SECTION 3

Wave Interactions

If you've ever seen a planet in the night sky, you may have had a hard time telling it apart from a star. Both planets and stars shine brightly, but the light waves that you see are from very different sources.

What You Will Learn

- Describe reflection, refraction, diffraction, and interference.
- Compare destructive interference with constructive interference.
- Describe resonance, and give examples.

Vocabulary

reflection
refraction
diffraction
interference
standing wave
resonance

READING STRATEGY

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

All stars, including the sun, produce light. But planets do not produce light. So, why do planets shine so brightly? The planets and the moon shine because light from the sun *reflects* off them. Without reflection, you would not be able to see the planets. Reflection is one of the wave interactions that you will learn about in this section.

Reflection

Reflection happens when a wave bounces back after hitting a barrier. All waves—including water, sound, and light waves—can be reflected. The reflection of water waves is shown in **Figure 1.** Light waves reflecting off an object allow you to see that object. For example, light waves from the sun are reflected when they strike the surface of the moon. These reflected waves allow us to enjoy moonlit nights. A reflected sound wave is called an *echo*.

Waves are not always reflected when they hit a barrier. If all light waves were reflected when they hit your eyeglasses, you would not be able to see anything! A wave is *transmitted* through a substance when it passes through the substance.

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

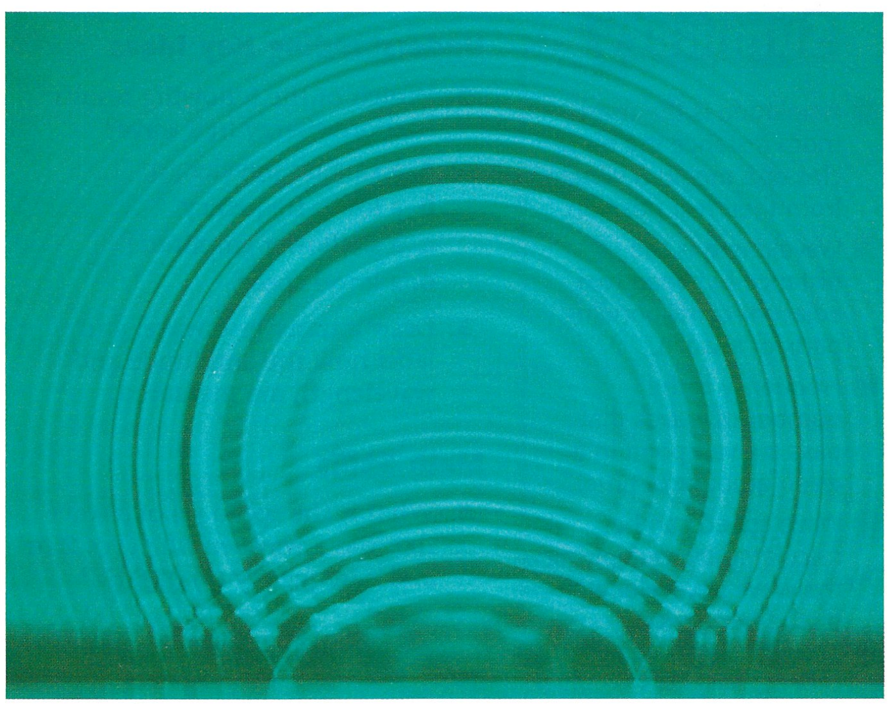


Figure 1 *These water waves are reflecting off the side of the container.*

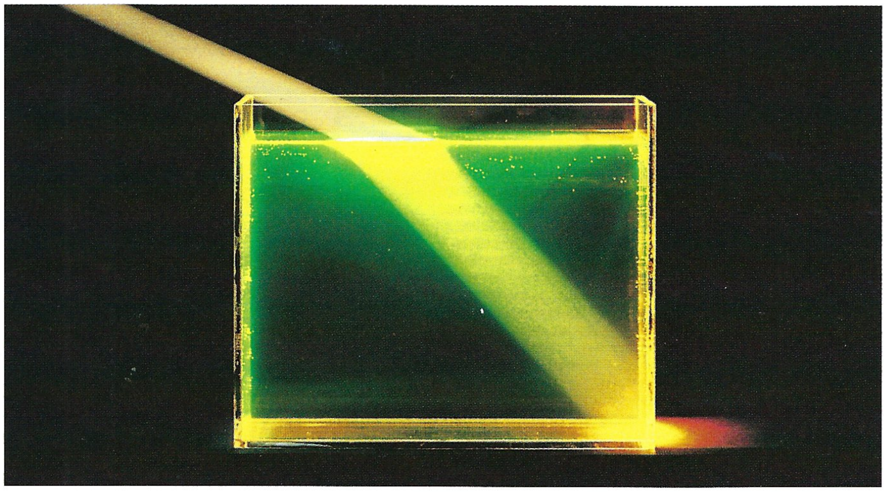


Figure 2 *A light wave passing at an angle into a new medium—such as water—is refracted because the speed of the wave changes.*

