SECTION 1
The Nature of Electromagnetic Waves

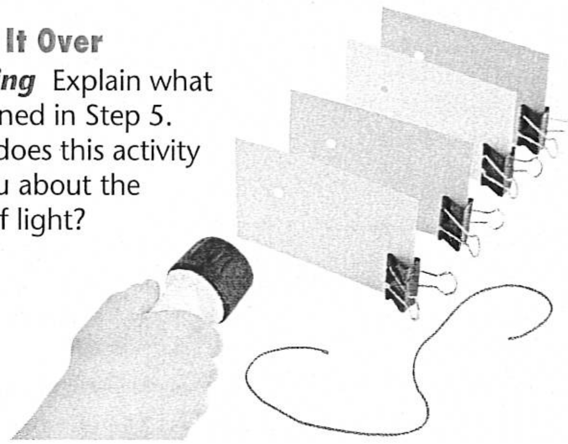
DISCOVER ACTIVITY

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 is light?

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

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" all the time. 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.

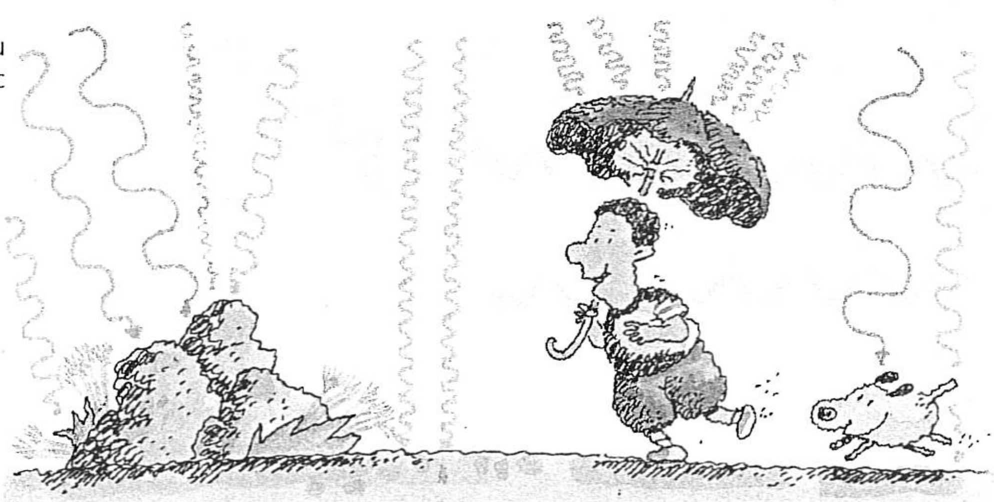


Figure 1 Even though you cannot feel electromagnetic waves, you are being showered by them.

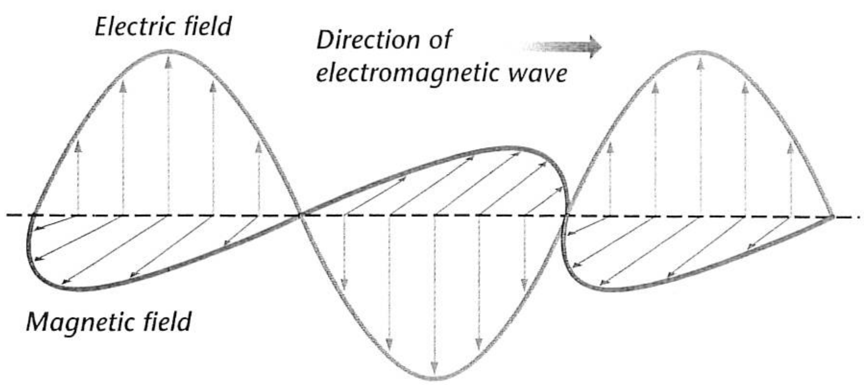


Figure 2 An electromagnetic wave occurs when electric and magnetic fields vibrate at right angles to each other.

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.

But a group of waves called electromagnetic waves can transfer energy 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 Figure 2.

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.

How Do Light Beams Behave?

ACTIVITY

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.

Speed of Electromagnetic Waves All electromagnetic waves travel at the same speed—about 300,000,000 meters per second in a vacuum. This rate can also be expressed as 300,000 kilometers per second. At this speed, light from the sun travels the 150 million kilometers to Earth in about 8 minutes. 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* *What is the speed of electromagnetic waves in a vacuum?*

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 in Figure 3, 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.

