

**BIG Idea**

Electromagnetic waves can transfer energy through matter and space.

**12.1 What are electromagnetic waves?****MAIN Idea**

Electromagnetic waves are transverse waves that can be produced by vibrating electric charges.

**12.2 The Electromagnetic Spectrum****MAIN Idea**

Each type of electromagnetic wave has a certain range of frequencies and wavelengths.

**12.3 Radio Communication****MAIN Idea**

Signals and information can be transmitted using radio waves.

**How's the reception?**

These giant 25-m dishes aren't picking up TV signals. Instead, they are part of a group of 27 antennas that detect radio waves coming from distant stars and galaxies. Radio waves, like microwaves and light waves, are electromagnetic waves. All objects, including you, emit electromagnetic waves.

**Science Journal**

List six objects around you that emit light or feel warm.

# Electromagnetic Waves





# Start-Up Activities



## Can electromagnetic waves change materials?

You often hear about the danger of the Sun's ultraviolet rays, which can damage the cells of your skin. When the exposure isn't too great, your cells can repair themselves, but too much at one time can cause a painful sunburn. Repeated overexposure to the Sun over many years can damage cells and cause skin cancer. In the lab below, observe how energy carried by ultraviolet waves can cause changes in other materials.

1. Cut a sheet of red construction paper in half.
2. Place one piece outside in direct sunlight. Place the other in a shaded location.
3. Keep the construction paper in full sunlight for at least 45 min. If possible, allow it to stay there for 3 h or more before taking it down. Be sure the other piece remains in the shade.
4. **Think Critically** In your Science Journal, describe any differences you notice in the two pieces of construction paper. Comment on your results.

## FOLDABLES™ Study Organizer

### Electromagnetic Waves

Make the following Foldable to help you understand electromagnetic waves.

- STEP 1** **Fold** a vertical sheet of paper in half from top to bottom.



- STEP 2** **Fold** in half from side to side with the fold at the top.



- STEP 3** **Unfold** the paper once. **Cut** only the fold of the top flap to make two tabs.



- STEP 3** **Write** on the front tabs as shown.

How do electromagnetic waves travel through space?

How do electromagnetic waves transfer energy to matter?

**Identify Questions** As you read the chapter, write answers to the questions on the back of the appropriate tabs.



Preview this chapter's content and activities at [gpscience.com](http://gpscience.com)

# What are electromagnetic waves?

## Reading Guide

### What You'll Learn

- **Describe** how electric and magnetic fields form electromagnetic waves.
- **Explain** how vibrating charges produce electromagnetic waves.
- **Describe** properties of electromagnetic waves.

### Why It's Important

You, and all the objects and materials around you, are radiating electromagnetic waves.

### Review Vocabulary

**Hertz:** the SI unit of frequency, abbreviated Hz; 1 Hz equals one vibration per second

### New Vocabulary

- electromagnetic wave
- radiant energy
- photon

## Waves in Space

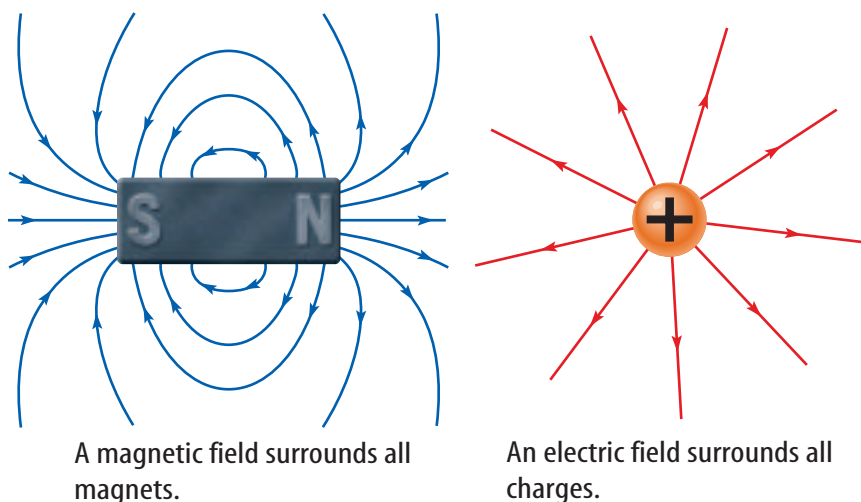
Stay calm. Do not panic. As you are reading this sentence, no matter where you are, you are surrounded by electromagnetic waves. Even though you can't feel them, some of these waves are traveling right through your body. They enable you to see. They make your skin feel warm. You use electromagnetic waves when you watch television, talk on a cordless phone, or prepare popcorn in a microwave oven.

**Sound and Water Waves** Waves are produced by something that vibrates, and they carry energy from one place to another. Look at the sound wave and the water wave in **Figure 1**. Both waves are moving through matter. The sound wave is moving through air and the water wave through water. These waves travel because energy is transferred from particle to particle. Without matter to transfer the energy, they cannot move.

**Electromagnetic Waves** However, electromagnetic waves do not require matter to transfer energy. **Electromagnetic waves** are made by vibrating electric charges and can travel through space where matter is not present. Instead of transferring energy from particle to particle, electromagnetic waves travel by transferring energy between vibrating electric and magnetic fields.



**Figure 1** Water waves and sound waves require matter to move through. Energy is transferred from one particle to the next as the wave travels through the matter.



**Figure 2** Fields enable magnets and charges to exert forces at a distance. These fields extend throughout space.

**Explain** how you could detect a magnetic field.

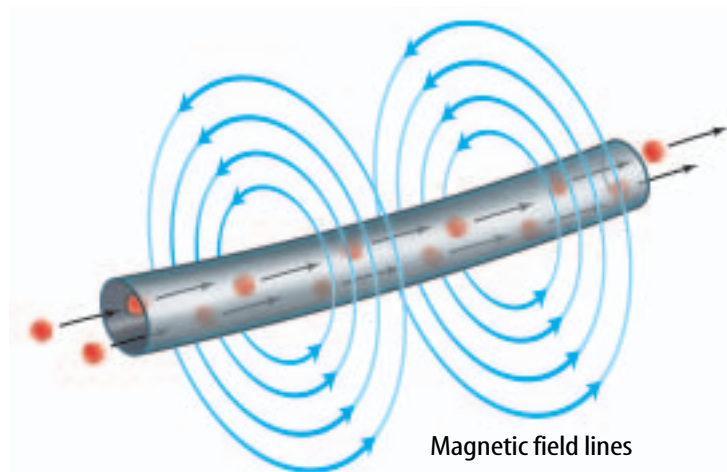
## Electric and Magnetic Fields

When you bring a magnet near a metal paper clip, the paper clip moves toward the magnet and sticks to it. The paper clip moved because the magnet exerted a force on it. The magnet exerted this force without having to touch the paper clip. The magnet exerts a force without touching the paper clip because all magnets are surrounded by a magnetic field, as shown in **Figure 2**. Magnetic fields exist around magnets even if the space around the magnet contains no matter.

Just as magnets are surrounded by magnetic fields, electric charges are surrounded by electric fields, also shown in **Figure 2**. An electric field enables charges to exert forces on each other even when they are far apart. Just as a magnetic field around a magnet can exist in empty space, an electric field exists around an electric charge even if the space around it contains no matter.

### Magnetic Fields and Moving Charges

Electric charges also can be surrounded by magnetic fields. An electric current flowing through a wire is surrounded by a magnetic field, as shown in **Figure 3**. An electric current in a wire is the flow of electrons in a single direction. It is the motion of these electrons that creates the magnetic field around the wire. In fact, any moving electric charge is surrounded by a magnetic field, as well as an electric field.



**Figure 3** Electrons moving in a wire are surrounded by a magnetic field.

**Describe** how you would confirm that a magnetic field exists around a current-carrying wire.



## Mini LAB

### Investigating Electromagnetic Waves

#### Procedure

1. Point your **television remote control** in different directions and observe whether it will still control the **television**.
2. Place various materials in front of the infrared receiver on the television and observe whether the remote still will control the television. Some materials you might try are **glass, a book, your hand, paper, and a metal pan**.

#### Analysis

1. Was it necessary for the remote to be pointing exactly toward the receiver to control the television? Explain.
2. Did the remote continue to work when the various materials were placed between it and the receiver? Explain why or why not.



**Figure 4** A vibrating electric charge creates an electromagnetic wave that travels outward in all directions from the charge. The wave in only one direction is shown here.

**Determine** whether an electromagnetic wave is a transverse wave or a compressional wave.

**Changing Electric and Magnetic Fields** A changing magnetic field creates a changing electric field. For example, in a transformer, changing electric current in the primary coil produces a changing magnetic field. This changing magnetic field then creates a changing electric field in the secondary coil that produces current in the coil. The reverse is also true—a changing electric field creates a changing magnetic field.

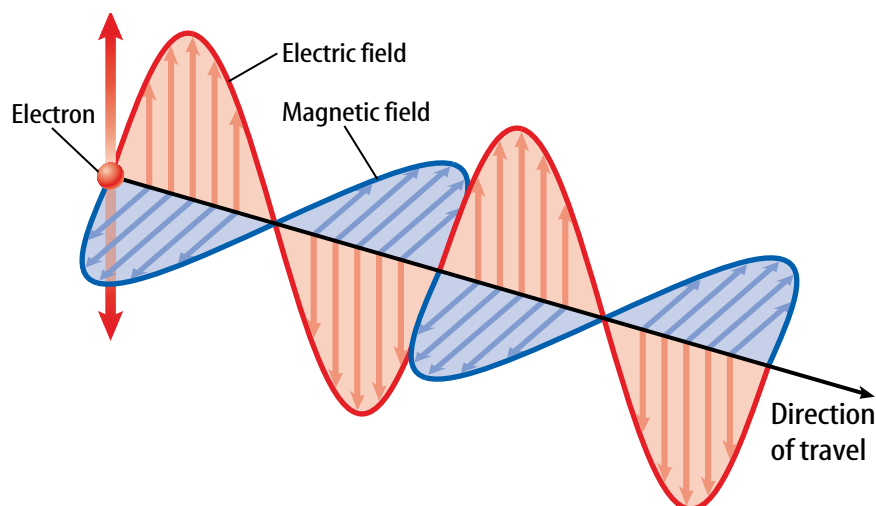
### Making Electromagnetic Waves

Waves such as sound waves are produced when something vibrates. Electromagnetic waves also are produced when something vibrates—an electric charge that moves back and forth.

