TOPIC
3.1

How does electromagnetic radiation shape your world?

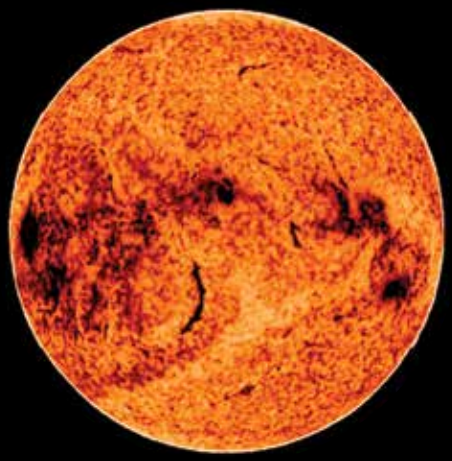
Electromagnetic radiation is a form of energy. It is given off by many different sources on Earth and throughout the universe. However, most of the electromagnetic radiation that reaches Earth comes from the Sun. The images shown here are all of the Sun. They are made by different telescopes, each of which detects a different type of electromagnetic radiation. Some types of electromagnetic radiation given off by the Sun are harmful to living things, including you. Other types are essential to the survival of life on Earth.

Key Concepts

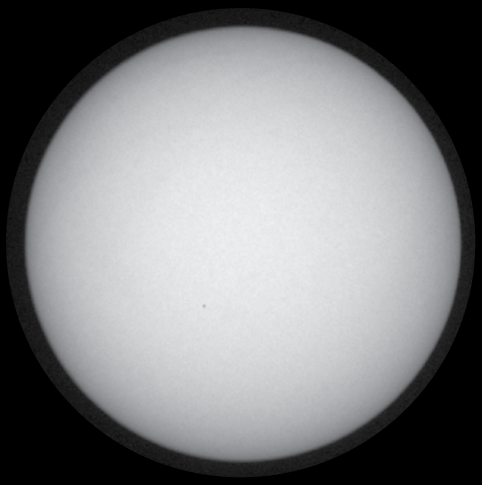
- Electromagnetic radiation is an important part of your world.
- Sources of electromagnetic radiation are all around you.
- Electromagnetic radiation enhances how we sense our world.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest
- Co-operatively design projects
- Identify a question to answer or a problem to solve through scientific inquiry
- Consider social, ethical, and environmental implications of the findings



Infrared telescope

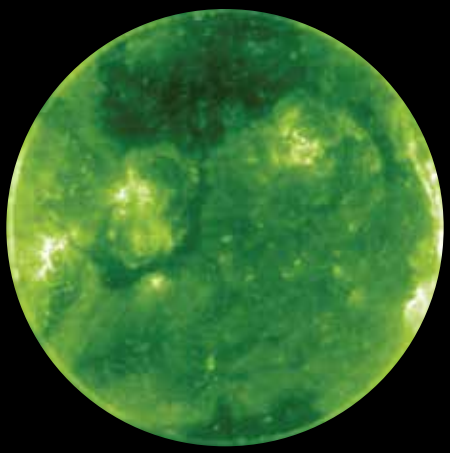


Optical telescope

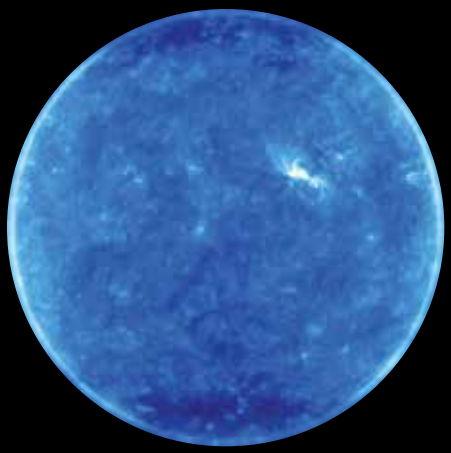
Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Visible light is only one type of electromagnetic radiation given off by the Sun. What other types have you heard of? How are they used? How do they affect your life?
2. **Communicating** Electromagnetic radiation is a form of energy. Use a graphic organizer to review what you already know about energy.
3. **Questioning and Predicting** Earth is knocked out of its orbit! It reads like the storyline of a science fiction movie, but imagine if this happened. Earth travels farther and farther from the Sun until the Sun is just a pinprick of light in a dark sky. What changes would take place on Earth if it no longer received the Sun's energy? Brainstorm as many ways as you can think of.



