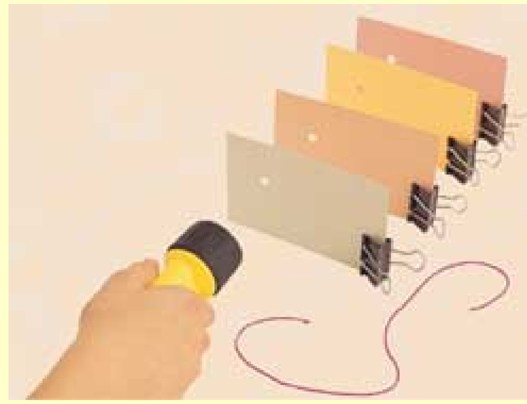
The Nature of Electromagnetic Waves

Discover Activity

How Does a Beam of Light Travel?



1. Punch a small hole (about 0.5 cm in diameter) in each of four large index cards.
2. Stand each card upright so that the long side of the index card is on the tabletop. Use binder clips or modeling clay to hold the cards upright.
3. Space the cards about 10 cm apart. To make sure the holes in the cards are in a straight line, run a piece of string through the four holes and pull it tight.
4. Place the flashlight in front of the card nearest you. Shut off all the lights, so that the only light you see comes from the flashlight. What do you see on the wall?
5. Move one of the cards sideways about 3 cm and repeat Step 4. Now what do you see on the wall?

Think It Over

Inferring Explain what happened in Step 5. What does this activity tell you about the path of light?

Guide for Reading

- What is an electromagnetic wave?
- What are the properties of light?

Reading Tip As you read, keep a list of the words that are used to describe the nature of electromagnetic waves.

Key Terms • electromagnetic wave • electromagnetic radiation • polarized light • photoelectric effect • photon

Close your eyes for a moment and imagine you are in a shower of rain. Are you getting wet? Do you feel anything? Believe it or not, you are being "showered." Not by rain but by waves, most of which you cannot feel or hear. As you read this, you are surrounded by radio waves, infrared waves, visible light, ultraviolet waves, and maybe even tiny amounts of X-rays and gamma rays. If you have ever tuned a radio, spoken on a cordless or cellular phone, felt warmth on your skin, turned on a light, or had an X-ray taken, you have experienced electromagnetic waves.

Even though you may not feel them, you are being showered by electromagnetic waves.

Electromagnetic Waves

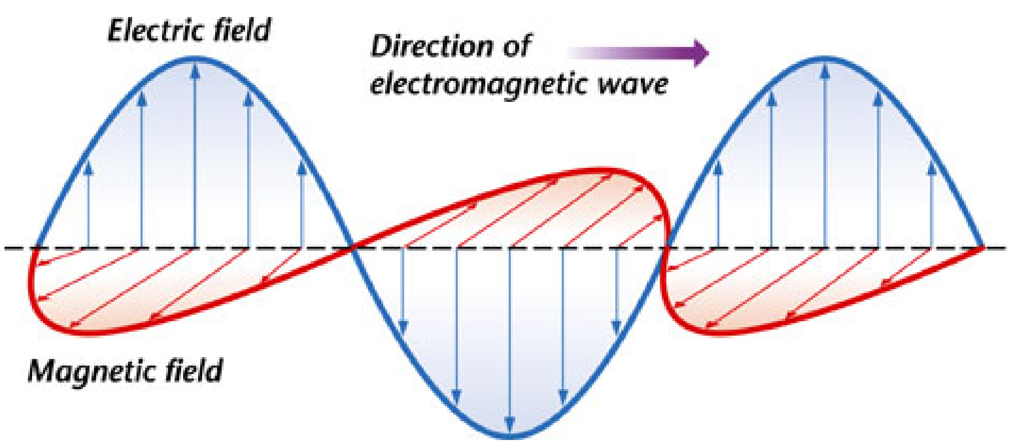
You have seen waves travel through water and move along ropes and springs. You have also heard sound waves travel through air, metal, and water. All these waves have two things in common—they transfer energy from one place to another, and they require a medium through which to travel. Recall that a medium is the matter through which a wave travels.

However, waves called electromagnetic waves can transfer energy with or without a medium. **Electromagnetic waves** are transverse waves that have some electrical properties and some magnetic properties. **An electromagnetic wave consists of changing electric and magnetic fields.**

Electric and Magnetic Fields Electromagnetic waves travel as vibrations in electric and magnetic fields. An electric field is a region in which charged particles can be pushed or pulled. Wherever there is an electric charge, there is an electric field associated with it. A moving electric charge is part of an electric current.

An electric current is surrounded by a magnetic field. A magnetic field is a region in which magnetic forces are present. If you place a paper clip near a magnet, the paper clip moves toward the magnet because of the magnetic field surrounding the magnet.

When the electric field changes, so does the magnetic field. The changing magnetic field causes the electric field to change. When one field vibrates, so does the other. In this way, the two fields constantly cause each other to change. The result is an electromagnetic wave, as shown in the diagram below.



Electromagnetic Wave An electromagnetic wave consists of electric and magnetic fields, which vibrate at right angles to each other.

