chapter 3

Electromagnetic Waves

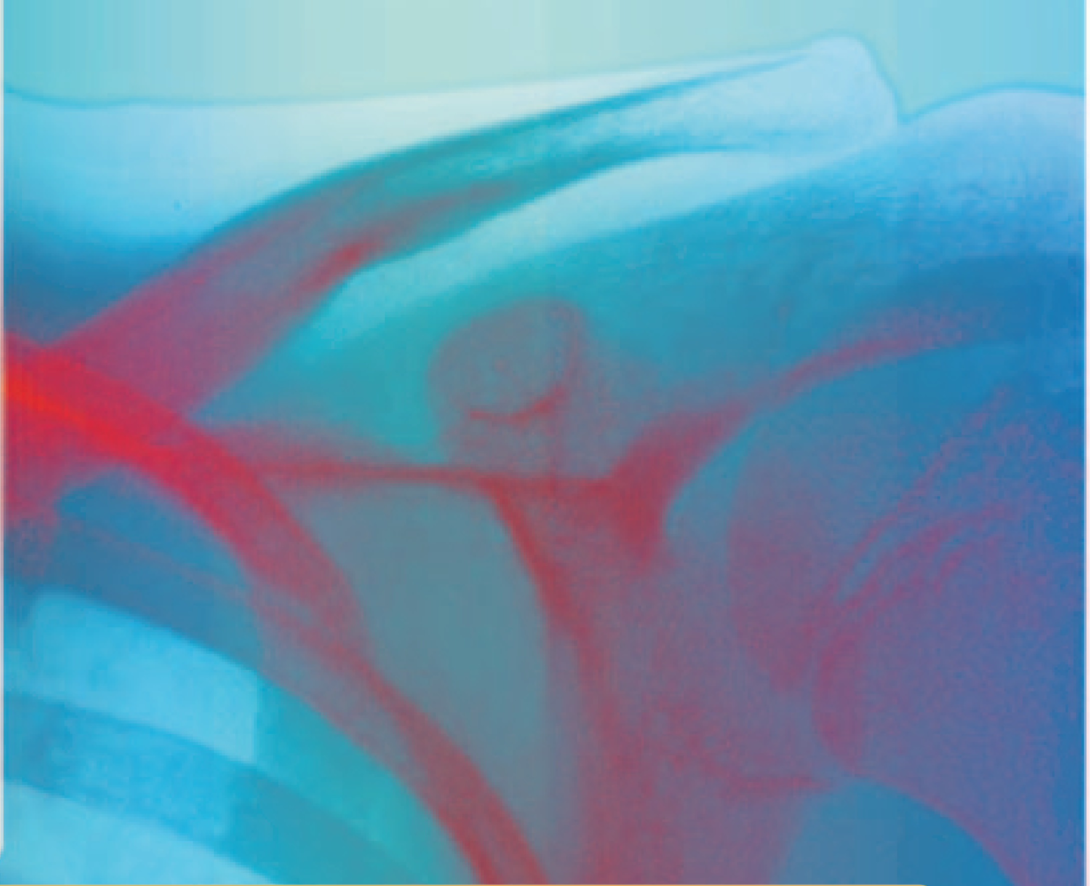
The BIG Idea

Electromagnetic waves are made of changing electric and magnetic fields.

SECTION 1
The Nature of Electromagnetic Waves
Main Idea Vibrating electric charges produce electromagnetic waves.

SECTION 2
The Electromagnetic Spectrum
Main Idea Different parts of the electromagnetic spectrum interact with matter in different ways.

SECTION 3
Using Electromagnetic Waves
Main Idea Electromagnetic waves are used to transmit and receive information.



Looking Through You

This color-enhanced X-ray image of a human shoulder and ribcage was made possible by electromagnetic waves. These waves are used to transmit the programs you watch on TV and they make your skin feel warm when you sit in sunlight. In fact, no matter where you go, you are always surrounded by electromagnetic waves.

Science Journal Describe how sitting in sunlight makes you feel. How can sunlight affect your skin?

Maxine Hall/CORBIS

Start-Up Activities

Launch LAB

Detecting Invisible Waves

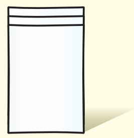
Light is a type of wave called an electromagnetic wave. You see light every day, but visible light is only one type of electromagnetic wave. Other electromagnetic waves are all around you, but you cannot see them. How can you detect electromagnetic waves that can't be seen with your eyes?

1. Cut a slit 2 cm long and 0.25 cm wide in the center of a sheet of black paper.
2. Cover a window that is in direct sunlight with the paper.
3. Position a glass prism in front of the light coming through the slit so it makes a visible spectrum on the floor or table.
4. Place one thermometer in the spectrum and a second thermometer just beyond the red light.
5. Measure the temperature in each region after 5 min.
6. **Think Critically** Write a paragraph in your Science Journal comparing the temperatures of the two regions and offer an explanation for the observed temperatures.

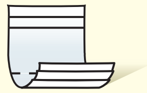
FOLDABLES™ Study Organizer

Electromagnetic Waves Make the following Foldable to help you understand the electromagnetic spectrum.

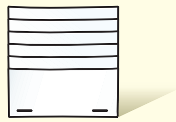
STEP 1 **Collect** 4 sheets of paper and layer them about 1 cm apart vertically. Keep the edges level.



STEP 2 **Fold** up the bottom edges of the paper to form 8 equal tabs.



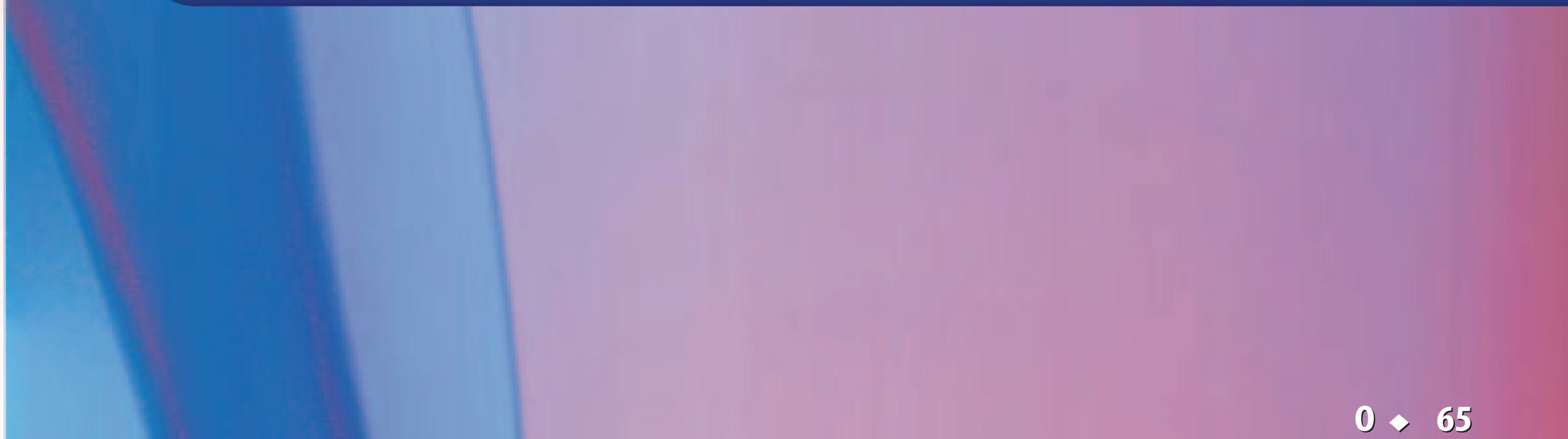
STEP 3 **Fold** the papers and crease well to hold the tabs in place. Staple along the fold. **Label** each tab as indicated below.



Sequence Turn your Foldable so the staples are at the top. Label the tabs, in order from top to bottom, *Electromagnetic Spectrum, Radio Waves, Microwaves, Infrared Rays, Visible Light, Ultraviolet Light, X Rays,* and *Gamma Rays*. As you read, write facts you learn about each topic under the appropriate tab.

Science Online

Preview this chapter's content and activities at booko.msscience.com



Maxine Hall/CORBIS

Get Ready to Read

Visualize

1 Learn It! Visualize by forming mental images of the text as you read. Imagine how the text descriptions look, sound, feel, smell, or taste. Look for any pictures or diagrams on the page that may help you add to your understanding.

2 Practice It! Read the following paragraph. As you read, use the underlined details to form a picture in your mind.

> A radar station sends out radio waves that bounce off an object, such as an airplane. Electronic equipment measures the time it takes for the radio waves to travel to the plane, be reflected, and return. Because the speed of the radio waves is known, the distance to the airplane can be determined from the measured time.
>
> — *from page 73*

Based on the description above, try to visualiz how radar is used. Now look at the diagram on page 527.

- How closely does it match your mental picture?
- Reread the passage and look at the diagram again. Did your ideas change?
- Compare your image with what others in your class visualized.

3 Apply It! Read the chapter and list three subjects you were able to visualize. Make a rough sketch showing what you visualized.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1. **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.
   - Write an **A** if you **agree** with the statement.
   - Write a **D** if you **disagree** with the statement.

2. **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.
   - If any of your answers changed, explain why.
   - Change any false statements into true statements.
   - Use your revised statements as a study guide.

Reading Tip

Forming your own mental images will help you remember what you read.

Before You Read A or D	Statement		After You Read A or D
	1	An electromagnetic wave is a mechanical wave.	
	2	An electromagnetic wave is produced by a moving particle.	
	3	A moving electric charge is surrounded by an electric field and a magnetic field.	
	4	All electromagnetic waves travel at the same speed in empty space.	
	5	Radio waves have the highest frequencies in the electromagnetic spectrum.	
	6	The Sun emits mostly ultraviolet waves.	
	7	Most telecommunication devices use radio waves to transmit information.	
	8	A loudspeaker converts sound waves into electromagnetic waves.	
	9	Radio waves can travel through Earth.	

Science Online

Print out a worksheet of this page at booko.msscience.com

section 1

The Nature of Electromagnetic Waves

as you read

What You'll Learn
- **Explain** how electromagnetic waves are produced.
- **Describe** the properties of electromagnetic waves.

Why It's Important

The energy Earth receives from the Sun is carried by electromagnetic waves.

Review Vocabulary

wave: a rhythmic disturbance that carries energy through matter or space

New Vocabulary
- electromagnetic wave
- radiant energy

Waves in Space

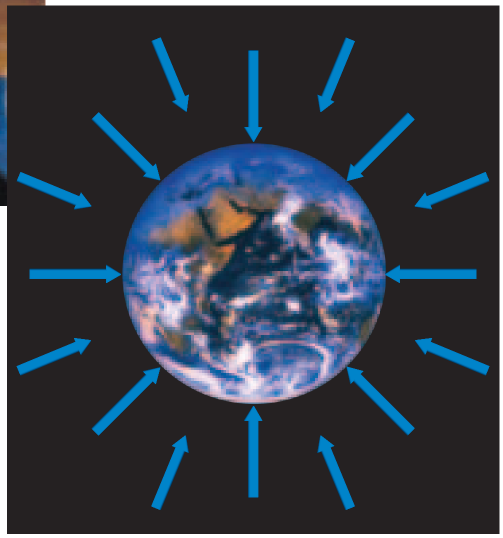
On a clear day you feel the warmth in the Sun's rays, and you see the brightness of its light. Energy is being transferred from the Sun to your skin and eyes. Who would guess that the way in which this energy is transferred has anything to do with radios, televisions, microwave ovens, or the X-ray pictures that are taken by a doctor or dentist? Yet the Sun and the devices shown in **Figure 1** use the same type of wave to move energy from place to place.