Ultraviolet telescope



X-ray telescope

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- electromagnetic radiation

Flip through the pages of this Topic to find this term. Add it to your class Word Wall along with its meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Electromagnetic radiation is an important part of your world.

Activity

Electromagnetic Radiation on Prime Time

Congratulations! Your production team has scored a job to produce a two minute science segment on a local news show. Your segment is called "Electromagnetic Radiation in Your World." It will feature one way that electromagnetic radiation is making headlines. You can research one of the ideas on these pages, or you can find another story that interests you. The format is up to you. Working with your team members, create a script to fill your air time.

As shown in Figure 3.1, **electromagnetic radiation** shapes your world. Without it, there would be no cell phones, television, wireless Internet, or even life on Earth. Scientists have defined seven different types of electromagnetic radiation. These are radio wave, microwave, infrared, visible light, ultraviolet, X-ray, and gamma-ray radiation. Each type has expanded human ability or discovery in some way.

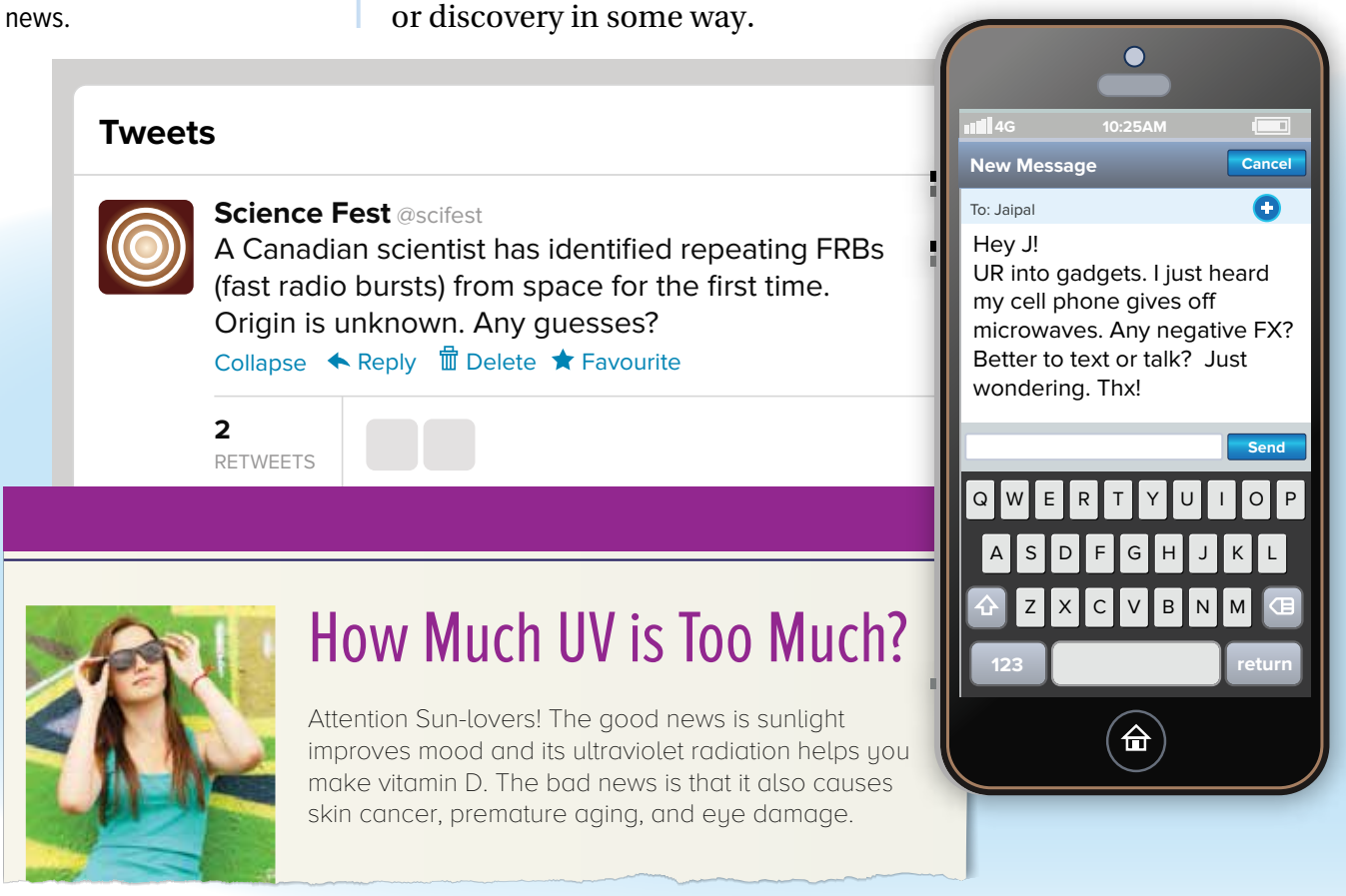
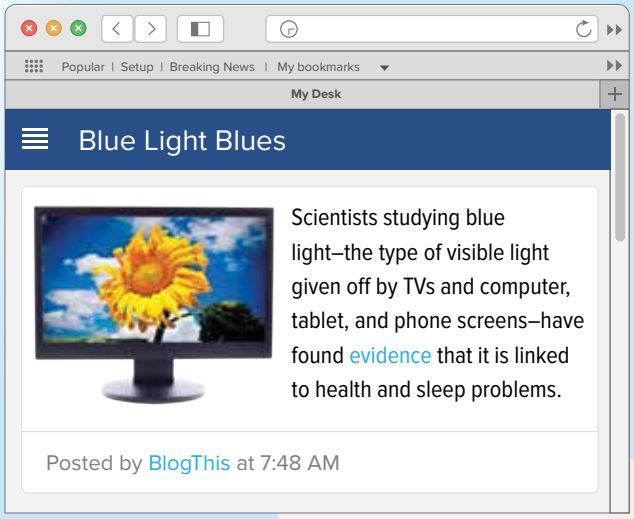