Electromagnetic Radiation The energy that is transferred by electromagnetic waves is called **electromagnetic radiation**. Because electromagnetic radiation does not need a medium, it can travel through the vacuum of outer space. If it could not, light from the sun and stars could not travel through space to Earth. NASA officials could not make contact with space shuttles in orbit.

The Nature of Waves

Speed of Electromagnetic Waves All electromagnetic waves travel at the same speed—about 300,000,000 meters per second in a vacuum. You can also express this as 300,000 kilometers per second. At this speed, light from the sun travels the 150 million kilometers to Earth in about 8 minutes. That's really fast! When electromagnetic waves travel through a medium such as the atmosphere or glass, they travel more slowly. But even at slower speeds, electromagnetic waves travel about a million times faster than sound can travel in air.

Checkpoint

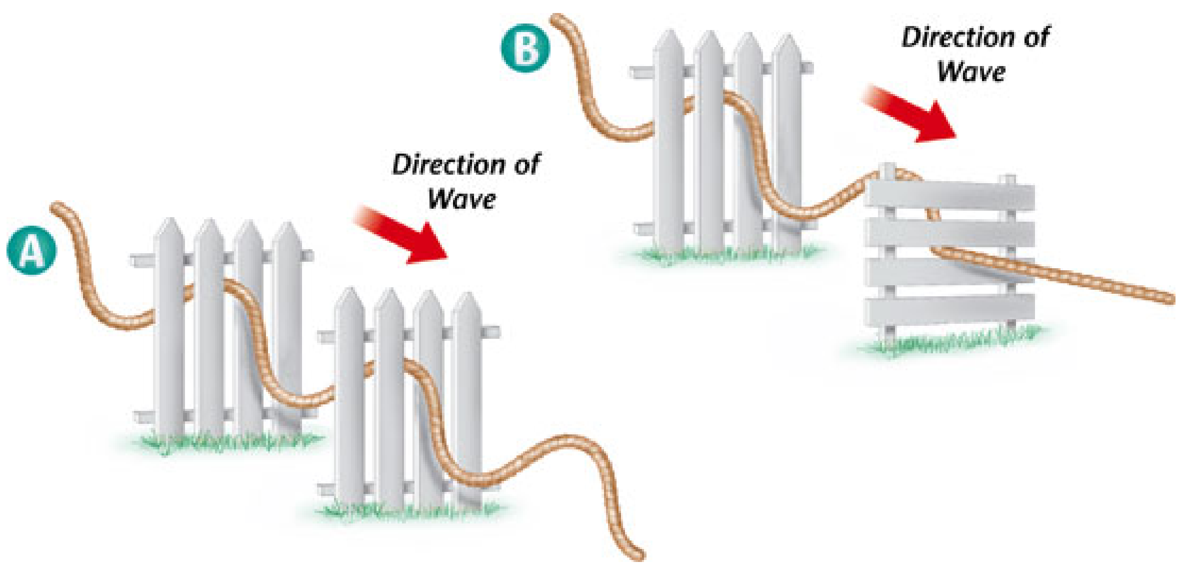
PRINT

Waves or Particles?

In general, the wave model can explain many of the properties of electromagnetic radiation. However, some properties of electromagnetic radiation do not fit the wave model. **Light has many of the properties of waves. But light can also act as though it is a stream of particles.**

When light passes through a polarizing filter, it has the properties of a wave. An ordinary beam of light has waves that vibrate in all directions. A polarizing filter acts as though it has tiny slits that are either horizontal or vertical. When light enters a polarizing filter, only some waves can pass through. The light that passes through is called **polarized light**.

To help you understand polarization, think of waves of light as being like transverse waves on a rope. They vibrate up and down, left and right, or at any other angle. If you shake a rope through a fence with vertical slats, as shown below, only waves that vibrate up and down will pass through. The other waves are blocked. A polarizing filter acts like the slats in a fence. It allows only waves that vibrate in one direction to pass through.



Polarization A polarizing filter acts like the slats in a fence. (A) A fence with vertical slats allows only waves that vibrate up and down to pass through. (B) Vertical waves cannot pass through a fence, or filter, with horizontal slats.

If you place one polarizing filter on top of another and rotate one of them, you will see how the amount of light coming through changes. If the two polarizing filters are placed so that one is rotated 90° from the other, no light can come through. All the light is blocked.

Polarizing Filters The first polarizing filter allows only waves that vibrate up and down to pass through. When a second polarizing filter is placed in front of the first, and at right angles to it, no light passes through. ***Applying Concepts*** Does the way that light passes through a polarizing filter support the wave model or the particle model of light?

Here is an example of how light can act like a stream of particles. When a beam of light shines on some substances, it causes the electrons of their atoms to move. This movement causes an electric current to flow. Sometimes light can even knock electrons out of the substance. This is called the **photoelectric effect**. The photoelectric effect can only be explained by thinking of light as a stream of tiny packets, or particles, of energy. Each packet is called a **photon**. Albert Einstein explained the photoelectric effect in 1905.

It may be difficult for you to picture light as being particles and waves at the same time. Many scientists find it difficult, too. However, both models are necessary to explain the properties of light and other forms of electromagnetic radiation.

TRY THIS

How Do Light Beams Behave?