Transferring Energy A wave transfers energy from one place to another without transferring matter. How do waves transfer energy? Waves, such as water waves and sound waves, transfer energy by making particles of matter move. The energy is passed along from particle to particle as they collide with their neighbors. Mechanical waves are the types of waves that use matter to transfer energy.

However, mechanical waves can't travel in the almost empty space between Earth and the Sun. So how can a wave transfer energy from the Sun to Earth? A different type of wave, called an electromagnetic wave, carries energy from the Sun to Earth. An **electromagnetic wave** is a wave that can travel through empty space or through matter and is produced by charged particles that are in motion.

Figure 1 Getting a dental X ray or talking on a cell phone uses energy carried by electromagnetic waves.

Figure 2 A gravitational field surrounds all objects. When a ball is thrown, Earth's gravitational field exerts a downward force on the ball at every point along the ball's path.



Earth's gravitational field extends out through space, exerting a force on all masses.
Determine *whether the forces exerted by Earth's gravitational field are attractive or repulsive.*

Forces and Fields

An electromagnetic wave is made of two parts—an electric field and a magnetic field. These fields are force fields. A force field enables an object to exert forces on other objects, even though they are not touching. Earth is surrounded by a force field called the gravitational field. This field exerts the force of gravity on all objects that have mass.

Reading Check *What force field surrounds Earth?*

How does Earth's force field work? If you throw a ball in the air as high as you can, it always falls back to Earth. At every point along the ball's path, the force of gravity pulls down on the ball, as shown in **Figure 2.** In fact, at every point in space above or at Earth's surface, a ball is acted on by a downward force exerted by Earth's gravitational field. The force exerted by this field on a ball could be represented by a downward arrow at any point in space. The diagram above shows this force field that surrounds Earth and extends out into space. It is Earth's gravitational field that causes the Moon to orbit Earth.

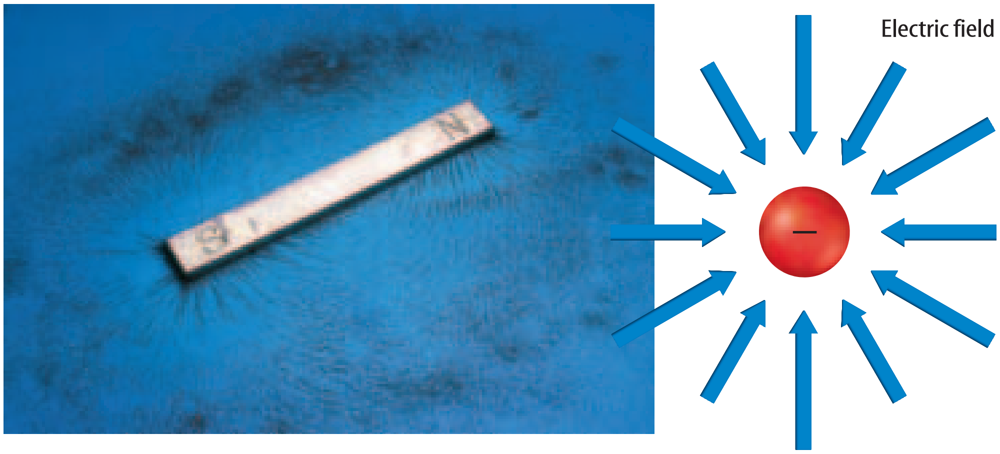
Magnetic Fields You know that magnets repel and attract each other even when they aren't touching. Two magnets exert a force on each other when they are some distance apart because each magnet is surrounded by a force field called a magnetic field. Just as a gravitational field exerts a force on a mass, a magnetic field exerts a force on another magnet and on magnetic materials. Magnetic fields cause other magnets to line up along the direction of the magnetic field.

Science Online

Topic: Force Fields
Visit to booko.msscience.com for Web links to information about Earth's gravitational and magnetic force fields.

Activity Write a paragraph comparing and contrasting the two force fields.

Figure 3 Force fields surround all magnets and electric charges.



A magnetic field surrounds all magnets. The magnetic field exerts a force on iron filings, causing them to line up with the field.

The electric field around an electric charge extends out through space, exerting forces on other charged particles.

Electric Fields Recall that atoms contain protons, neutrons, and electrons. Protons and electrons have a property called electric charge. The two types of electric charge are positive and negative. Protons have positive charge and electrons have negative charge.

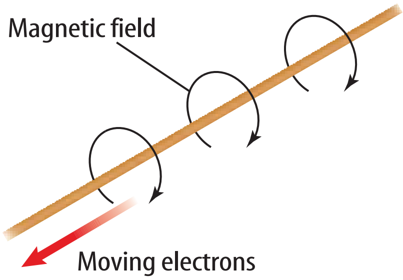
Just as a magnet is surrounded by a magnetic field, a particle that has electric charge, such as a proton or an electron, is surrounded by an electric field, as shown in **Figure 3.** The electric field is a force field that exerts a force on all other charged particles that are in the field.

Making Electromagnetic Waves

An electromagnetic wave is made of electric and magnetic fields. How is such a wave produced? Think about a wave on a rope. You can make a wave on a rope by shaking one end of the rope up and down. Electromagnetic waves are produced by charged particles, such as electrons, that move back and forth or vibrate.

A charged particle always is surrounded by an electric field. But a charged particle that is moving also is surrounded by a magnetic field. For example, electrons are flowing in a wire that carries an electric current. As a result, the wire is surrounded by a magnetic field, as shown in **Figure 4.** So a moving charged particle is surrounded by an electric field and a magnetic field.

Figure 4 Electrons moving in a wire produce a magnetic field in the surrounding space. This field causes iron filings to line up with the field.



(t)Grantpix/Photo Researchers, (b)Richard Megna/Fundamental Photographs

Producing Waves When you shake a rope up and down, you produce a wave that moves away from your hand. As a charged particle vibrates by moving up and down or back and forth, it produces changing electric and magnetic fields that move away from the vibrating charge in many directions. These changing fields traveling in many directions form an electromagnetic wave. **Figure 5** shows how the electric and magnetic fields change as they move along one direction.

Properties of Electromagnetic Waves

Like all waves, an electromagnetic wave has a frequency and a wavelength. You can create a wave on a rope when you move your hand up and down while holding the rope. Look at **Figure 5.** Frequency is how many times you move the rope through one complete up and down cycle in 1 s. Wavelength is the distance from one crest to the next or from one trough to the next.

Wavelength and Frequency An electromagnetic wave is produced by a vibrating charged particle. When the charge makes one complete vibration, one wavelength is created, as shown in **Figure 5.** Like a wave on a rope, the frequency of an electromagnetic wave is the number of wavelengths that pass by a point in 1 s. This is the same as the number of times in 1 s that the charged particle makes one complete vibration.

Mini LAB

Observing Electric Fields

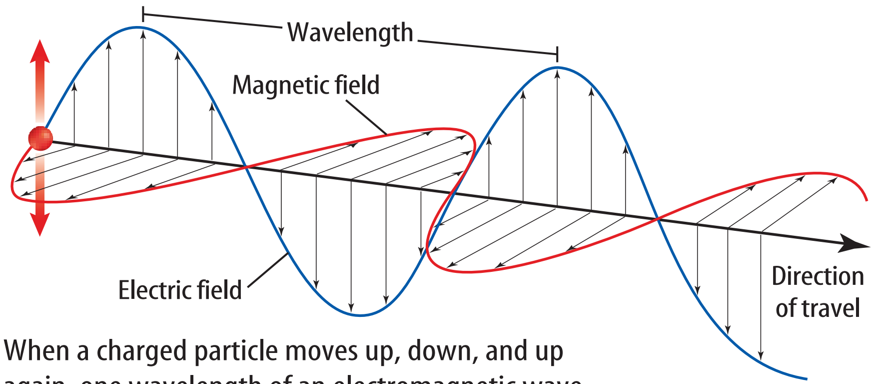
Procedure

1. Rub a **hard, plastic comb** vigorously with a **wool sweater or wool flannel shirt.**
2. Turn on a **water faucet** to create the smallest possible continuous stream of water.
3. Hold the comb near the stream of water and observe.

Analysis

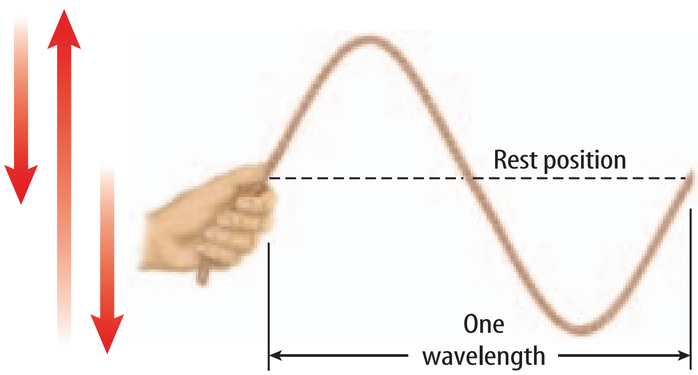
1. What happened to the stream of water when you held the comb near it?
2. Explain why the stream of water behaved this way.

Try at Home



When a charged particle moves up, down, and up again, one wavelength of an electromagnetic wave is produced.

Figure 5 The vibrating motion of an electric charge produces an electromagnetic wave. One complete cycle of vibration produces one wavelength of a wave.
Determine *the magnetic field when the electric field is zero.*



By shaking the end of a rope down, up, and down again, you make one wavelength.

Figure 6 The light that reaches Earth today from Alpha Centauri left the star more than four years ago.

Radiant Energy The energy carried by an electromagnetic wave is called **radiant energy.** What happens if an electromagnetic wave strikes a charged particle? The electric field part of the wave exerts a force on this particle and causes it to move. Some of the radiant energy carried by the wave is transferred into the energy of motion of the particle.

Reading Check *What is radiant energy?*

The amount of energy that an electromagnetic wave carries is determined by the wave's frequency. The higher the frequency of the electromagnetic wave, the more energy it has.

The Speed of Light All electromagnetic waves travel through space at the same speed—about 300,000 km/s. This speed sometimes is called the speed of light. Even though light travels incredibly fast, stars other than the Sun are so far away that it takes years for the light they emit to reach Earth. **Figure 6** shows Alpha Centauri, one of the closest stars to our solar system. This star is more than 40 trillion km from Earth.

section 1 review

Summary

Force Fields

- A charged particle is surrounded by an electric field that exerts forces on other charged particles.
- A magnet is surrounded by a magnetic field that exerts a force on other magnets.
- A moving charged particle is surrounded by electric and magnetic fields.

Electromagnetic Waves

- The changing electric and magnetic fields made by a vibrating electric charge form an electromagnetic wave.
- Electromagnetic waves carry radiant energy.
- All electromagnetic waves travel at the speed of light, which is about 300,000 km/s in empty space.

Self Check

1. **Describe** how electromagnetic waves are produced.
2. **Compare** the energy carried by high-frequency and low-frequency electromagnetic waves.
3. **Identify** what determines the frequency of an electromagnetic wave.
4. **Compare and contrast** electromagnetic waves with mechanical waves.
5. **Think Critically** Unlike sound waves, electromagnetic waves can travel in empty space. What evidence supports this statement?

Applying Math

6. **Use Ratios** To go from Earth to Mars, light waves take four min and a spacecraft takes four months. To go to the nearest star, light takes four years. How long would it take the spacecraft to go to the nearest star?

