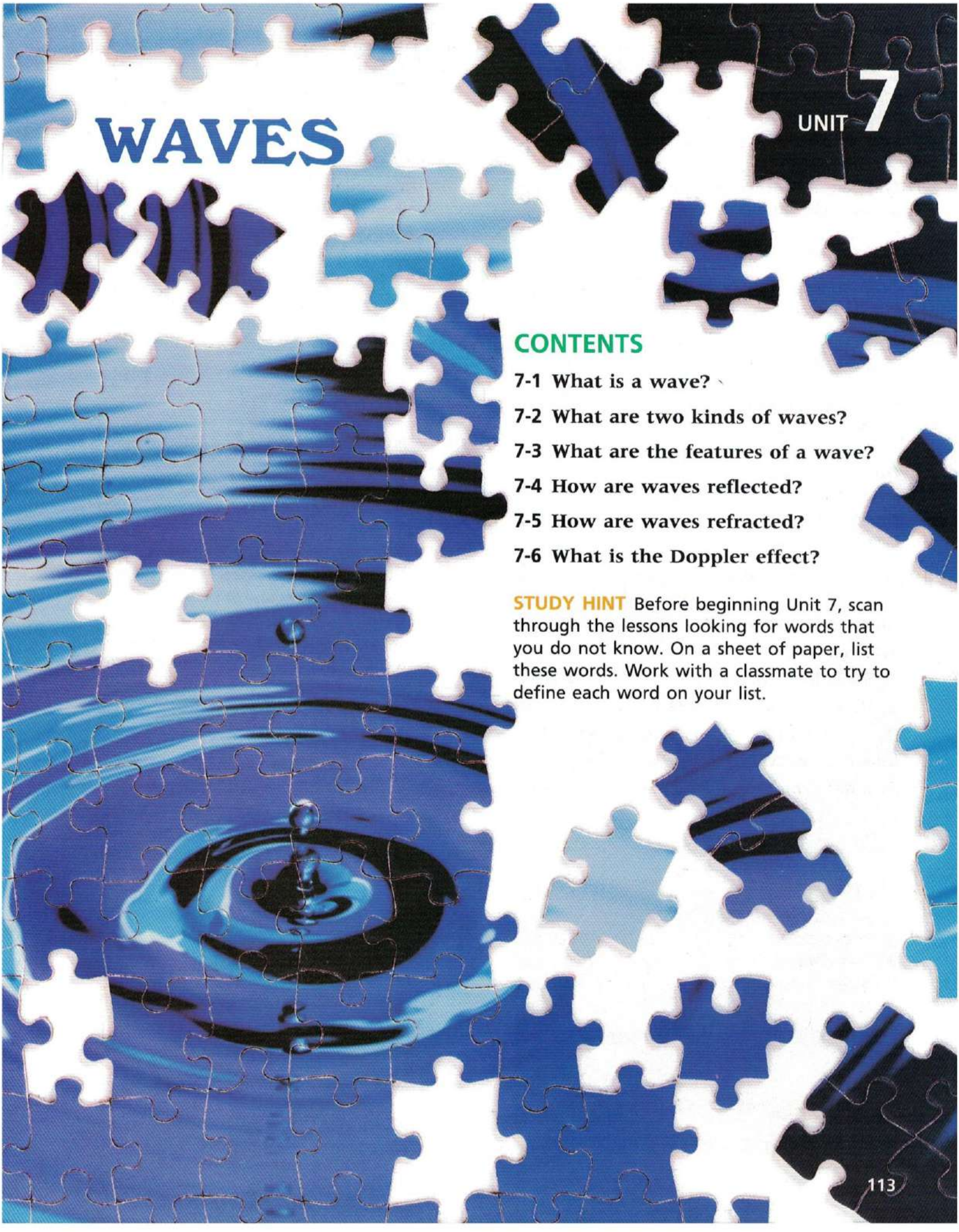


WAVES

UNIT 7

CONTENTS

STUDY HINT Before beginning Unit 7, scan through the lessons looking for words that you do not know. On a sheet of paper, list these words. Work with a classmate to try to define each word on your list.