1. Fill two plastic cups with water. Slowly pour the water from the two cups into a sink. Aim the stream of water from one cup across the path of the water from the other cup.
2. How do the two streams interfere with each other?
3. Now darken a room and project a slide from a slide projector onto the wall. Shine a flashlight beam across the projector beam.
4. How do the two beams of light interfere with each other? What effect does the interference have on the projected picture?

Drawing Conclusions How is the interference between light beams different from that between water streams? Does this activity support a wave model or a particle model of light? Explain.

Section 1 Review

Checkpoint

1. What do electromagnetic waves consist of? hint
2. Describe one behavior that shows that light is a stream of particles. hint
3. Describe one behavior that shows that light is a wave. hint
4. Thinking Critically Comparing and Contrasting How are light and sound alike? How are they different? hint

Science at Home

Sunglasses

On the next sunny day, have family members go outside wearing their sunglasses. Compare the sunglasses. Which sunglasses have polarizing lenses? How can you tell? Through the sunglasses, look at surfaces that create glare, such as water or glass. Compare the effects of different pairs of sunglasses. Which kind of sunglasses are best designed to reduce glare on a sunny day? CAUTION: Do not look directly at the sun.

PRINT

Section 2 Waves of the Electromagnetic Spectrum

Discover Activity

What Is White Light?

1. Line the inside of a cardboard box with white paper. Hold a small triangular prism up to direct sunlight. CAUTION: Do not look directly at the sun.
2. Rotate the prism until the light coming out of the prism appears on the inside of the box. What colors do you see? What is the order of the colors? Describe how the colors progress from one to the next.
3. Using colored pencils, draw a picture of what you see inside the box.

Think It Over

Forming Operational Definitions The term *spectrum* describes a range. How do you think this term is related to what you just observed?

Guide for Reading

- How do electromagnetic waves differ from each other?
- How does the energy in electromagnetic waves interact with matter?

Reading Tip Before you read, use the headings to make an outline about the different electromagnetic waves. As you read, make notes about each type of wave.

Key Terms • electromagnetic spectrum • radio wave • microwaves • radar • magnetic resonance imaging • infrared rays • thermogram • visible light • ultraviolet rays • X-rays • gamma rays

Can you imagine trying to keep food warm with a flashlight? How about trying to tune in a radio station on your television? Light and radio waves are both electromagnetic. But each has properties that make it useful for some purposes and useless for others. What makes radio waves different from light or ultraviolet rays?

Characteristics of Electromagnetic Waves

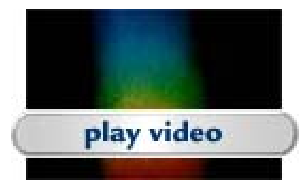
All electromagnetic waves travel at the same speed, but they have different wavelengths and different frequencies. Radiation in the wavelengths that your eyes can see is called visible light. Only a small portion of electromagnetic radiation is visible light. The rest of the wavelengths are invisible. Your radio detects wavelengths that are much longer and have a lower frequency than visible light.

Recall how speed, wavelength, and frequency are related:

Speed = Wavelength × Frequency

Since the speed of all electromagnetic waves is the same, as wavelength decreases, frequency increases. Waves with the longest wavelengths have the lowest frequencies. Waves with the shortest wavelengths have the highest frequencies. The amount of energy carried by an electromagnetic wave increases with frequency. The higher the frequency of a wave, the higher its energy.

Electromagnetic Waves



The **electromagnetic spectrum** is the name for the range of electromagnetic waves when they are placed in order of increasing frequency. Click on the button at right to learn about the electromagnetic spectrum. **The electromagnetic waves in the electromagnetic spectrum possess energy. Complex interactions occur between the energy in electromagnetic waves and matter.**

Exploring the Electromagnetic Spectrum

Checkpoint

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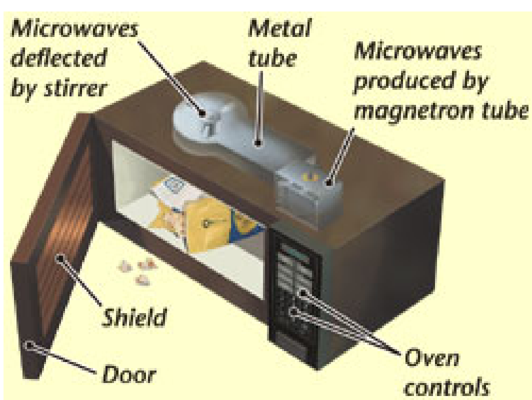
Radio Waves

Radio waves are the electromagnetic waves with the longest wavelengths and lowest frequencies. Like all electromagnetic waves, radio waves can travel through a vacuum. Most of the radio waves we receive, though, have traveled through air. Antennas pick up radio waves from the air and send them through wires to your radio. The radio converts the electromagnetic waves into the sound that comes out of the radio speakers.

Each radio station in an area broadcasts at a different frequency. To change the station on your radio, you adjust the tuning dial or press a button. This makes the tuner pick up waves of a different frequency. The numbers on your radio tell you the frequency of the station you are listening to.