#### Reading Check What produces an electromagnetic wave?

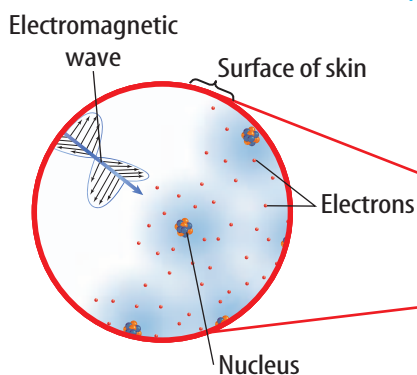
When an electric charge vibrates, the electric field around it changes. Because the electric charge is in motion, it also has a magnetic field around it. This magnetic field also changes as the charge vibrates. As a result, the vibrating electric charge is surrounded by changing electric and magnetic fields.

How do the vibrating electric and magnetic fields around the charge become a wave that travels through space? The changing electric field around the charge creates a changing magnetic field. This changing magnetic field then creates a changing electric field. This process continues, with the magnetic and electric fields continually creating each other. These vibrating electric and magnetic fields are perpendicular to each other and travel outward from the moving charge, as shown in **Figure 4**. Because the electric and magnetic fields vibrate at right angles to the direction the wave travels, an electromagnetic wave is a transverse wave.



## Properties of Electromagnetic Waves

All matter contains charged particles that are always in motion. As a result, all objects emit electromagnetic waves. The wavelengths of the emitted waves become shorter as the temperature of the material increases. As an electromagnetic wave moves, its electric and magnetic fields encounter objects. These vibrating fields can exert forces on charged particles and magnetic materials, causing them to move. For example, electromagnetic waves from the Sun cause electrons in your skin to vibrate and gain energy, as shown in **Figure 5**. The energy carried by an electromagnetic wave is called **radiant energy**. Radiant energy makes a fire feel warm and enables you to see.



**Figure 5** As an electromagnetic wave strikes your skin, electrons in your skin gain energy from the vibrating electric and magnetic fields.



### Applying Science

**THE SPEED OF LIGHT IN WATER** The speed of light in water is 226,000 km/s. Write this number in scientific notation.

**IDENTIFY** known values and the unknown value

Identify the known values:

The speed of light in water is 226,000 km/s.

Identify the unknown value:

the number 226,000 written in scientific notation

**SOLVE** the problem

A number written in scientific notation has the form  $M \times 10^N$ .  $N$  is the number of places the decimal point in the number has to be moved so that the number  $M$  that results has only one digit to the left of the decimal point.

Write the number in scientific notation form:  $226,000. \times 10^N$

Move the decimal point five places to the left:  $2.26000 \times 10^N$

The decimal point was moved 5 places, so  $N$  equals 5:  $2.26000 \times 10^5$

Delete remaining zeroes at the end of the number.  $2.26 \times 10^5$

**CHECK** your answer

Add zeroes to the end of the number and move the decimal point in the opposite direction five places. The result should be the original number.

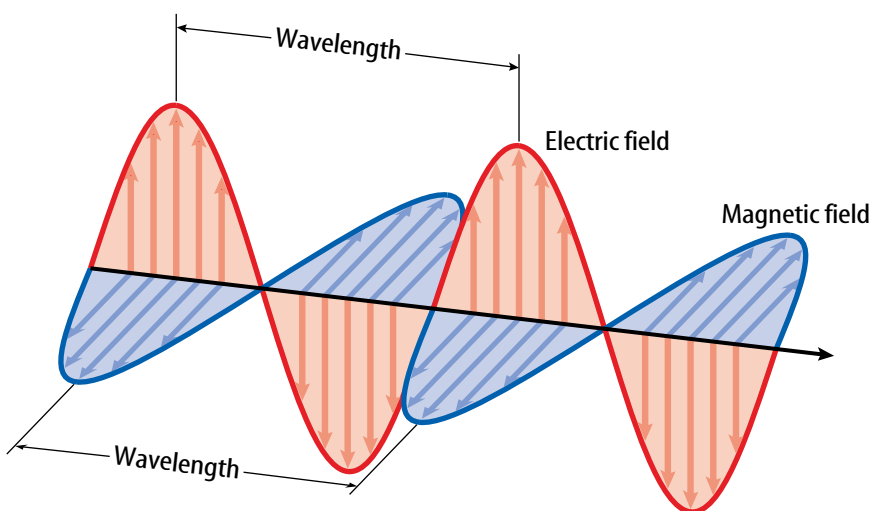
### Practice Problem

Write the following numbers in scientific notation: 433; 812,000,000; 73,000,000,000; 84,500.

For more practice problems go to page 834, and visit [gpscience.com/extra\\_problems](http://gpscience.com/extra_problems).

| Table 1 Speed of Visible Light |                            |
|--------------------------------|----------------------------|
| Material                       | Speed (km/s)               |
| Vacuum                         | 300,000                    |
| Air                            | slightly less than 300,000 |
| Water                          | 226,000                    |
| Glass                          | 200,000                    |
| Diamond                        | 124,000                    |

**Figure 6** The wavelength of an electromagnetic wave is the distance between the crests of the vibrating electric field or magnetic field.



**Wave Speed** All electromagnetic waves travel at 300,000 km/s in the vacuum of space. Because light is an electromagnetic wave, the speed of electromagnetic waves in space is usually called the “speed of light.” The speed of light is nature’s speed limit—nothing travels faster than the speed of light. In matter, the speed of electromagnetic waves depends on the material they travel through. Electromagnetic waves usually travel the slowest in solids and the fastest in gases. **Table 1** lists the speed of visible light in various materials.

**Reading Check** What is the speed of light?

**Wavelength and Frequency** Like all waves, electromagnetic waves can be described by their wavelength and frequency. The wavelength of an electromagnetic wave is the distance from one crest to another, as shown in **Figure 6**.

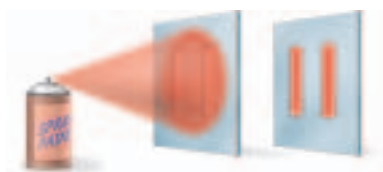
The frequency of any wave is the number of wavelengths that pass a point in 1 s. The frequency of an electromagnetic wave also equals the frequency of the vibrating charge that produces the wave. This frequency is the number of vibrations, or back and forth movements, of the charge in one second. The frequency and wavelength of electromagnetic waves are related. As the frequency increases, the wavelength becomes smaller.

## Waves and Particles

The difference between a wave and a particle might seem obvious—a wave is a disturbance that carries energy, and a particle is a piece of matter. However, in reality the difference is not so clear.

**Waves as Particles** In 1887, Heinrich Hertz found that by shining light on a metal, electrons were ejected from the metal.

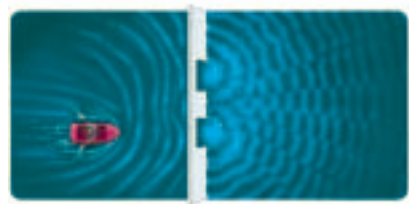
Hertz found that whether or not electrons were ejected depended on the frequency of the light and not the amplitude. Because the energy carried by a wave depends on its amplitude and not its frequency, this result was mysterious. Years later, Albert Einstein provided an explanation—electromagnetic waves can behave as a particle, called a **photon**, whose energy depends on the frequency of the waves.



Particles of paint sprayed through two slits coat only the area behind the slits.



Electrons fired at two closely-spaced openings form a wave-like interference pattern.



Water waves produce an interference pattern after passing through two openings.

**Particles as Waves** Because electromagnetic waves could behave as a particle, others wondered whether matter could behave as a wave. If a beam of electrons were sprayed at two tiny slits, you might expect that the electrons would strike only the area behind the slits, like the spray paint in **Figure 7**. Instead, it was found that the electrons formed an interference pattern. This type of pattern is produced by waves when they pass through two slits and interfere with each other, as the water waves do in **Figure 7**. This experiment showed that electrons can behave like waves. It is now known that all particles, not only electrons, can behave like waves.

**Figure 7** When electrons are sent through two narrow slits, they behave as a wave.

## section

## 1

## review

### Summary

#### Making Electromagnetic Waves

- Moving electric charges are surrounded by an electric field and a magnetic field.
- A vibrating electric charge produces an electromagnetic wave.
- An electromagnetic wave consists of vibrating electric and magnetic fields that are perpendicular to each other and travel outward from the vibrating electric charge.

#### Properties of Electromagnetic Waves

- Electromagnetic waves carry radiant energy.
- In empty space electromagnetic waves travel at 300,000 km/s—the speed of light.
- Electromagnetic waves travel slower in matter, with a speed that depends on the material.

#### Waves and Particles

- Electromagnetic waves can behave as particles that are called photons.
- In some circumstances, particles, such as electrons can behave as waves.

### Self Check

1. **Explain** why an electromagnetic wave is a transverse wave and not a compressional wave.
2. **Compare** the frequency of an electromagnetic wave with the frequency of the vibrating charge that produces the wave.
3. **Describe** how electromagnetic waves transfer radiant energy to matter.
4. **Explain** why an electromagnetic wave can travel through empty space that contains no matter.
5. **Think Critically** Suppose a moving electric charge was surrounded only by an electric field. Infer whether or not a vibrating electric charge would produce an electromagnetic wave.

### Applying Math

6. **Calculate Time** How many minutes does it take an electromagnetic wave to travel 150,000,000 km?
7. **Use Scientific Notation** Calculate the distance an electromagnetic wave in space would travel in one day. Express your answer in scientific notation.