7-1 What is a wave?

Objective ▸ Identify a wave as energy traveling through a medium.

TechTerms

- **medium:** substance through which waves can travel
- **waves:** disturbances that transfer energy from place to place

Waves and Energy Have you ever seen ocean **waves** crashing on a coastline? Waves are disturbances that transfer energy from place to place. Ocean waves carry energy along the surface of the water. Where does the energy come from? The energy of ocean waves comes from wind moving over the water.

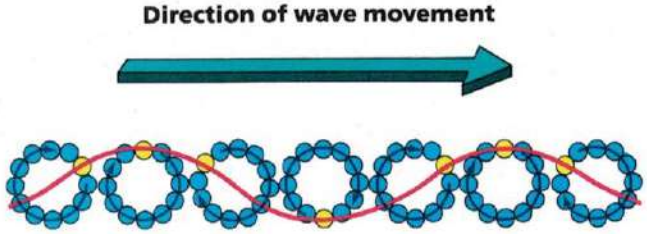
Throw a stone into a still pond. What do you see? Small circular waves move outward along the surface of the pond. When the stone hits the pond, it has kinetic (ki-NET-ik) energy. Kinetic energy is energy of motion. Some of the stone's kinetic energy is transmitted to the water particles. The energy causes the particles to move. This movement produces a wave. The wave carries the energy across the surface of the pond.

Define: What are waves?

Energy and Matter Water is a **medium** for waves. Any substance through which waves can travel is a medium. Air is a medium for sound waves. Some waves do not need a medium. Light waves can travel through the vacuum of space. When a wave travels through a medium, only energy moves from place to place. The particles of the medium do not move forward with the wave. Think of a cork floating on water. What happens as a wave moves past the cork? The cork moves up and down. It does not move in the same direction as the wave. The wave moves through the water.

State: Do all waves need a medium?

Particles in a Medium When a wave moves through a medium, the particles of the medium move in small circles. The diagram shows a wave moving through water. As the wave goes past, each water particle moves in a small circle. This is why a floating cork bobs up and down as a wave passes. The energy of the wave moves forward. The water does not move forward.



Describe: What happens to water particles as a wave moves through the water?

LESSON SUMMARY

- Waves are disturbances that transfer energy from place to place.
- Any substance through which waves can travel is called a medium.
- The particles of a medium do not move in the same direction as a wave.
- The particles of a medium move in small circles.

CHECK *Complete the following.*

1. Water waves carry _____ .
2. Water is a _____ for waves.
3. The _____ energy of moving particles produces a wave.
4. Some waves, such as _____ waves, do not require a medium.
5. Light waves can travel through a _____ .
6. When a wave moves through a medium, only _____ moves from place to place.

APPLY *Complete the following.*

7. Imagine you are sitting in a rowboat in the middle of a lake. A motorboat passes by, making waves that hit your boat. Describe what happens to your boat.
8. **Infer:** Waves can often be seen moving across fields of wheat. What is the medium for these waves?
9. **Hypothesize:** Earthquakes cause waves to travel through the earth. What is the source of energy for these waves?

Health and Safety Tip

During a hurricane or other large storm, a great deal of energy is carried by ocean waves. Storm waves can cause serious damage when they hit the shore. You should never be anywhere near the shore during a hurricane. Check with your local Red Cross, or use library references, to find out what safety precautions you should take during a hurricane.

LEISURE ACTIVITY

SURFING

Can you "hang ten"? Have you ever "cracked a wave"? These terms are used in surfing. When you hang ten, you hook your toes over the end of a surfboard. To crack a wave means to ride a big wave successfully.

Many people who live near the ocean enjoy the exciting sport of surfing. In surfboard riding, surfers try to catch a big wave and get their boards onto the crest of the wave. The surfers then stand up and try to ride the wave in to shore. Standing on a surfboard on top of a wave requires good balance and quick reflexes. Surfers also must be good swimmers.