Microwaves The radio waves with the shortest wavelengths and the highest frequencies are **microwaves**. One of their most common uses is in microwave ovens. When you switch on a microwave oven, it gives off electromagnetic waves that bounce around inside the oven, penetrating the food. Matter and energy interact when water molecules in the food absorb the energy from the microwaves, causing the food to get hot.

Microwaves can pass right through some substances, such as glass and plastic. For this reason, microwaves do not heat glass and plastic containers. If the container gets hot, it is because the food in the container transfers heat to the container. Other substances, such as metals, reflect microwaves. If you have ever accidentally put a metal object, such as a piece of aluminum foil, into a microwave oven, you may have seen sparks. The sparks are the result of a buildup of electrical energy in the metal caused by the microwaves. Metal containers and utensils should never be used in microwave ovens.



Microwaves Microwaves produced in a microwave oven are absorbed by water molecules in foods. The energy raises the temperature of the food faster than an ordinary oven, so the food takes less time to cook. ***Applying Concepts*** Why are metal containers not suitable for use in a microwave oven?

Microwaves are not easily blocked by structures such as trees, buildings, and mountains. For this reason, microwaves are used to transmit cellular telephone calls. You will read more about cellular phones in Section 4.

Radar Short-wavelength microwaves are used in radar. **Radar**, which stands for **ra**dio **d**etection **a**nd **r**anging, can be used to locate objects. A radar device sends out short pulses of radio waves. These waves are reflected by objects that they strike. A receiver detects the stronger reflected waves and measures the time it takes for them to come back. From the time and the known speed of the waves, the receiver calculates the distance to the object. Radar is used to monitor airplanes landing and taking off at airports. Radar is also used to locate ships at sea and to track weather systems.

In Chapter 5, you learned how the frequency of a sound wave seems to change when the source of the sound moves toward you or away from you. The Doppler effect occurs with electromagnetic waves too, and has some very useful applications. Police use radio waves and the Doppler effect to find the speeds of vehicles. A radar gun sends blips of radio waves toward a moving car. The waves are then reflected. Because the car is moving, the frequency at which the reflected blips arrive is different from the frequency at which the waves were sent out. The radar device uses the difference in frequency to calculate the speed of the car. If the car is going faster than the speed limit, the police often give a speeding ticket.

Radar is also used at some sports events to measure the speed of a moving ball. The radio waves bounce off a moving ball. The speed at which the ball is hit or thrown can then be displayed on a board.

INTEGRATING HEALTH

Magnetic Resonance Imaging (MRI) Radio waves are also used in medicine to produce pictures of tissues in the human body. This process is called **magnetic resonance imaging**, or MRI. A person is placed in an MRI machine that produces strong magnetic fields, causing the body's atoms to line up in one direction. The machine then gives out short bursts of radio waves that knock the atoms out of alignment. As the atoms realign, data is produced. A computer analyzes this data and creates pictures of the internal body organs. The pictures show clear images of muscles and other soft tissues not shown on X-rays. MRI is used to detect brain disorders and soft tissue disorders near the spine.

Checkpoint

Social Studies CONNECTION

In 1920, only about 20,000 people using homemade radio sets were receiving radio signals. As an experiment, Frank Conrad of the Westinghouse Company began to broadcast recorded music and sports results. Because public response was so enthusiastic, the company began broadcasting programs on a regular basis. By 1922, there were more than 500 radio stations in the United States.

In Your Journal

Imagine you are the advertising director for an early radio station. Write a letter to a business of your choice telling the owners why they should buy advertising time from your radio station.

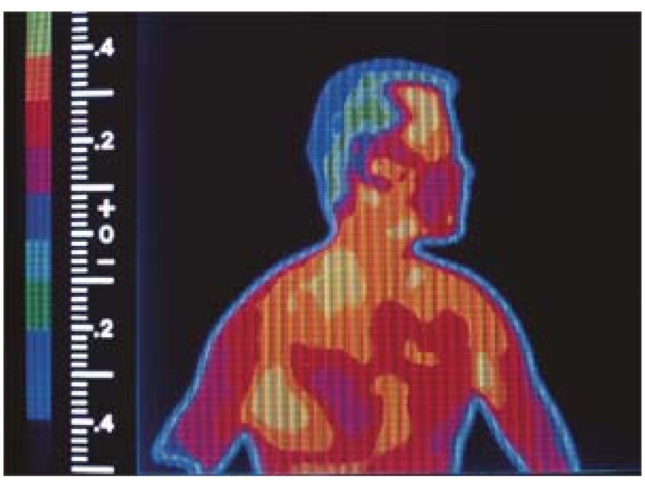
Infrared Rays

If you switch on an electric stove, you can feel infrared rays even before the element turns red. As the element warms up, it gives off energy as light and heat. Much of this energy is infrared radiation, or infrared rays. **Infrared rays** have shorter wavelengths and higher frequencies than radio waves.

Infra- is a Latin prefix that means "below." Put *infra-* and *red* together, and you get *infrared,* which means "below red." The next waves in the spectrum are red light.

Infrared rays range in wavelength from a little shorter than radio waves to just longer than visible red light. Because you can feel the longest infrared rays as warmth, these rays are often called heat rays. Heat lamps have bulbs that give off more infrared rays and less visible light than regular bulbs. Some people have heat lamps in their bathrooms. You may also have seen heat lamps keeping food warm at cafeteria counters.

