SECTION 3

Light and Technology

What do cameras, telescopes, lasers, cellular telephones, and satellite televisions have in common?

They are all types of technology that use light or other electromagnetic waves. Read on to learn how these and other types of light technology are useful in your everyday life.

What You Will Learn

- Describe three optical instruments.
- Explain what laser light is, and identify uses for lasers.
- Describe how optical fibers work.
- Explain polarized light.
- Explain how radio waves and microwaves are used in four types of communication technology.

Vocabulary

laser
hologram

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Optical Instruments

Optical instruments are devices that use mirrors and lenses to help people make observations. Some optical instruments help you see things that are very far away. Others help you see things that are very small. Some optical instruments record images. The optical instrument that you are probably most familiar with is the camera.

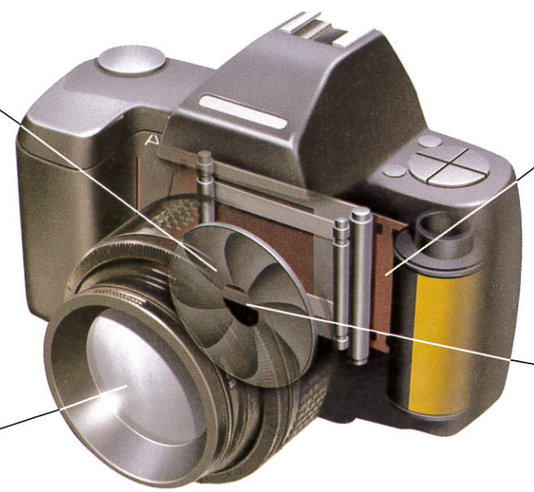
Cameras

Cameras are used to record images. **Figure 1** shows the parts of a 35 mm camera. A digital camera has a lens, a shutter, and an aperture (AP uhr chuhr) like a 35 mm camera has. But instead of using film, a digital camera uses light sensors to record images. The sensors send an electrical signal to a computer in the camera. This signal contains data about the image that is stored in the computer, on a memory stick, card, or disk.

Figure 1 How a Camera Works

The **shutter** opens and closes behind the lens to control how much light enters the camera. The longer the shutter is open, the more light enters the camera.

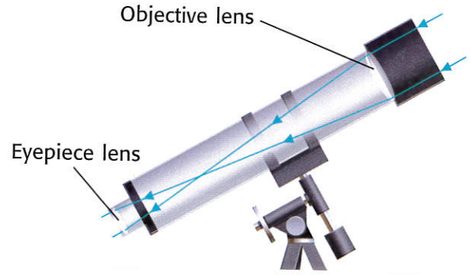
The **lens** of a camera is a convex lens that focuses light on the film. Moving the lens focuses light from objects at different distances.



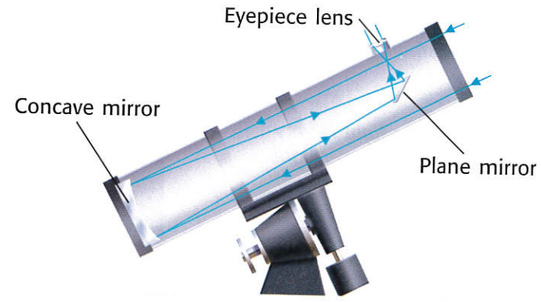
The **film** is coated with chemicals that react when they are exposed to light. The result is an image stored on the film.

The **aperture** is an opening that lets light into the camera. The larger the aperture is, the more light enters the camera.

Figure 2 How Refracting and Reflecting Telescopes Work



A **refracting telescope** has two convex lenses. Light enters through the objective lens and forms a real image. This real image is then magnified by the eyepiece lens. You see this magnified image when you look through the eyepiece lens.



A **reflecting telescope** has a concave mirror that collects and focuses light to form a real image. The light strikes a plane mirror that directs the light to the convex eyepiece lens, which magnifies the real image.

Telescopes

Telescopes are used to see detailed images of large, distant objects. Astronomers use telescopes to study things in space, such as the moon, planets, and stars. Telescopes are classified as either refracting or reflecting. *Refracting telescopes* use lenses to collect light. *Reflecting telescopes* use mirrors to collect light. **Figure 2** shows how these two kinds of telescopes work.