Most surfboards used today are made of fiberglass. A surfboard is about 3 m long, 80 cm wide, and 8 cm thick. Surfboards can weigh from about 4 kg to 7 kg.

Surfing began in Hawaii hundreds of years ago. It is now a popular sport all over the world. In the United States, the best waves are found in Hawaii and southern California.

7-3 What are the features of a wave?

Objectives ▸ Describe the features of a wave. ▸ Relate wave speed, frequency, and wavelength.

TechTerms

- **amplitude** (AM-pluh-tood): height of a wave
- **frequency** (FREE-kwun-see): number of complete waves passing a point in a given time
- **hertz** (HURTS): unit used to measure the frequency of a wave
- **wavelength:** distance between two neighboring crests or troughs

Features of Waves All waves have three basic features. These features are amplitude (AM-pluh-tood), wavelength, and frequency (FREE-kwun-see).

- When a wave moves through a medium, the particles of the medium are moved from their rest position. The distance the particles are moved is called the **amplitude,** or height, of the wave.
- All waves have a certain length. The distance from the crest or trough of one wave to the crest or trough of the next wave is the **wavelength.** Wavelength can be measured in meters or centimeters.
- A certain number of waves pass a point in a given amount of time. The number of complete waves per unit time is called the **frequency.** Frequency is measured in waves per second.

The diagram shows the relationship among amplitude, wavelength, and frequency.

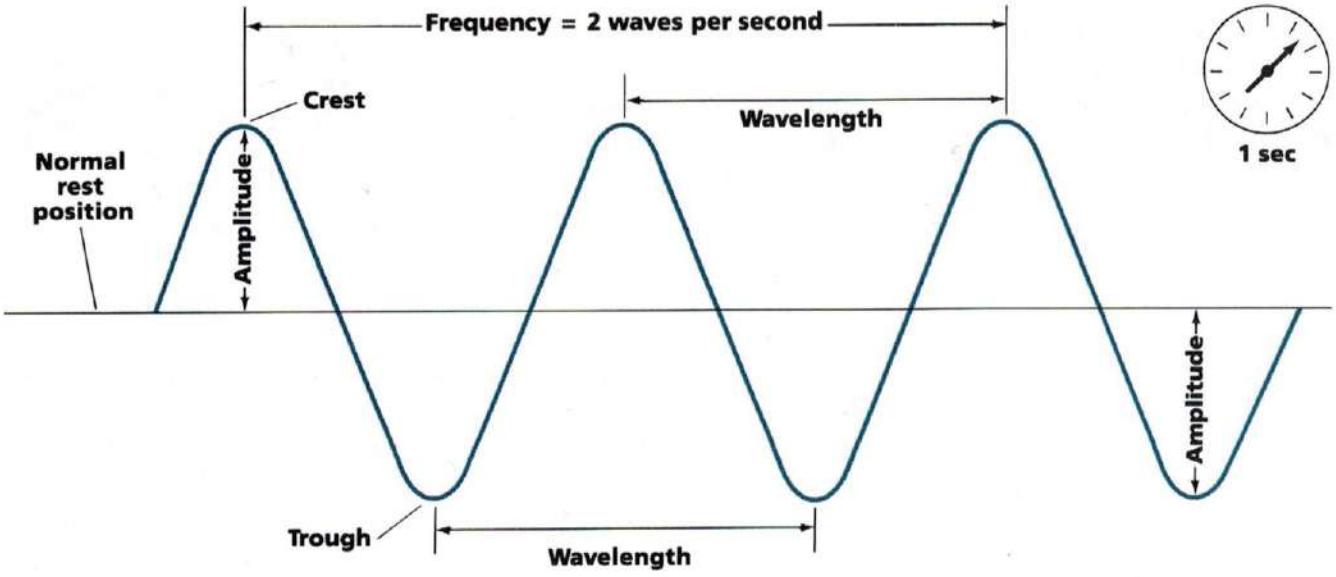
List: What are the three features of a wave?