# The Electromagnetic Spectrum

## Reading Guide

### What You'll Learn

- **Describe** the waves in the different regions of the electromagnetic spectrum.
- **Compare** the properties of different electromagnetic waves.
- **Identify** uses for different types of electromagnetic waves.

### Why It's Important

Every day, waves in different regions of the electromagnetic spectrum are used in many ways.



### Review Vocabulary

**spectrum:** a continuous sequence arranged by a particular property

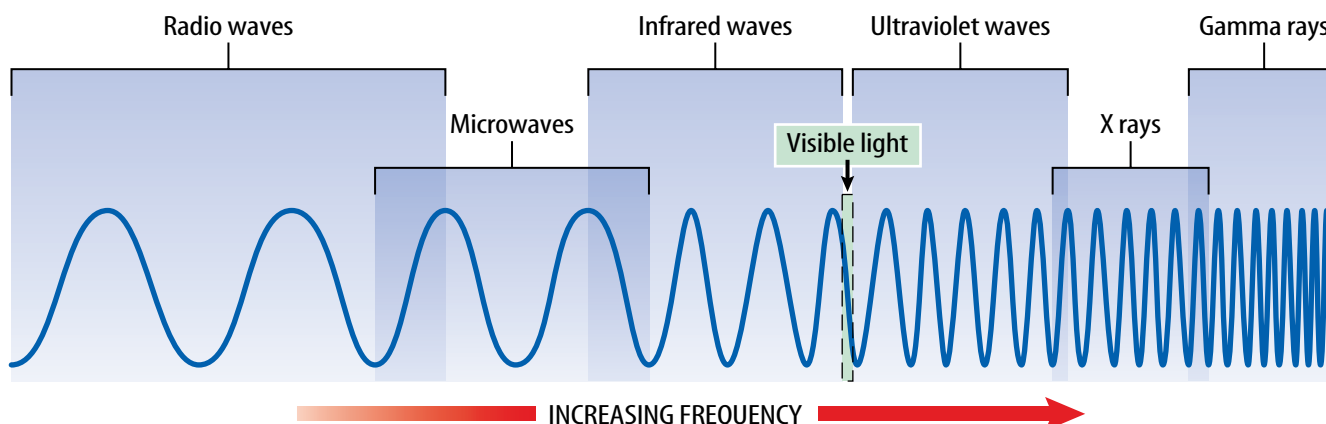
### New Vocabulary

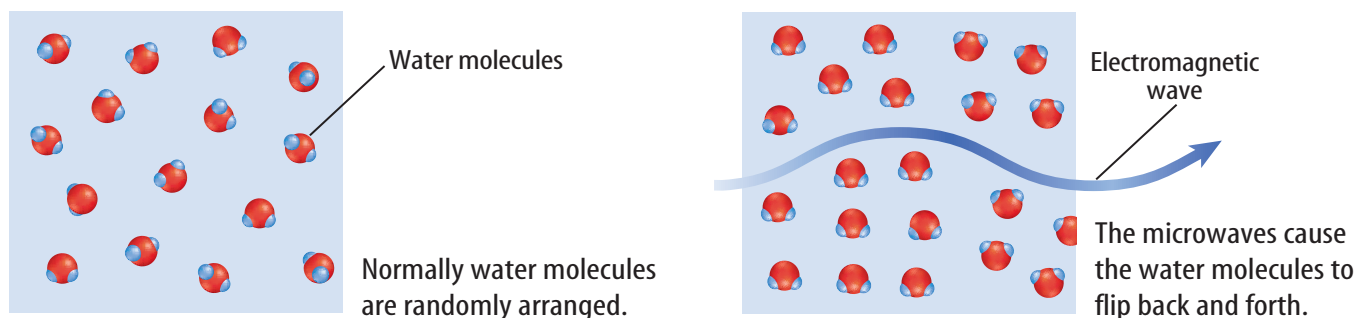
- radio wave
- microwave
- infrared wave
- visible light
- ultraviolet wave
- X ray
- gamma ray

## A Range of Frequencies

Electromagnetic waves can have a wide variety of frequencies. They might vibrate once each second or trillions of times each second. The entire range of electromagnetic wave frequencies is known as the electromagnetic spectrum, shown in **Figure 8**. Various portions of the electromagnetic spectrum interact with matter differently. As a result, they are given different names. The electromagnetic waves that humans can detect with their eyes, called visible light, are a small portion of the entire electromagnetic spectrum. However, various devices have been developed to detect the other frequencies. For example, the antenna of your radio detects radio waves.

**Figure 8** Electromagnetic waves are described by different names depending on their frequency and wavelength.





## Radio Waves

Stop and look around you. Even though you can't see them, radio waves are moving everywhere you look. Some radio waves carry an audio signal from a radio station to a radio. However, even though these radio waves carry information that a radio uses to create sound, you can't hear radio waves. You hear a sound wave when the compressions and rarefactions the sound wave produces reach your ears. A radio wave does not produce compressions and rarefactions as it travels through air.

**Microwaves** **Radio waves** are low-frequency electromagnetic waves with wavelengths longer than about 1 mm. Radio waves with wavelengths of less than about 30 cm are called **microwaves**. Microwaves with wavelengths of about 1 cm to 20 cm are widely used for communication, such as for cellular telephones and satellite signals. You are probably most familiar with microwaves because of their use in microwave ovens.

### Reading Check

*What is the difference between a microwave and a radio wave?*

Microwave ovens heat food when microwaves interact with water molecules in food, as shown in **Figure 9**. Each water molecule is positively charged on one side and negatively charged on the other side. The vibrating electric field inside a microwave oven causes water molecules in food to rotate back and forth billions of times each second. This rotation causes a type of friction between water molecules that generates thermal energy. It is the thermal energy produced by the interactions between the water molecules that causes your food to cook.

**Radar** Another use for radio waves is to find the position and movement of objects by a method called radar. Radar stands for **R**adio **D**etecting **A**nd **R**anging. With radar, radio waves are transmitted toward an object. By measuring the time required for the waves to bounce off the object and return to a receiving antenna, the location of the object can be found. Law enforcement officers use radar to measure how fast a vehicle is moving. Radar also is used for tracking the movement of aircraft, watercraft, and spacecraft.

**Figure 9** Microwave ovens use electromagnetic waves to heat food.



## Heating with Microwaves

### Procedure

1. Obtain two small beakers or baby-food jars. Place 50 mL of dry sand into each. To one of the jars, add 20 mL of room-temperature water and stir well.
2. Record the temperature of the sand in each jar.
3. Together, microwave both jars of sand for 10 s and immediately record the temperature again.

### Analysis

1. Compare the initial and final temperatures of the wet and dry sand.
2. Infer why there was a difference.



**Figure 10** Magnetic resonance imaging technology uses radio waves as an alternative to X-ray imaging.

**Magnetic Resonance Imaging (MRI)** In the early 1980s, medical researchers developed a technique called Magnetic Resonance Imaging, which uses radio waves to help diagnose illness. The patient lies inside a large cylinder, like the one shown in **Figure 10**. Housed in the cylinder is a powerful magnet, a radio wave emitter, and a radio wave detector. Protons in hydrogen atoms in bones and soft tissue behave like magnets and align with the strong magnetic field. Energy from radio waves causes some of the protons to flip their alignment. As the protons flip, they release radiant energy. A radio receiver detects this released energy. The amount of energy a proton releases depends on the type of tissue it is part of. The released energy detected by the radio receiver is used to create a map of the different tissues. A picture of the inside of the patient's body is produced painlessly.

## Infrared Waves

Most of the warm air in a fireplace moves up the chimney, yet when you stand in front of a fireplace, you feel the warmth of the blazing fire. Why do you feel the heat? The warmth you feel is thermal energy transmitted to you by **infrared waves**, which are a type of electromagnetic wave with wavelengths between about 1 mm and about 750 billionths of a meter.

You use infrared waves every day. A remote control emits infrared waves to control your television. A computer uses infrared waves to read CD-ROMs. In fact, every object emits infrared waves. Hotter objects emit more infrared waves than cooler objects emit. The wavelengths emitted also become shorter as the temperature increases. Infrared detectors can form images of objects from the infrared radiation they emit. Infrared sensors on satellites can produce infrared images that can help identify the vegetation over a region. **Figure 11** shows how cities appear different from surrounding vegetation in infrared satellite imagery.

**Figure 11** Infrared images and visible light images can provide different types of information.

This visible light image of the region around San Francisco Bay in California was taken from an aircraft at an altitude of 20,000 m.



This infrared image of the same area was taken from a satellite. In this image, vegetation is red and buildings are gray.





## Visible Light

**Visible light** is the range of electromagnetic waves that you can detect with your eyes. Light differs from radio waves and infrared waves only by its frequency and wavelength. Visible light has wavelengths around 750 billionths to 400 billionths of a meter. Your eyes contain substances that react differently to various wavelengths of visible light, so you see different colors. These colors range from short-wavelength blue to long-wavelength red. If all the colors are present, you see the light as white.

## Ultraviolet Waves

**Ultraviolet waves** are electromagnetic waves with wavelengths from about 400 billionths to 10 billionths of a meter. Ultraviolet waves are energetic enough to enter skin cells. Overexposure to ultraviolet rays can cause skin damage and cancer. Most of the ultraviolet radiation that reaches Earth's surface are longer-wavelength UVA rays. The shorter-wavelength UVB rays cause sunburn, and both UVA and UVB rays can cause skin cancers and skin damage such as wrinkling. Although too much exposure to the Sun's ultraviolet waves is damaging, some exposure is healthy. Ultraviolet light striking the skin enables your body to make vitamin D which is needed for healthy bones and teeth.