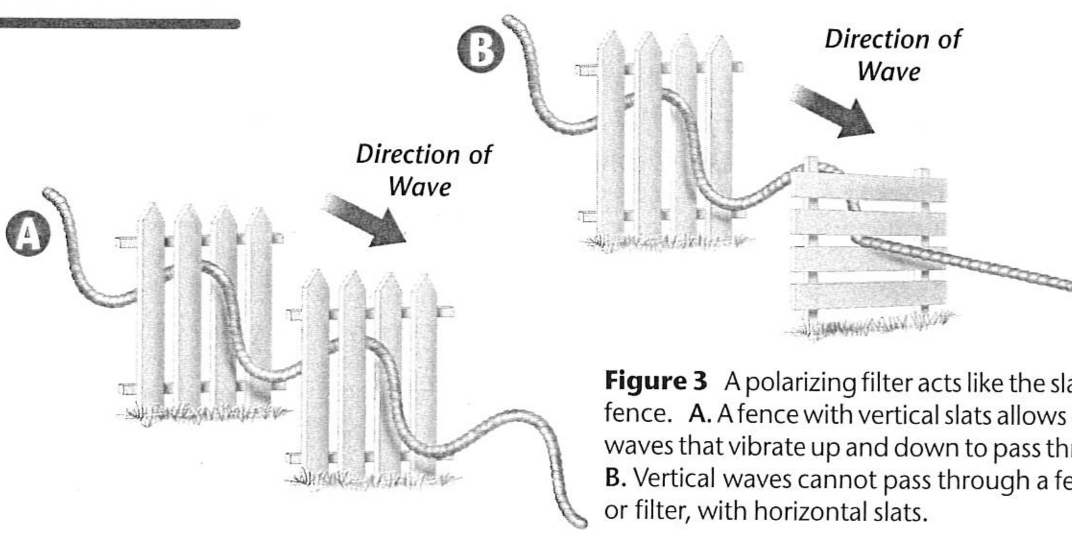
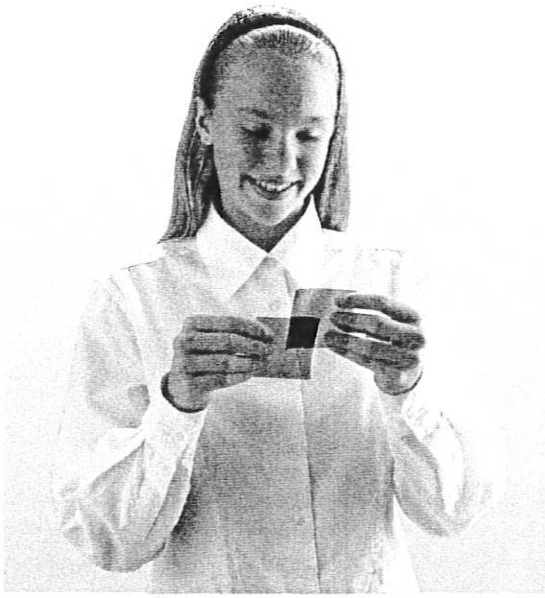


Figure 3 A polarizing filter acts like the slats in a fence. **A.** A fence with vertical slats allows only waves that vibrate up and down to pass through. **B.** Vertical waves cannot pass through a fence, or filter, with horizontal slats.



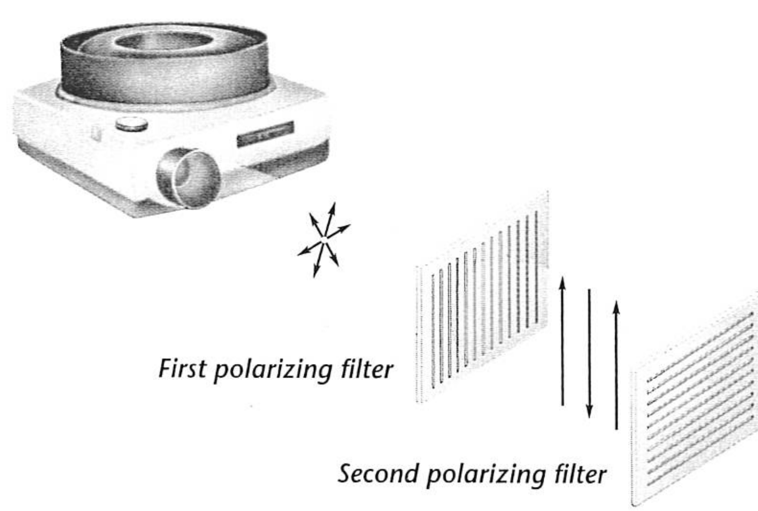


Figure 4 The first polarizing filter allows only waves that vibrate up and down to pass through. When a second polarizing filter is placed in front of the first, and at right angles to it, no light passes through. *Applying Concepts Does the way that light passes through a polarizing filter support the wave model or the particle model of light?*

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.

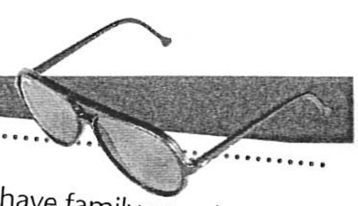
Here is an example of how light can act like a stream of particles. When a beam of light shines on some substances, it causes tiny particles called electrons to move. This movement causes an electric current to flow. Sometimes light can even knock electrons out of the substance. This is called the **photoelectric 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's explanation of the photoelectric effect in 1905 was important for our understanding of photons as particles of light.

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

Section 1 Review

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

Science at Home



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.*