Speed of a Wave All waves move at a certain speed. The speed of a wave is related to the frequency and wavelength of the wave. Wave speed is equal to the frequency times the wavelength.

speed = frequency × wavelength

Scientists use a unit called a **hertz** (HURTS) to measure frequency. One hertz (Hz) is equal to one wave per second. When frequency is measured in hertz and wavelength is measured in meters, speed is measured in meters per second (m/sec).

Identify: What is the equation used to find the speed of a wave?



LESSON SUMMARY

- All waves have three basic features.
- Amplitude is the height of a wave.
- Wavelength is the distance from crest to crest or from trough to trough.
- Frequency is the number of complete waves passing a point each second.
- The speed of a wave is equal to the frequency times the wavelength.

CHECK *Complete the following.*

1. All waves have amplitude, _____, and frequency.
2. Amplitude is the _____ of a wave.
3. Wavelength can be measured in _____ or centimeters.
4. The number of _____ passing a point in one second is called frequency.
5. The speed of a wave is equal to _____ times wavelength.
6. The _____ is the unit used to measure frequency.
7. One hertz is equal to one _____ per second.

APPLY *Use the equation speed = frequency × wavelength to complete the following.*

8. A wave has a frequency of 50 Hz and a wavelength of 10 m. What is the speed of the wave?
9. The speed of a wave is 5 m/sec. Its wavelength is 2 m. What is the frequency of the wave?
10. The frequency of a wave is 20 Hz. Its speed is 100 m/sec. What is the wavelength of the wave?

InfoSearch

Read the passage. Ask two questions about the topic that you cannot answer from the information in the passage.

Heinrich Hertz The unit used to measure the frequency of waves is named after Heinrich Hertz. Hertz was a German physicist. He discovered electromagnetic waves in the 1880s. He also showed that light waves are the same as electromagnetic waves.

SEARCH: Use library references to find answers to your questions.

ACTIVITY

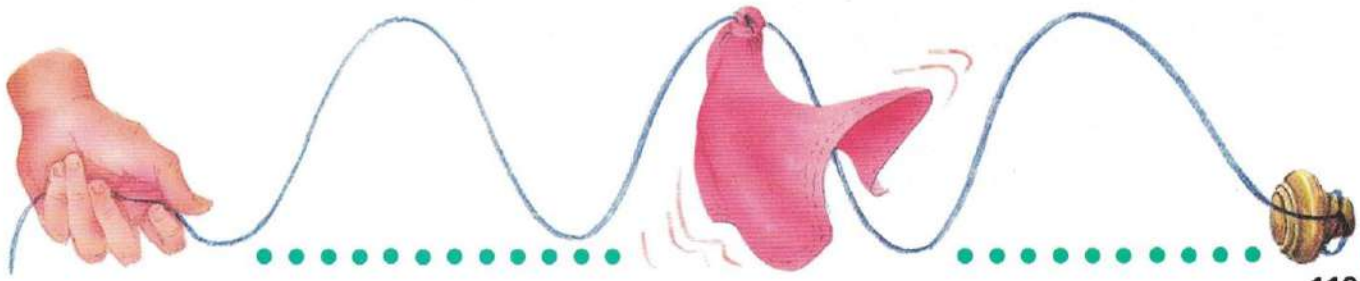
OBSERVING WAVES IN A ROPE

You will need a piece of rope about 3 m long, a ribbon, and a doorknob.

1. Tie a brightly colored ribbon to the middle of a 3-m length of rope.
2. Tie one end of the rope to a doorknob.
3. Hold the other end of the rope and stand opposite the door. Quickly move your end of the rope up and down. Observe the motion of the ribbon.
4. Increase the speed at which you move the end of the rope up and down. Observe the resulting waves in the rope.

Questions

1. What happened to the ribbon when you moved your end of the rope?
2. What kind of waves did you make?
3. **a.** What happened to the frequency of the waves when you increased the speed of your movements? **b.** What happened to the wavelength?



7-4 How are waves reflected?

Objectives ▸ Describe what happens when a wave strikes a barrier. ▸ State the law of reflection.