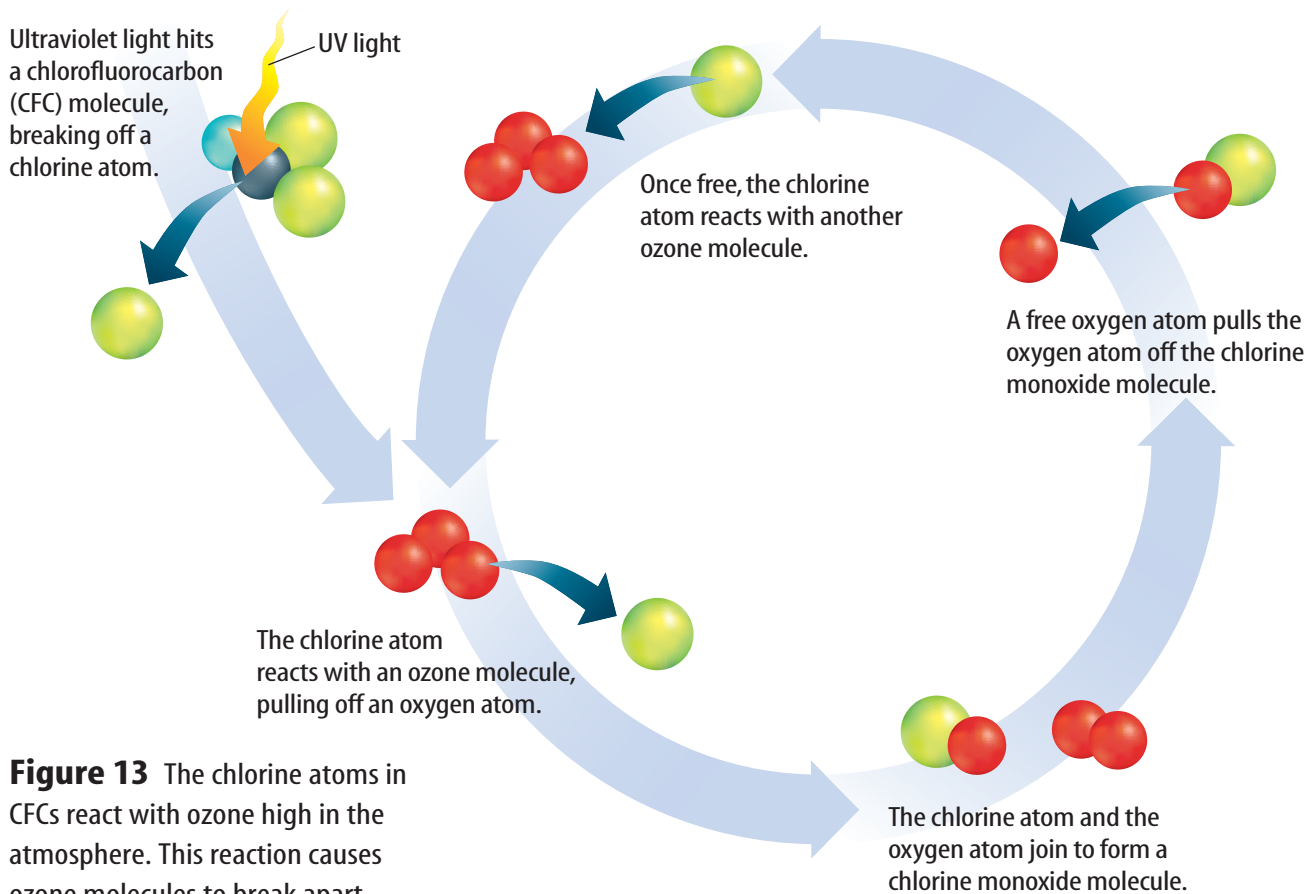
**Useful UVs** A useful property of ultraviolet waves is their ability to kill bacteria on objects such as food or medical supplies. When ultraviolet light enters a cell, it damages protein and DNA molecules. For some single-celled organisms, damage can mean death, which can be a benefit to health. Ultraviolet waves are also useful because they make some materials fluoresce (floor ES). Fluorescent materials absorb ultraviolet waves and reemit the energy as visible light. As shown in **Figure 12**, police detectives sometimes use fluorescent powder to show fingerprints when solving crimes.

**Figure 12** The police detective in this picture is shining ultraviolet light on a fingerprint dusted with fluorescent powder.





**CT Scans** In certain situations, doctors will perform a CT scan on a patient instead of a traditional X ray. Research to find out more about CT scans. Compare and contrast CT scans with X rays. What are the advantages and disadvantages of a CT scan? Write a paragraph about your findings in your Science Journal.



**Figure 13** The chlorine atoms in CFCs react with ozone high in the atmosphere. This reaction causes ozone molecules to break apart.

**The Ozone Layer** About 20 to 50 km above Earth's surface in the stratosphere is a region called the ozone layer. Ozone is a molecule composed of three oxygen atoms. It is continually being formed and destroyed by ultraviolet waves high in the atmosphere. The ozone layer is vital to life on Earth because it absorbs most of the Sun's harmful ultraviolet waves. However, over the past few decades the amount of ozone in the ozone layer has decreased. Averaged globally, the decrease is about three percent, but is greater at higher latitudes.

#### Reading Check

*Why is the ozone layer vital to life on Earth?*



The decrease in ozone is caused by the presence of certain chemicals, such as CFCs, high in Earth's atmosphere. CFCs are chemicals called chlorofluorocarbons that have been widely used in air conditioners, refrigerators, and cleaning fluids. When CFC molecules reach the ozone layer, they react chemically with ozone molecules as shown in **Figure 13**. One chlorine atom from a CFC molecule can break apart thousands of ozone molecules. As a result, many countries are reducing the use of CFCs and other ozone-depleting chemicals.

## X Rays and Gamma Rays

The electromagnetic waves with the shortest wavelengths and highest frequencies are X rays and gamma rays. Both X rays and gamma rays are high energy electromagnetic waves. **X rays** have wavelengths between about ten billionths of a meter and ten trillionths of a meter. Doctors and dentists use low doses of X rays to form images of internal organs, bones, and teeth, like the image shown in **Figure 14**. X rays also are used in airport screening devices to examine the contents of luggage.

Electromagnetic waves with wavelengths shorter than about 10 trillionths of a meter are **gamma rays**. These are the highest-energy electromagnetic waves and can penetrate through several centimeters of lead. Gamma rays are produced by processes that occur in atomic nuclei. Both X rays and gamma rays are used in a technique called radiation therapy to kill diseased cells in the human body. A beam of X rays or gamma rays can damage the biological molecules in living cells, causing both healthy and diseased cells to die. However, by carefully controlling the amount of X ray or gamma ray radiation received by the diseased area, the damage to healthy cells can be reduced.



**Figure 14** Bones are more dense than surrounding tissues and absorb more X rays. The image of a bone on an X ray is the shadow cast by the bone as X rays pass through the soft tissue.

### section 2 review

#### Summary

##### Radio Waves and Infrared Waves

- Radio waves are electromagnetic waves with wavelengths longer than about 1 mm.
- Microwaves are radio waves with wavelengths between about 1 mm and 1 m.
- Infrared waves have wavelengths between about 1 mm and 750 billionths of a meter.

##### Visible Light and Ultraviolet Waves

- Visible light waves have wavelengths between about 750 and 400 billionths of a meter.
- Ultraviolet waves have wavelengths between about 400 and 40 billionths of a meter.
- Most of the harmful ultraviolet waves emitted by the Sun are absorbed by the ozone layer.

##### X Rays and Gamma Rays

- X rays and gamma rays are the most energetic electromagnetic waves.
- Gamma rays have wavelengths less than 10 trillionths of a meter and are produced in the nuclei of atoms.

#### Self Check

1. **Explain** A mug of water is heated in a microwave oven. Explain why the water gets hotter than the mug.
2. **Describe** why you can see visible light waves, but not other electromagnetic waves.
3. **List** the beneficial effects and the harmful effects of human exposure to ultraviolet rays.
4. **Identify** three objects in a home that produce electromagnetic waves and describe how the electromagnetic waves are used.
5. **Think Critically** What could an infrared image of their house reveal to the homeowners?

#### Applying Math

6. **Use Scientific Notation** Express the range of wavelengths corresponding to visible light, ultraviolet waves, and X rays in scientific notation.
7. **Convert Units** A nanometer, abbreviated nm, equals one billionth of a meter, or  $10^{-9}$  meters. Express the range of wavelengths corresponding to visible light, ultraviolet waves and X rays in nanometers.



## The Shape of Satellite Dishes

Communications satellites transmit signals with a narrow beam pointed toward a particular area of Earth. To detect this signal, receivers are typically large, parabolic dishes.

### Real-World Question

How does the shape of a satellite dish improve reception?

#### Goals

- **Make** a model of a satellite reflecting dish.
- **Observe** how the shape of the dish affects reception.

#### Materials

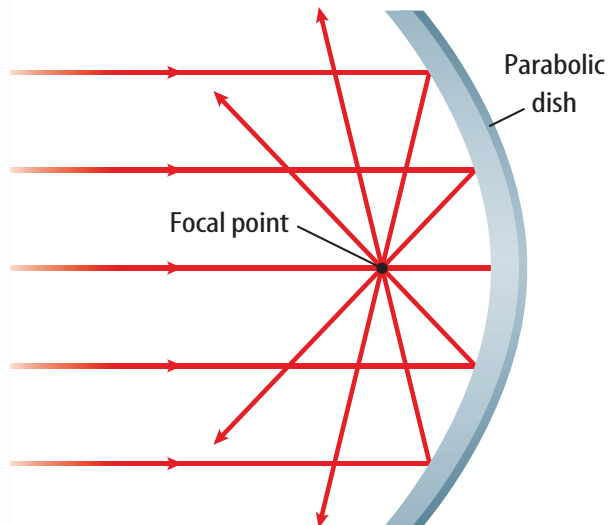
|               |                      |
|---------------|----------------------|
| flashlight    | small bowl           |
| several books | *large, metal spoon  |
| aluminum foil | *Alternate materials |

#### Safety Precautions



### Procedure

1. Cover one side of a book with aluminum foil. Be careful not to wrinkle the foil.
2. Line the inside of the bowl with foil, also keeping it as smooth as possible.
3. Place some of the books on a table. Put the flashlight on top of the books so that its beam of light will shine several centimeters above and across the table.
4. Hold the foil-covered book on its side at a right angle to the top of the table. The foil-covered side should face the beam of light.
5. **Observe** the intensity of the light on the foil.



