SECTION 3

Interactions of Light Waves

Have you ever seen a cat's eyes glow in the dark when light shines on them? Cats have a special layer of cells in the back of their eyes that reflects light.

This layer helps the cat see better by giving the eyes another chance to detect the light. Reflection is one interaction of electromagnetic waves. Because we can see visible light, it is easier to explain all wave interactions by using visible light.

What You Will Learn

- Describe how reflection allows you to see things.
- Describe absorption and scattering.
- Explain how refraction can create optical illusions and separate white light into colors.
- Explain the relationship between diffraction and wavelength.
- Compare constructive and destructive interference of light.

Vocabulary

reflection
absorption
scattering
refraction
diffraction
interference

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

Reflection

Reflection happens when light waves bounce off an object. Light reflects off objects all around you. When you look in a mirror, you are seeing light that has been reflected twice—first from you and then from the mirror. If light is reflecting off everything around you, why can't you see your image on a wall? To answer this question, you must learn the law of reflection.

The Law of Reflection

Light reflects off surfaces the same way that a ball bounces off the ground. If you throw the ball straight down against a smooth surface, it will bounce straight up. If you bounce it at an angle, it will bounce away at an angle. The *law of reflection* states that the angle of incidence is equal to the angle of reflection. *Incidence* is the arrival of a beam of light at a surface. **Figure 1** shows this law.

Reading Check **What is the law of reflection?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 **The Law of Reflection**

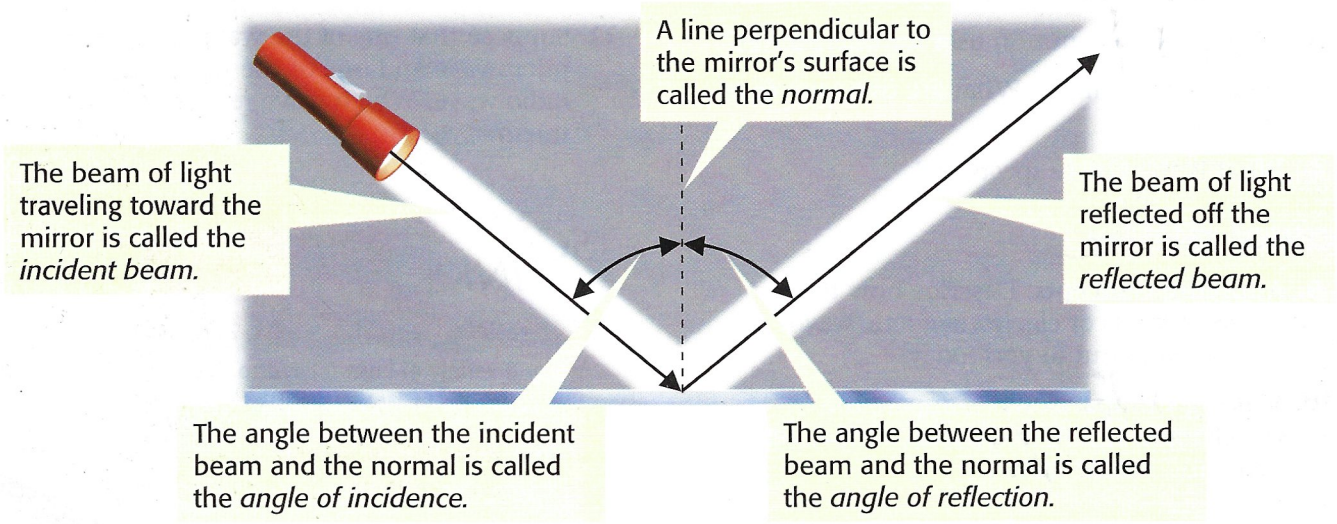
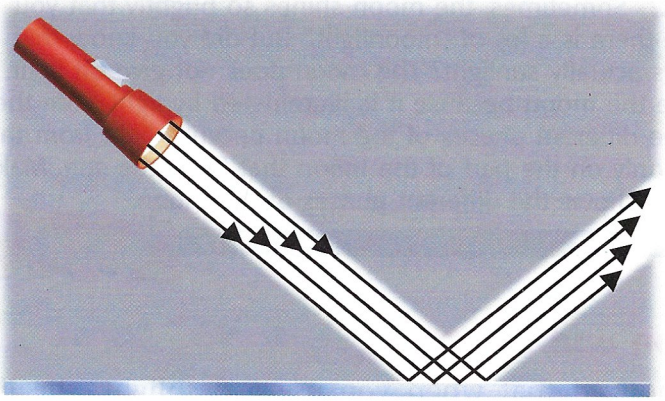
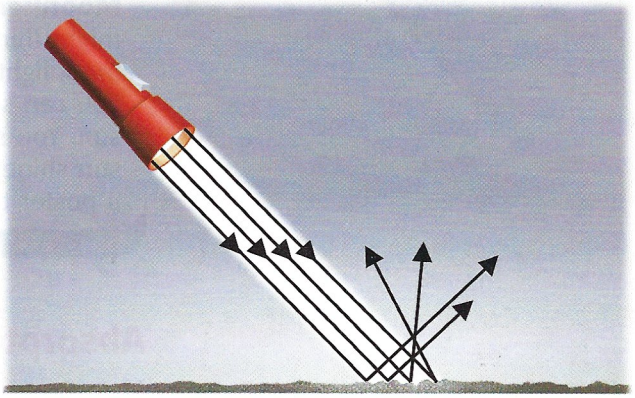