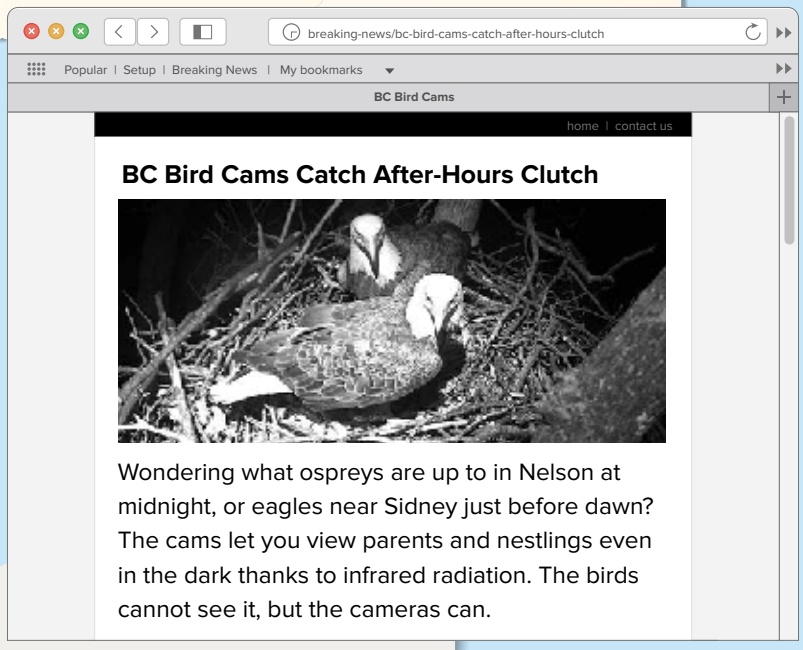
Figure 3.1 Electromagnetic radiation is often discussed online and covered by the news.

