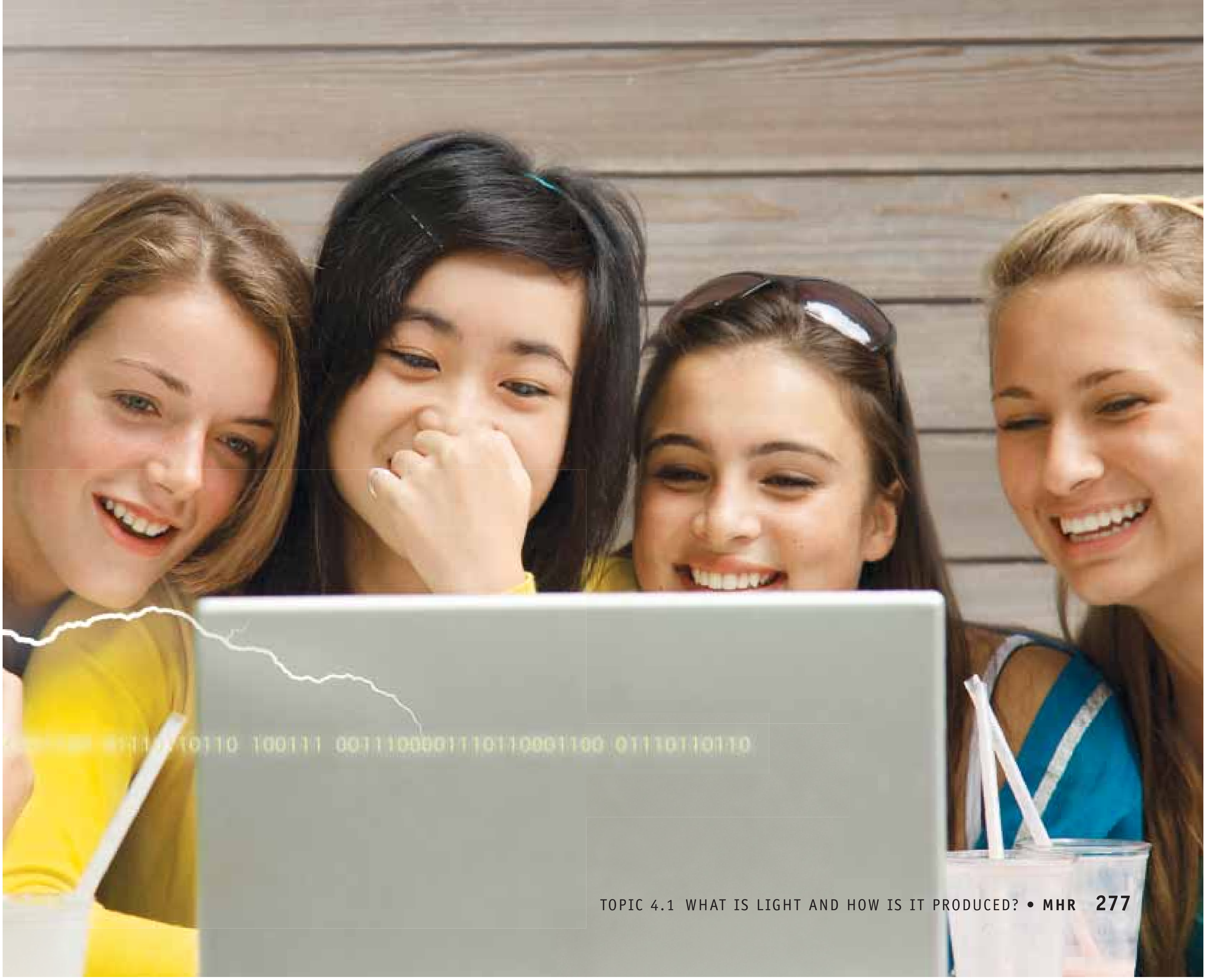
Today, on the other hand, messages can be transmitted at rates of millions of pulses per second. Laser light pulsed through optical-fibre cables and microwaves beamed between relay towers and Earth-orbiting satellites carry tens of thousands of messages over vast distances in a matter of moments.