6. Repeat steps 4 and 5, replacing the foil-covered book with the bowl.

### Conclude and Apply

1. **Compare** the brightness of the light reflected from the two surfaces.
2. **Explain** why the light you see from the curved surface is brighter.
3. **Infer** why bowl-shaped dishes are used to receive signals from satellites.

### Communicating Your Data

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

# Radio Communication

## Reading Guide

### What You'll Learn

- **Explain** how modulating carrier waves enables information to be transmitted by radio waves.
- **Distinguish** between amplitude modulation and frequency modulation.
- **Identify** various ways of communicating using radio waves.

### Why It's Important

Every day you use radio waves to communicate.



### Review Vocabulary

**modulate:** to vary the amplitude or frequency of a wave in order to transmit information

### New Vocabulary

- carrier wave
- cathode-ray tube
- transceiver
- Global Positioning System (GPS)

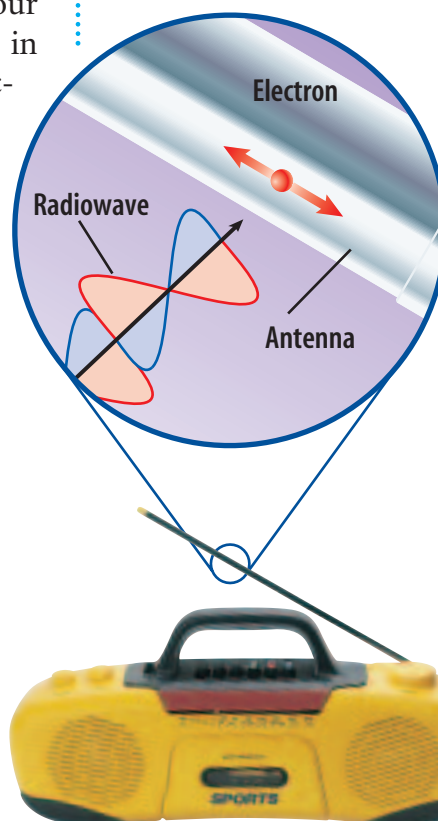
## Radio Transmission

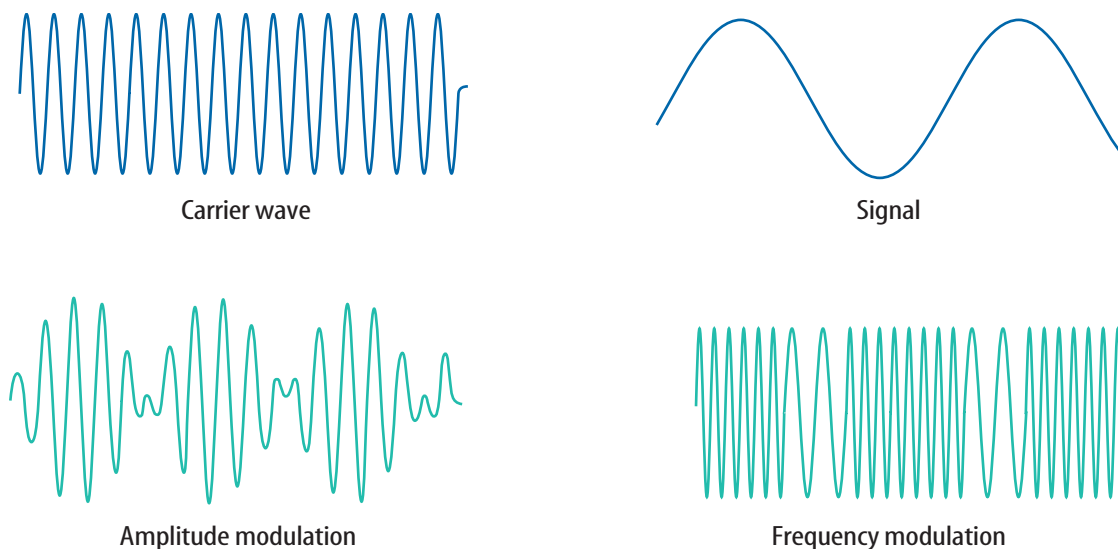
When you listen to the radio, you hear music and words that are produced at a distant location. The music and words are sent to your radio by radio waves. The metal antenna of your radio detects radio waves. As the electromagnetic waves pass by your radio's antenna, the electrons in the metal vibrate, as shown in **Figure 15**. These vibrating electrons produce a changing electric current that contains the information about the music and words. An amplifier boosts the current and sends it to speakers, causing them to vibrate. The vibrating speakers create sound waves that travel to your ears. Your brain interprets these sound waves as music and words.

**Dividing the Radio Spectrum** Each radio station is assigned to broadcast at one particular radio frequency. Turning the tuning knob on your radio allows you to select a particular frequency to listen to. The specific frequency of the electromagnetic wave that a radio station is assigned is called the **carrier wave**.

The radio station must do more than simply transmit a carrier wave. The station has to send information about the sounds that you are to receive. This information is sent by modifying the carrier wave. The carrier wave is modified to carry information in one of two ways, as shown in **Figure 16**.

**Figure 15** Radio waves exert a force on the electrons in an antenna, causing the electrons to vibrate.



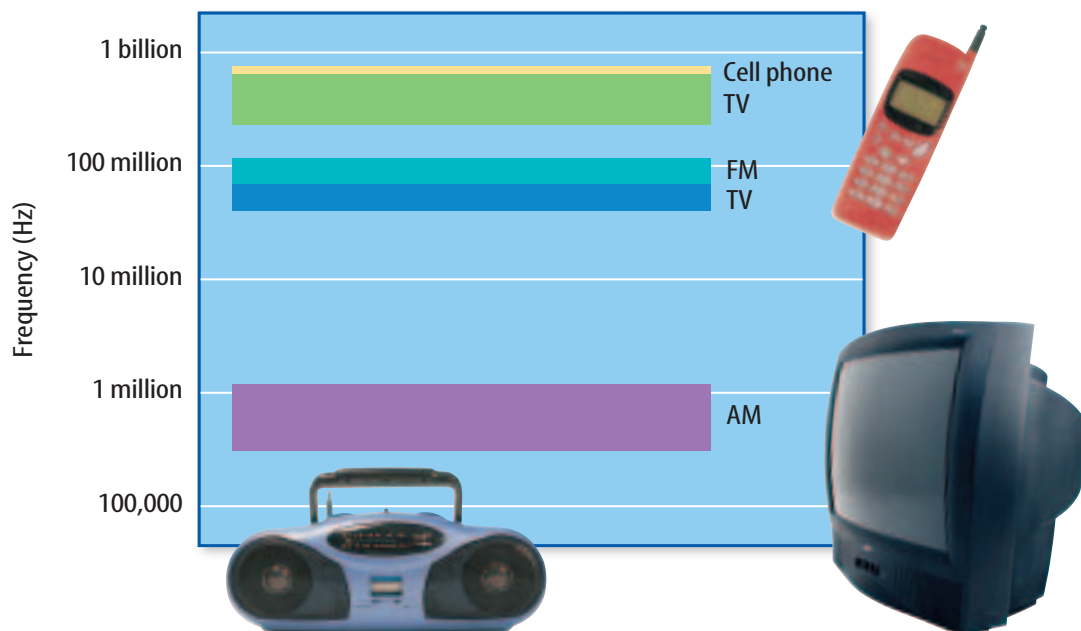


**Figure 16** A carrier wave broadcast by a radio station can be altered in one of two ways to transmit a signal: amplitude modulation (AM) or frequency modulation (FM).

**AM Radio** An AM radio station broadcasts information by varying the amplitude of the carrier wave, as shown in **Figure 16**. Your radio detects the variations in amplitude of the carrier wave and produces a changing electric current from these variations. The changing electric current makes the speaker vibrate. AM carrier wave frequencies range from 540,000 to 1,600,000 Hz.

**FM Radio** Electronic signals are transmitted by FM radio stations by varying the frequency of the carrier wave, as in **Figure 16**. Your radio detects the changes in frequency of the carrier wave. Because the strength of the FM waves is kept fixed, FM signals tend to be more clear than AM signals. FM carrier frequencies range from 88 million to 108 million Hz. This is much higher than AM frequencies, as shown in **Figure 17**. **Figure 18** shows how radio signals are broadcast.

**Figure 17** Cell phones, TVs, and radios broadcast at frequencies that range from more than 500,000 Hz to almost 1 billion Hz.

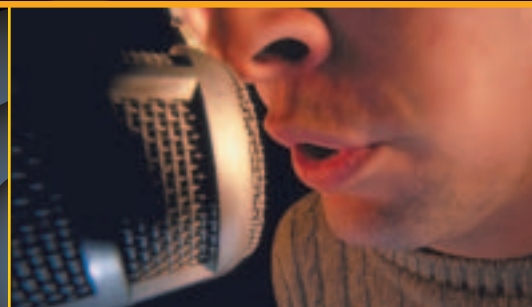




# NATIONAL GEOGRAPHIC VISUALIZING RADIO BROADCASTS

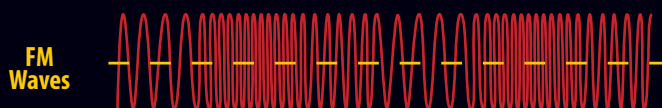
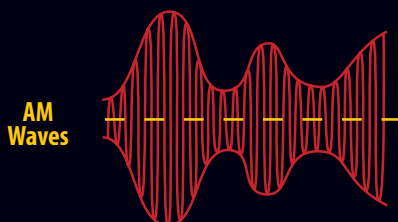
**Figure 18**

**Y**ou flick a switch, turn the dial, and music from your favorite radio station fills the room. Although it seems like magic, sounds are transmitted over great distances by converting sound waves to electromagnetic waves and back again, as shown here.



**A** At the radio station, musical instruments and voices create sound waves by causing air molecules to vibrate. Microphones convert these sound waves to a varying electric current, or electronic signal.