Refraction

Try this simple activity: Place a pencil in a half-filled glass of water. Now, look at the pencil from the side. The pencil appears to be broken into two pieces! But as you can see when you take the pencil out of the water, it is still in one piece.

What you saw in this experiment was the result of the *refraction* of light waves. **Refraction** is the bending of a wave as the wave passes from one medium to another at an angle. Refraction of a flashlight beam as the beam passes from air to water is shown in **Figure 2.**

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

When a wave moves from one medium to another, the wave's speed changes. When a wave enters a new medium, the wave changes wavelength as well as speed. As a result, the wave bends and travels in a new direction.

Reading Check **What happens to a wave when it moves from one medium to another at an angle?** (*See the Appendix for answers to Reading Checks.*)

Refraction of Different Colors

When light waves from the sun pass through a droplet of water in a cloud or through a prism, the light is refracted. But the different colors in sunlight are refracted by different amounts, so the light is *dispersed,* or spread out, into its separate colors. When sunlight is refracted this way through water droplets, you can see a rainbow. Why does that happen?

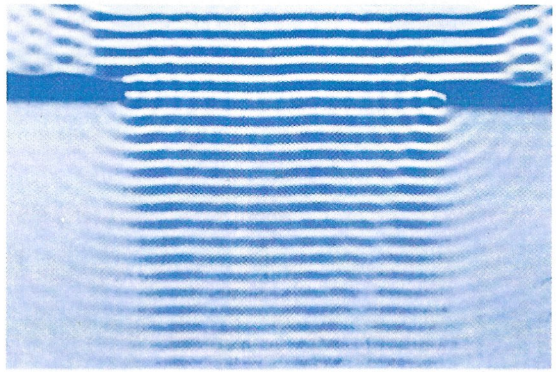
Although all light waves travel at the same speed through empty space, when light passes through a medium such as water or glass, the speed of the light wave depends on the wavelength of the light wave. Because the different colors of light have different wavelengths, their speeds are different, and they are refracted by different amounts. As a result, the colors are spread out, so you can see them individually.

CONNECTION TO Language Arts

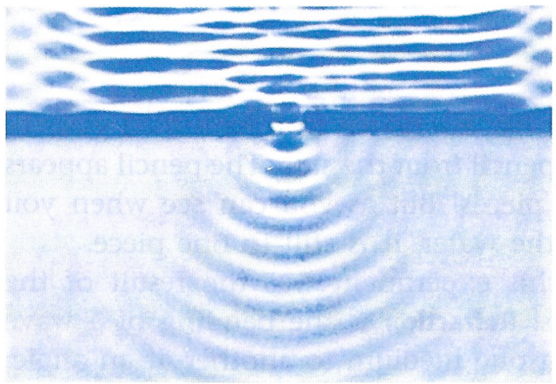
WRITING SKILL **The Colors of the Rainbow** People have always been fascinated by the beautiful array of colors that results when sunlight strikes water droplets in the air to form a rainbow. The knowledge science gives us about how they form makes them no less breathtaking.

In the library, find a poem that you like about rainbows. In your **science journal,** copy the poem, and write a paragraph in which you discuss how your knowledge of refraction affects your opinion about the poem.

Figure 3 Diffraction Through an Opening



If the barrier or opening is larger than the wavelength of the wave, there is only a small amount of diffraction.



If the barrier or opening is the same size or smaller than the wavelength of an approaching wave, the amount of diffraction is large.

SCHOOL to HOME

What if Light Diffracted?

With an adult, take a walk around your neighborhood. Light waves diffract around corners of buildings much less than sound waves do. Imagine what would happen if light waves diffracted around corners much more than sound waves did. Write a paragraph in your **science journal** describing how this would change what you see and hear as you walk around your neighborhood.