Light Microscopes

Simple light microscopes are similar to refracting telescopes. These microscopes have two convex lenses. An objective lens is close to the object being studied. An eyepiece lens is the lens you look through. Microscopes are used to see magnified images of tiny, nearby objects.

Lasers and Laser Light

A **laser** is a device that produces intense light of only one color and wavelength. Laser light is different from nonlaser light in many ways. One important difference is that laser light is *coherent*. When light is coherent, light waves move together as they travel away from their source. The crests and troughs of coherent light waves are aligned. So, the individual waves behave as one wave.

Reading Check **What does it mean for light to be coherent?** (*See the Appendix for answers to Reading Checks.*)

MATH PRACTICE

Microscope Magnification

Some microscopes use more than one lens to magnify objects. The power of each lens indicates the amount of magnification the lens gives. For example, a 10× lens magnifies objects 10 times. To find the amount of magnification given by two or more lenses used together, multiply the powers of the lenses. What is the magnification given by a 5× lens used with a 20× lens?

laser a device that produces intense light of only one wavelength and color

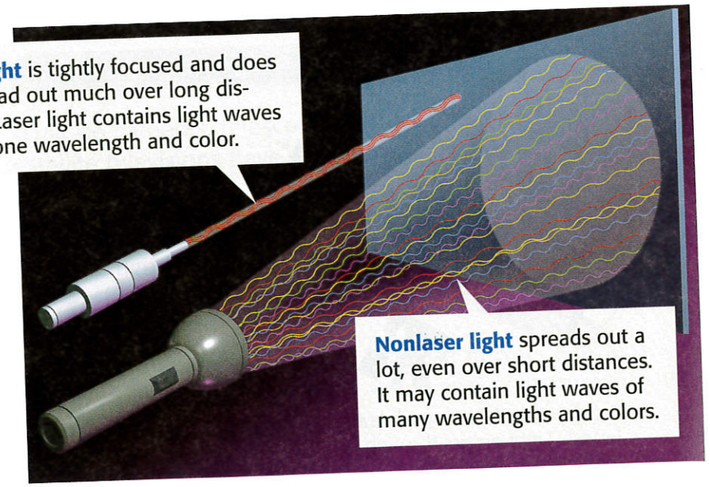


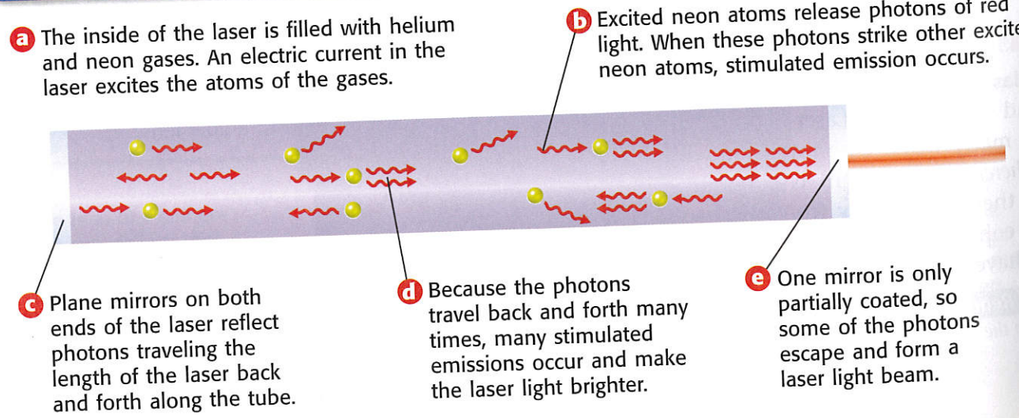
Figure 3 *Laser light is very different from nonlaser light.*

How Lasers Produce Light

Figure 3 compares laser and nonlaser light. The word *laser* stands for light amplification by stimulated emission of radiation. *Amplification* is the increase in the brightness of the light. *Radiation* is energy transferred as electromagnetic waves.

What is stimulated emission? In an atom, an electron can move from one energy level to another. A photon (a particle of light) is released when an electron moves from a higher energy level to a lower energy level. The release of photons is called *emission*. *Stimulated emission* occurs when a photon strikes an atom that is in an excited state and makes the atom emit another photon. The newly emitted photon is identical to the first photon. The two photons travel away from the atom together. **Figure 4** shows how laser light is produced.