Science Online booko.msscience.com/self_check_quiz

section 2

The Electromagnetic Spectrum

Electromagnetic Waves

The room you are sitting in is bathed in a sea of electromagnetic waves. These electromagnetic waves have a wide range of wavelengths and frequencies. For example, TV and radio stations broadcast electromagnetic waves that pass through walls and windows. These waves have wavelengths from about 1 m to over 500 m. Light waves that you see are electromagnetic waves that have wavelengths more than a million times shorter than the waves broadcast by radio stations.

Classifying Electromagnetic Waves The wide range of electromagnetic waves with different frequencies and wavelengths forms the **electromagnetic spectrum.** The electromagnetic spectrum is divided into different parts. **Figure 7** shows the electromagnetic spectrum and the names given to the electromagnetic waves in different parts of the spectrum. Even though electromagnetic waves have different names, they all travel at the same speed in empty space—the speed of light. Remember that for waves that travel at the same speed, the frequency increases as the wavelength decreases. So as the frequency of electromagnetic waves increases, their wavelength decreases.

as you read

What You'll Learn

- **Explain** differences among kinds of electromagnetic waves.
- **Identify** uses for different kinds of electromagnetic waves.

Why It's Important

Electromagnetic waves are used to cook food, to send and receive information, and to diagnose medical problems.

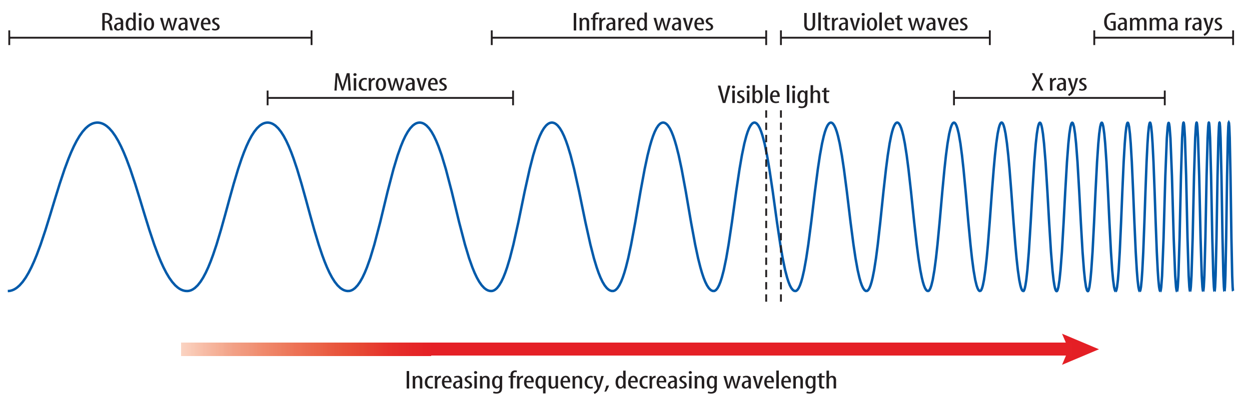
Review Vocabulary

spectrum: a continuous series of waves arranged in order of increasing or decreasing wavelength or frequency

New Vocabulary

- electromagnetic spectrum
- radio wave
- infrared wave
- visible light
- ultraviolet radiation
- X ray
- gamma ray

Figure 7 The electromagnetic spectrum consists of electromagnetic waves arranged in order of increasing frequency and decreasing wavelength.



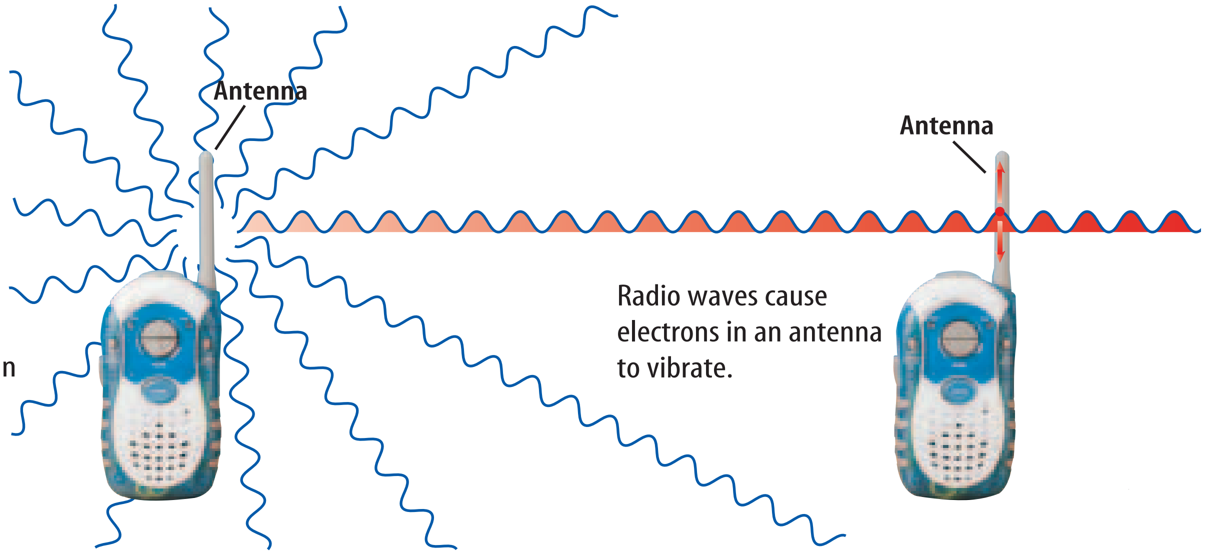


Figure 8 Antennas are used to generate and detect radio waves. **Describe** *some objects that have antennas.*

Radio Waves

Electromagnetic waves with wavelengths longer than about 0.001 m are called radio waves. **Radio waves** have the lowest frequencies of all the electromagnetic waves and carry the least energy. Television signals, as well as AM and FM radio signals, are types of radio waves. Like all electromagnetic waves, radio waves are produced by moving charged particles. One way to make radio waves is to make electrons vibrate in a piece of metal, as shown in **Figure 8.** This piece of metal is called an antenna. By changing the rate at which the electrons vibrate, radio waves of different frequencies can be produced that travel outward from the antenna.

Figure 9 Towers such as the one shown here are used to send and receive microwaves.

Detecting Radio Waves These radio waves can cause electrons in another piece of metal, such as another antenna, to vibrate, as shown in **Figure 8.** As the electrons in the receiving antenna vibrate, they form an alternating current. This alternating current can be used to produce a picture on a TV screen and sound from a loudspeaker. Varying the frequency of the radio waves broadcast by the transmitting antenna changes the alternating current in the receiving antenna. This produces the different pictures you see and sounds you hear on your TV.

Microwaves Radio waves with wavelengths between about 0.3 m and 0.001 m are called microwaves. They have a higher frequency and a shorter wavelength than the waves that are used in your home radio. Microwaves are used to transmit some phone calls, especially from cellular and portable phones. **Figure 9** shows a microwave tower.

Microwave ovens use microwaves to heat food. Microwaves produced inside a microwave oven cause water molecules in your food to vibrate faster, which makes the food warmer.

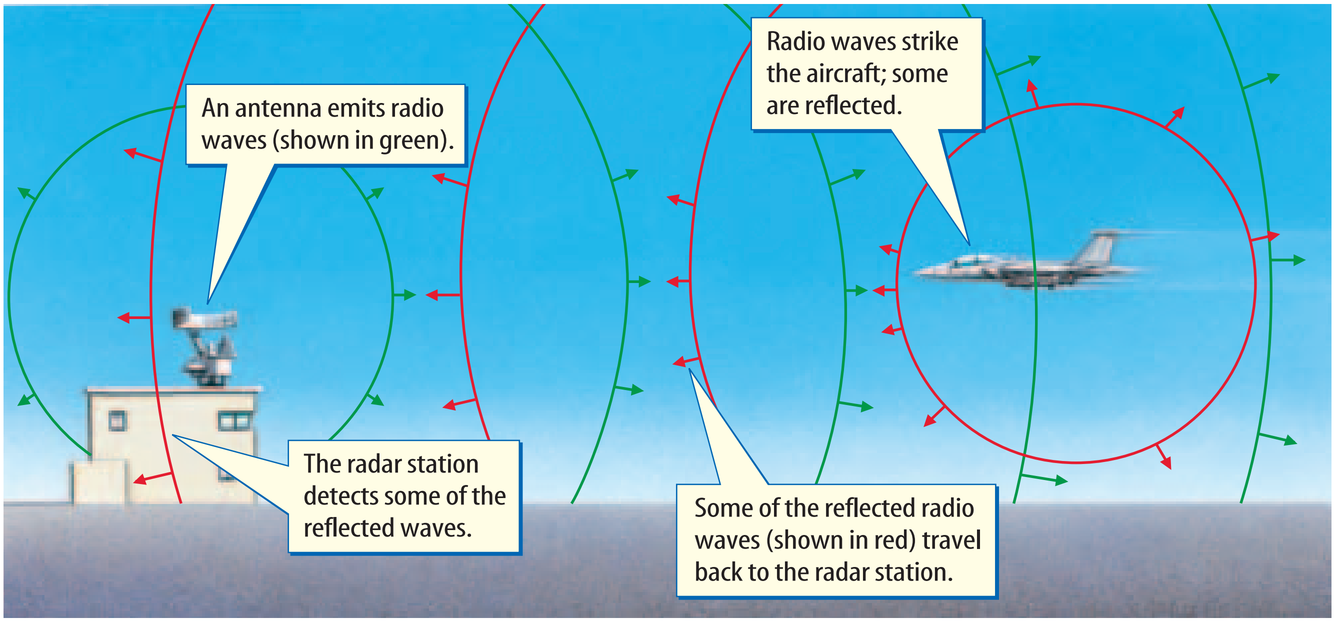


Figure 10 Radar stations use radio waves to determine direction, distance, and speed of aircraft.

Radar You might be familiar with echolocation, in which sound waves are reflected off an object to determine its size and location. Some bats and dolphins use echolocation to navigate and hunt. Radar, an acronym for RAdio Detecting And Ranging, uses electromagnetic waves to detect objects in the same way. Radar was first used during World War II to detect and warn of incoming enemy aircraft.

Reading Check *What does radar do?*

A radar station sends out radio waves that bounce off an object such as an airplane. Electronic equipment measures the time it takes for the radio waves to travel to the plane, be reflected, and return. Because the speed of the radio waves is known, the distance to the airplane can be determined from the measured time.

An example of radar being used is shown in **Figure 10.** Because electromagnetic waves travel so quickly, the entire process takes only a fraction of a second.

Infrared Waves

You might know from experience that when you stand near the glowing coals of a barbecue or the red embers of a campfire, your skin senses the heat and becomes warm. Your skin may also feel warm near a hot object that is not glowing. The heat you are sensing with your skin is from electromagnetic waves. These electromagnetic waves are called **infrared waves** and have wavelengths between about one thousandth and 0.7 millionths of a meter.

Mini LAB

Observing the Focusing of Infrared Rays

Procedure

1. Place a **concave mirror** 2 m to 3 m away from an **electric heater.** Turn on the heater.
2. Place the palm of your hand in front of the mirror and move it back until you feel heat on your palm. Note the location of the warm area.
3. Move the heater to a new location. How does the warm area move?

Analysis

1. Did you observe the warm area? Where?
2. Compare the location of the warm area to the location of the mirror.

Figure 11 A pit viper hunting in the dark can detect the infrared waves emitted from the warm body of its prey.

Detecting Infrared Waves Electromagnetic waves are emitted by every object. In any material, the atoms and molecules are in constant motion. Electrons in the atoms and molecules also are vibrating, and so they emit electromagnetic waves. Most of the electromagnetic waves given off by an object at room temperature are infrared waves and have a wavelength of about 0.000 01 m, or one hundred thousandth of a meter.