Most objects give off some infrared rays. Warmer matter gives off infrared rays with higher energy than cooler matter. An infrared camera takes pictures using infrared rays instead of light. These pictures are called thermograms. The photo below shows a thermogram of a person. A **thermogram** shows regions of different temperatures in different colors. Thermograms identify the warm and cool parts of an object by analyzing the infrared rays it gives off. Thermograms are especially useful for checking structures, such as houses, for energy leaks.



Thermogram Infrared rays can be used to produce a thermogram. ***Inferring*** What color do you think represents cooler body temperatures?

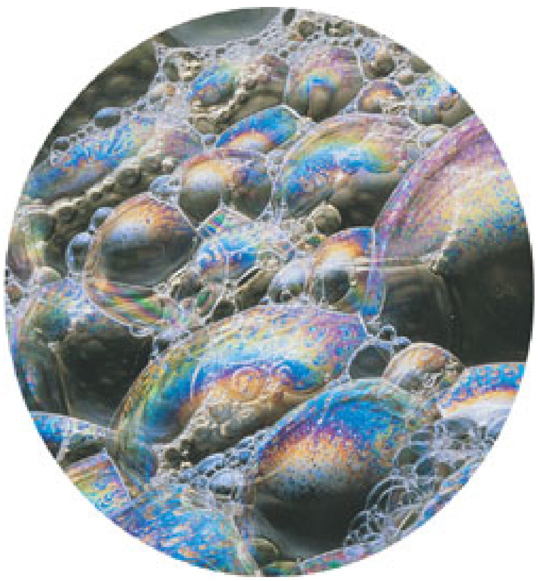
Even though your eyes cannot see the wavelengths of infrared rays, you can use an infrared camera or binoculars to detect people or animals in the dark. Satellites in space use infrared cameras to study the growth of plants and to observe the motions of clouds to help determine weather patterns.

SECTION 2

Visible Light

The electromagnetic waves that you can see are visible light. They make up only a small part of the electromagnetic spectrum. **Visible light** has shorter wavelengths and higher frequencies than infrared waves. The longest wavelengths of visible light are red. As the wavelengths decrease and the frequencies increase, you can see other colors of light. The shortest wavelengths are purple, or violet.

Have you ever seen a rainbow in the sky, colors on a bubble, or light passing through a prism? Recall what happens when waves enter a new medium, such as water or glass. The waves bend, or refract. Different wavelengths of light refract by different amounts, so the waves separate into the various colors of the visible spectrum. The colors are red, orange, yellow, green, blue, and violet, in order of increasing frequencies. Most visible light is made up of a mixture of these colors.



Visible Light Visible light is made up of different wavelengths. Each wavelength has its own color. When light bounces off a bubble, interference removes some of the colors of the visible spectrum and leaves others for us to see.

Checkpoint

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SECTION 2

Ultraviolet Rays

Electromagnetic waves with wavelengths just shorter than those of visible light are called **ultraviolet rays**, or UV. *Ultra-* is a Latin prefix that means “beyond.” So *ultraviolet* means “beyond violet.” UV waves have higher frequencies than visible light, so they carry more energy. Because the energy of ultraviolet rays interacts with matter, they can damage or kill living cells. Ultraviolet lamps are often used to kill bacteria on hospital equipment and in food processing plants.

Small doses of ultraviolet rays are beneficial to humans. Ultraviolet rays cause skin cells to produce vitamin D, which is needed for healthy bones and teeth. Ultraviolet lamps are used to treat jaundice, a condition of the liver that causes yellowing of the skin, in newborn babies.

The ultraviolet rays present in sunlight can burn your skin. Too much exposure can cause skin cancer and damage your eyes. If you apply sunblock lotion and wear sunglasses, you can limit the damage to your body caused by UV rays.

INTEGRATING LIFE SCIENCE

Although ultraviolet light is invisible to humans, many insects can see it. For example, bees have good color vision, but they do not see the same range of wavelengths that humans do. Bees see less of the lower frequency red waves and more of the higher frequency ultraviolet waves. Flowers that appear to be one color to a human appear very different to a honeybee. To the bee, the part of a flower that contains nectar looks different from the rest of the flower. The bee can head straight for the nectar!

TRY THIS

What Does a Bee See?

Load a roll of UV-sensitive film into a camera. Take photos of a variety of flowers. Include white flowers and flowers that you see bees near. Have the film developed and look at the prints.

Observing What can bees see that you cannot? How is this useful to the bees?

X-Rays

X-rays are electromagnetic waves with very short wavelengths. Their frequencies are just a little higher than ultraviolet rays. Because of their high frequencies, X-rays carry more energy than ultraviolet rays and can interact with most matter. Dense matter, such as bone or lead, absorbs X-rays and does not allow them to pass through. For this reason, X-rays are used to make images of bones inside the body. X-rays pass right through both skin and soft tissues and change the photographic film in the X-ray machine so that it darkens when it is developed. The bones, which absorb X-rays, appear as the lighter areas on the film, as shown in the photo below.