Figure 2 Regular Reflection Vs. Diffuse Reflection



Regular reflection occurs when light beams are reflected at the same angle. When your eye detects the reflected beams, you can see a reflection on the surface.



Diffuse reflection occurs when light beams reflect at many different angles. You can't see a reflection because not all of the reflected light is directed toward your eyes.

Types of Reflection

So, why can you see your image in a mirror but not in a wall? The answer has to do with the differences between the two surfaces. A mirror's surface is very smooth. Thus, light beams reflect off all points of the mirror at the same angle. This kind of reflection is called *regular reflection*. A wall's surface is slightly rough. Light beams will hit the wall's surface and reflect at many different angles. This kind of reflection is called *diffuse reflection*. **Figure 2** shows the difference between the two kinds of reflection.

reflection the bouncing back of a ray of light, sound, or heat when the ray hits a surface that it does not go through

Light Source or Reflection?

If you look at a TV set in a bright room, you see the cabinet around the TV and the image on the screen. But if you look at the same TV in the dark, you see only the image on the screen. The difference is that the screen is a light source, but the cabinet around the TV is not.

You can see a light source even in the dark because its light passes directly into your eyes. The tail of the firefly in **Figure 3** is a light source. Flames, light bulbs, and the sun are also light sources. Objects that produce visible light are called *luminous* (LOO muh nuhs).

Most things around you are not light sources. But you can still see them because light from light sources reflects off the objects and then travels to your eyes. A visible object that is not a light source is *illuminated*.

Figure 3 *You can see the tail of this firefly because it is luminous. But you see its body because it is illuminated.*

Reading Check List four different light sources.

CONNECTION TO Astronomy

Moonlight? Sometimes, the moon shines so brightly that you might think there is a lot of "moonlight." But did you know that moonlight is actually sunlight? The moon does not give off light. You can see the moon because it is illuminated by light from the sun. You see different phases of the moon because light from the sun shines only on the part of the moon that faces the sun. Make a poster that shows the different phases of the moon.

ACTIVITY

Absorption and Scattering

absorption in optics, the transfer of light energy to particles of matter

scattering an interaction of light with matter that causes light to change its energy, direction of motion, or both

Have you noticed that when you use a flashlight, the light shining on things closer to you appears brighter than the light shining on things farther away? The light is less bright the farther it travels from the flashlight. The light is weaker partly because the beam spreads out and partly because of absorption and scattering.

Absorption of Light

The transfer of energy carried by light waves to particles of matter is called **absorption.** When a beam of light shines through the air, particles in the air absorb some of the energy from the light. As a result, the beam of light becomes dim. The farther the light travels from its source, the more it is absorbed by particles, and the dimmer it becomes.

Figure 4 *A beam of light becomes dimmer partly because of scattering.*

Scattering of Light

Scattering is an interaction of light with matter that causes light to change direction. Light scatters in all directions after colliding with particles of matter. Light from the ship shown in **Figure 4** is scattered out of the beam by air particles. This scattered light allows you to see things that are outside the beam. But, because light is scattered out of the beam, the beam becomes dimmer.

Scattering makes the sky blue. Light with shorter wavelengths is scattered more than light with longer wavelengths. Sunlight is made up of many different colors of light, but blue light (which has a very short wavelength) is scattered more than any other color. So, when you look at the sky, you see a background of blue light.