Starting Point Activity

Your challenge is to communicate a message to your partner. Follow these rules.

- You must stand on opposite sides of the classroom facing the wall. You are back to back and cannot turn your heads to look at each other.
- You cannot use any form of sound.
- You cannot use anything that involves electronics. This means you cannot use a cell phone.
- Your message must be at least three words long.

Discuss with your partner how you will communicate. Obtain any objects or materials that you will need to use. Demonstrate to the class how you communicated without using sound or electronics.



Many technologies produce light by converting other forms of energy.

incandescence: light given off by an object because it is very hot

luminescence: light given off by an object that has not been heated

We use the energy of light to help us communicate. But we also use light for an equally important purpose: to see and to illuminate the world around us.

Some objects give off light because they are hot. The light produced by these objects is called **incandescence**. Other objects give off light without needing to become hot. The light produced by these objects is called **luminescence**. A variety of technologies have been developed to produce light by incandescence and by luminescence.

Producing Light by Incandescence

For thousands of years, people have depended on fuel-burning technologies such as those shown in Figure 4.1 to produce light. Burning a fuel transforms the chemical energy of fuel into heat and light. Fuel-burning is an inefficient source of light because most of the chemical energy stored in the fuel is converted into heat.

▶ Figure 4.1 Fuels that are burned to produce light include wood, natural gas, petroleum oils, fish oils, and wax. In all cases, chemical energy is transformed into heat and light energy.

A: The flame carried by Olympics relay runners may burn a mixture of gases such as butane and propane. In the past, fuels as varied as olive oil, whale oil, fish oil, kerosene, and even gunpowder have been used.

B: Butane lamps are a cheap, common source of lighting for campers and for people in rural areas during power outages.

▲ Figure 4.2 The filament of an incandescent light bulb reaches a temperature of about 3000°C.

Incandescent light bulbs have been a commonly used technology for many years. In an incandescent bulb like the one in Figure 4.2, electrical current runs through a tiny metal filament, making the filament so hot that it glows. However, the incandescent light bulb is very inefficient. More than 90 percent of the electrical energy it uses is given off as heat. Less than 10 percent of the electrical energy is transformed into light.

Producing Light by Luminescence

Neon signs produce light without heating, so they are an example of light produced by luminescence. **Table 4.1** shows three more examples of technologies that involve luminescence.

Table 4.1 Examples of Light-producing Technologies from Luminescence

Examples	Energy Transformation	Type of Luminescence
You have probably seen glow sticks in the form of jewellery. When glass capsules inside the plastic stick are broken, a chemical inside the glass mixes with another chemical inside the plastic. The chemical reaction that results releases light.	chemical energy to light energy 	*Chemiluminescence* is light that is released during chemical reactions.
Many street lights are electric discharge lights. You might have noticed some street lights that have a slightly yellowish tint. These are called sodium vapour lights. Some sodium and a small amount of mercury are sealed inside the tube. A little heat will cause them to form a vapour, and the electric discharge will cause the vapour to emit light with a yellow colour.	electrical energy to light energy 	*Electric discharge* is carried out in a sealed glass tube. One or more gases are sealed in the glass. An electrode at one end emits high-energy electrons, and an electrode at the other end attracts them. As the energetic electrons collide with particles of gas, they transfer energy to them. The gases release the energy as light.
For many years, long tubular fluorescent lights were used in schools and businesses. More recently, small compact fluorescent bulbs have come into use in homes. Because these bulbs produce light without becoming very hot, they are more efficient than incandescent bulbs. Thus, they conserve energy.	electrical energy to light energy  	*Fluorescence* is a form of electric discharge. However, the gases emit ultraviolet light. The inner walls of the glass tube are covered with a substance called a phosphor. The ultraviolet light transfers energy to the phosphor, which then releases the energy as light.