X-Ray Image X-rays pass through softer human tissues and cause the photographic plate to darken behind them when developed. Bones absorb X-rays, so they show up as lighter areas. ***Applying Concepts*** Why do you think that dental X-rays are useful to dentists?

Too much exposure to X-rays can cause cancer. If you've ever had a dental X-ray, you'll remember how the dentist gave you a lead apron to wear during the procedure. The lead absorbs X-rays and prevents them from reaching your body.

X-rays are sometimes used in industry and engineering. For example, to find out if a steel or concrete structure has tiny cracks, engineers can take an X-ray image of the structure. X-rays will pass through tiny cracks that are invisible to the human eye. Dark areas on the X-ray film show the cracks. This technology is often used to check the quality of joints in oil and gas pipelines.

PRINT

Gamma Rays

Gamma rays have the shortest wavelengths and highest frequencies of the electromagnetic spectrum. Because they have the greatest amount of energy, they are the most penetrating of all the electromagnetic waves.

Some radioactive substances and certain nuclear reactions produce gamma rays. Because of their great ability to penetrate matter, gamma rays can cause serious illness. However, when used in controlled conditions, gamma rays have some medical uses. For example, gamma rays can be used to kill cancer cells in radiation therapy. Gamma rays can also be used to examine the body’s internal structures. A patient can be injected with a fluid that emits gamma rays. Then a gamma ray detector can form an image of the inside of the body.

INTEGRATING SPACE SCIENCE

Some objects far out in space give off bursts of gamma rays. The gamma rays travel for billions of years before they reach Earth. Earth’s atmosphere blocks these gamma rays, so gamma-ray telescopes that detect them must orbit above Earth’s atmosphere. Astronomers think that collisions of dying stars in distant galaxies are one way of producing these gamma rays. Some gamma-ray telescopes detected the stronger gamma rays given off in the atmosphere as a result of nuclear weapons tests on Earth.

PRINT

Section 2 Review

Checkpoint

1. How are all electromagnetic waves alike? How are they different? hint
2. Give examples of how three different types of electromagnetic waves interact with matter. hint
3. Explain how radio waves are used to find the speed of a moving object. hint
4. How are X-rays useful? How are they dangerous? hint
5. Thinking Critically Applying Concepts As the wavelength of electromagnetic waves decreases, what happens to the frequency? To the energy? hint

Check Your Progress

Write the questions for your survey. Some categories you might want to include are types of communication devices, how often they are used, when and where they are used, and the purposes for which they are used. Do people use these devices for personal reasons or for business? (*Hint:* To make your survey easy to complete, ask questions that require short answers.) Give the survey sheet to your classmates and other students in the school for their families and neighbors to complete.

Generating Visible Light Waves

DISCOVER ACTIVITY

How Do Light Bulbs Differ?

1. Your teacher will give you one incandescent and one fluorescent light bulb.
2. Examine each bulb closely. What is the shape and size of each? Describe the differences between the bulbs. Draw each type of bulb and record your observations.
3. How do you think each bulb produces light?

Think It Over

Posing Questions Make a list of five questions you could ask to help you understand how each bulb works.

GUIDE FOR READING

- What happens when matter and energy interact in a light bulb?
- What colors of light does an incandescent bulb generate?

Reading Tip As you read, compare and contrast the different ways in which light can be generated.

Key Terms • illuminated • luminous • spectroscope • incandescent light • fluorescent light • neon light • sodium vapor light • tungsten–halogen light • bioluminescence

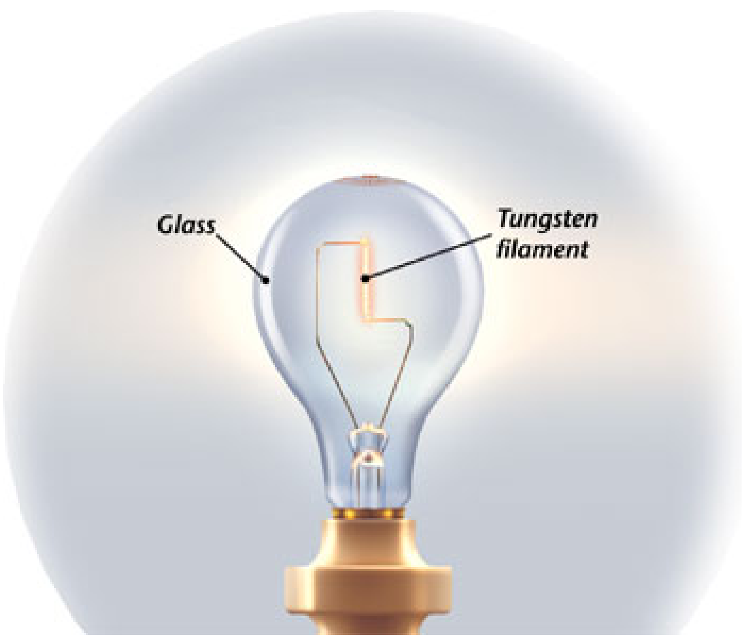
Look around the room. Most of the matter you see is visible because it reflects light. If no light source were present, you could not see matter. An object that can be seen because it reflects light is an **illuminated** object. Light illuminates the page you are reading and your desk. An object that gives off its own light is a **luminous** object. A light bulb, a burning match, and the sun are examples of luminous objects.