**B** This signal then is added to the station's carrier wave. If the station is an AM station, the electronic signal modifies the amplitude of the carrier wave. If the station is a FM station, the electronic signal modifies the frequency of the carrier wave.



**C** The modified carrier wave is used to vibrate electrons in the station's antenna. These vibrating electrons create a radio wave that travels out in all directions at the speed of light.



**D** The radio wave from the station makes electrons in your radio's antenna vibrate. This creates an electric current. If your radio is tuned to the station's frequency, the carrier wave is removed from the original electronic signal. This signal then makes the radio's speaker vibrate, creating sound waves that you hear as music.



## INTEGRATE Career

**Astronomers** Do you ever look up at the stars at night and wonder how they were formed? With so many stars and so many galaxies, life might be possible on other planets. Research ways that astronomers use electromagnetic waves to investigate the universe. Choose one project astronomers currently are working on that interests you, and write about it in your Science Journal. Discuss the benefits of a career in astronomy.

## Television

What would people hundreds of years ago have thought if they had seen a television? They might seem like magic, but not if you know how they work. Television and radio transmissions are similar. At the television station, sound and images are changed into electronic signals. These signals are broadcast by carrier waves. The audio part of television is sent by FM radio waves. Information about the color and brightness is sent at the same time by AM signals.

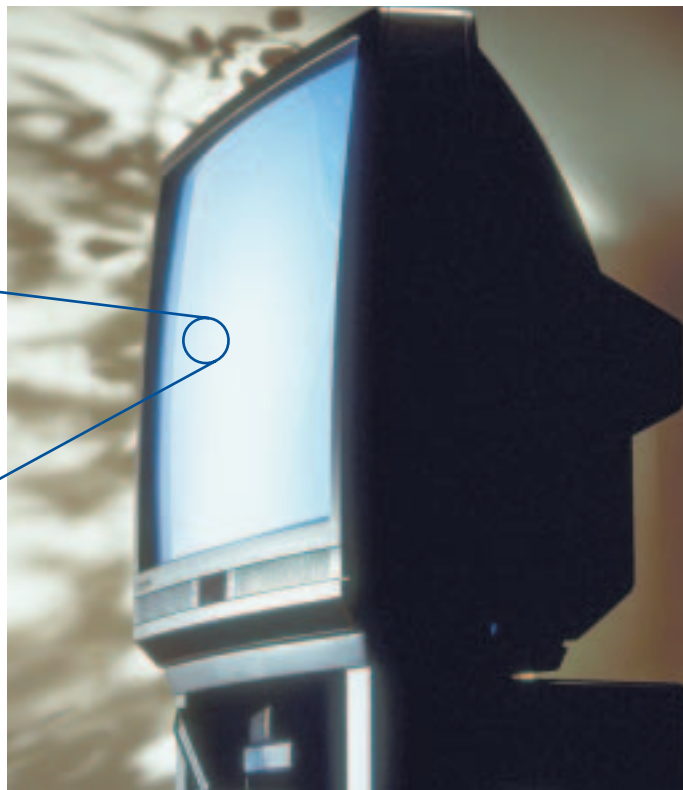
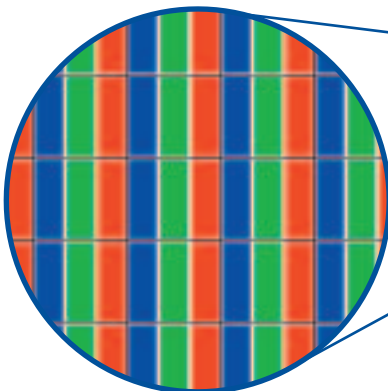
**Cathode-Ray Tubes** In many television sets, images are displayed on a cathode-ray tube (CRT), as shown in **Figure 19**. A **cathode-ray tube** is a sealed vacuum tube in which one or more beams of electrons are produced. The CRT in a color TV produces three electron beams that are focused by a magnetic field and strike a coated screen. The screen is speckled with more than 100,000 rectangular spots that are of three types. One type glows red, another glows green, and the third type glows blue when electrons strike it. The spots are grouped together with a red, green, and blue spot in each group.

An image is created when the three electron beams of the CRT sweep back and forth across the screen. Each electron beam controls the brightness of each type of spot, according to the information in the video signal from the TV station. By varying the brightness of each spot in a group, the three spots together can form any color so that you see a full-color image.



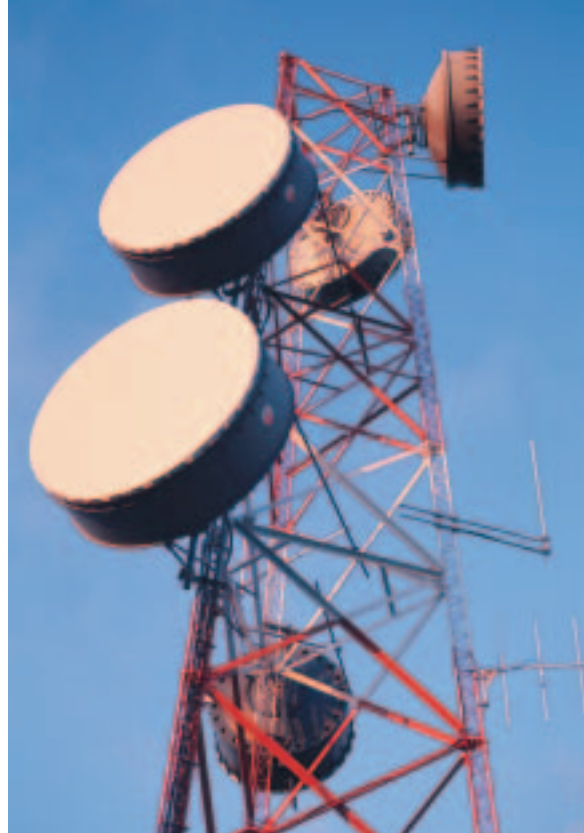
**Reading Check** *What is a cathode-ray tube?*

**Figure 19** Cathode-ray tubes produce the images you see on television. The inside surface of a television screen is covered by groups of spots that glow red, green, or blue when struck by an electron beam.



## Telephones

Until about 1950, human operators were needed to connect many calls between people. Just 20 years ago you never would have seen someone walking down the street talking on a telephone. Today, cell phones are seen everywhere. When you speak into a telephone, a microphone converts sound waves into an electrical signal. In cell phones, this current is used to create radio waves that are transmitted to and from a microwave tower, as shown in **Figure 20**. A cell phone uses one radio signal for sending information to a tower at a base station. It uses another signal for receiving information from the base station. The base stations are several kilometers apart. The area each one covers is called a cell. If you move from one cell to another while using a cell phone, an automated control station transfers your signal to the new cell.



 **Reading Check** *What are the cells in a cell phone system?*

**Cordless Telephones** Like a cellular telephone, a cordless telephone is a transceiver. A **transceiver** transmits one radio signal and receives another radio signal from a base unit. Having two signals at different frequencies allows you to talk and listen at the same time. Cordless telephones work much like cell phones. With a cordless telephone, however, you must be close to the base unit. Another drawback is that when someone nearby is using a cordless telephone, you could hear that conversation on your phone if the frequencies match. For this reason, many cordless phones have a channel button. This allows you to switch your call to another frequency.

**Pagers** Another method of transmitting signals is a pager, which allows messages to be sent to a small radio receiver. A caller leaves a message at a central terminal by entering a call-back number through a telephone keypad or by entering a text message from a computer. At the terminal, the message is changed into an electronic signal and transmitted by radio waves. Each pager is given a unique number for identification. This identification number is sent along with the message. Your pager receives all messages that are transmitted in the area at its assigned frequency. However, your pager responds only to messages with its particular identification number. Newer pagers can send data as well as receive them.

**Figure 20** The antenna at the top of a microwave tower receives signals from nearby cell phones. **Determine** whether any microwave towers are located near your school or home. Describe their locations.



### **Topic: Radio Wave Technology**

Visit [gpscience.com](http://gpscience.com) for Web links to information about advances in radio wave technology.

**Activity** List the advances you find, and write about the significance of each one in your Science Journal.



**Figure 21** Communications satellites, like the one shown here, use solar panels to provide the electrical energy they need to communicate with receivers on Earth. The solar panels are the structures on either side of the central body of the satellite.



## Communications Satellites

Since satellites were first developed, thousands have been launched into Earth's orbit. Many of these, like the one in **Figure 21**, are used for communication. A station broadcasts a high-frequency microwave signal to the satellite. The satellite receives the signal, amplifies it, and transmits it to a particular region on Earth. To avoid interference, the frequency broadcast by the satellite is different than the frequency broadcast from Earth.

**Satellite Telephone Systems** If you have a mobile telephone, you can make a phone call when sailing across the ocean. To call on a mobile telephone, the telephone transmits radio waves directly to a satellite. The satellite relays the signal to a ground station, and the call is passed on to the telephone network. Satellite links work well for one-way transmissions, but two-way communications can have an annoying delay caused by the large distance the signals travel to and from the satellite.

**Television Satellites** The satellite-reception dishes that you sometimes see in yards or attached to houses are receivers for television satellite signals. Satellite television is used as an alternative to ground-based transmission. Communications satellites use microwaves rather than the longer-wavelength radio waves used for normal television broadcasts. Short-wavelength microwaves travel more easily through the atmosphere. The ground receiver dishes are rounded to help focus the microwaves onto an antenna.