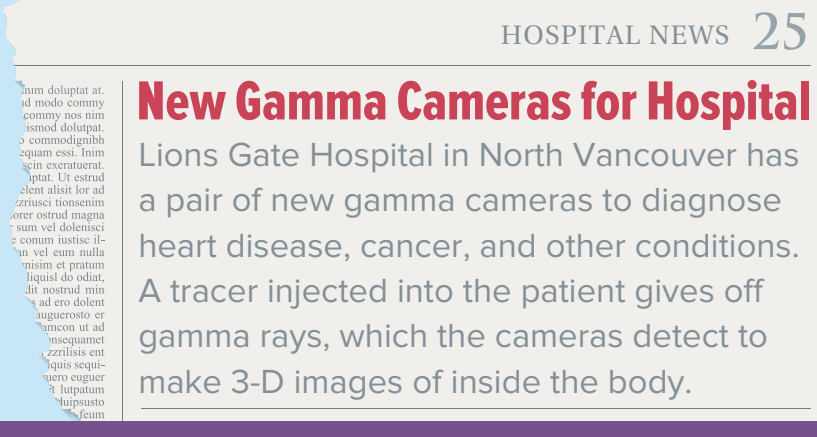
Dig This

X-Rays Solve Mystery

Archaeologists studying First Nations artifacts at the Sunshine Coast Museum have dated some to be over 5000 years old. X-ray technology has uncovered other information, too. A technique called X-ray fluorescence has helped archaeologists determine where the stone came from originally.






HOSPITAL NEWS 25

New Gamma Cameras for Hospital

Lions Gate Hospital in North Vancouver has a pair of new gamma cameras to diagnose heart disease, cancer, and other conditions. A tracer injected into the patient gives off gamma rays, which the cameras detect to make 3-D images of inside the body.

Before you leave this page . . .

1. Why do you think sunglasses have special lenses that filter out ultraviolet radiation?
2. Why might you want to limit the amount of time you spend in front of an electronic screen at night?

CONCEPT 2

Sources of electromagnetic radiation are all around you.

Activity

Electromagnetic Radiation Inventory

A lot of things you are familiar with give off electromagnetic radiation. As a class, brainstorm as many as you can. Then answer the questions below.

1. Which sources can be found in your home or school? in your community or region?
2. What other questions or concerns do you have about sources of electromagnetic radiation? Discuss these as a class.

Now that you have a better understanding of how electromagnetic radiation shapes your world, where do you think it comes from? There are many different sources of electromagnetic radiation. Some sources are familiar, like cell phones and light bulbs. Others, like X-ray tubes, may be unfamiliar. Some sources are artificial, while others are natural, including living organisms. **Figure 3.2** explores several of these sources. You may be surprised to learn that even you are a source of electromagnetic radiation.

As you read about these sources, keep in mind that electromagnetic radiation is energy. That means it is neither created nor destroyed. Instead, it is transferred from one object to another or transformed into another kind of energy.

Figure 3.2 Some sources of electromagnetic radiation.

The Sun: A Source of All Types of Electromagnetic Radiation

The Sun gives off all types of electromagnetic radiation. The energy carried by this radiation is produced by nuclear fusion. During fusion, hydrogen nuclei collide and combine to form helium. Fusion releases an enormous amount of energy. How enormous? When 1 g of hydrogen atoms fuses, the reaction releases 65 billion kJ of energy—the amount of energy in over 50 000 pieces of pizza. More than 500 trillion grams of hydrogen fuse in the Sun every second. The incredible amount of energy released by the Sun supports life on Earth.

Chemical Reactions in Living Organisms: A Source of Visible Light

Chemical reactions can give off visible light. Some of these reactions occur in living organisms. The female anglerfish shown here lives deep in the ocean where sunlight cannot reach. It has a lure that gives off visible light to attract its prey (fish it eats). The lure dangles from a spine over the anglerfish's head. Bacteria living in the lure produce the light.

Heated Materials: A Source of Visible Light and Infrared Radiation

All objects, including you, give off infrared radiation. As an object gets hotter, it gives off more infrared radiation. You sense this energy as heat. If objects are very hot, they can give off visible light as well. For example, a wood fire, a candle flame, and a hot element on a stovetop give off light. Infrared radiation and light are also given off by light bulbs. For example, halogen bulbs have a thin tungsten wire enclosed in quartz. When the bulb is turned on, the tungsten gets very hot and gives off light. The bulbs are filled with halogen gas, which allows them to become very hot without burning out. Halogen bulbs are often used in high-intensity desk lamps.