Figure 4 How a Helium-Neon Laser Works



Uses for Lasers

Lasers are used to make holograms, such as the one shown in **Figure 5.** A **hologram** is a piece of film that produces a three-dimensional image of an object. Holograms are similar to photographs because both are images recorded on film. However, unlike photographs, the images you see in holograms are not on the surface of the film. The images appear in front of or behind the film. If you move the hologram, you will see the image from different angles.

Lasers are also used for other tasks. For example, lasers are used to cut materials such as metal and cloth. Doctors sometimes use lasers for surgery. And CD players have lasers. Light from the laser in a CD player reflects off patterns on a CD's surface. The reflected light is converted to a sound wave.

Reading Check **How are holograms like photographs?**

hologram a piece of film that produces a three-dimensional image of an object; made by using laser light

Figure 5 *Some holograms make three-dimensional images that look so real that you might want to reach out and touch them!*

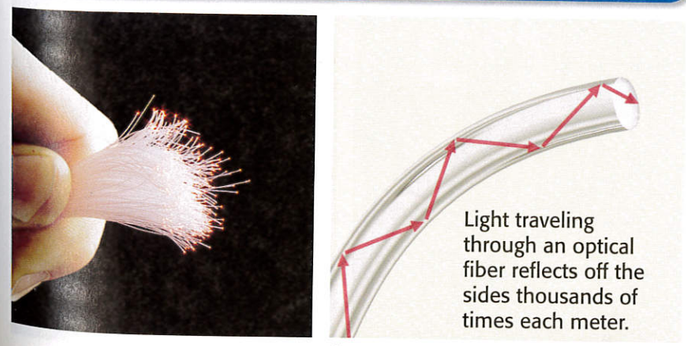
Optical Fibers

Imagine a glass thread that transmits more than 1,000 telephone conversations at the same time with flashes of light. This thread, called an *optical fiber,* is a thin, glass wire that transmits light over long distances. Some optical fibers are shown in **Figure 6.** Transmitting information through telephone cables is the most common use of optical fibers. Optical fibers are also used to network computers. And they allow doctors to see inside patients' bodies without performing major surgery.

Light in a Pipe

Optical fibers are like pipes that carry light. Light stays inside an optical fiber because of total internal reflection. *Total internal reflection* is the complete reflection of light along the inside surface of the material through which it travels. **Figure 6** shows total internal reflection in an optical fiber.

Figure 6 How Optical Fibers Work



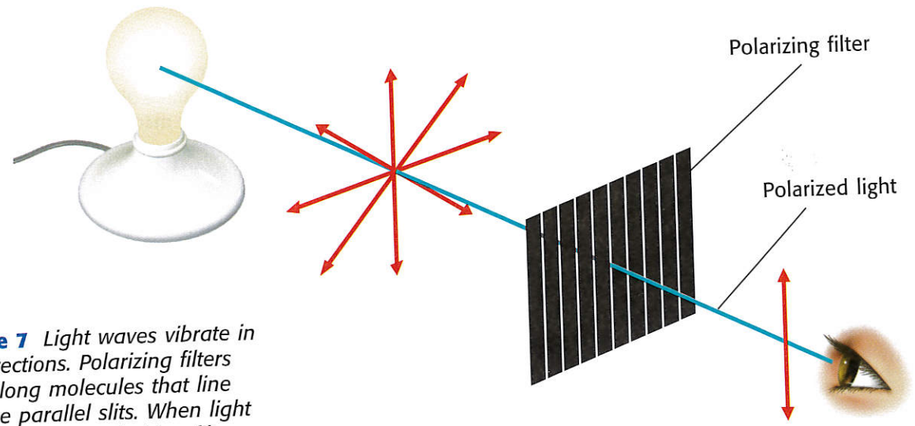


Figure 7 *Light waves vibrate in all directions. Polarizing filters have long molecules that line up like parallel slits. When light waves strike a polarizing filter, only the light waves vibrating in the same direction as the slits pass through.*

Polarized Light

The next time you shop for sunglasses, look for some that have lenses that polarize light. Such sunglasses are good for reducing glare. *Polarized light* consists of light waves that vibrate in only one plane. **Figure 7** illustrates how light is polarized.