LEARNING CHECK

1. Make a t-chart to compare the two main types of light production and examples of technologies that make use of them.
2. Fireflies (also called lightning bugs) produce light called bioluminescence. From what you have learned about producing light, infer how bioluminescence works.
3. Infer the type of light that is produced by the Sun.
4. Some governments are considering banning incandescent light bulbs. Why do you think they are considering this?

Light is energy and travels like a wave.

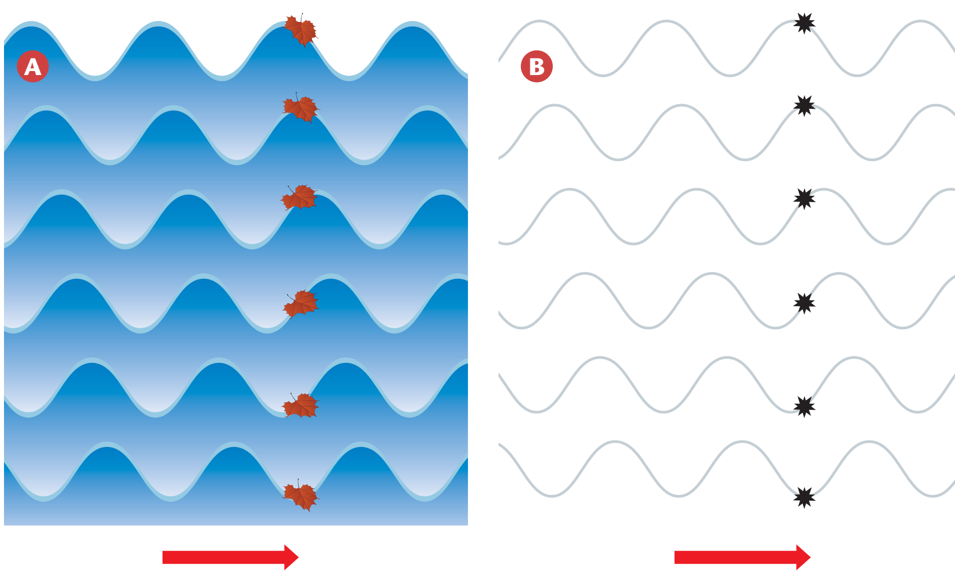
electromagnetic waves: waves that carry electrical energy and magnetic energy

The energy that we call light is related to certain other forms of energy that you have heard of—microwaves, ultraviolet waves, X rays, to name a few. These forms of energy are grouped together under the more general name, electromagnetic waves. **Electromagnetic waves** are made up of electrical energy and magnetic energy.

Waves Carry Energy

You use electromagnetic waves when you watch TV, listen to the radio, or use a cellular phone. Electromagnetic waves are invisible, so you cannot see them carry energy. However, all waves have similar characteristics, so you can learn a lot about all types of waves by observing waves that you *can* see: water waves.

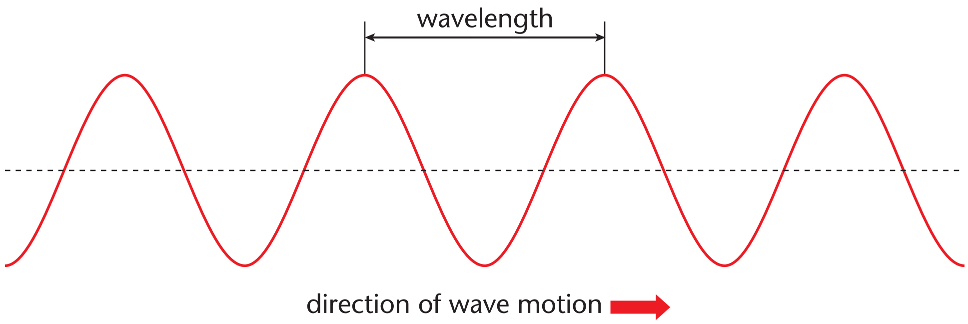
Figure 4.3A shows a leaf floating on water while a wave passes by. Each line represents the same wave just a moment after the line above it. Notice how the leaf just moves up and down while the wave appears to be going from left to right. When any object is moving, the object has energy. The energy of motion is called kinetic energy. In **Figure 4.3A**, the water wave is giving the leaf kinetic energy. The water and the leaf are moving up and down but they are not moving from left to right. *It is the energy that is moving from left to right.* **Figure 4.3B** represents an electromagnetic wave. You cannot see it but if a charged particle is in the path of an electromagnetic wave, the charged particle moves up and down.