TechTerms

- **incident wave:** wave that strikes a barrier
- **normal:** line at right angles to a barrier
- **reflected wave:** wave that bounces back from a barrier
- **reflection:** bouncing back of a wave after striking a barrier

Waves and Barriers What happens when a wave hits a barrier? Remember that all waves carry energy. Some of the wave's energy may be absorbed by the barrier. If the barrier does not absorb the wave's energy, the wave bounces back from the barrier. This bouncing back of a wave is called **reflection.**

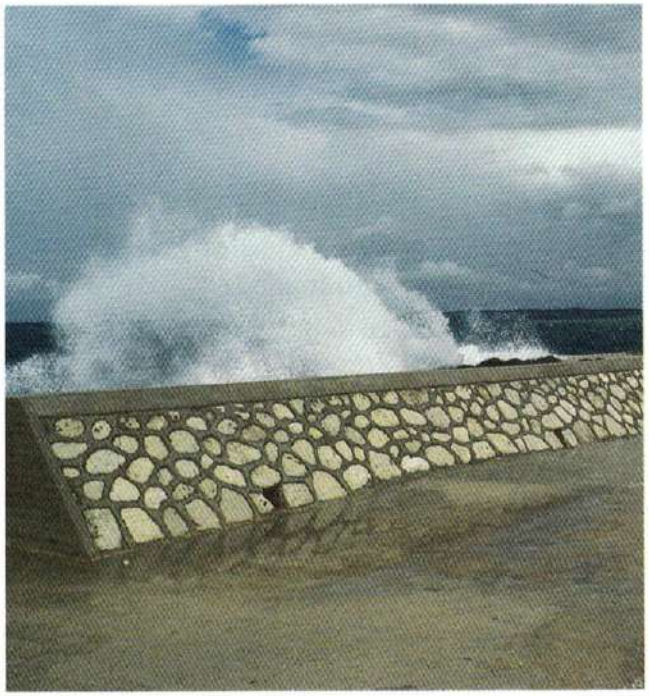


Figure 1

Describe: What happens when a wave strikes a barrier that does not absorb all of its energy?

Reflection Figure 2 shows what happens when a wave strikes a barrier. The arrows show the direction of the wave. The wave that strikes the barrier is called the **incident wave.** The wave that bounces off the barrier is called the **reflected wave.**

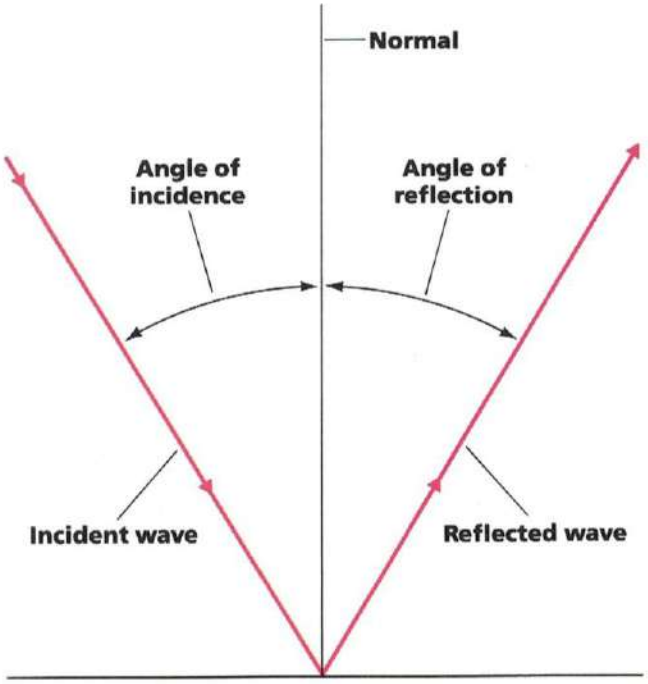


Figure 2
Angle of incidence = Angle of reflection

Define: What is a reflected wave?