Reading Check **Why can you see things outside a beam of light?**

Scattering Milk

1. Fill a **2 L clear plastic bottle** with **water.**
2. Turn the lights off, and shine a **flashlight** through the water. Look at the water from all sides of the bottle. Write a description of what you see.
3. Add **3 drops of milk** to the water, and shake the bottle to mix it up.
4. Repeat step 2. Describe any color changes. If you don't see any, add more milk until you do.
5. How is the water-and-milk mixture like air particles in the atmosphere? Explain your answer.

Refraction

Imagine that you and a friend are at a lake. Your friend wades into the water. You look at her, and her feet appear to have separated from her legs! What has happened? You know her feet did not fall off, so how can you explain what you see? The answer has to do with refraction.

Refraction and Material

Refraction is the bending of a wave as it passes at an angle from one substance, or material, to another. **Figure 5** shows a beam of light refracting twice. Refraction of light waves occurs because the speed of light varies depending on the material through which the waves are traveling. In a vacuum, light travels at 300,000 km/s, but it travels more slowly through matter. When a wave enters a new material at an angle, the part of the wave that enters first begins traveling at a different speed from that of the rest of the wave.

refraction the bending of a wave as the wave passes between two substances in which the speed of the wave differs

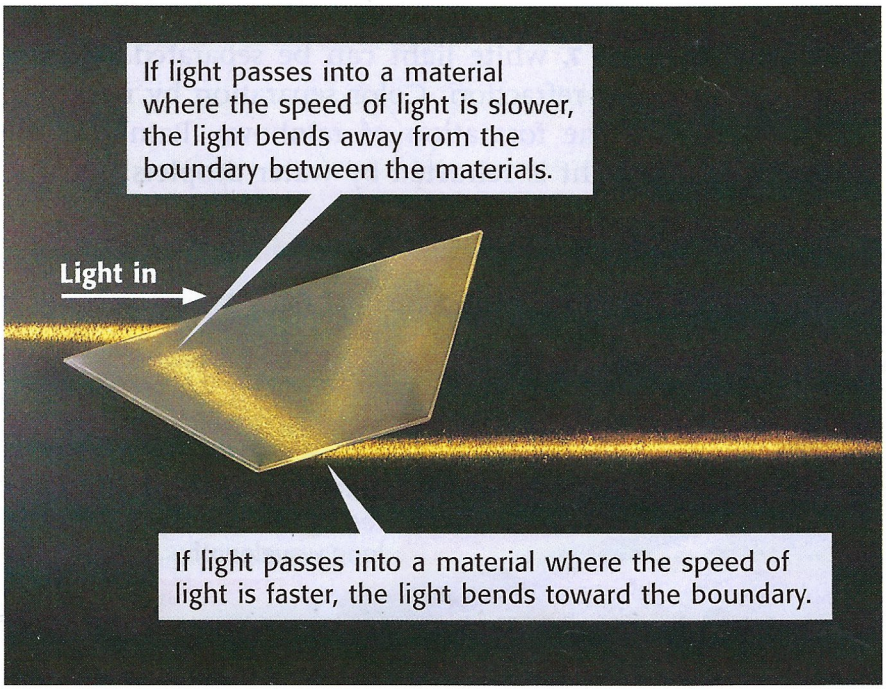


Figure 5 *Light travels more slowly through glass than it does through air. So, light refracts as it passes at an angle from air to glass or from glass to air. Notice that the light is also reflected inside the prism.*

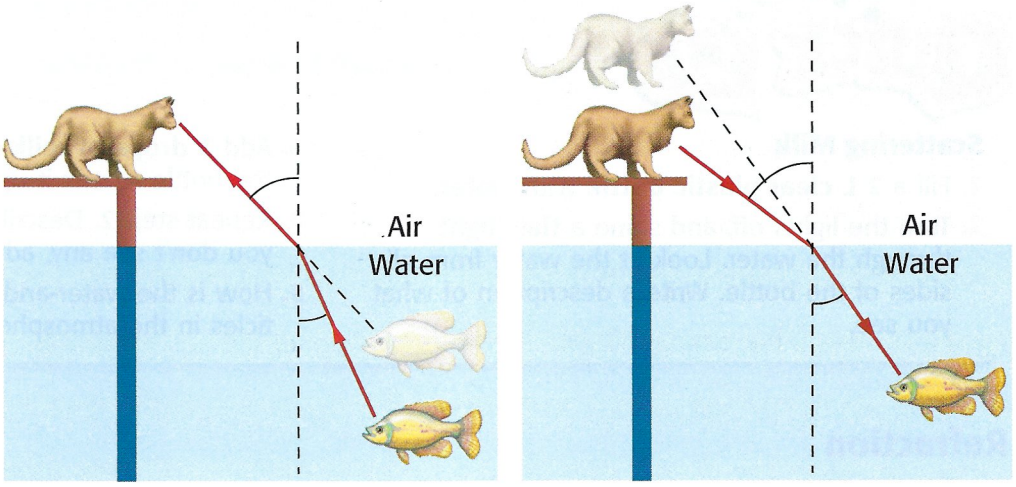


Figure 6 *Because of refraction, the cat and the fish see optical illusions. To the cat, the fish appears closer than it really is. To the fish, the cat appears farther away than it actually is.*