▲ **Figure 4.3** Comparing water waves and electromagnetic waves. As the water wave in A passes by, the leaf moves up and down. As the electromagnetic wave in B passes by, the charged particle moves straight up and down.

The graph in **Figure 4.4** can represent any type of wave. One of the most important characteristics of a wave is its wavelength. The **wavelength** is the distance from one peak to the next. You will see, when you turn the page, that the wavelength of an electromagnetic wave determines how it can be used and whether you can see it.

wavelength: the distance between peaks on a wave



▲ **Figure 4.4** This wave can represent a water wave, an electromagnetic wave, a sound wave, or any other kind of a wave.

Inquiry Focus

Activity 4.1

TRANSFERRING ENERGY

Can you ring a bell without touching it? Sound is a form of energy. So, to ring a bell, you have to transfer energy to the bell. In this activity, you will test one way of transferring energy to the bell without touching it. While you are carrying out this activity, try to think of other ways that you could transfer energy to the bell and make it ring without touching it. If possible, test your ideas.

What You Need

- rope (about 2 m long)
- jingle bell or other small bell (very lightweight)

What To Do

1. Tie the bell to the centre of the rope.
2. Hold one end of the rope and have a partner hold the other end. You could also tie the other end to a doorknob or to the leg of a chair or desk.
3. Shake your end of the rope up and down two or three times. Observe the motion of the rope and the bell.

What Did You Find Out?

1. Describe the motion of the rope.
2. What was the direction of the motion of the bell?
3. Sound is a form of energy. What was the source of the energy that was transformed into the sound energy of the bell?
4. What moved along the rope?
5. How do your observations relate to the properties of light?
6. If you were able to test one of your own ideas, explain how energy was transferred to the bell to make it ring.