When light reflects off a horizontal surface, such as a car hood or a body of water, the light is polarized horizontally. You see this polarized light as glare. Polarizing sunglasses reduce glare from horizontal surfaces because the lenses have vertically polarized filters. These filters allow only vertically vibrating light waves to pass through them. Polarizing filters are also used by photographers to reduce glare in their photographs, as shown in **Figure 8.**

Figure 8 *These two photos were taken by the same camera and from the same angle. There is less reflected light in the photo at right because a polarizing filter was placed over the lens of the camera.*

QUICK LAB

Blackout!

1. Hold a **lens from a pair of polarizing sunglasses** up to your eye, and look through the lens. Record your observations.
2. Put a **second polarizing lens** over the first lens. Make sure both lenses are right side up. Look through both lenses, and describe your observations.
3. Rotate one lens slowly as you look through both lenses, and describe what happens.
4. Why can't you see through the lenses when they are aligned a certain way?

Communication Technology

You may think that talking on the telephone has nothing to do with light. But if you are talking on a cordless telephone or a cellular telephone, you are using a form of light technology! Light is an electromagnetic wave. There are many different kinds of electromagnetic waves. Radio waves and microwaves are kinds of electromagnetic waves. And cordless telephones and cellular telephones use radio waves and microwaves to send signals.

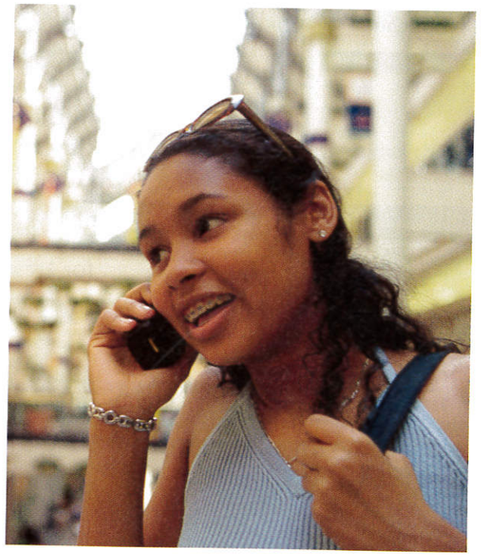


Figure 9 *You can make and receive calls with a cellular telephone almost everywhere you go.*

Cordless Telephones

Cordless telephones are a combination of a regular telephone and a radio. There are two parts to a cordless telephone—the base and the handset. The base is connected to a telephone jack in the wall of a building. The base receives calls through the phone line. The base then changes the signal to a radio wave and sends the signal to the handset. The handset changes the radio signal to sound for you to hear. The handset also changes your voice to a radio wave that is sent back to the base.

Reading Check **What kind of electromagnetic wave does a cordless telephone use?**

Cellular Telephones

The telephone in **Figure 9** is a cellular telephone. Cellular telephones are similar to the handset part of a cordless telephone because they send and receive signals. But a cellular telephone receives signals from tower antennas located across the country instead of from a base. And instead of using radio waves, cellular telephones use microwaves to send information.

Satellite Television

Another technology that uses electromagnetic waves to transmit data is satellite television. Satellite television companies broadcast microwave signals from human-made satellites in space. Broadcasting from space allows more people to receive the signals than broadcasting from an antenna on Earth. Small satellite dishes on the roofs of houses or outside apartments collect the signals. The signals are then sent to the customer's television set. People who have satellite television usually have better TV reception than people who receive broadcasts from antennas on Earth.

The Global Positioning System

The Global Positioning System (GPS) is a network of 27 satellites that orbit Earth. These satellites continuously send microwave signals. The signals can be picked up by a GPS receiver on Earth and used to measure positions on the Earth's surface. **Figure 10** explains how GPS works. GPS was originally used by the United States military. But now, anyone in the world who has a GPS receiver can use the system. People use GPS to avoid getting lost and to have fun. Some cars have GPS road maps that can tell the car's driver how to get to a certain place. Hikers and campers use GPS receivers to find their way in the wilderness. And some people use GPS receivers for treasure-hunt games.