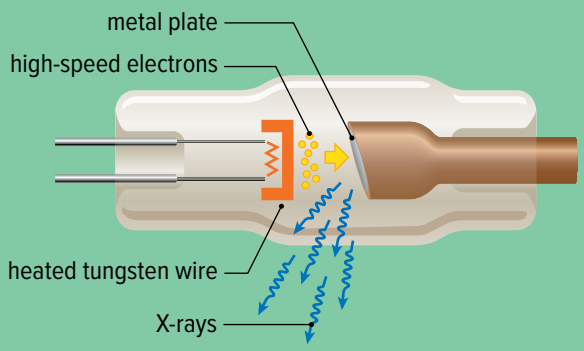
Telecommunications: A Source of Microwaves and Radio Waves

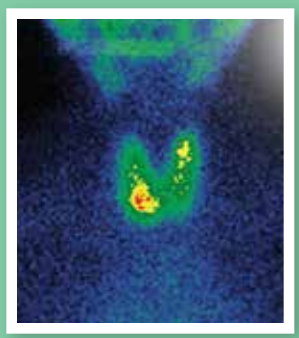
Your cell phone is a source of microwaves. The microwaves carry the information you put into the phone, whether speaking or texting, to a nearby cell phone tower. Wires then carry the information farther. If the information is going to another cell phone, it travels to the tower nearest that cell phone. The tower creates microwaves that carry the information to the other phone.

Commercial radio stations generate radio waves to send signals that radio receivers convert into sound. Communication systems used by police, fire, and emergency workers also generate radio waves. They use them for on-the-job communication.

X-ray Tubes: A Source of X-rays

X-rays are produced by a change in the speed of very fast-moving electrons. In an X-ray tube, high-speed electrons are released from a super-heated tungsten wire. The electrons then collide with a metal surface that stops them suddenly. This sudden change in speed generates X-rays, which can be used to create images of teeth or bones.





Radioisotopes: A Source of Gamma Rays

Gamma rays are produced by unstable nuclei of certain atoms. Atoms with unstable nuclei are called *radioisotopes*. Radioisotopes have too much energy. To become stable, they give off energy in different forms, including gamma rays.

Iodine-131 is a radioisotope that gives off gamma rays. It is used to treat thyroid cancer. When a cancer patient ingests (swallows) iodine-131, nearly all of it will go to the thyroid gland and kill the cancer cells. It will also kill some healthy cells, but this usually does not harm the person.

Radioactive iodine can also be used to study body functions. The gamma camera image on the left shows an overactive thyroid gland that was injected with radioactive iodine. Part of the gland looks brighter and larger. It has taken up more iodine, so the camera detects more gamma rays from that area.

Extending the Connections

The X-Ray Files

Many sources of electromagnetic radiation are truly out of this world!

1. Carry out research to find out more about extraterrestrial sources of electromagnetic radiation. (Extraterrestrial refers to anything that is beyond Earth.)
2. Choose one that interests you. Do more research to find the following information:
   - a description of the source
   - what type(s) of electromagnetic radiation the source gives off
   - how we measure or detect the electromagnetic radiation
   - one question you have about the source and the answer you found to it
   - an image of the source, if available
3. Use your findings to create a file about the source. Share your file with the class.

Before you leave this page . . .

1. What type or types of electromagnetic radiation are given off by the following sources?
   - **a)** a halogen light bulb
   - **b)** the Sun
   - **c)** iodine-131
   - **d)** you
2. Identify three sources of electromagnetic radiation that you interacted with this week.
3. A type of starfish uses electromagnetic radiation to warn predators that it does not taste good. What type of electromagnetic radiation is most likely given off by the starfish?

CONCEPT 3

Electromagnetic radiation enhances how we sense our world.

Activity

Electromagnetic Radiation Mnemonic

A mnemonic (neh-mon-ik) is a trick you can use to remember a list of names or words. For example, a mnemonic that can help you remember the seven different types of electromagnetic radiation is Radical Musicians In Vanderhoof Undo Xylophone Glue. Each word starts with the same letter as a type of electromagnetic radiation. Create your own mnemonic to help you remember the types of electromagnetic radiation.

You are an electromagnetic radiation detector. Special cells in your skin sense infrared radiation and send a message to your brain that is interpreted as heat. Your eyes sense visible light to see brightness, objects, and colour. Modern technology has also opened the door to new ways for humans to sense the world, and beyond. **Figures 3.3** to **3.6** explore just a few ways that law enforcement officers, medical professionals, and scientists use electromagnetic radiation and technology to "see" in a whole new way.

Solving Crimes

Electromagnetic radiation helps criminal investigators find evidence that is invisible to the unaided eye.