There are many different types of light bulbs. Common types of light bulbs include incandescent, fluorescent, neon, sodium vapor, and tungsten-halogen. **Complex interactions between matter and energy occur in light bulbs to generate a spectrum of wavelengths.** An instrument called a **spectroscope** can be used to view the different colors of light produced by each type of bulb.

Incandescent Lights

Have you heard the phrase “red hot”? When some objects get hot enough, they glow, giving off a faint red light. If they get even hotter, the glow turns into white light. The objects are said to be “white hot.” **Incandescent lights** (in kun des unt) glow when a filament inside them gets hot.

Look closely at a clear, unlit incandescent bulb. Notice inside the thin wire coil called a filament. It is made of a metal called tungsten. When an electric current passes through the filament, it heats up. When the filament gets hot enough, it gives off red light, which has low frequencies. As it gets hotter, the filament gives off light with higher frequencies. Once the filament gets hot enough to give off enough violet light, all the frequencies of light combine to produce white light. **Incandescent lights give off all the colors of visible light: red, orange, yellow, green, blue, and violet.**



Incandescent Light An incandescent light bulb glows when electricity passes through the tungsten filament.

The American inventor Thomas Edison is credited with developing a long-lasting incandescent light bulb in 1879. Edison knew that if he passed an electric current through a wire, it would get hot and glow. By experimenting with different types of filaments, Edison developed a light bulb that would glow for a long time.

Incandescent bulbs are not very efficient in giving off light. Less than ten percent of the energy is actually given out as light. Most of the energy produced by an incandescent bulb is given off as infrared rays. Incandescent bulbs can get quite hot when they have been left on for a while.

Fluorescent Lights

Have you ever noticed the long, narrow light bulbs in stores and offices? They are **fluorescent lights** (floo res uhnt). Maybe you have some in your school. Each glass tube contains a gas and is coated on the inside with a powder.

When an electric current passes through a fluorescent bulb, it causes the gas to emit ultraviolet waves. When the ultraviolet waves hit the powder coating inside the tube, the coating emits visible light. This process is called fluorescing.

Unlike incandescent lights, fluorescent lights give off most of their energy as light. They usually last longer than incandescent bulbs and use less electricity for the same brightness, which makes them less expensive to run.

Checkpoint

Sharpen your Skills

Observing

Use a spectroscope to observe light from different sources. CAUTION: Do not look at the sun with the spectroscope.

1. Look through the spectroscope at an incandescent light. Using colored pencils, draw and label the band of colors as they appear in the spectroscope.
2. Now, look at a fluorescent light through the spectroscope. Again, draw and label what you see.

How are the two bands of color the same? How are they different? Can you explain the differences?

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Neon Lights

Some gases can be made to produce light by passing an electric current through them. For example, a **neon light** consists of a sealed glass tube filled with neon. When an electric current passes through the neon gas, matter interacts with energy as the gas absorbs the energy. However, the gas cannot hold the energy for very long. The energy is released by the gas in the form of light. This process is called electric discharge through gases.

Pure neon gives out red light. Often, what is called a neon light has a different gas, or a mixture of gases, in the tube. Different gases produce different colors of light. For example, both argon gas and mercury vapor produce greenish blue light. Helium gives a pink light. Krypton gives a pale violet light. Sometimes the gases are put into colored glass tubes to produce other colors. Neon lights are commonly used for bright, flashy signs.

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Sodium Vapor Lights

Sodium vapor lights contain a small amount of solid sodium as well as some neon and argon gas. When the neon and argon gas are heated, they begin to glow. This glow heats up the sodium, causing it to change from a solid into a gas. The particles of sodium vapor give off energy in the form of yellow light.

Sodium vapor lights are commonly used for street lighting. They require very little electricity to give off a great deal of light, so they are quite economical.

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Tungsten-Halogen Lights

Tungsten-halogen lights work partly like incandescent bulbs. They have tungsten filaments and contain a gas. The gas is one of a group of gases called the halogens. When electricity passes through the filament, the filament gets hot and glows. The halogen makes the filament give off a bright white light.

Tungsten-halogen lights have become very popular. These small bulbs use relatively little electricity for the bright light they provide. They are used in overhead projectors and in floor lamps. Because some halogen bulbs become very hot, they must be kept away from flammable materials, such as paper and curtains.

SECTION 3

Bioluminescence

INTEGRATING LIFE SCIENCE

Have you ever seen a firefly? On a warm summer evening, they flash their lights in patterns to attract mates. Fireflies are examples of organisms that produce their own light in a process called bioluminescence. **Bioluminescence** (by oh loo muh nes uns) occurs as a result of a chemical reaction among proteins and oxygen in an organism. The reaction produces energy that is given off in the form of light. Recall from Chapter 1 that an energy-producing chemical reaction is called an exothermic reaction. Unlike a light bulb, which gives off most of its energy as infrared rays, the reaction that produces bioluminescence gives off almost all of its energy as light.