Infrared detectors can detect objects that are warmer or cooler than their surroundings. For example, areas covered with vegetation, such as forests, tend to be cooler than their surroundings. Using infrared detectors on satellites, the areas covered by forests and other vegetation, as well as water, rock, and soil, can be mapped. Some types of night vision devices use infrared detectors that enable objects to be seen in nearly total darkness.

Animals and Infrared Waves Some animals also can detect infrared waves. Snakes called pit vipers, such as the one shown in **Figure 11,** have a pit located between the nostril and the eye that detects infrared waves. Rattlesnakes, copperheads, and water moccasins are pit vipers. These pits help pit vipers hunt at night by detecting the infrared waves their prey emits.

Visible Light

As the temperature of an object increases, the atoms and molecules in the object move faster. The electrons also vibrate faster, and produce electromagnetic waves of higher frequency and shorter wavelength. If the temperature is high enough, the object might glow, as in **Figure 12.** Some of the electromagnetic waves that the hot object is emitting are now detectable with your eyes. Electromagnetic waves you can detect with your eyes are called **visible light.** Visible light has wavelengths between about 0.7 and 0.4 millionths of a meter. What you see as different colors are electromagnetic waves of different wavelengths. Red light has the longest wavelength (lowest frequency), and blue light has the shortest wavelength (highest frequency).

Most objects that you see do not give off visible light. They simply reflect the visible light that is emitted by a source of light, such as the Sun or a lightbulb.

Figure 12 When objects are heated, their electrons vibrate faster. When the temperature is high enough, the vibrating electrons will emit visible light.
Describe *an object that emits visible light when heated.*

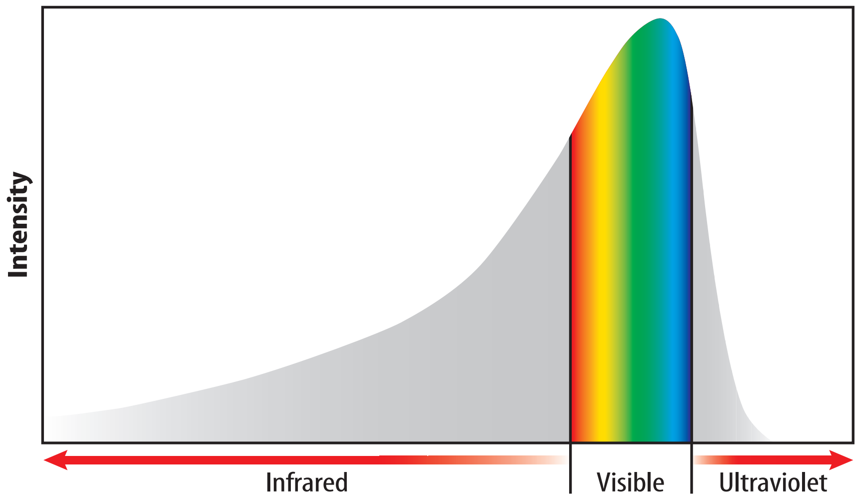


Figure 13 The Sun emits mainly infrared waves and visible light. Only about 8 percent of the electromagnetic waves emitted by the Sun are ultraviolet radiation.
Identify *the electromagnetic waves emitted by the Sun that have the highest intensity.*

Ultraviolet Radiation

Ultraviolet radiation is higher in frequency than visible light and has even shorter wavelengths—between 0.4 millionths of a meter and about ten billionths of a meter. Ultraviolet radiation has higher frequencies than visible light and carries more energy. The radiant energy carried by an ultraviolet wave can be enough to damage the large, fragile molecules that make up living cells. Too much ultraviolet radiation can damage or kill healthy cells.

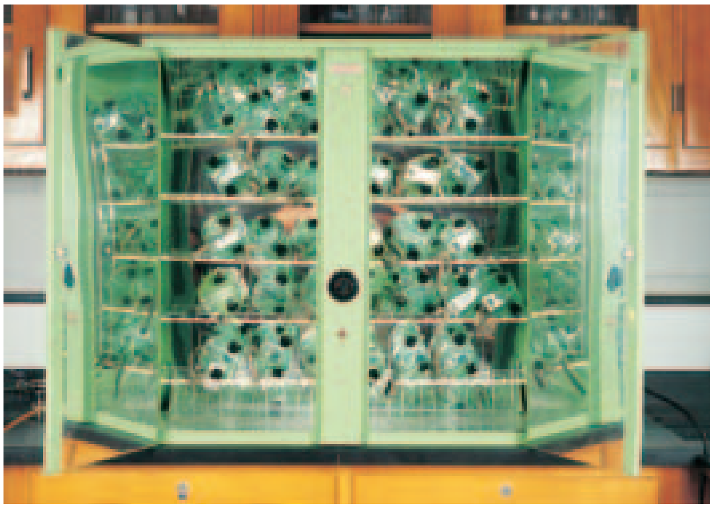
Figure 13 shows the intensity of electromagnetic waves emitted by the Sun. Too much exposure to the Sun's ultraviolet waves can cause sunburn. Exposure to these waves over a long period of time can lead to early aging of the skin and possibly skin cancer. You can reduce the amount of ultraviolet radiation you receive by wearing sunglasses and sunscreen, and staying out of the Sun when it is most intense.

Reading Check *Why can too much exposure to the Sun be harmful?*

Beneficial Uses of UV Radiation A few minutes of exposure each day to ultraviolet radiation from the Sun enables your body to produce the vitamin D it needs. Most people receive that amount during normal activity. The body's natural defense against too much ultraviolet radiation is to tan. However, a tan can be a sign that overexposure to ultraviolet radiation has occurred.

Because ultraviolet radiation can kill cells, it is used to disinfect surgical equipment in hospitals. In some chemistry labs, ultraviolet rays are used to sterilize goggles, as shown in **Figure 14.**

Figure 14 Sterilizing devices, such as this goggle sterilizer, use ultraviolet waves to kill organisms on the equipment.



Aaron Haupt

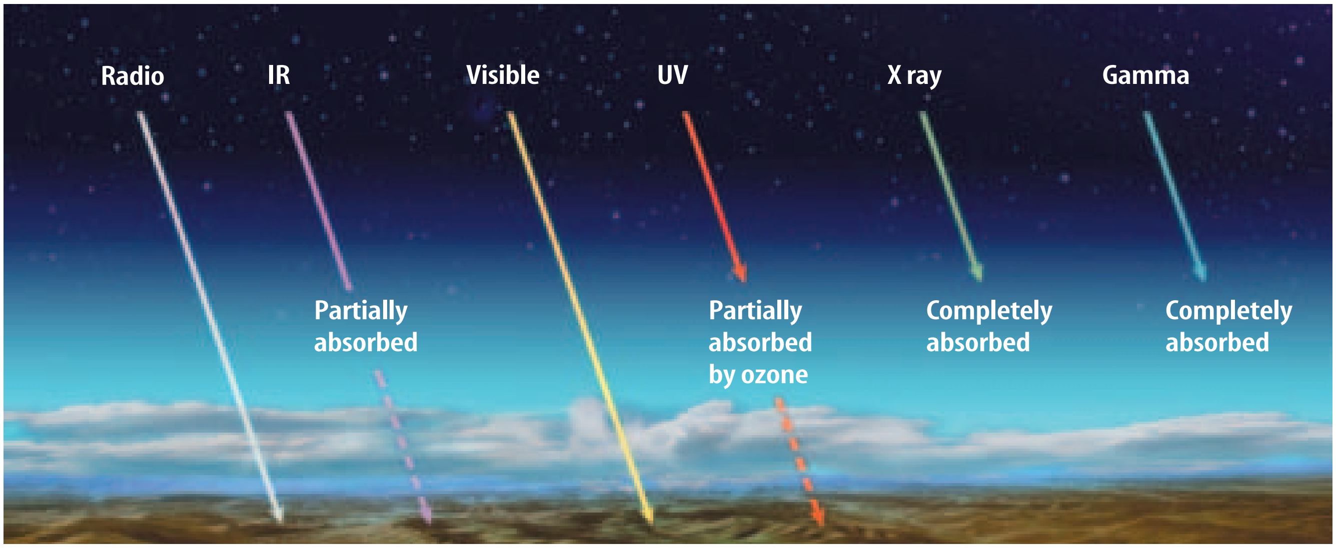


Figure 15 Earth's atmosphere serves as a shield to block some types of electromagnetic waves from reaching Earth's surface.

INTEGRATE Life Science

Body Temperature Warm-blooded animals, such as mammals, produce their own body heat. Cold-blooded animals, such as reptiles, absorb heat from the environment. Brainstorm the possible advantages of being either warm-blooded or cold-blooded. Which animals would be easier for a pit viper to detect?

The Ozone Layer Much of the ultraviolet radiation arriving at Earth is absorbed in the upper atmosphere by ozone, as shown in **Figure 15.** Ozone is a molecule that has three oxygen atoms and is formed high in Earth's atmosphere.

Chemical compounds called CFCs, which are used in air conditioners and refrigerators, can react with ozone molecules and break them apart. There is evidence that these reactions play a role in forming the seasonal reduction in ozone over Antarctica, known as the ozone hole. To prevent this, the use of CFC's is being phased out.

Ultraviolet radiation is not the only type of electromagnetic wave absorbed by Earth's atmosphere. Higher energy waves of X rays and gamma rays also are absorbed. The atmosphere is transparent to radio waves and visible light and partially transparent to infrared waves.

X Rays and Gamma Rays

Ultraviolet rays can penetrate the top layer of your skin. **X rays,** with an even higher frequency than ultraviolet rays, have enough energy to go right through skin and muscle. A shield made from a dense metal, such as lead, is required to stop X rays.

Gamma rays have the highest frequency and, therefore, carry the most energy. Gamma rays are the hardest to stop. They are produced by changes in the nuclei of atoms. When protons and neutrons bond together in nuclear fusion or break apart from each other in nuclear fission, enormous quantities of energy are released. Some of this energy is released as gamma rays.

Just as too much ultraviolet radiation can hurt or kill cells, too much X-ray or gamma radiation can have the same effect. Because the energy of X rays and gamma rays is greater, the exposure that is needed to cause damage is much less.

Using High-Energy Electromagnetic Radiation The fact that X rays can pass through the human body makes them useful for medical diagnosis, as shown in **Figure 16.** X rays pass through the less dense tissues in skin and other organs. These X rays strike a film, creating a shadow image of the denser tissues. X-ray images help doctors detect injuries and diseases, such as broken bones and cancer. A CT scanner uses X rays to produce images of the human body as if it had been sliced like a loaf of bread.

Although the radiation received from getting one medical or dental X ray is not harmful, the cumulative effect of numerous X rays can be dangerous. The operator of the X-ray machine usually stands behind a shield to avoid being exposed to X rays. Lead shields or aprons are used to protect the parts of the patient's body that are not receiving the X rays.

Using Gamma Rays Although gamma rays are dangerous, they also have beneficial uses, just as X rays do. A beam of gamma rays focused on a cancerous tumor can kill the tumor. Gamma radiation also can kill disease-causing bacteria in food. More than 1,000 Americans die each year from *Salmonella* bacteria in poultry and *E. coli* bacteria in meat. Although gamma radiation has been used since 1963 to kill bacteria in food, this method is not widely used in the food industry.

Figure 16 Dense tissues such as bone absorb more X rays than softer tissues do. Consequently, dense tissues leave a shadow on an X ray film that can be used to diagnose medical and dental conditions.