- Luminol is used to find traces of blood at a crime scene, as shown in **Figure 3.3**. This chemical undergoes a reaction with the iron in blood to give off visible light.
- Infrared photography creates images by sensing temperature differences. It is often used to find hidden evidence, such as weapons and other objects placed within walls.
- Investigators use X-ray, infrared, and ultraviolet radiation to uncover art forgeries. The radiation can help show an artist's unique brushstrokes, identify pigments and varnishes, and uncover other paintings an artist has painted over.

Figure 3.3 Luminol is sprayed at a crime scene to test for blood.

Connect to Investigation 3-A on page 200

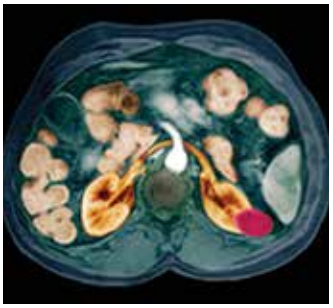


Figure 3.4 This MRI image shows a cross-section of a human abdomen. It has been coloured to help show the different organs.

Diagnosing Disease

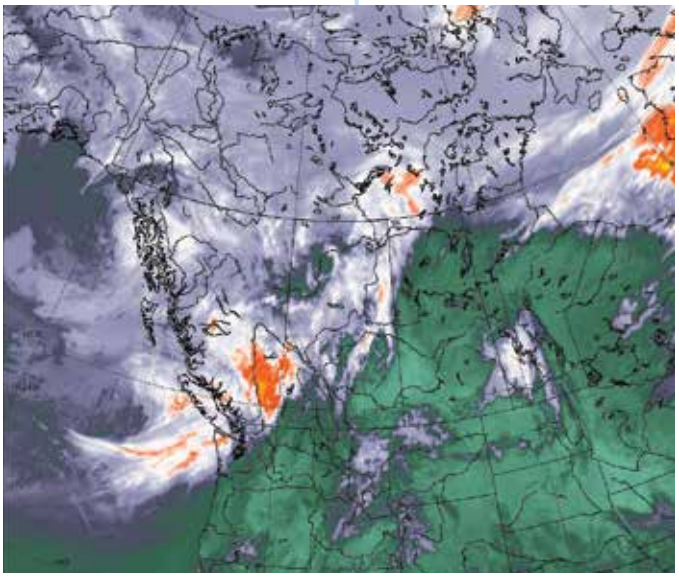
Different kinds of electromagnetic radiation are used to identify medical problems.

- Radio waves and magnets work together in magnetic resonance imaging (MRI). The signals generated are used to create an image of the tissues being tested. Unhealthy tissues look different from healthy ones. An MRI image is shown in **Figure 3.4**.
- X-ray imaging is useful for diagnosing conditions like broken bones and cavities in teeth. X-rays are absorbed by bones and teeth but pass through most other body tissues.
- The B.C. Cancer Agency was the first to develop a handheld device that dentists and doctors can use to shine blue light into the mouth to detect cancer. The tongue normally glows under blue light or ultraviolet radiation, but cancerous tissue looks dark.

Seeing Earth from Space

Electromagnetic radiation gives us a unique view of Earth. Satellites orbit high above Earth's surface. They use different types of electromagnetic radiation to gather information about our planet. This technology is called *remote sensing*.

- Weather satellites use reflected visible light and infrared radiation coming from Earth to obtain information about weather conditions (**Figure 3.5**). They can detect the location and movement of clouds and the amount of moisture in the atmosphere.



- LANDSAT is a satellite that measures visible light and infrared radiation coming from Earth's land surface to map it. Its images help with everything from monitoring loss of rain forests to finding near-shore shipwrecks.

Figure 3.5 Satellite images of Earth help meteorologists forecast the weather.

Viewing the Universe

Electromagnetic radiation is being used to study the universe.

- The Hubble Space Telescope orbits Earth. It uses mirrors, one of which is over 2.4 m wide, to collect and focus visible light. *Focus* means to bring light to a point to form a clear image. The images produced are clearer than those from telescopes on Earth, because the blurring effect of Earth's atmosphere is avoided. Other instruments on the telescope sense ultraviolet and infrared radiation.
- The Very Large Array is the largest radio telescope on Earth. It consists of 27 receivers that work together to sense radio wave radiation from space. Other telescopes sense microwave, X-ray, and gamma ray radiation (Figure 3.6) to view the universe.