Law of Reflection The law of reflection describes what happens when a wave is reflected from a barrier. The angle at which an incident wave strikes a barrier is called the angle of incidence, or i. The angle at which the wave is reflected is called the angle of reflection, or r. These angles are measured from a line called the **normal.** The normal is a line at a right angle to the barrier. A right angle is equal to 90°. The law of reflection states that the angle of incidence is equal to the angle of reflection. Suppose a wave strikes a barrier at a 45° angle. The reflected wave will bounce back from the barrier at a 45° angle.

State: What is the law of reflection?

LESSON SUMMARY

- When a barrier does not absorb a wave's energy, the wave is reflected.
- A wave that strikes a barrier is called the incident wave.
- A wave that bounces back from a barrier is called the reflected wave.
- The law of reflection states that the angle of incidence is equal to the angle of reflection.

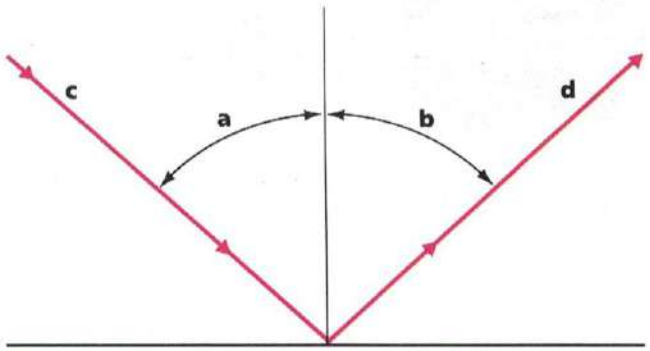
CHECK *Complete the following.*

1. What happens when a wave strikes a barrier?
2. What is reflection?
3. What is a wave that strikes a barrier called?
4. What is a wave that bounces back from a barrier called?
5. What is the normal?
6. What is the angle formed by the normal and the barrier?

APPLY *Complete the following.*

7. **Contrast:** What is the difference between the angle of incidence and the angle of reflection?

Use the diagram to complete the following.



8. Which arrow represents the incident wave?
9. Which arrow represents the reflected wave?
10. Which angle is the angle of incidence?
11. Which angle is the angle of reflection?

Skill Builder

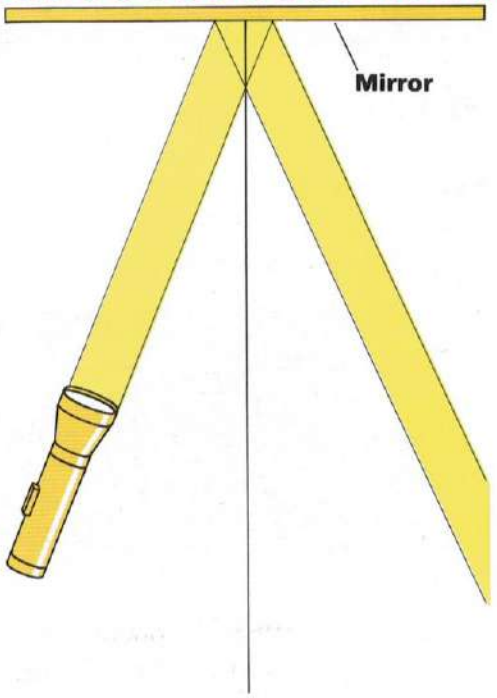
Researching Use library references to find out what standing waves are and how they are formed. Write a report of your findings. Include a diagram of standing waves in a rope.

ACTIVITY

MEASURING THE ANGLE OF INCIDENCE AND ANGLE OF REFLECTION

You will need a flat mirror, a flashlight, a sheet of paper, a protractor, a marking pen, and a ruler.

1. Draw a straight line across a sheet of paper.
2. Place a flat mirror on the paper so that the edge of the mirror is on the line.
3. Shine a flashlight at an angle onto the mirror.
4. Use a marking pen to trace the path of the beam.
5. Remove the flashlight and the mirror. Draw a line at a right angle to the line representing the mirror.
6. Label the angle of incidence and the angle of reflection. Use a protractor to measure the angle of incidence and the angle of reflection.