ACTIVITY

Diffraction

Suppose you are walking down a city street and you hear music. The sound seems to be coming from around the corner, but you cannot see where the music is coming from because a building on the corner blocks your view. Why do sound waves travel around a corner better than light waves do?

Most of the time, waves travel in straight lines. For example, a beam of light from a flashlight is fairly straight. But in some circumstances, waves curve or bend when they reach the edge of an object. The bending of waves around a barrier or through an opening is known as **diffraction.**

If You Can Hear It, Why Can't You See It?

The amount of diffraction of a wave depends on its wavelength and the size of the barrier or opening the wave encounters, as shown in **Figure 3.** You can hear music around the corner of a building because sound waves have long wavelengths and are able to diffract around corners. However, you cannot see who is playing the music because the wavelengths of light waves are much shorter than sound waves, so light is not diffracted very much.

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

Interference

You know that all matter has volume. Therefore, objects cannot be in the same space at the same time. But waves are energy, not matter. So, more than one wave can be in the same place at the same time. In fact, two waves can meet, share the same space, and pass through each other! When two or more waves share the same space, they overlap. The result of two or more waves overlapping is called **interference.** **Figure 4** shows what happens when waves occupy the same space and interfere with each other.

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

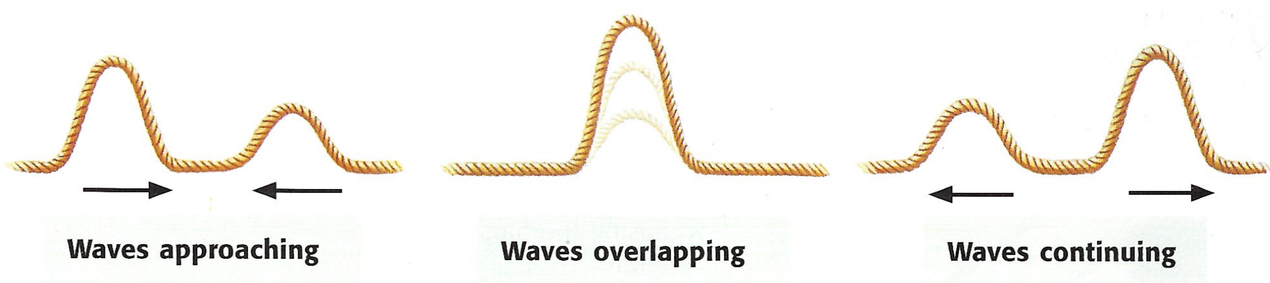
Constructive Interference

Constructive interference happens when the crests of one wave overlap the crests of another wave or waves. The troughs of the waves also overlap. When waves combine in this way, the energy carried by the waves is also able to combine. The result is a new wave that has higher crests and deeper troughs than the original waves had. In other words, the resulting wave has a larger amplitude than the original waves had.

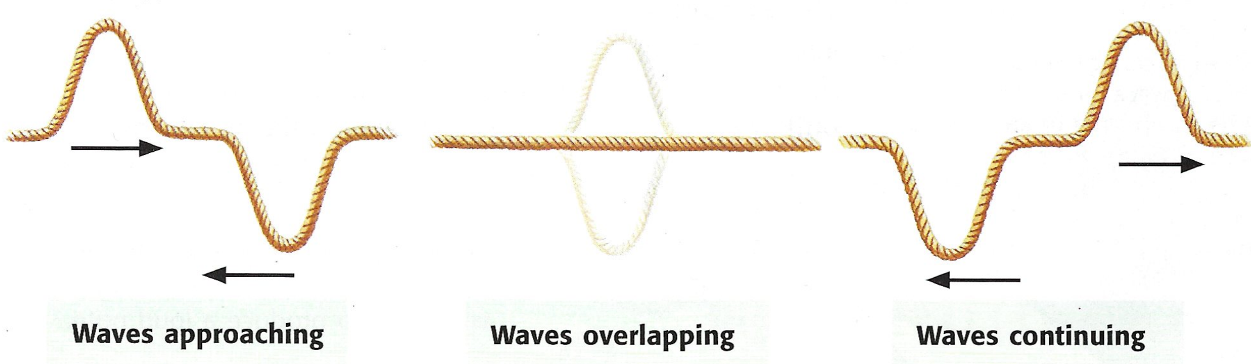
Reading Check How does constructive interference happen?

Figure 4 Constructive and Destructive Interference

Constructive Interference When waves combine by constructive interference, the combined wave has a larger amplitude.