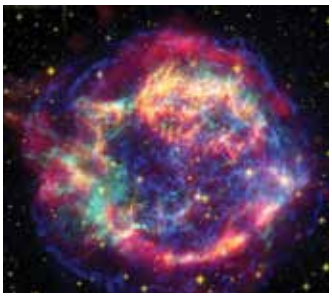


Figure 3.6 This image of a supernova (exploding star) combines data from telescopes sensing different kinds of electromagnetic radiation.

Activity

Electromagnetic Radiation Detective

Choose one of the problems below that interests you. Then carry out research as an electromagnetic radiation detective to solve it.

A. Crime Scene Challenge: You are a rookie detective in Fort St. John. You arrive at a crime scene with your supervisor. "The forensics team is here already. They're looking for body fluids with that ultraviolet light," says your supervisor. "Can you tell me which body fluids ultraviolet radiation can detect and how it detects them?" How do you respond?

B. Diagnosing Patient X: You are a student doctor in Victoria. You suspect that one of your patients has poor circulation in his hand. The senior doctor recommends a type of medical image called a thermogram. "Can you tell me how medical thermography works and what sort of electromagnetic radiation it uses?" the senior doctor asks. "What will the thermogram look like if the hand has poor circulation?" How do you respond? (Hint: A hand with poor circulation is cooler than a hand with normal circulation.)

Before you leave this page . . .

1. Describe how you are an electromagnetic radiation detector.
2. Use the information in this Concept to create a scenario like the ones in the activity above. Exchange scenarios with another student and try to solve the one you receive.

Connect to Investigation 3-B on page 201

AT ISSUE

How Can a Solar Superstorm Affect Earth?

What's the Issue?

AUGUST 28, 1859

On the night of Sunday, August 28, a mysterious event shut down telegraph communications across much of the world. (Telegraph machines once sent Morse code messages along telegraph lines linking different stations.) In Pittsburgh, Pennsylvania, the telegraph manager saw streams of fire that could not have been produced by the machines' batteries. Equipment became so hot that it couldn't be touched. Auroras, which mainly occur in the far north, were visible as far south as the Caribbean. Magnetic compasses went haywire. Instruments recording Earth's magnetic field recorded that the planet's magnetism had gone off the chart. The cause? A solar superstorm was raging on the Sun's surface. It lasted for six days.

July 2012

Technology has advanced in leaps and bounds since 1859. In 2012, the largest solar storm in recorded history occurred. Its harmful electromagnetic radiation, charged solar particles, and clouds of solar atmospheric material just narrowly missed Earth. Such a storm would have interfered with radio signals, affecting aircraft communications and GPS satellites. Scientists believe it would have shut down telecommunications and power grids around the world. The damage could have taken years to fix. If the storm had struck just one week earlier, Earth would have been directly in its path.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Find out how the amount of electromagnetic radiation reaching Earth can change during a solar storm and how this change can affect modern technology on Earth.
2. Find out what scientists and governments are doing to protect us from the effects of solar superstorms. How effective do you think their efforts will be?
3. Do you think more funding should be given to scientists who study solar storms and their effects? Why or why not?

Focus on Physics

Solar Electric Contractor

Alarm System Technician

Medical Imaging Technician

What kinds of jobs are there that involve electromagnetic radiation?

Laser Aesthetician

Photographer

Lighting Technician

From Ballet B.C. to your favourite indie band, lighting technicians use light and colour to bring stage performances alive, often in unexpected ways.

Air Traffic Controller

Air traffic controllers are responsible for thousands of lives each day. They rely on a clear head and technology based on electromagnetic radiation.

Astronomer

Feel like exploring new horizons? There are endless mysteries beyond our solar system that astronomers and the technologies they use can shed light on.

Questions

1. What other jobs and careers do you know or can you think of that involve electromagnetic radiation?
2. Research a job or career related to Unit 3 that interests you. What attracts you to it? What kinds of things do you have to know, do, and understand for this job or career?

TAKE a Stand

Make a Difference

Evaluate Cell Phone Safety

Microwave towers have sprung up across the country to accommodate the tens of millions of Canadian cell phone users. Health Canada publishes guidelines for safe exposure to microwave radiation from cell phone and other wireless communication signals (wi-fi). However, not everyone agrees with these guidelines. In 2015, *The Canadian Medical Association Journal* (CMAJ) published its concerns over Health Canada's guidelines. CMAJ interviewed many experts in the field who believe that allowable levels of microwave radiation in homes, schools, and workplaces are "a disaster to public health."