Refraction and Optical Illusions

Usually, when you look at an object, the light reflecting off the object travels in a straight line from the object to your eye. Your brain always interprets light as traveling in straight lines. But when you look at an object that is underwater, the light reflecting off the object does not travel in a straight line. Instead, it refracts. **Figure 6** shows how refraction creates an optical illusion. This kind of illusion causes a person's feet to appear separated from the legs when the person is wading.

Refraction and Color Separation

White light is composed of all the wavelengths of visible light. The different wavelengths of visible light are seen by humans as different colors. When white light is refracted, the amount that the light bends depends on its wavelength. Waves with short wavelengths bend more than waves with long wavelengths. As shown in **Figure 7,** white light can be separated into different colors during refraction. Color separation by refraction is responsible for the formation of rainbows. Rainbows are created when sunlight is refracted by water droplets.

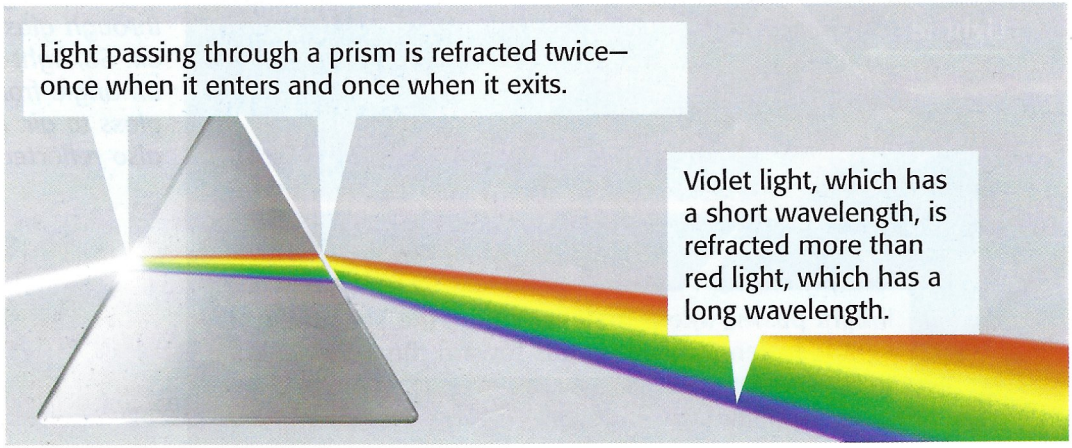


Figure 7 *A prism is a piece of glass that separates white light into the colors of visible light by refraction.*

Refraction Rainbow

1. **Tape** a **piece of construction paper** over the end of a **flashlight.** Use **scissors** to cut a slit in the paper.
2. Turn on the flashlight, and lay it on a table. Place a **prism** on end in the beam of light.
3. Slowly rotate the prism until you can see a rainbow on the surface of the table. Draw a diagram of the light beam, the prism, and the rainbow.

Diffraction

Refraction isn't the only way light waves are bent. **Diffraction** is the bending of waves around barriers or through openings. The amount a wave diffracts depends on its wavelength and the size of the barrier or the opening. The greatest amount of diffraction occurs when the barrier or opening is the same size or smaller than the wavelength.

diffraction a change in the direction of a wave when the wave finds an obstacle or an edge, such as an opening

Reading Check **The amount a wave diffracts depends on what two things?**

Diffraction and Wavelength

The wavelength of visible light is very small—about 100 times thinner than a human hair! So, a light wave cannot bend very much by diffraction unless it passes through a narrow opening, around sharp edges, or around a small barrier, as shown in **Figure 8.**

Light waves cannot diffract very much around large obstacles, such as buildings. Thus, you can't see around corners. But light waves always diffract a small amount. You can observe light waves diffracting if you examine the edges of a shadow. Diffraction causes the edges of shadows to be blurry.