Astronomy with Different Wavelengths

Some astronomical objects produce no visible light and can be detected only through the infrared and radio waves they emit. Some galaxies emit X rays from regions that do not emit visible light. Studying stars and galaxies like these using only visible light would be like looking at only one color in a picture. **Figure 17** shows how different electromagnetic waves can be used to study the Sun.

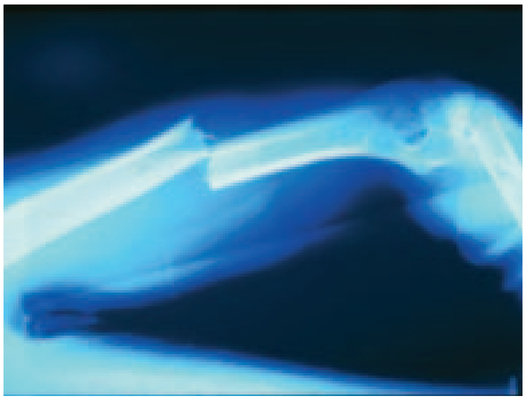
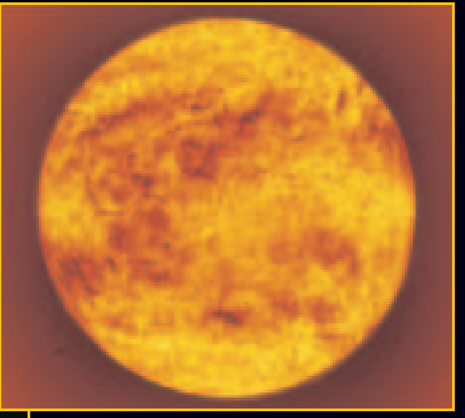
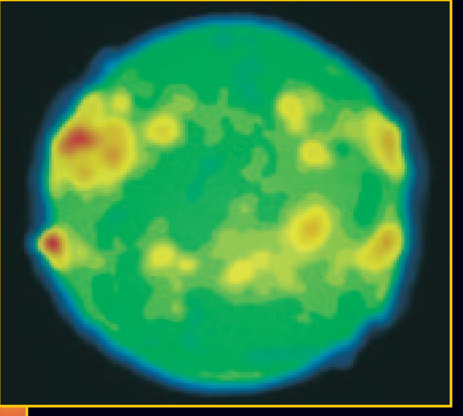


Figure 17

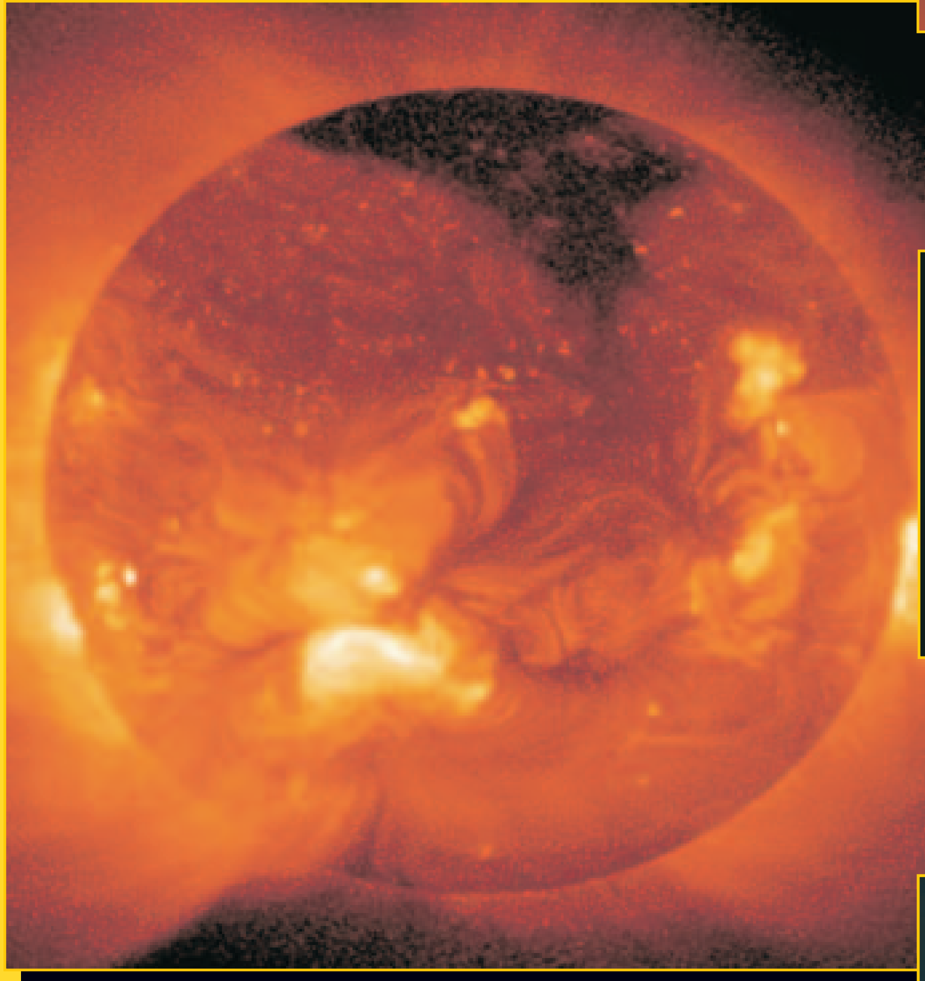
For centuries, astronomers studied the universe using only the visible light coming from planets, moons, and stars. But many objects in space also emit X rays, ultraviolet and infrared radiation, and radio waves. Scientists now use telescopes that can detect these different types of electromagnetic waves. As these images of the Sun reveal, the new tools are providing more information of objects in the universe.



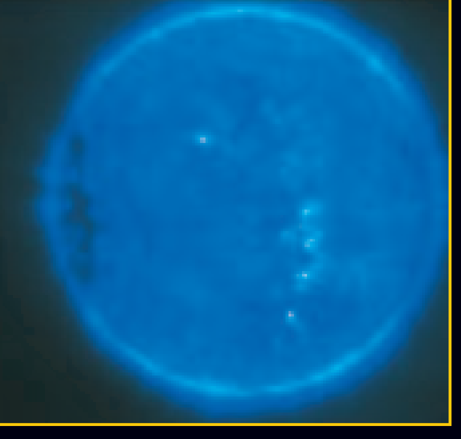
▲ **INFRARED RADIATION** An infrared telescope reveals that the Sun's surface temperature is not uniform. Some areas are hotter than others.



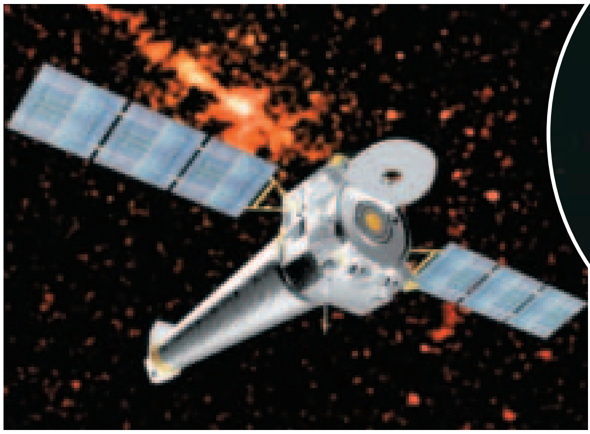
▲ **RADIO WAVES** Radio telescopes detect radio waves given off by the Sun, which have much longer wavelengths than visible light.

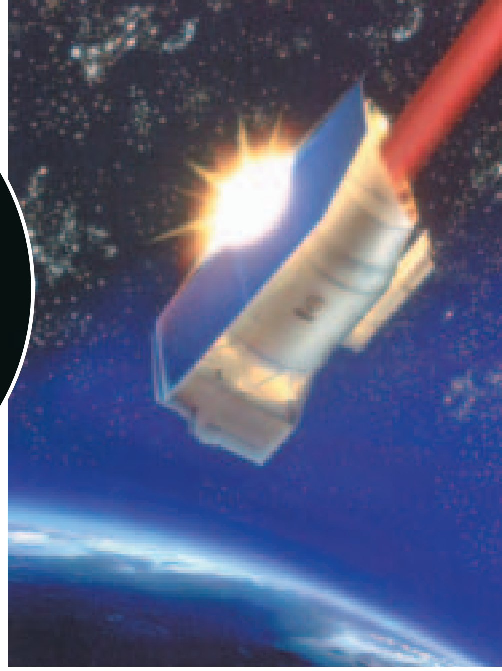


▲ **X RAYS** X-ray telescopes can detect the high-energy, short-wavelength X rays produced by the extreme temperatures in the Sun's outer atmosphere.



▶ **ULTRAVIOLET RADIATION** Telescopes sensitive to ultraviolet radiation—electromagnetic waves with shorter wavelengths than visible light—can "see" the Sun's outer atmosphere.





INTEGRATE Astronomy

Satellite Observations Recall from **Figure 15** that Earth's atmosphere blocks X rays, gamma rays, most ultraviolet rays, and some infrared rays. However, telescopes in orbit above Earth's atmosphere can detect the electromagnetic waves that can't pass through the atmosphere. **Figure 18** shows three such satellites—the Extreme Ultraviolet Explorer (EUVE), the Chandra X-Ray Observatory, and the Infrared Space Observatory (ISO).

Figure 18 Launching satellite observatories above Earth's atmosphere is the only way to see the universe at electromagnetic wavelengths that are absorbed by Earth's atmosphere.

section 2 review

Summary

Radio Waves

- Radio waves have wavelengths longer than about 0.3 m.

Infrared Waves and Visible Light

- Infrared waves have wavelengths between about one thousandth and 0.7 millionths of a meter.
- The wavelengths of infrared waves emitted by an object get shorter as the object's temperature increases.
- Visible light waves have wavelengths between about 0.7 and 0.4 millionths of a meter.

Ultraviolet Waves, X Rays, and Gamma Rays

- Ultraviolet radiation has wavelengths between about 0.4 millionths of a meter and 10 billionths of a meter.
- Prolonged exposure to ultraviolet waves from the Sun can cause skin damage.
- X rays and gamma rays are the most energetic electromagnetic waves.

Self Check

1. **Explain** why ultraviolet radiation is more damaging to living cells than infrared waves.
2. **Compare and contrast** X rays and gamma rays.
3. **Describe** how infrared detectors on satellites can be used to obtain information about the location of vegetation on Earth's surface.
4. **Explain** why X rays and gamma rays coming from space do not reach Earth's surface.
5. **Explain** how the energy of electromagnetic waves change as the wavelength of the waves increase.
6. **Think Critically** Why does the Sun emit mostly infrared waves and visible light, and Earth emits infrared waves?

Applying Skills

7. **Make a table** listing five objects in your home that produce electromagnetic waves. In another column, list next to each object the type of electromagnetic wave or waves produced. In a third column describe each object's use.

(l)Harvard-Smithsonian Center for Astrophysics, (c)NASA/Science Photo Library/Photo Researchers, (r)European Space Agency

LAB

Prisms of Light

Do you know what light is? Many would answer that light is what you turn on to see at night. However, white light is made of many different frequencies of the electromagnetic spectrum. A prism can separate white light into its different frequencies. You see different frequencies of light as different colors. What colors do you see when light passes through a prism?

Real-World Question

What happens to visible light as it passes through a prism?

Goals

- **Construct** a prism and observe the different colors that are produced.
- **Infer** how the bending of light waves depends on their wavelength.