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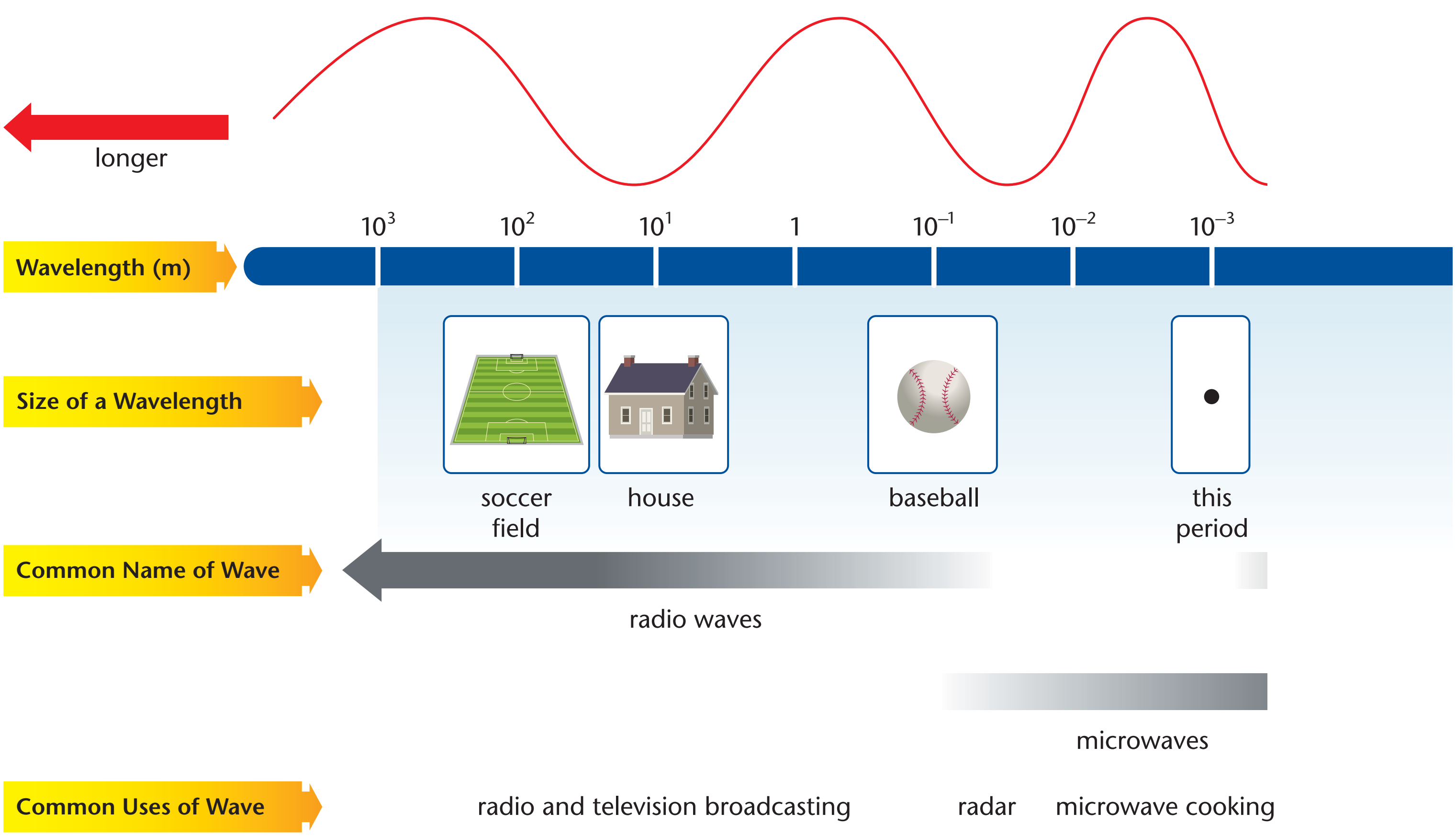
electromagnetic spectrum: a representation of the types of electromagnetic waves arranged according to wavelength

The Electromagnetic Spectrum

There are many types of electromagnetic waves. The main difference among them is their wavelength. When the types of electromagnetic waves are arranged according to wavelength, the diagram is called an **electromagnetic spectrum**. **Figure 4.5** shows the wavelengths and the uses of different types of electromagnetic waves.

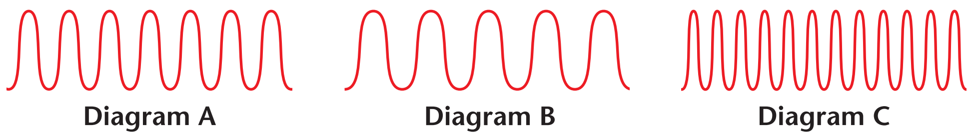
The only waves of the electromagnetic spectrum that you can see are those of visible light. As you can see in **Figure 4.5**, visible light is a very small part of the electromagnetic spectrum. It has been enlarged so you can see that the colours are just different wavelengths of light. The longest wavelengths of visible light are red (7.0×10^{-7} m) and the shortest wavelengths are blue (4.0×10^{-7} m).