Destructive Interference When two waves with the same amplitude combine by destructive interference, they cancel each other out.



Destructive Interference

Destructive interference happens when the crests of one wave and the troughs of another wave overlap. The new wave has a smaller amplitude than the original waves had. When the waves involved in destructive interference have the same amplitude and meet each other at just the right time, the result is no wave at all.

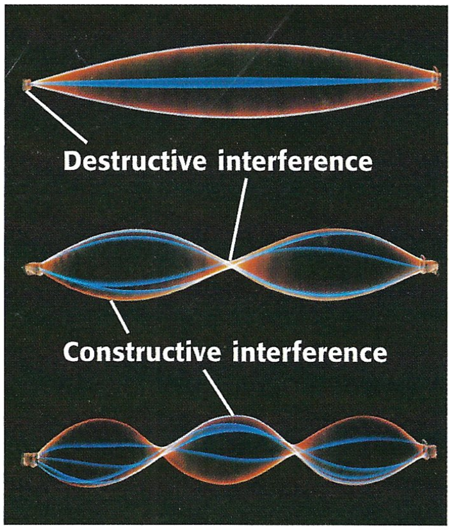


Figure 5 *When you move a rope at certain frequencies, you can create different standing waves.*

Standing Waves

If you tie one end of a rope to the back of a chair and move the other end up and down, the waves you make go down the rope and are reflected back. If you move the rope at certain frequencies, the rope appears to vibrate in loops, as shown in **Figure 5.** The loops come from the interference between the wave you made and the reflected wave. The resulting wave is called a **standing wave.** In a standing wave, certain parts of the wave are always at the rest position because of total destructive interference between all the waves. Other parts have a large amplitude because of constructive interference.

A standing wave only *looks* as if it is standing still. Waves are actually going in both directions. Standing waves can be formed with transverse waves, such as when a musician plucks a guitar string, as well as with longitudinal waves.

✓ **Reading Check** **How can interference and reflection cause standing waves?**

Figure 6 *A marimba produces notes through the resonance of air columns.*

Resonance

The frequencies at which standing waves are made are called *resonant frequencies.* When an object vibrating at or near the resonant frequency of a second object causes the second object to vibrate, **resonance** occurs. A resonating object absorbs energy from the vibrating object and vibrates, too. An example of resonance is shown in **Figure 6** on the previous page.

You may be familiar with another example of resonance at home—in your shower. When you sing in the shower, certain frequencies create standing waves in the air that fills the shower stall. The air resonates in much the same way that the air column in a marimba does. The amplitude of the sound waves becomes greater. So your voice sounds much louder.

standing wave a pattern of vibration that simulates a wave that is standing still

resonance a phenomenon that occurs when two objects naturally vibrate at the same frequency; the sound produced by one object causes the other object to vibrate

SECTION Review

Summary

- Waves reflect after hitting a barrier.
- Refraction is the bending of a wave when it passes through different media.
- Waves bend around barriers or through openings during diffraction.
- The result of two or more waves overlapping is called interference.
- Amplitude increases during constructive interference and decreases during destructive interference.
- Resonance occurs when a vibrating object causes another object to vibrate at one of its resonant frequencies.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

refraction	reflection
diffraction	interference

1. ___ happens when a wave passes from one medium to another at an angle.
2. The bending of a wave around a barrier is called ___.
3. We can see the moon because of the ___ of sunlight off it.

Understanding Key Ideas

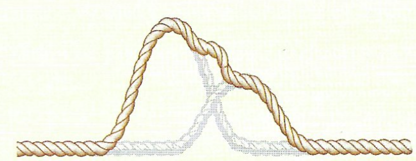
4. The combining of waves as they overlap is known as
   a. interference.
   b. diffraction.
   c. refraction.
   d. resonance.
5. Name two wave interactions that can occur when a wave encounters a barrier.
6. Explain why you can hear two people talking even after they walk around a corner.
7. Explain what happens when two waves encounter one another in destructive interference.

Critical Thinking

8. **Making Inferences** Sometimes, when music is played loudly, you can feel your body shake. Explain what is happening in terms of resonance.
9. **Applying Concepts** How could two waves on a rope interfere so that the rope did not move at all?