Materials

microscope slides (3)
transparent tape
clay
flashlight
water
**prism*

**Alternate materials*

Safety Precautions

Procedure

1. Carefully tape the three slides together on their long sides so they form a long prism.
2. Place one end of the prism into a softened piece of clay so the prism is standing upright.
3. Fill the prism with water and put it on a table that is against a dark wall.
4. Shine a flashlight beam through the prism so the light becomes visible on the wall.

Conclude and Apply

1. **List** the order of the colors you saw on the wall.
2. **Describe** how the position of the colors on the wall changes as you change the direction of the flashlight beam.
3. **Describe** how the order of colors on the wall changes as you change the direction of the flashlight beam.
4. **Infer** which color light waves have changed direction, or have been bent, the most after passing through the prism. Which color has been bent the least?
5. **Infer** how the bending of a light wave depends on its wavelength.

Communicating Your Data

Compare your conclusions with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

Timothy Fuller

section 3

Using Electromagnetic Waves

Telecommunications

In the past week, have you spoken on the phone, watched television, done research on the Internet, or listened to the radio? Today you can talk to someone far away or transmit and receive information over long distances almost instantly. Thanks to telecommunications, the world is becoming increasingly connected through the use of electromagnetic waves.

Using Radio Waves

Radio waves usually are used to send and receive information over long distances. Using radio waves to communicate has several advantages. For example, radio waves pass through walls and windows easily. Radio waves do not interact with humans, so they are not harmful to people like ultraviolet rays or X rays are. So most telecommunication devices, such as TVs, radios, and telephones, use radio waves to transmit information such as images and sounds. **Figure 19** shows how radio waves can be used to transmit information—in this case transmitting information that enables sounds to be reproduced at a location far away.

as you read

What You'll Learn

- **Describe** different ways of using electromagnetic waves to communicate.
- **Compare and contrast** AM and FM radio signals.

Why It's Important

Using elecromagnetic waves to communicate enables you to contact others worldwide.

Review Vocabulary
satellite: a natural or artificial object that orbits a planet

New Vocabulary
- carrier wave
- Global Positioning System

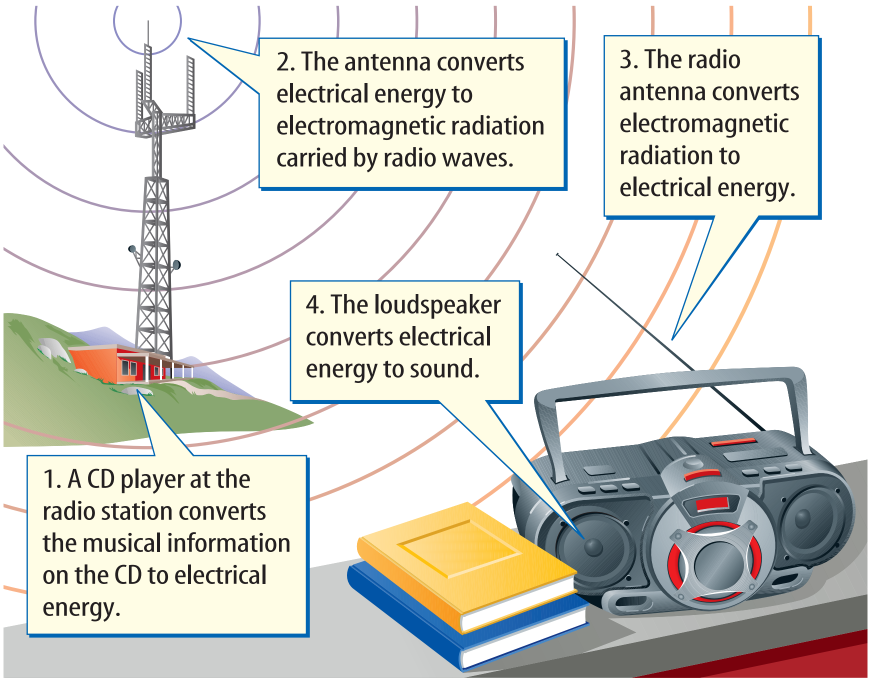
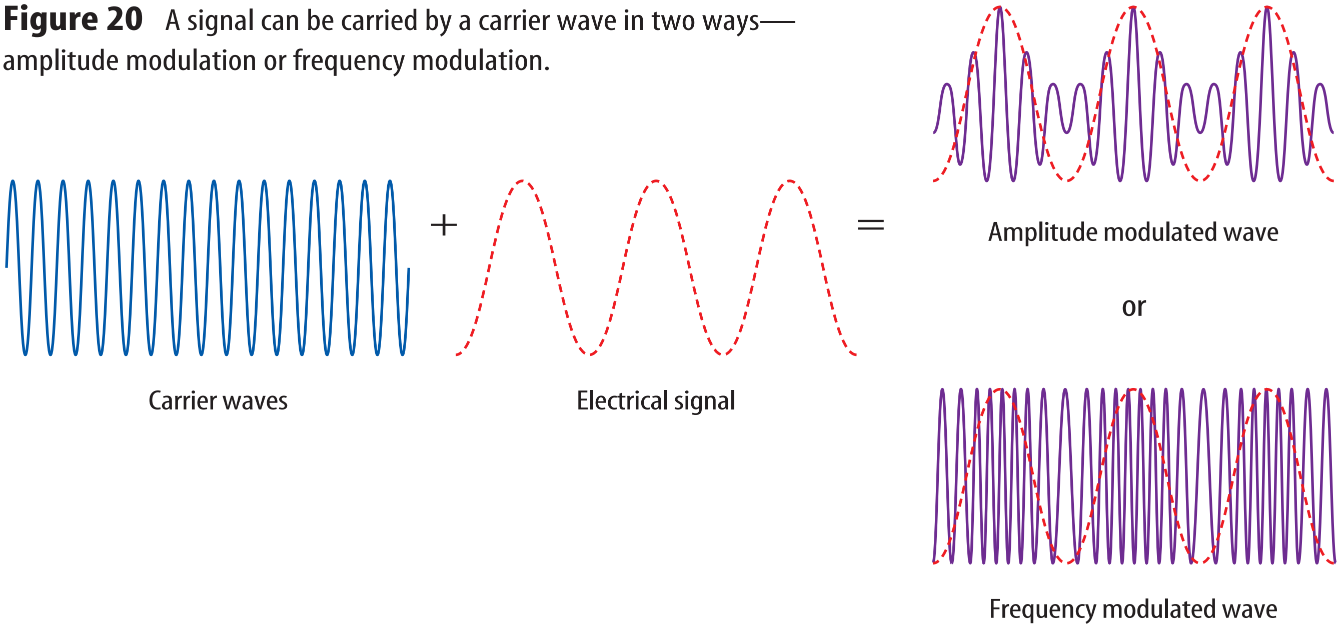


Figure 19 Radio waves are used to transmit information that can be converted to other forms of energy, such as electrical energy and sound.

Figure 20 A signal can be carried by a carrier wave in two ways—amplitude modulation or frequency modulation.



Radio Transmission How is information, such as images or sounds, broadcast by radio waves? Each radio and television station is assigned a particular frequency at which it broadcasts radio waves. The radio waves broadcast by a station at its assigned frequency are the **carrier waves** for that station. To listen to a station you tune your radio or television to the frequency of the station's carrier waves. To carry information on the carrier wave, either the amplitude or the frequency of the carrier wave is changed, or modulated.

Amplitude Modulation The letters *AM* in AM radio stand for amplitude modulation, which means that the amplitude of the carrier wave is changed to transmit information. The original sound is transformed into an electrical signal that is used to vary the amplitude of the carrier wave, as shown in **Figure 20.** Note that the frequency of the carrier wave doesn't change—only the amplitude changes. An AM receiver tunes to the frequency of the carrier wave. In the receiver, the varying amplitude of the carrier waves produces an electrical signal. The radio's loudspeaker uses this electric signal to produce the original sound.

Frequency Modulation FM radio works in much the same way as AM radio, but the frequency instead of the amplitude is modulated, as shown in **Figure 20.** An FM receiver contains electronic components that use the varying frequency of the carrier wave to produce an electric signal. As in an AM radio, this electric signal is converted into sound waves by a loudspeaker.

Reading Check ***What is frequency modulation?***

INTEGRATE History

Pulsars and Little Green Men A type of collapsed star called a pulsar emits pulses of radio waves at extremely regular intervals. Pulsars were first discovered by Jocelyn Bell-Burnell and Anthony Hewish in 1967. Puzzled by a regular sequence of radio pulses they detected, they considered the possibility that the pulses might be coming from an alien civilization. They jokingly labeled the pulses LGMs, for "little green men." Soon other signals were detected that proved the pulses were coming from collapsed stars. Research the role Jocelyn Bell-Burnell played in the discovery of pulsars.

Telephones

A telephone contains a microphone in the mouthpiece that converts a sound wave into an electric signal. The electric signal is carried through a wire to the telephone switching systems. There, the signal might be sent through other wires or be converted into a radio or microwave signal for transmission through the air. The electric signal also can be converted into a light wave for transmission through fiber-optic cables.

At the receiving end, the signal is converted back to an electric signal. A speaker in the earpiece of the phone changes the electric signal into a sound wave.

Reading Check *What device converts sound into an electric signal?*

Applying Math — Solve a Simple Equation

WAVELENGTH OF AN FM STATION You are listening to an FM radio station with a frequency of 94.9 MHz, which equals 94,900,000 Hz. What is the wavelength of these radio waves. Use the wave speed equation $v = \lambda f$, and assume the waves travel at the speed of light, 300,000.0 km/s.

Solution

1 *This is what you know:*
- frequency: $f = 94{,}900{,}000$ Hz
- wave speed: $v = 300{,}000.0$ km/s

2 *This is what you need to find:*
- wavelength: $\lambda = ?$ m

3 *This is the procedure you need to use:*

Solve the wave equation for wavelength, λ, by dividing each side by the frequency, f. Then substitute the known values for frequency and wave speed into the equation you derived:

$$\lambda = \frac{v}{f} = \frac{300{,}000.0 \text{ km/s}}{94{,}900{,}000 \text{ Hz}} = \frac{300{,}000.0 \text{ km } 1/\text{s}}{94{,}900{,}000 \ 1/\text{s}}$$

$$= 0.00316 \text{ km} = 0.00316 \text{ km} \times (1{,}000 \text{ m/km})$$

$$= 3.16 \text{ m}$$

4 *Check your answer:*

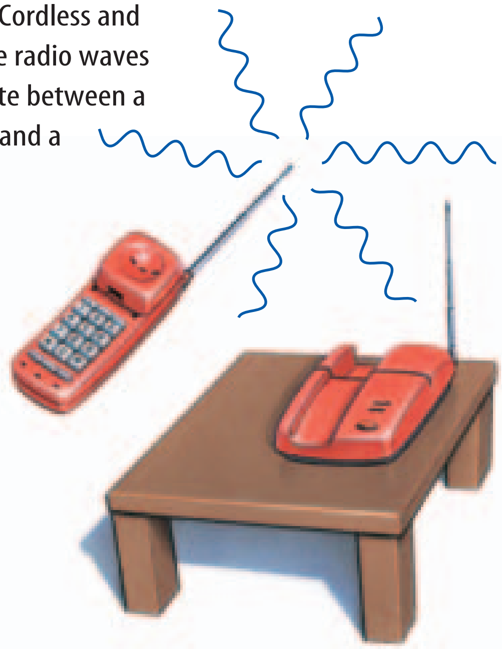
Multiply your answer by the given frequency. The result should be the given wave speed.

Practice Problems

1. Your friend is listening to an AM station with a frequency of 1,520 kHz. What is the wavelength of these radio waves?
2. What is the frequency of the radio waves broadcast by an AM station if the wave length of the radio waves is 500.0 m?