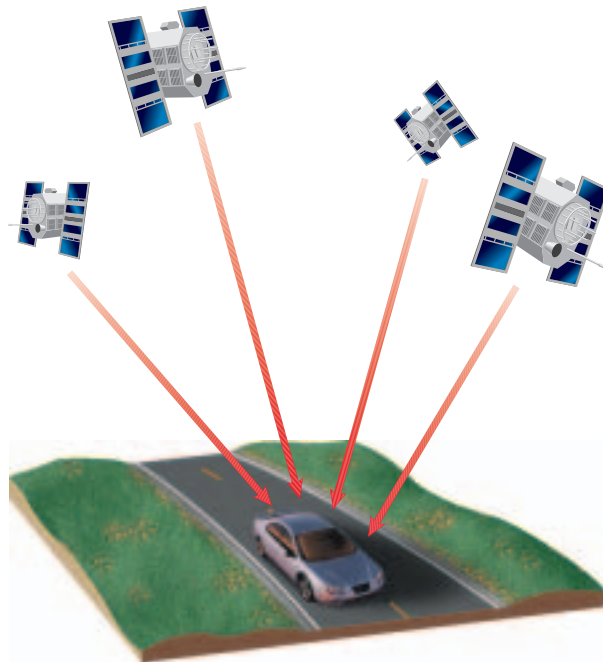
### Topic: Satellite Communication

Visit [gpscience.com](http://gpscience.com) for Web links to information about ways satellites are used for communication.

**Activity** Write a paragraph describing the advantages of placing a communications satellite in a geosynchronous orbit. Include a diagram.

## The Global Positioning System

Getting lost while hiking is not uncommon, but if you are carrying a Global Positioning System receiver, it is much less likely to happen. The **Global Positioning System (GPS)** is a system of satellites, ground monitoring stations, and receivers that determine your exact location at or above Earth's surface. The 24 satellites necessary for 24-hour, around-the-world coverage became fully operational in 1995. GPS satellites are owned and operated by the United States Department of Defense, but the microwave signals they send out can be used by anyone. As shown in **Figure 22**, signals from four satellites are needed to determine the location of an object using a GPS receiver. Today GPS receivers are used in airplanes, ships, cars, and even by hikers.



**Figure 22** A GPS receiver uses signals from orbiting satellites to determine the receiver's location.

### section 3 review

#### Summary

##### Radio Transmission

- Radio stations transmit electromagnetic waves that receivers convert to sound waves.
- Each AM radio station is assigned a carrier wave frequency and varies the amplitude of the carrier waves to transmit a signal.
- Each FM radio station is assigned a carrier wave frequency and varies the frequency of the carrier waves to transmit a signal.

##### Television

- TV sets use cathode-ray tubes to convert electronic signals from TV stations into both sound and images.

##### Telephones

- Telephones contain transceivers that convert sound waves into electrical signals and also convert electrical signals into sound waves.
- Wires, microwave towers, and satellites are used to transmit and receive telephone signals.

##### Global Positioning System

- The Global Positioning System uses a system of satellites to determine your exact position.

#### Self Check

1. **Explain** the difference between AM and FM radio. Make a sketch of how a carrier wave is modulated in AM and FM radio.
2. **Define** a cathode-ray tube, and explain how it is used in a television.
3. **Describe** what happens if you are talking on a cell phone while riding in a car and you travel from one cell to another cell.
4. **Explain** some of the uses of a Global Positioning System. Why might emergency vehicles all be equipped with GPS receivers?
5. **Think Critically** Why do cordless telephones stop working if you move too far from the base unit?

#### Applying Math

6. **Calculate a Ratio** A group of red, green and blue spots on a TV screen is a pixel. A standard TV has 460 pixels horizontally and 360 pixels vertically. A high-definition TV has 1,920 horizontal and 1,080 vertical pixels. What is the ratio of the number of pixels in a high-definition TV to the number in a standard TV?

## Radio Frequencies

### Goals

- **Research** which frequencies are used by different radio stations.
- **Observe** the reception of your favorite radio station.
- **Make** a chart of your findings and communicate them to other students.

### Data Source



Visit [gpscience.com/internet\\_lab](http://gpscience.com/internet_lab) for more information on radio frequencies, different frequencies of radio stations around the country, and the ranges of AM and FM broadcasts.

### Real-World Question

The signals from many radio stations broadcasting at different frequencies are hitting your radio's antenna at the same time. When you tune to your favorite station, the electronics inside your radio amplify the signal at the frequency broadcast by the station. The signal from your favorite station is broadcast from a transmission site that may be several miles away.

You may have noticed that if you're listening to a radio station while driving in a car, sometimes the station gets fuzzy and you'll hear another station at the same time. Sometimes you lose the station completely. How far can you drive before that happens? Does the distance vary depending on the station you listen to? What are the ranges of radio stations? Form a hypothesis about how far you think a radio station can transmit? Which type of signal, AM or FM, has a greater range? Form a hypothesis about the range of your favorite radio station.

### Make a Plan

1. **Research** what frequencies are used by AM and FM radio stations in your area and other areas around the country.
2. **Determine** these stations' broadcast locations.
3. **Determine** the broadcast range of radio stations in your area.
4. **Observe** how frequencies differ. What is the maximum difference between frequencies for FM stations in your area? AM stations?





## Using Scientific Methods

### Follow Your Plan

1. **Make** sure your teacher approves your plan before you start.
2. Visit the link shown below for links to different radio stations.
3. **Compare** the different frequencies of the stations and the locations of the broadcasts.
4. **Determine** the range of radio stations in your area and the power of their broadcast signal in watts.
5. **Record** your data in your Science Journal.

### Analyze Your Data

1. **Make** a map of the radio stations in your area. Do the ranges of AM stations differ from FM stations?
2. **Make** a map of different radio stations around the country. Do you see any patterns in the frequencies for stations that are located near each other?
3. **Write** a description that compares how close the frequencies of AM stations are and how close the frequencies of FM stations are. Also compare the power of their broadcast signals and their ranges.
4. **Share** your data by posting it at the link shown below.

### Conclude and Apply

1. **Compare** your findings to those of your classmates and other data that was posted at the link shown below. Do all AM stations and FM stations have different ranges?
2. **Observe** your map of the country. How close can stations with similar frequencies be? Do AM and FM stations appear to be different in this respect?
3. **Infer** The power of the broadcast signal also determines its range. How does the power (wattage) of the signals affect your analysis of your data?



### Communicating Your Data

Find this lab using the link below. Post your data in the table provided. **Compare** your data to that of other students. Then combine your data with theirs and make a map for your class that shows all of the data.

 ScienceOnline

[gpscience.com/internet\\_lab](http://gpscience.com/internet_lab)

# Riding a Beam of Light

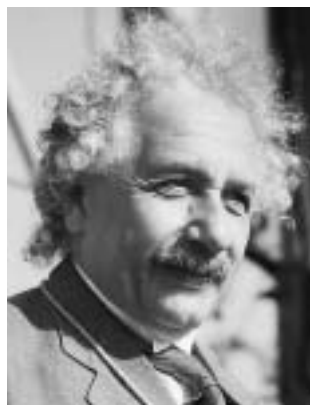
## Einstein and the Special Theory of Relativity

### Catch a Wave

At age sixteen, Albert Einstein wondered “What would it be like to ride a beam of light?” He imagined what might happen if he turned on a flashlight while riding a light beam. Because the flashlight was already traveling at the speed of light, would light from the flashlight travel at twice the speed of light?

### What’s so special?

Einstein thought about this problem and in 1905 he published the special theory of relativity. This theory stated that the speed of light measured by any observer



that moves with a constant speed always would be the same. The measured speed of light would not depend on the speed of the observer or on how fast the source of light was moving. Einstein answered the question he asked

himself when he was sixteen. He had found the universal speed limit that can’t be broken.

### It Doesn’t Add Up

According to Einstein, electromagnetic waves like light waves behave very differently from other waves. For example, sound waves from the siren of an ambulance moving toward you move faster than they would if the ambulance were not moving. The speed of the ambulance adds to the speed of the sound waves. However, for light waves, the speed of a light source doesn’t add to the speed of light.

### Very Strange But True

Einstein’s special theory of relativity makes other strange predictions. According to this theory, no object can travel faster than the speed of light. Another prediction is that the measured length of a moving object is shorter than when the object is at rest. Also, moving clocks should run slower than when they are at rest. These predictions have been confirmed by experiments. Measurements have shown, for example, that a moving clock does run slower.

**Communicate** Research the life of Albert Einstein and make a timeline showing important events in his life. Also include on your timeline major historical events that occurred during Einstein’s lifetime.

Science **online**

For more information, visit  
[gpscience.com/time](http://gpscience.com/time)

## Reviewing Main Ideas

## Section 1

**What are electromagnetic waves?**

1. Electromagnetic waves consist of vibrating electric and magnetic fields, and are produced by vibrating electric charges.



2. Electromagnetic waves carry radiant energy and can travel through a vacuum or through matter.
3. Electromagnetic waves sometimes behave like particles called photons.

## Section 2

**The Electromagnetic Spectrum**

1. Electromagnetic waves with the longest wavelengths are called radio waves. Radio waves have wavelengths greater than about 1 mm. Microwaves are radio waves with wavelengths between about 1 m and 1 mm.
2. Infrared waves have wavelengths between about 1 mm and 750 billionths of a meter. Warmer objects emit more infrared waves than cooler objects.

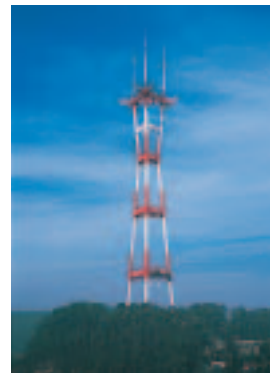


3. Visible light rays have wavelengths between about 750 and 400 billionths of a meter. Substances in your eyes react with visible light to enable you to see.
4. Ultraviolet waves have frequencies between about 400 and 10 billionths of a meter. Excessive exposure to ultraviolet waves can damage human skin.
5. X rays and gamma rays are high-energy electromagnetic waves with wavelengths less than 10 billionths of a meter. X rays are used in medical imaging.

## Section 3

**Radio Communication**

1. Modulated radio waves are used often for communication. AM and FM are two forms of carrier wave modulation.
2. Television signals are transmitted as a combination of AM and FM waves.
3. Cellular telephones, cordless telephones, and pagers use radio waves to transmit signals. Communications satellites are used to relay telephone and television signals over long distances.
4. The Global Positioning System enables an accurate position on Earth to be determined.