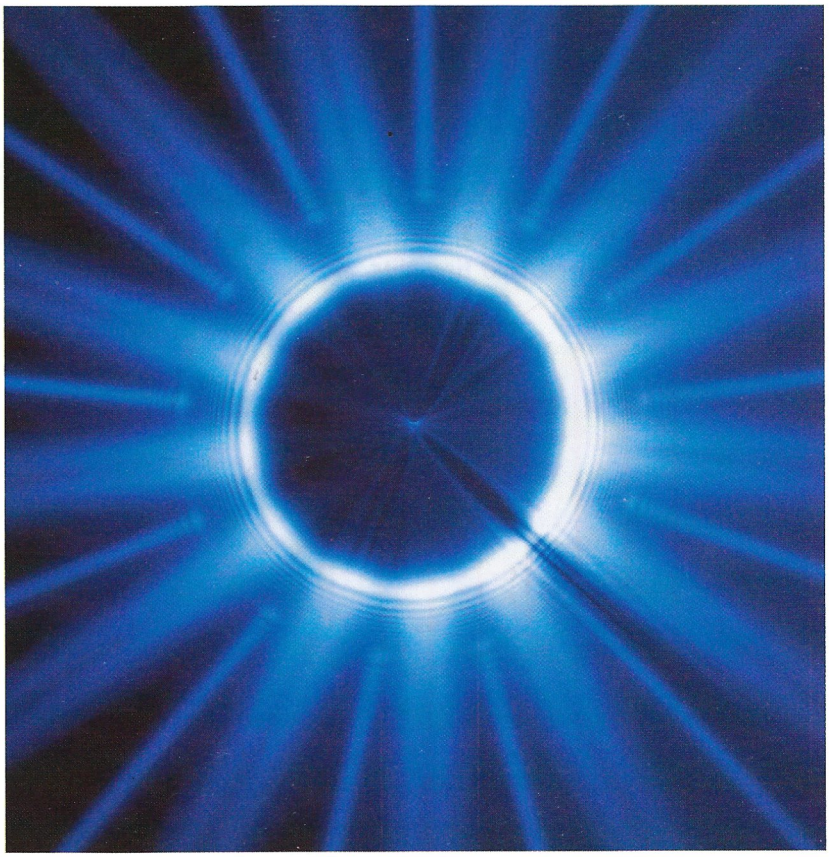


Figure 8 *This diffraction pattern is made by light of a single wavelength shining around the edges of a very tiny disk.*

interference the combination of two or more waves that results in a single wave

Interference

Interference is a wave interaction that happens when two or more waves overlap. Overlapping waves can combine by constructive or destructive interference.

Constructive Interference

When waves combine by *constructive interference,* the resulting wave has a greater amplitude, or height, than the individual waves had. Constructive interference of light waves can be seen when light of one wavelength shines through two small slits onto a screen. The light on the screen will appear as a series of alternating bright and dark bands, as shown in **Figure 9.** The bright bands result from light waves combining through constructive interference.

Reading Check **What is constructive interference?**

INTERNET ACTIVITY

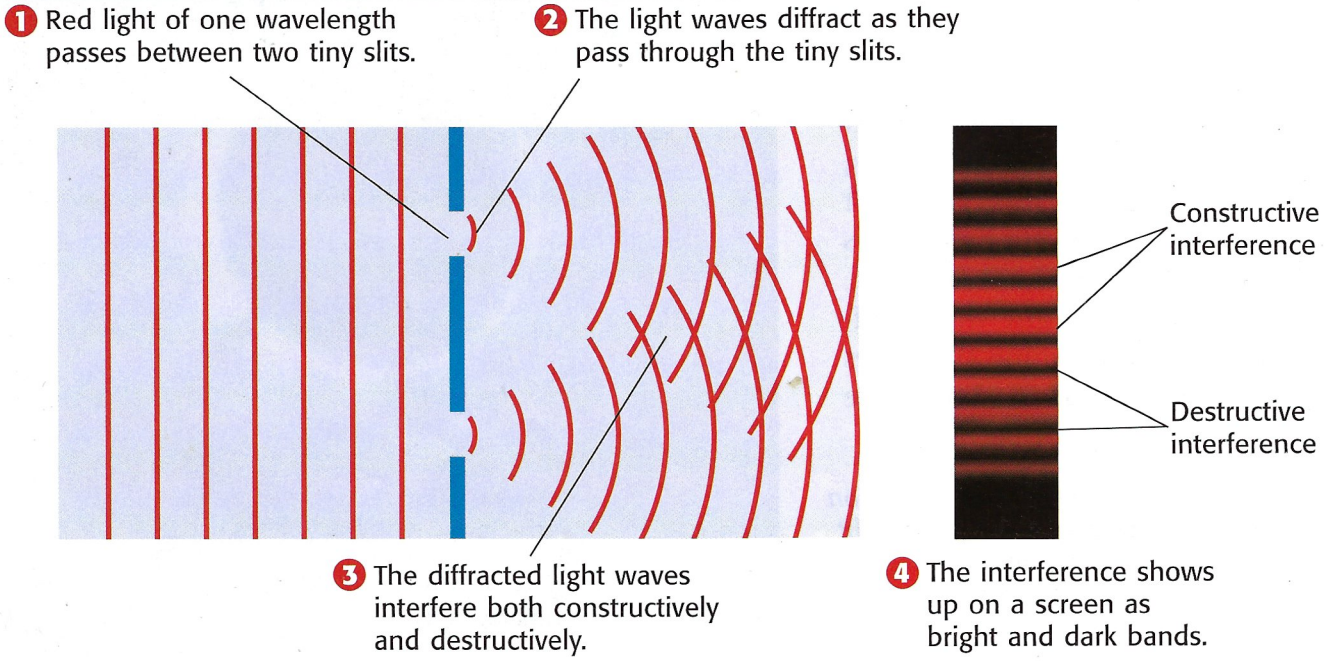
For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5LGTW.**