Science Online — For more practice, visit booko.msscience.com/math_practice

Figure 21 Cordless and cell phones use radio waves to communicate between a mobile phone and a base station.



A A cordless phone can be used more than 0.5 km from its base station.

B Cell phones communicate with a base station that can be several kilometers away, or more.

Remote Phones A telephone does not have to transmit its signal through wires. In a cordless phone, the electrical signal produced by the microphone is transmitted through an antenna in the phone to the base station. **Figure 21A** shows how incoming signals are transmitted from the base station to the phone. A cellular phone communicates with a base station that can be many kilometers away. The base station uses a large antenna, as shown in **Figure 21B,** to communicate with the cell phone and with other base stations in the cell phone network.

Pagers The base station also is used in a pager system. When you dial a pager, the signal is sent to a base station. From there, an electromagnetic signal is sent to the pager. The pager beeps or vibrates to indicate that someone has called. With a touch-tone phone, you can transmit numeric information, such as your phone number, which the pager will receive and display.

Communications Satellites

How do you send information to the other side of the world? Radio waves can't be sent directly through Earth. Instead, radio signals are sent to satellites. The satellites can communicate with other satellites or with ground stations. Some communications satellites are in geosynchronous orbit, meaning each satellite remains above the same point on the ground.

Science Online

Topic: Satellite Communications

Visit booko.msscience.com for Web links to information about how satellites are used in around-the-world communications.

Activity Create a table listing satellites from several countries, their names and their communications function.

The Global Positioning System

Satellites also are used as part of the **Global Positioning System,** or GPS. GPS is used to locate objects on Earth. The system consists of satellites, ground-based stations, and portable units with receivers, as illustrated in **Figure 22.**

A GPS receiver measures the time it takes for radio waves to travel from several satellites to the receiver. This determines the distance to each satellite. The receiver then uses this information to calculate its latitude, longitude, and elevation. The accuracy of GPS receivers ranges from a few hundred meters for handheld units, to several centimeters for units that are used to measure the movements of Earth's crust.

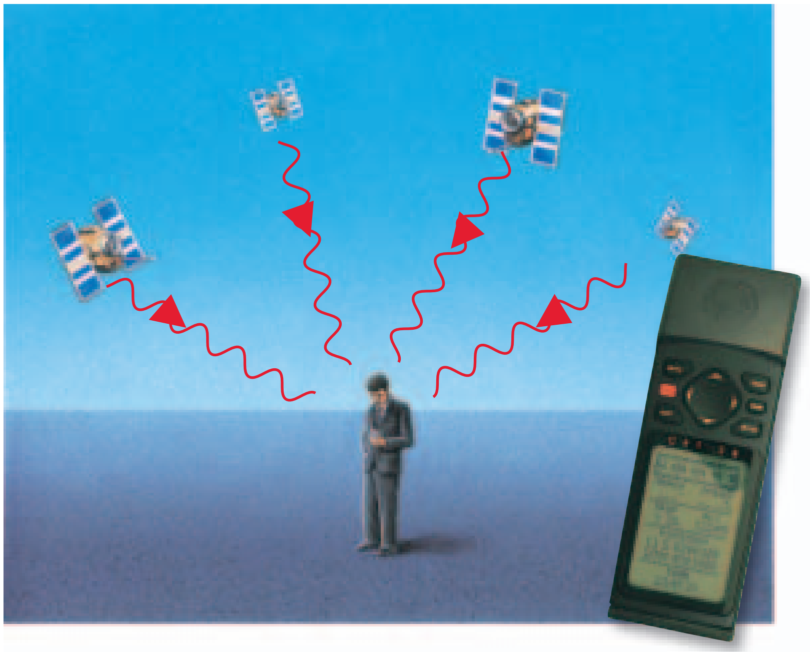


Figure 22 The signals broadcast by GPS satellites enable portable, handheld receivers to determine the position of an object or person.

section 3 review

Summary

Using Radio Waves

- Radio waves are used for communication because they can pass through most objects.
- Amplitude modulation transmits information by modifying the amplitude of a carrier wave.
- Frequency modulation transmits information by modifying the frequency of a carrier wave.

Cordless Phones and Cell Phones

- Cordless phones use radio waves to transmit signals between the base and the handset.
- Cellular phones use radio waves to transmit signals between the phone and cell phone radio towers.

Communications Satellites

- Communications satellites in geosynchronous orbits relay radio signals from one part of the world to another.
- The Global Positioning System uses radio waves to enable a user to accurately determine their position on Earth's surface.

Self Check

1. **Describe** how a cordless phone is different from a cell phone.
2. **Explain** how a communications satellite is used.
3. **Describe** the types of information a GPS receiver provides.
4. **Describe** how an AM radio signal is used to transmit information.
5. **Think Critically** Explain why ultraviolet waves are not used to transmit signals to and from communications satellites.

Applying Skills

6. **Make an events chain** showing the sequence of energy transformations that occur when live music is broadcast by a radio station and played by a radio.
7. **Make a Diagram** showing how geosynchronous satellites and ground stations could be used to send information from you to someone on the other side of Earth.

LAB

Design Your Own

Spectrum Inspection

Goals

- **Design** an experiment that determines the relationship between brightness and the wavelengths emitted by a lightbulb.
- **Observe** the wavelengths of light emitted by a lightbulb as its brightness changes.

Possible Materials

diffraction grating
power supply with variable resistor switch
clear, tubular lightbulb and socket
red, yellow, and blue colored pencils

Safety Precautions

WARNING: *Be sure all electrical cords and connections are intact and that you have a dry working area. Do not touch the bulbs as they may be hot.*

Real-World Question

You've heard the term "red-hot" used to describe something that is unusually hot. When a piece of metal is heated it may give off a red glow or even a yellow glow. All objects emit electromagnetic waves. How do the wavelengths of these waves depend on the temperature of the object?

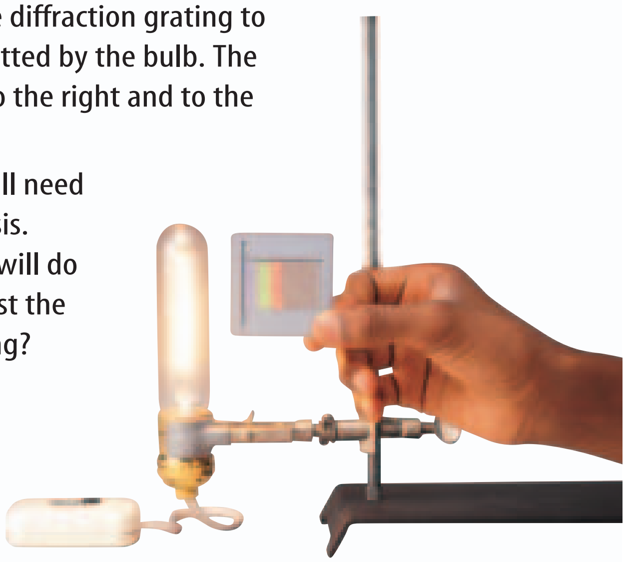
Form a Hypothesis

The brightness of a lightbulb increases as its temperature increases. Form a hypothesis describing how the wavelengths emitted by a lightbulb will change as the brightness of a lightbulb changes.

Test Your Hypothesis

Make a Plan

1. **Decide** how you will determine the effect of lightbulb brightness on the colors of light that are emitted.
2. As shown in the photo at the right, you will look toward the light through the diffraction grating to detect the colors of light emitted by the bulb. The color spectrum will appear to the right and to the left of the bulb.
3. **List** the specific steps you will need to take to test your hypothesis. Describe precisely what you will do in each step. Will you first test the bulb at a bright or dim setting? How many settings will you test? (Try at least three.) How will you record your observations in an organized way?



(t)Michael Thomas/Stock South/PictureQuest, (b)Dominic Oldershaw

4. **List** the materials you will need for your experiment. Describe exactly how and in which order you will use these materials.
5. **Identify** any constants and variables in your experiment.

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. **Perform** your experiment as planned.
3. While doing your experiment, write down any observations you make in your Science Journal.

Analyze Your Data

1. Use the colored pencils to draw the color spectrum emitted by the bulb at each brightness.
2. Which colors appeared as the bulb became brighter? Did any colors disappear?
3. How did the wavelengths emitted by the bulb change as the bulb became brighter?
4. **Infer** how the frequencies emitted by the lightbulb changed as it became hotter.

Conclude and Apply

1. **Infer** If an object becomes hotter, what happens to the wavelengths it emits?
2. How do the wavelengths that the bulb emits change if it is turned off?
3. **Infer** from your results whether red stars or yellow stars are hotter.

Communicating Your Data

Compare your results with others in your class. How many different colors were seen?

Michael Thomas/Stock South/PictureQuest

TIME

SCIENCE AND HISTORY

SCIENCE CAN CHANGE THE COURSE OF HISTORY!

Hedy Lamarr, actor and inventor

Hopping the Frequencies

Ringgggg. There it is—that familiar beep! Out come all the cellular phones. At any given moment, a million wireless signals are flying through the air—and not just cell phone signals. With radio and television signals, Internet data, and even Global Positioning System information, the air seems like a pretty crowded place. How does a cellular phone pick out its own signal from among the clutter? The answer lies in a concept developed in 1940 by Hedy Lamarr.

Lamarr was born in Vienna, Austria. In 1937, she left Austria to escape Hitler's invading Nazi army. She also left to pursue a career as an actor. And she became a famous movie star.

In 1940, Lamarr came up with an idea to keep radio signals that guided torpedoes from being jammed. Her idea, called frequency hopping, involved breaking the radio signal that was guiding the torpedo into tiny parts and rapidly changing their frequency. The enemy would not be able to keep up with the frequency changes and thus would not be able to divert the torpedo from its target.

Spread Spectrum

Lamarr's idea was ahead of its time. The digital technology that allowed efficient operation of her system wasn't invented until decades later. However, after 1962, frequency hopping was adopted and used in U.S. military communications. It was the development of wireless phones, however, that benefited the most from Lamarr's concept.

Cordless phones and other wireless technologies operate by breaking their signals into smaller parts, called packets. The frequency of the packets switches rapidly, preventing interference with other calls and enabling millions of callers to use the same narrow band of frequencies.

A torpedo is launched during World War II.

Brainstorm How are you using wireless technology in your life right now? List ways it makes your life easier. Are there drawbacks to some of the uses for wireless technology? What are they?

Science Online

For more information, visit booko.msscience.com/time

Reviewing Main Ideas

Section 1 The Nature of Electromagnetic Waves

1. Vibrating charges generate vibrating electric and magnetic fields. These vibrating fields travel through space and are called electromagnetic waves.
2. Electromagnetic waves have wavelength, frequency, amplitude, and carry energy.