There are also bioluminescent organisms in the oceans. Some types of jellyfish give off light when they are disturbed. Deep in the ocean, where sunlight cannot reach, bioluminescence is the only source of light. Some deep-sea fish use bioluminescence to search for food or to attract mates.

PRINT

SECTION 3

Section 3 Review

Checkpoint

1. How do light bulbs generate light? hint
2. How does an incandescent light bulb generate white light? hint
3. Compare luminous objects with illuminated objects. Give two examples of each. hint
4. Why are fluorescent lights commonly used in businesses and schools? hint
5. Thinking Critically Making Judgments Which type of light is best for each room in your home? Give reasons for your choices. hint

Science at Home

Buying Bulbs

Invite family members to visit a hardware store that sells light bulbs. Ask the salesperson to describe the different kinds of bulbs available. Read the information about each bulb on the side panel of each package. Ask the salesperson to explain any terms you don’t understand. Look for the cost and expected life of the bulbs, too. How does this information help you and your family purchase the most economical bulbs?

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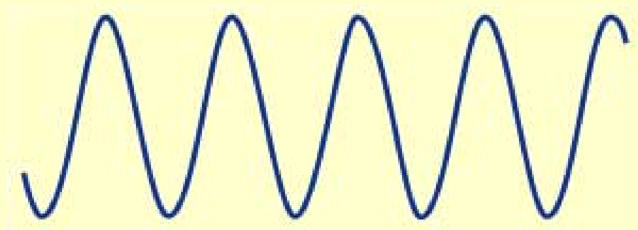
Wireless Communication

INTEGRATING TECHNOLOGY

Discover Activity

How Can Radio Waves Change?



1. Trace the wave diagram onto a piece of tracing paper. Then transfer the wave diagram onto a flat piece of latex from a balloon or latex glove.
2. Stretch the latex horizontally. How is the stretched wave different from the wave on the tracing paper?
3. Now stretch the latex vertically. How is this wave different from the wave on the tracing paper? How is it different from the wave in Step 2?

Think It Over

Making Models Which stretch changes the amplitude of the wave? Which stretch changes the frequency of the wave?

Guide for Reading

- How do AM and FM radio waves transmit information?
- How do cellular phones and pagers use electromagnetic waves?
- How are satellites used to relay information?

Reading Tip Before you read, preview the diagrams and captions in the section. List any terms you are not familiar with. As you read, write the definition of each term on your list.

Key Terms • amplitude modulation (AM) • frequency modulation (FM)

Recent advances in technology have turned our world into a global village. Today you can communicate with people on the other side of the world in just seconds. You can watch a television broadcast of a soccer game from Europe or a news report from the Middle East. Once scientists discovered that messages could be carried on electromagnetic waves, they realized that communication signals could travel at the speed of light.

Wireless Communication

SCIENCE & History
show detail

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SECTION 4

Cellular Telephones

Cellular phones have become very common. **Cellular telephones transmit and receive signals using high-frequency radio waves, or microwaves.** The cellular system works over regions divided up into many small cells. Each cell has its own transmitter and receiver. Cells that are next to each other are assigned different frequencies, but cells that are not next to each other can be assigned the same frequency. Cellular telephone signals are strong enough to reach only a few nearby cells. They cannot travel great distances. This allows many phones in different areas to use the same frequency at the same time, without interfering with each other.

As cellular phone users travel from one cell to another, the signals are transferred from one cell to another with very little interruption. If you travel outside one cellular phone company's area, another company becomes responsible for transmitting the signals.

Many cellular phones are more expensive to use than wired phones. But they are becoming more affordable and more popular. Cellular phones allow users to make and receive calls without having to use someone else's phone or to look for a pay phone.

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Cordless Telephones

Cellular telephones should not be confused with cordless telephones. The bases of cordless telephones are connected to the telephone system just like ordinary phones. The only difference is that there is no cord between the handset and the base. The information is transmitted from the handset to the base by radio waves, so you can walk away from the base as you talk on the phone.

Pagers

Pagers are small electronic devices that people can carry in their pockets or attached to their clothes. Have you ever paged someone? You dial the telephone number of the pager from a telephone or another pager. Depending on the pager, you can then enter your telephone number or leave a voice message, which will appear as a text message on the pager's screen.

When you leave a message for a pager, the information is first sent to a receiving station. There it is coded and sent as electromagnetic waves to the correct pager. The pager then beeps or vibrates, letting the owner know that there is a message. Some pagers are two-way pagers. This means that the pager can return electromagnetic signals to the receiving station, which sends them to the person who sent the original message.

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SECTION 4

Section 4 Review

Checkpoint

1. Describe how the sounds from a radio station, such as speech or music, are converted into radio waves. hint

2. What is the difference between AM and FM radio broadcasts? hint

3. How does the cellular phone system work? hint

4. How does a satellite relay radio and television signals? hint

5. Thinking Critically Predicting What do you think might happen if the Federal Communications Commission did not control the use of different frequencies of radio waves? hint

Chapter Project: Check Your Progress

Collect your surveys and tally your results. As you analyze your data, look for patterns. You can use bar graphs or circle graphs to display your findings. Include information about cost, time, and any other questions you asked in your survey. Write one or two paragraphs explaining your conclusions.