Evaluate and Communicate

1. Carry out research to find out more about the effects of cell phone and wi-fi microwave radiation on human health.
   - **a)** Explain how you assessed your sources for accuracy and reliability. (How did you know your sources were correctly representing information?)
   - **b)** Explain where you stand on this issue. Use your research to support your opinion.
   - **c)** Create a plan to share your research findings with other teens.
2. Find out more about Health Canada's guidelines.
   - **a)** Take a survey of a group of your choice, such as your friends or members of your community. Do they know about the guidelines? Do they follow them?
   - **b)** Summarize the results of your survey and discuss them as a class.

Check Your Understanding of **Topic 3.1**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Identify two natural sources of electromagnetic radiation and two artificial (human-made) sources of electromagnetic radiation. PA
2. Describe two ways in which electromagnetic radiation helps to carry out a task. PA
3. Describe two ways in which electromagnetic radiation can cause harm to living things. PA
4. Your eyes can sense light, and your skin can sense infrared. Describe a way that technology allows you to sense another type of electromagnetic radiation. PA AI
5. A criminal investigator testifies in court that traces of blood were found at the scene of a crime, even after the suspect tried to clean it up. Describe a technique the investigator could have used to find the evidence. PA AI
6. The Vancouver Art Gallery has been donated a previously unknown painting by B.C. artist Emily Carr. The donor claimed that the painting was made in 1929. As the curator, you are concerned that it may be a forgery. How could electromagnetic radiation be used to find out if it is a fake? PA AI
7. A weather forecast indicates that extremely heavy rainfall is approaching Port Alberni. The storm is expected to arrive within 24 hours. Describe the role electromagnetic radiation might have played in forecasting these weather conditions. PA AI

Connecting Ideas

8. These two images were made using electromagnetic radiation. PA E AI

   a) State the type of radiation you think was used to make each image. Justify your response.
   b) Which image do you think would give a doctor more information? Explain your reasoning.
   c) Why might a doctor choose to use the imaging technology that produces a less detailed view?

Making New Connections

9. Electromagnetic radiation has a huge impact on our ability to communicate. QP PA E AI C
   a) Describe three ways in which electromagnetic radiation helps us communicate.
   b) Explain how communications technology affects our ability to share knowledge, ideas, and feelings with people locally and globally.
   c) What, if any, responsibility do we have to use our ability for rapid communication wisely? What can happen when we don't?

INVESTIGATION
3-A

STRUCTURED INQUIRY AND GUIDED INQUIRY

Exploring Medical Imaging Technologies

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

PART A: USING IMAGING TECHNOLOGY—STRUCTURED INQUIRY

Question

How can X-ray images be used to diagnose and treat medical problems?

Procedure

1. On an X-ray image, bone appears white, air appears black, and other structures appear in shades of grey. The images in A and B are from different patients.
2. Which image shows damage? What might have caused it?

Process and Analyze

1. How could X-ray images help a doctor treat a patient?
2. How could X-ray images help a doctor assess the effectiveness of the treatment?

PART B: ASSESSING IMAGING TECHNOLOGY—GUIDED INQUIRY

Question

How is imaging beneficial and harmful?

Procedure

1. Choose a medical imaging technology that uses electromagnetic radiation.
2. Find out how the imaging technology can help patients.
3. Find out how the radiation it uses can be harmful.

Evaluate and Communicate

1. Use a medium of your choice to communicate what you learned to patients.

INVESTIGATION
3-B

OPEN INQUIRY

Electromagnetic Radiation in Your Community

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

Electromagnetic radiation is a part of your community. It can play an everyday role, such as in telecommunications or simple Sun exposure. It may have a more unique application, such as a solar farm or space observatory.

Question

You will determine your own question to investigate. See step 3 of the Procedure.

Procedure

1. Find an example of how electromagnetic radiation is a part of your community.
2. Write out any questions you have about the example. Use the 5 W's (who; what; when; where; why) to help you brainstorm questions.
3. Decide which questions you will investigate, and plan how you will answer them.
4. Get your teacher to approve your plan.
5. Carry out your plan.

Evaluate and Communicate

1. How can you assess the reliability of the sources you are using in your research?
2. Create a plan to share what you have learned with your community. Keep in mind that your community includes people of different ages and backgrounds. How can you reach the most people in your community? If your teacher agrees, carry out your plan.