Section 2 The Electromagnetic Spectrum

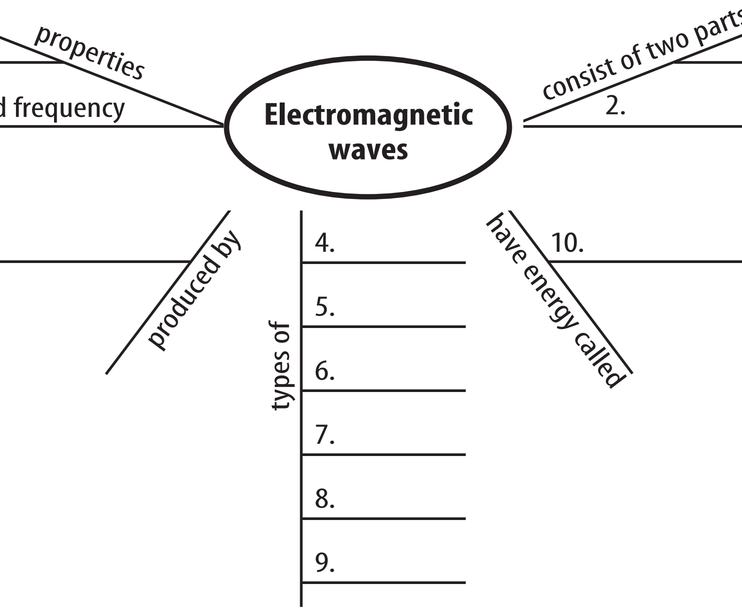
1. Radio waves have the longest wavelength and lowest energy. Radar uses radio waves to locate objects.
2. All objects emit infrared waves. Most objects you see reflect the visible light emitted by a source of light.
3. Ultraviolet waves have a higher frequency and carry more energy than visible light.
4. X rays and gamma rays are highly penetrating and can be dangerous to living organisms.

Section 3 Using Electromagnetic Waves

1. Communications systems use electromagnetic waves to transmit information.
2. Radio and TV stations use modulated carrier waves to transmit information.
3. Cordless and cell phones use radio waves to communicate between the mobile phone and a base station.
4. Radio waves are used to send information between communications satellites and ground stations on Earth.

Visualizing Main Ideas

Copy and complete the following spider map about electromagnetic waves.



chapter 3 Review

Using Vocabulary

carrier wave p. 82
electromagnetic spectrum p. 71
electromagnetic wave p. 66
gamma ray p. 76
Global Positioning System p. 85
infrared wave p. 73
radiant energy p. 70
radio wave p. 72
ultraviolet radiation p. 75
visible light p. 74
X ray p. 76

Explain the difference between the terms in each of the following pairs.

1. infrared wave—radio wave
2. radio wave—carrier wave
3. communications satellite—Global Positioning System
4. visible light—ultraviolet radiation
5. X ray, gamma ray
6. electromagnetic wave—radiant energy
7. carrier wave—AM radio signal
8. infrared wave—ultraviolet wave

Checking Concepts

Choose the word or phrase that best answers the question.

9. Which of the following transformations can occur in a radio antenna?
   A) radio waves to sound waves
   B) radio waves to an electric signal
   C) radio waves to infrared waves
   D) sound waves to radio waves
10. Electromagnetic waves with wavelengths between about 0.7 millionths of a meter and 0.4 millionths of a meter are which of the following?
    A) gamma rays **C)** radio waves
    B) microwaves **D)** visible light
11. Which of the following is the speed of light in space?
    A) 186,000 km/s **C)** 3,000,000 km/s
    B) 300,000 km/s **D)** 30,000 km/s
12. Which of the following types of electromagnetic waves has the lowest frequency?
    A) infrared waves **C)** radio waves
    B) visible light **D)** gamma rays
13. Compared to an electric charge that is not moving, a moving electric charge is surrounded by which of the following additional fields?
    A) magnetic **C)** electric
    B) microwave **D)** gravitational
14. Most of the electromagnetic waves emitted by an object at room temperature are which of the following?
    A) visible light **C)** infrared waves
    B) radio waves **D)** X rays
15. Which of the following color of visible light has the highest frequency?
    A) green **C)** yellow
    B) blue **D)** red
16. Which type of electromagnetic waves are completely absorbed by Earth's atmosphere?
    A) radio waves **C)** gamma rays
    B) infrared waves **D)** visible light
17. Sunburn is caused by excessive exposure to which of the following?
    A) ultraviolet waves
    B) infrared waves
    C) visible light
    D) gamma rays
18. How does the frequency of a gamma ray change as its wavelength decreases?
    A) It increases.
    B) It decreases.
    C) It doesn't change.
    D) The frequency depends on the speed.

Science Online booko.msscience.com/vocabulary_puzzlemaker

Thinking Critically

19. Infer why communications systems usually use radio waves to transmit information.

20. Classify List the colors of the visible light spectrum in order of increasing frequency.

21. Compare and contrast an electromagnetic wave with a transverse wave traveling along a rope.

22. Explain Some stars form black holes when they collapse. These black holes sometimes can be found by detecting X rays and gamma rays that are emitted as matter falls into the black hole. Explain why it would be difficult to detect these X rays and gamma rays using detectors at Earth's surface.

Use the table below to answer question 23.

Speed of Light in Various Materials

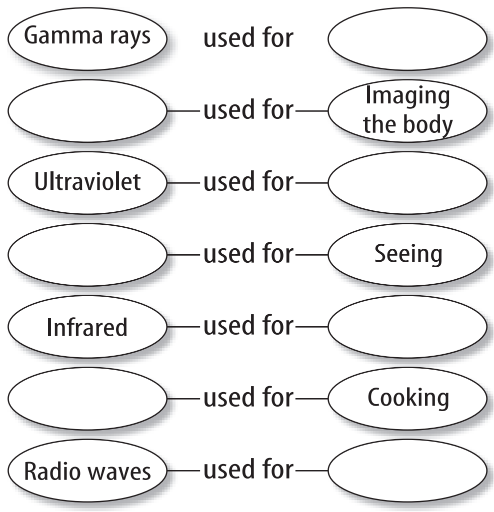
Materials	Speed (km/s)
Air	300,000
Water	226,000
Polystyrene Plastic	189,000
Diamond	124,000

23. Calculate A radio wave has a frequency of 500,000 Hz. If the radio wave has the same frequency in air as in water, what is the ratio of the wavelength of the radio wave in air to its wavelength in water?

24. Explain how you could determine if there are electromagnetic waves traveling in a closed, completely dark room in a building.

25. Infer Light waves from a distant galaxy take 300 million years to reach Earth. How does the age of the galaxy when it emitted the light waves compare with the age of the galaxy when we see the light waves?

26. Concept Map Electromagnetic waves are grouped according to their frequencies. In the following concept map, write each frequency group and one way humans make use of the electromagnetic waves in that group. For example, in the second set of ovals, you might write *X rays* and *to see inside the body.* **Do not write in this book.**



Performance Activities

27. Oral Presentation Explain to the class how a radio signal is generated, transmitted, and received.

28. Poster Make a poster showing the parts of the electromagnetic spectrum. Show how frequency, wavelength, and energy change throughout the spectrum. How is each wave generated? What are some uses of each?

Applying Math

29. Distance How long would it take a radio signal to travel from Earth to the Moon, a distance of 384,000 km?

30. Wavelength The frequency of a popular AM radio station is 720 kHz. What is the wavelength of the radio waves broadcast by this station?

chapter 3 Standardized Test Practice

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which of the following types of electromagnetic waves has a frequency greater than visible light?

A. infrared waves
B. radio waves
C. ultraviolet waves
D. microwaves

2. Which of the following properties of a transverse wave is the distance from one crest to the next?

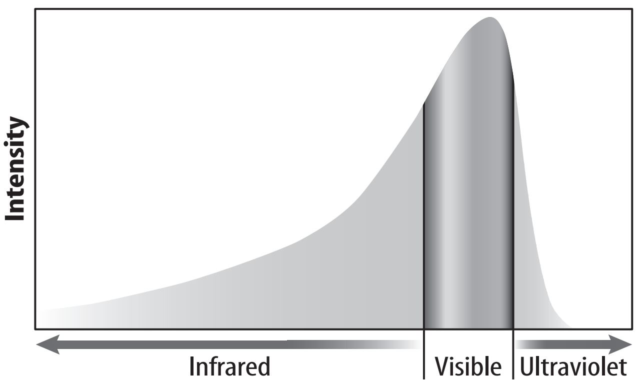
A. intensity
B. amplitude
C. frequency
D. wavelength

3. Which of the following types of electromagnetic waves enables your body to produce vitamin D?

A. gamma rays
B. ultraviolet waves
C. visible light
D. infrared waves

Use the illustration below to answer question 4.

Electromagnetic Waves from the Sun



4. How does the intensity of ultraviolet waves emitted by the Sun change as the wavelength of the ultraviolet waves decreases?

A. The intensity increases.
B. The intensity decreases.
C. The intensity doesn't change.
D. The intensity increases, then decreases.

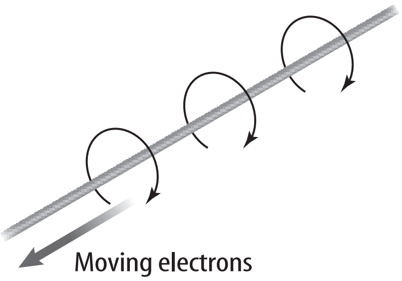
5. The color of visible light waves depends on which of the following wave properties?

A. wavelength
B. amplitude
C. direction
D. speed

6. Which of the following is NOT true about electromagnetic waves?

A. They can travel through matter.
B. They move by transferring matter.
C. They are produced by vibrating charges.
D. They can travel through empty space.

Use the illustration below to answer question 7.



7. Which of the following is represented by the circular lines around the current-carrying wire?

A. direction of current
B. electric and magnetic field lines
C. magnetic field lines
D. electric field lines

8. How are gamma rays produced?

A. by vibrating electric fields
B. by vibrating magnetic fields
C. by the absorption of infrared waves
D. by nuclear fission or fusion

9. Earth's atmosphere is transparent to which type of electromagnetic waves?

A. gamma rays
B. ultraviolet waves
C. infrared waves
D. radio waves

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the photograph below to answer question 10.

10. If the microwaves produced in a microwave oven have a frequency of 2,450 MHz, what is the wavelength of the microwaves?

11. You turn on a lamp that is plugged into an electric outlet. Does a magnetic field surround the wire that connects the lamp to the outlet? Explain.

12. A carrier wave broadcast by a radio station has a wavelength of 3.0 m. What is the frequency of the carrier wave?

13. Explain how the wavelengths of the electromagnetic waves emitted by an object change as the temperature of the object increases.

14. Explain why X rays can form images of dense tissues in the human body.

15. If the planet Mars is 80,000,000 km from Earth, how long will it take an electromagnetic wave to travel from Earth to Mars?

Test-Taking Tip

Recheck Answers Double check your answers before turning in the test.

Part 3 Open Ended

Record your answers on a sheet of paper.

16. Describe the sequence of events that occur when a radar station detects an airplane and determines the distance to the plane.

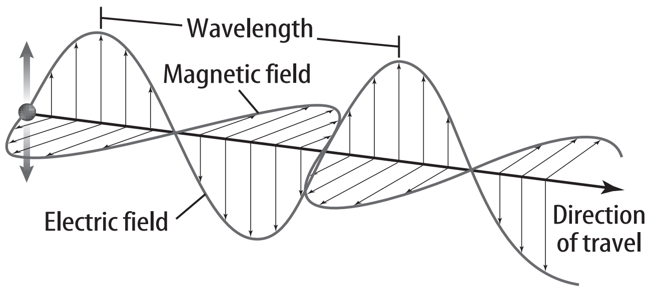
17. Explain why infrared detectors on satellites can detect regions covered by vegetation.

18. The carrier waves broadcast by a radio station are altered in order to transmit information. The two ways of altering a carrier wave are amplitude modulation (AM) and frequency modulation (FM). Draw a carrier wave, an AM wave, and an FM wave.

19. Describe the effect of the ozone layer on electromagnetic waves that strike Earth's atmosphere.

20. List the energy conversions that occur when a song recorded on a CD is broadcast as radio waves and then reproduced as sound.

Use the illustration below to answer questions 21 and 22.



21. Explain how the vibrating electric and magnetic fields are produced.

22. Infer how the directions of the electric field and the magnetic field are related to the direction that the electromagnetic wave travels.