Interpreting Graphics

10. In the image below, what sort of wave interaction is happening?



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Chapter Review

USING KEY TERMS

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

1. *longitudinal wave* and *transverse wave*
2. *wavelength* and *amplitude*
3. *reflection* and *refraction*

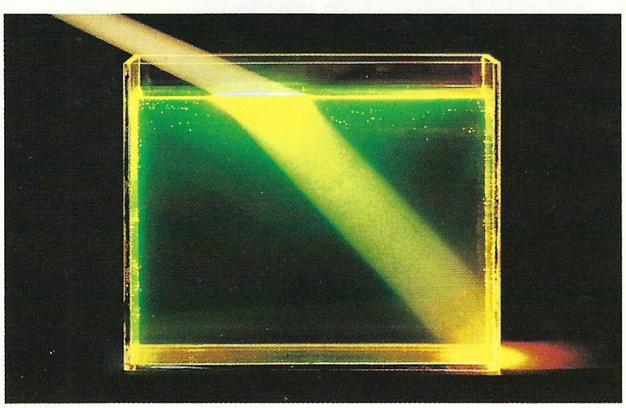
UNDERSTANDING KEY IDEAS

Multiple Choice

4. As the wavelength increases, the frequency
   a. decreases.
   b. increases.
   c. remains the same.
   d. increases and then decreases.

5. Waves transfer
   a. matter.
   b. energy.
   c. particles.
   d. water.

6. Refraction occurs when a wave enters a new medium at an angle because
   a. the frequency changes.
   b. the amplitude changes.
   c. the wave speed changes.
   d. None of the above



7. The wave property that is related to the height of a wave is the
   a. wavelength.
   b. amplitude.
   c. frequency.
   d. wave speed.

8. During constructive interference,
   a. the amplitude increases.
   b. the frequency decreases.
   c. the wave speed increases.
   d. All of the above

9. Waves that don't require a medium are
   a. longitudinal waves.
   b. electromagnetic waves.
   c. surface waves.
   d. mechanical waves.

Short Answer

10. Draw a transverse wave and a longitudinal wave. Label a crest, a trough, a compression, a rarefaction, and wavelengths. Also, label the amplitude on the transverse wave.

11. What is the relationship between frequency, wave speed, and wavelength?

Math Skills

12. A fisherman in a row boat notices that one wave crest passes his fishing line every 5 s. He estimates the distance between the crests to be 1.5 m and estimates that the crests of the waves are 0.5 m above the troughs. Using this data, determine the amplitude and speed of the waves.

CRITICAL THINKING

13 **Concept Mapping** Use the following terms to create a concept map: *wave, refraction, transverse wave, longitudinal wave, wavelength, wave speed,* and *diffraction.*

14 **Analyzing Ideas** You have lost the paddles for the canoe you rented, and the canoe has drifted to the center of a pond. You need to get it back to the shore, but you do not want to get wet by swimming in the pond. Your friend suggests that you drop rocks behind the canoe to create waves that will push the canoe toward the shore. Will this solution work? Why or why not?

15 **Applying Concepts** Some opera singers can use their powerful voices to break crystal glasses. To do this, they sing one note very loudly and hold it for a long time. While the opera singer holds the note, the walls of the glass move back and forth until the glass shatters. Explain in terms of resonance how the glass shatters.

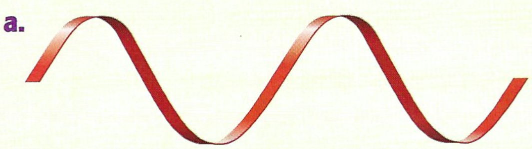
16 **Analyzing Processes** After setting up stereo speakers in your school's music room, you notice that in certain areas of the room, the sound from the speakers is very loud. In other areas, the sound is very soft. Using the concept of interference, explain why the sound levels in the music room vary.

17 **Predicting Consequences** A certain sound wave travels through water with a certain wavelength, frequency, and wave speed. A second sound wave with twice the frequency of the first wave then travels through the same water. What is the second wave's wavelength and wave speed compared to those of the first wave?

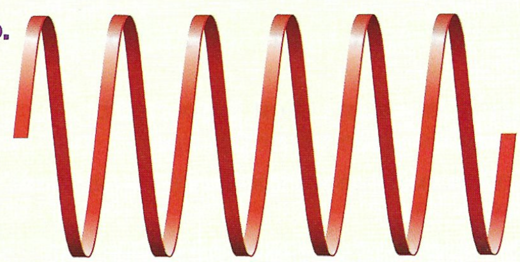
INTERPRETING GRAPHICS

18 Look at the waves below. Rank the waves from highest energy to lowest energy, and explain your reasoning.

a.



b.



c.