▼ **Figure 4.5** The electromagnetic spectrum

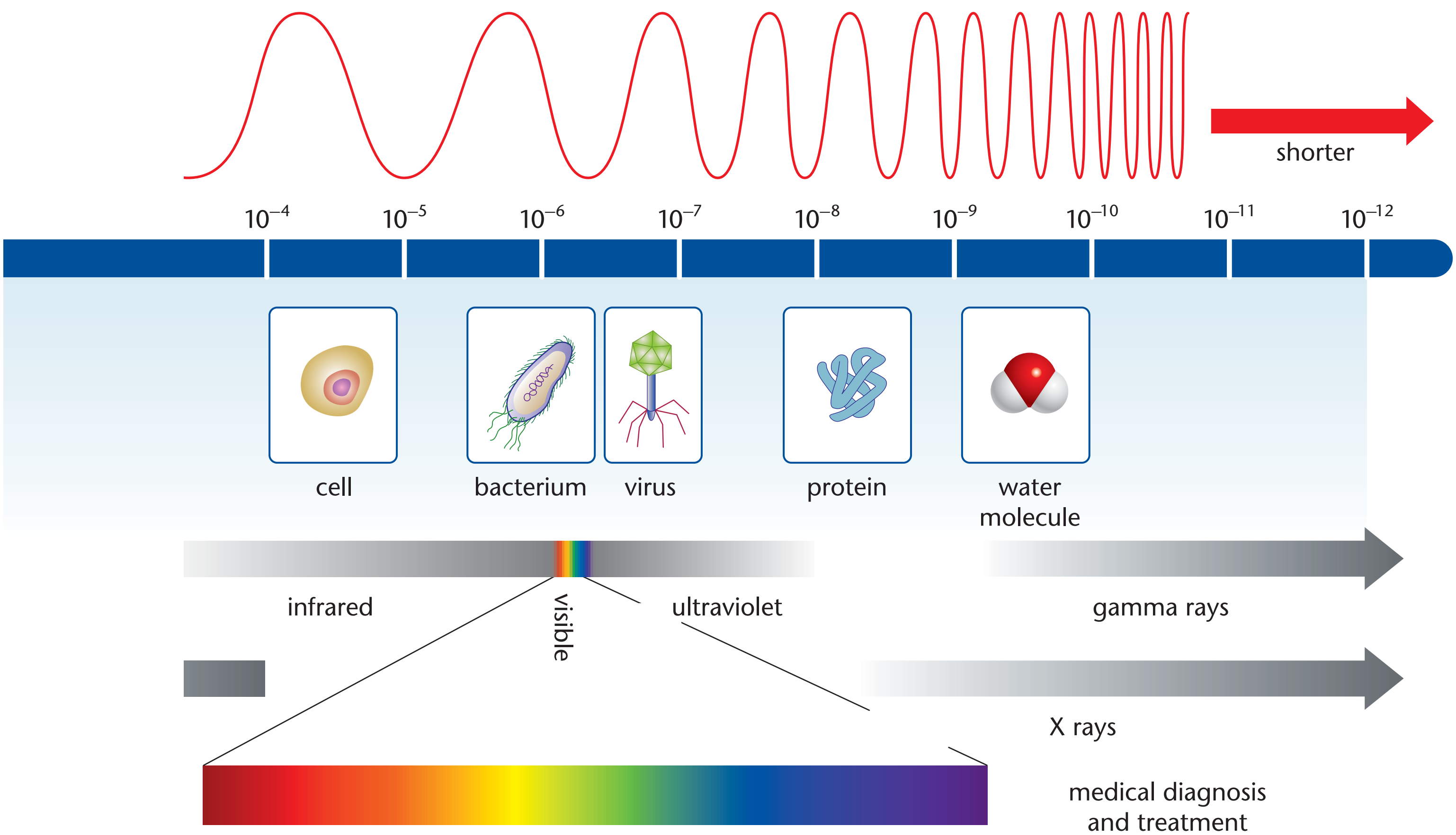


LEARNING CHECK

1. Sort the following parts of the electromagnetic spectrum in order from shortest wavelength to longest wavelength: microwaves, ultraviolet, green, X rays, red, infrared, purple, yellow.
2. The diagrams below show the wavelengths of three waves. Assume that they represent electromagnetic waves in three regions of the spectrum; visible light, infrared waves, and X rays. Compare the wavelengths, and state which would represent visible light, infrared waves, and X rays. Explain how you made your decision.



3. **a)** What type of wave has a wavelength about the size of a house?
   b) What type of wave has a wavelength about the size of a bacterium?
   c) What is one use of a wave that has a wavelength about the size of a water molecule?



Making a DIFFERENCE

Charlie Sobcov has always had a passion for animals. When he read that millions of birds are killed each year when they fly into the glass windows of skyscrapers, he was inspired to invent a device to save them. He invented plastic decals painted with ultraviolet paint. Birds can see ultraviolet but humans cannot. Therefore, the decals are visible to birds but appear clear to humans. The decals are made of a plastic that clings to windows through static electricity. They can be peeled off one window and re-used on another window.