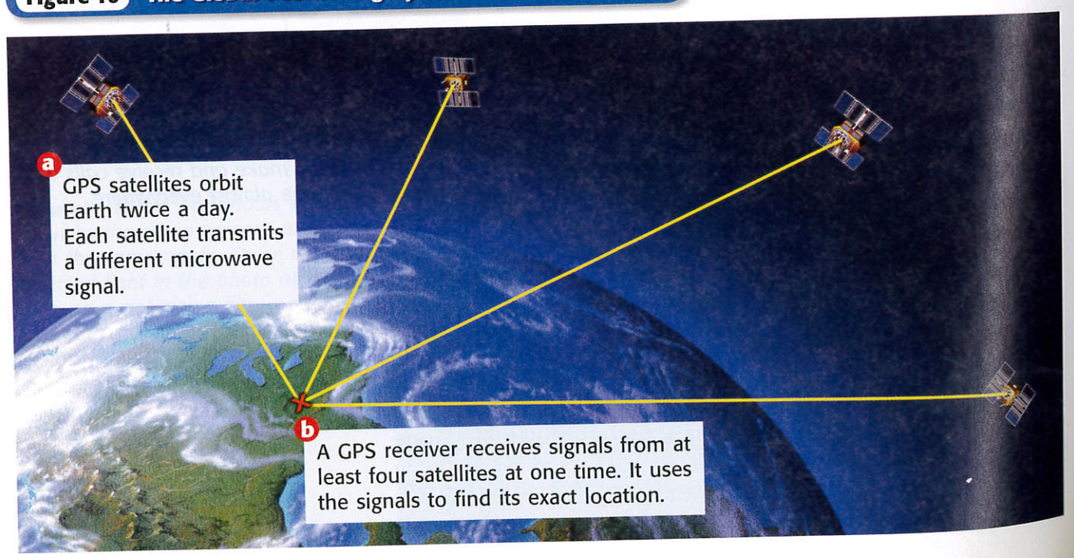
Reading Check **What are two uses for GPS?**

CONNECTION TO Social Studies

Navigation GPS is a complex navigation system. Before GPS was developed, travelers and explorers used other techniques, such as compasses and stars, to find their way. Research an older form of navigation, and make a poster that summarizes what you learn.

ACTIVITY

Figure 10 The Global Positioning System



SECTION Review

Summary

- Optical instruments, such as cameras, telescopes, and microscopes, are devices that help people make observations.
- Lasers are devices that produce intense, coherent light of only one wavelength and color. Lasers produce light by a process called *stimulated emission*.
- Optical fibers transmit light over long distances.
- Polarized light contains light waves that vibrate in only one direction.
- Cordless telephones are a combination of a telephone and a radio. Information is transmitted in the form of radio waves between the handset and the base.
- Cellular phones transmit information in the form of microwaves to and from antennas.
- Satellite television is broadcast by microwaves from satellites in space.
- GPS is a navigation system that uses microwave signals sent by a network of satellites in space.

Using Key Terms

1. Use each of the following terms in a separate sentence: *laser* and *hologram*.

Understanding Key Ideas

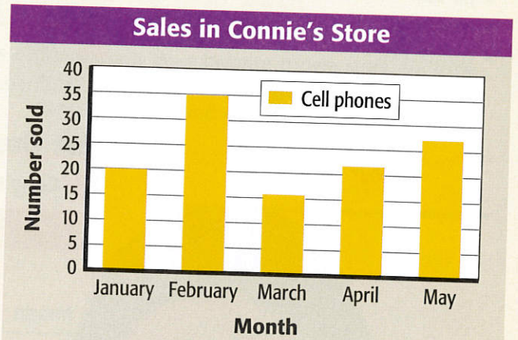
2. Which of the following statements about laser light is NOT true?
   a. Laser light is coherent.
   b. Laser light contains light of only one wavelength.
   c. Laser light is produced by stimulated emission.
   d. Laser light spreads out over short distances.
3. List three optical instruments, and describe what they do.
4. What are four uses for lasers?
5. Describe how optical fibers work.
6. What is polarized light?
7. Describe two ways that satellites in space are useful in everyday life.

Critical Thinking

8. **Making Comparisons** Compare how a cordless telephone works with how a cellular telephone works.
9. **Making Inferences** Why do you think optical fibers can transmit information over long distances without losing much of the signal?

Interpreting Graphics

Use the graph below to answer the questions that follow.



10. In which two months did Connie's store sell the most cellular telephones?
11. How many cellular telephones were sold in January?

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