Destructive Interference

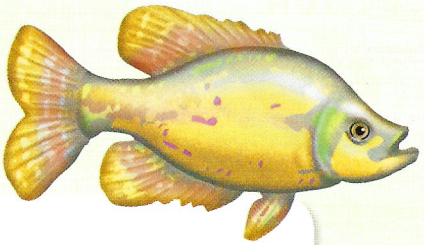
When waves combine by *destructive interference,* the resulting wave has a smaller amplitude than the individual waves had. So, when light waves interfere destructively, the result will be dimmer light. Destructive interference forms the dark bands seen in **Figure 9.**

You do not see constructive or destructive interference of white light. To understand why, remember that white light is composed of waves with many different wavelengths. The waves rarely line up to combine in total destructive interference.

Figure 9 **Constructive and Destructive Interference**



SECTION Review



Summary

- The law of reflection states that the angle of incidence is equal to the angle of reflection.
- Things that are luminous can be seen because they produce their own light. Things that are illuminated can be seen because light reflects off them.
- Absorption is the transfer of light energy to particles of matter. Scattering is an interaction of light with matter that causes light to change direction.
- Refraction of light waves can create optical illusions and can separate white light into separate colors.
- How much light waves diffract depends on the light's wavelength. Light waves diffract more when traveling through a narrow opening.
- Interference can be constructive or destructive. Interference of light waves can cause bright and dark bands.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *refraction* and *diffraction*
2. *absorption* and *scattering*

Understanding Key Ideas

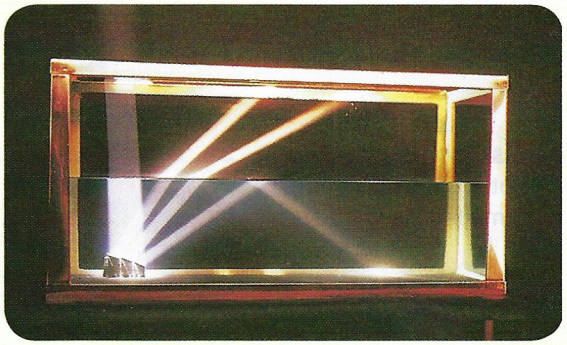
3. Which light interaction explains why you can see things that do not produce their own light?
   - **a.** absorption
   - **b.** reflection
   - **c.** refraction
   - **d.** scattering
4. Describe how absorption and scattering can affect a beam of light.
5. Why do objects that are underwater look closer than they actually are?
6. How does a prism separate white light into different colors?
7. What is the relationship between diffraction and the wavelength of light?

Critical Thinking

8. **Applying Concepts** Explain why you can see your reflection on a spoon but not on a piece of cloth.
9. **Making Inferences** The planet Mars does not produce light. Explain why you can see Mars shining like a star at night.
10. **Making Comparisons** Compare constructive interference and destructive interference.

Interpreting Graphics

Use the image below to answer the questions that follow.



11. Why doesn't the large beam of light bend like the two beams in the middle of the tank?
12. Which light interaction explains what is happening to the bottom light beam?