After creating his invention, Charlie put an advertisement in a local newspaper to ask people to help him test it. The test results have been positive. They have also helped him improve his design. Charlie's life-saving project has also earned him several awards and interviews with news media.

How else could ultraviolet paint help birds and other animals such as bees that can see ultraviolet waves?

Pénélope Robinson and Maude Briand-Lemay used their knowledge of mirrors and reflection to double energy production from solar panels on residential roofs.

Residential solar panels are installed on the south side of a sloped roof where they receive more sunlight. Pénélope and Maude's system includes a mirror on a pole. When the Sun's rays hit the mirror, they are reflected toward solar panels on the north side of the roof.

Pénélope and Maude tested their system. Without the mirror, solar panels on the north side did not collect solar energy. With the mirror, the same amount of energy was collected from solar panels on both sides of the roof.

Pénélope and Maude earned an award for their project at the 2007 Canada Wide Science Fair. They have since registered a patent for their design.

In what other ways could mirrors be used to harness the Sun's energy?

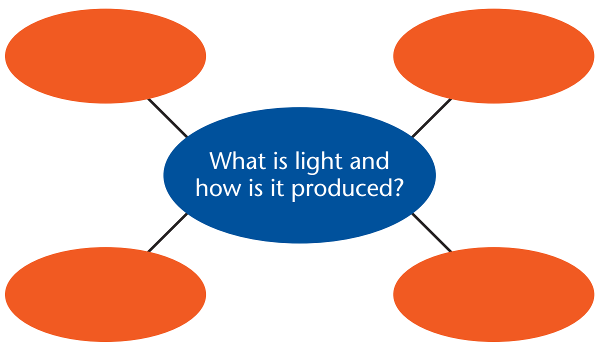
Topic 4.1 Review

Key Concept Summary

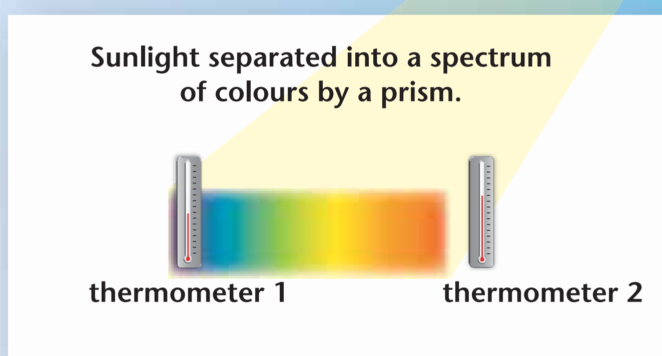
- Many technologies generate light by converting other forms of energy.
- Light is energy and travels like a wave.

Review the Key Concepts

1. K/U Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. C Describe at least two pieces of evidence that show waves carry energy.
3. K/U What property of electromagnetic waves determines the colour of light?
4. K/U Make a sketch of the electromagnetic spectrum. Label the visible and invisible regions. Which region is largest?
5. K/U Use a Venn diagram to compare incandescence and luminescence.
6. C Use a flowchart to outline the steps that occur in an incandescent light bulb to make it light up.
7. A Name two places that you would expect to find electric discharge technology.
8. T/I In 1800, Sir Frederick William Herschel made an important discovery about the electromagnetic spectrum. He made a slit in a sheet of dark material that allowed a small ray of sunlight through. He directed the ray through a prism, which separated the sunlight into the colours of the spectrum as shown below. He placed one thermometer in several different colours of light to see which carried the most heat. He placed another thermometer beside the red light where no light was visible. Surprised, he saw that the thermometer beside the red end showed a higher temperature than thermometers placed in any of the colours. Infer what Herschel discovered. Explain your answer.



Thermometer 1 was used to measure the temperature of each colour. Violet had the lowest temperature, and red had the highest. The temperature of the other colours increases steadily from violet to red. Thermometer 2 was placed beside the red end.