**FOLDABLES**

Use the Foldable that you made at the beginning of this chapter to help you review electromagnetic waves.



## Using Vocabulary

|                                  |                          |
|----------------------------------|--------------------------|
| carrier wave p. 367              | microwaves p. 361        |
| cathode-ray tube p. 370          | photon p. 358            |
| electromagnetic wave p. 354      | radiant energy p. 357    |
| gamma rays p. 365                | radio waves p. 361       |
| Global Positioning System p. 373 | transceiver p. 371       |
| infrared waves p. 362            | ultraviolet waves p. 363 |
|                                  | visible light p. 363     |
|                                  | X rays p. 365            |

Complete each statement using the correct word or words from the vocabulary list above.

- \_\_\_\_\_ are the type of electromagnetic waves often used for communication.
- A remote control uses \_\_\_\_\_ to communicate with a television set.
- Electromagnetic waves carry \_\_\_\_\_.
- If you stay outdoors too long, your skin might be burned by exposure to \_\_\_\_\_ from the Sun.
- A radio station broadcasts radio waves called \_\_\_\_\_ that have the specific frequency assigned to the station.
- The image on a television screen is produced by a \_\_\_\_\_.
- Transverse waves that are produced by vibrating electric charges and consist of vibrating electric and magnetic fields are \_\_\_\_\_.
- Electromagnetic waves can behave like what type of particle?
  - electrons
  - molecules
  - photons
  - atoms
- Which type of electromagnetic wave enables skin cells to produce vitamin D?
  - visible light
  - ultraviolet waves
  - infrared waves
  - X rays
- Which of the following describes X rays?
  - short wavelength, high frequency
  - short wavelength, low frequency
  - long wavelength, high frequency
  - long wavelength, low frequency
- Which of the following is changing in an AM radio wave?
  - speed
  - frequency
  - amplitude
  - wavelength
- Which type of electromagnetic wave has wavelengths greater than about 1 mm?
  - X rays
  - radio waves
  - gamma rays
  - ultraviolet waves
- What is the name of the ability of some materials to absorb ultraviolet light and re-emit it as visible light?
  - modulation
  - handoff
  - transmission
  - fluorescence
- Which of these colors of visible light has the shortest wavelength?
  - blue
  - green
  - red
  - white
- Which type of electromagnetic wave has wavelengths slightly longer than humans can see?
  - X rays
  - ultraviolet waves
  - infrared waves
  - gamma rays

## Checking Concepts

Choose the word or phrase that best answers the question.

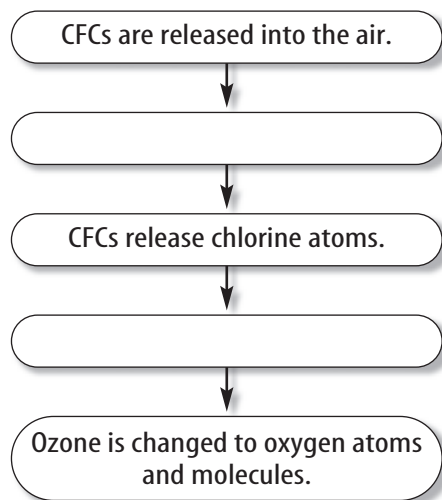
- Which type of electromagnetic wave is the most energetic?
  - gamma rays
  - ultraviolet waves
  - infrared waves
  - microwaves

### Interpreting Graphics

17. Copy and complete the following table about the electromagnetic spectrum.

| Uses of Electromagnetic Waves |                                                |
|-------------------------------|------------------------------------------------|
| Type of Electromagnetic Waves | Examples of How Electromagnetic Waves Are Used |
|                               | radio, TV transmission                         |
| Infrared waves                |                                                |
| Visible light                 | vision                                         |
|                               |                                                |
| X rays                        |                                                |
|                               | destroying harmful cells                       |

18. Copy and complete the following events chain about the destruction of ozone molecules in the ozone layer by CFC molecules.



### Thinking Critically

19. **Explain** why X rays are used in medical imaging.
20. **Predict** whether an electromagnetic wave would travel through space if its electric and magnetic fields were not changing with time. Explain your reasoning.
21. **Infer** Electromagnetic waves consist of vibrating electric and magnetic fields. A magnetic field can make a compass needle. Why doesn't a compass needle move when visible light strikes the compass?
22. **Classify** Look around your home, school, and community. Make a list of the different devices that use electromagnetic waves. Beside each device, write the type of electromagnetic wave the device uses.
23. **Form a hypothesis** to explain why communications satellites don't use ultraviolet waves to receive information and transmit signals to Earth's surface.
24. **Compare** the energy of photons corresponding to infrared waves with the energy of photons corresponding to ultraviolet waves.
25. **Determine** whether or not all electromagnetic waves always travel at the speed of light. Explain.

### Applying Math

26. **Use Fractions** When visible light waves travel in ethyl alcohol, their speed is three fourths of the speed of light in air. What is the speed of light in ethyl alcohol?
27. **Use Scientific Notation** The speed of light in a vacuum has been determined to be 299, 792, 458 m/s. Express this number to four significant digits using scientific notation.
28. **Calculate Wavelength** A radio wave has a frequency of 540,000 Hz and travels at a speed of 300,000 km/s. Use the wave speed equation to calculate the wavelength of the radio wave. Express your answer in meters.

**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 produces electromagnetic waves?
- A. vibrating charge
  - B. direct current
  - C. static charge
  - D. constant magnetic field

Use the photograph below to answer questions 2 and 3.



2. A television image is produced by three electron beams. What device inside a television set produces the electron beams?
- A. transceiver
  - B. transmitter
  - C. antenna
  - D. cathode-ray tube
3. What colors are the three types of glowing spots that are combined to form the different colors in the image on the screen?
- A. red, yellow, blue
  - B. red, green, blue
  - C. cyan, magenta, yellow
  - D. cyan, magenta, blue

**Test-Taking Tip**

**Marking on Tests** Be sure to ask if it is okay to write on the test booklet when taking the test, but make sure you mark all answers on your answer sheet.

4. Which of the following explains how interference is avoided between the signals communications satellites receive and the signals they broadcast?
- A. The signals travel at different speeds.
  - B. The signals have different amplitudes.
  - C. The signals have different frequencies.
  - D. The signals are only magnetic.
5. Which of the following people explained how light can behave as a particle, called a photon, whose energy depends on the frequency of light?
- A. Einstein
  - B. Hertz
  - C. Newton
  - D. Galileo

Use the table below to answer questions 6 and 7.

| Regions of the Electromagnetic Spectrum |               |                   |
|-----------------------------------------|---------------|-------------------|
| Infrared waves                          | Radio waves   | Gamma rays        |
| X rays                                  | Visible light | Ultraviolet waves |

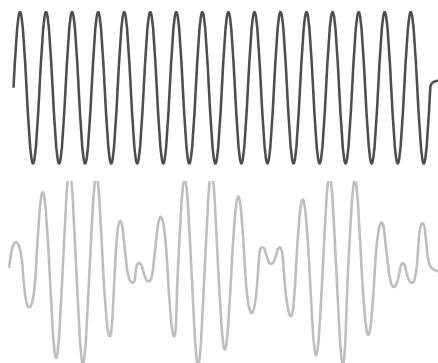
6. If you arranged the list of electromagnetic waves shown above in order from shortest to longest wavelength, which would be first on the list?
- A. radio waves
  - B. X rays
  - C. gamma rays
  - D. visible light
7. Which region of the electromagnetic spectrum listed in the table above includes microwaves?
- A. gamma rays
  - B. radio waves
  - C. ultraviolet waves
  - D. infrared waves
8. The warmth you feel when you stand in front of a fire is thermal energy transmitted to you by what type of electromagnetic waves?
- A. X rays
  - B. microwaves
  - C. ultraviolet waves
  - D. infrared 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 illustrations below to answer questions 9 and 10.



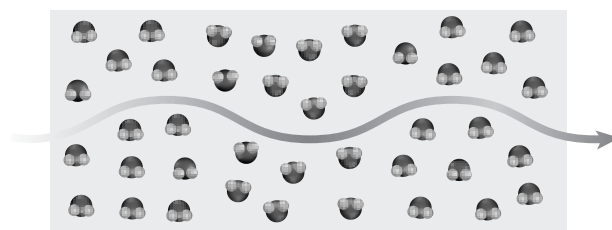
9. The illustration above shows two radio waves broadcast by a radio station. What is the upper, unmodulated wave called?
10. The lower figure shows the same wave that has been modulated to carry sound information. What type of modulation does it show?
11. The frequency of electromagnetic waves is measured in what units? What does this unit mean?
12. Even on a cloudy day, you can get sunburned outside. However, inside a glass greenhouse, you won't get sunburned. Which type of electromagnetic waves will pass through clouds, but not glass?
13. What term refers to the energy carried by an electromagnetic wave?
14. The following sentence is *not* true: A magnetic field creates an electric field, and an electric field creates a magnetic field. Rewrite the sentence so that it is true.
15. Which type of radio station transmits radio waves that have a higher frequency, AM stations or FM stations?

## Part 3 Open Ended

Record your answers on a sheet of paper.

16. A CD player converts the musical information on a CD to a varying electric current. Describe how the varying electric current produced by a CD player in a radio station is converted into radio waves.
17. Explain how an electromagnetic wave that strikes a material transfers radiant energy to the atoms in the material.
18. How would changing the amount of ozone in the ozone layer affect the amount of the different types of electromagnetic waves emitted by the Sun that reach Earth's surface?
19. Explain how the cathode-ray tube in a television is able to produce all the colors that you see in an image on a television screen, using just three electron beams.
20. If all atoms contain electric charges, and if all atoms are constantly in motion, explain why all objects should emit electromagnetic waves.

Use the illustration below to answer questions 21 and 22.



21. The illustration above shows microwaves interacting with water molecules in food. How does the electric field in microwaves affect water molecules?
22. Describe how thermal energy inside food is produced by microwaves interacting with water molecules.