Questions

1. What is the size of the angle of incidence?
2. What is the size of the angle of reflection?

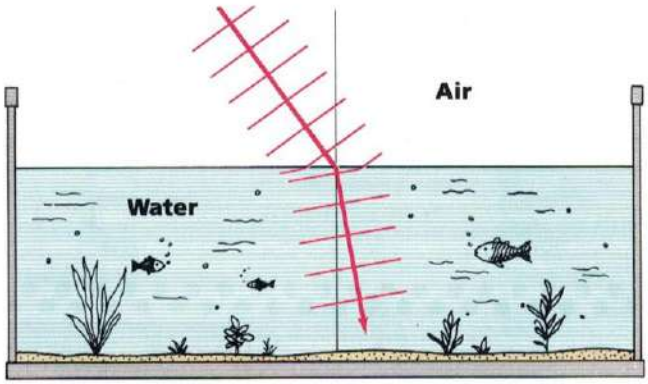
7-5 How are waves refracted?

Objective ▸ Describe what happens to a wave when it moves from one medium to another.

TechTerm

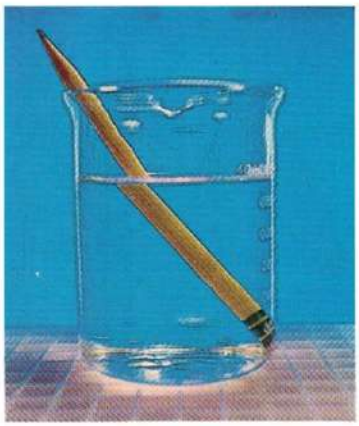
- **refraction:** bending of a wave as it moves from one medium to another

Changing the Medium Waves travel in straight lines through a medium. What happens to a wave when it moves from one medium to another? Suppose a wave moves from air into water. If the wave enters the water at an angle, the wave bends. This bending of a wave as it moves from one medium to another is called **refraction.**



Define: What is refraction?

Refraction and Wave Speed Waves bend when they go from one medium to another because they change speed. Water is denser than air.

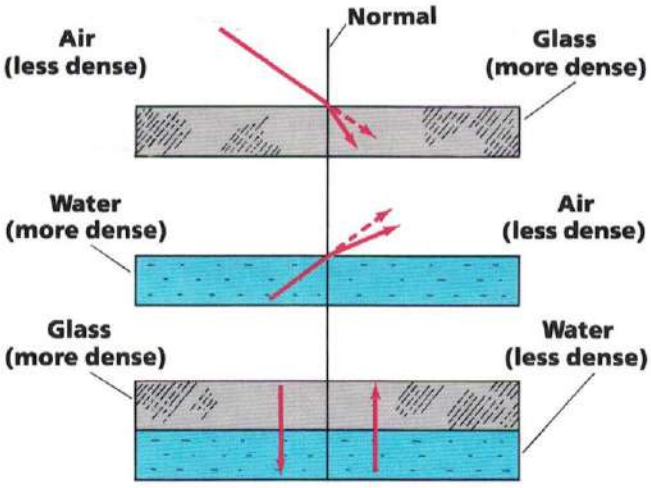


When a light wave moves from air into water, it slows down. When a light wave moves from water into air, it speeds up. This change in speed causes the wave to be refracted, or bent.

You can see the results of refraction by performing a simple experiment. Place a pencil into a glass of water at an angle. The pencil appears to be broken where it enters the water. As light waves move from air into water, they slow down. This change in speed causes the light waves to bend. As a result, the pencil appears broken.

Explain: What causes refraction as waves move from one medium to another?

Laws of Refraction The three laws of refraction describe how waves are refracted when they move from one medium to another.



- When a wave moves at an angle from a less dense medium to a more dense medium, it is bent toward the normal.
- When a wave moves at an angle from a more dense medium to a less dense medium, it is bent away from the normal.
- When a wave moves from one medium to another along the normal, it is not bent.

Describe: In what direction is a wave bent when it moves at an angle from a more dense medium to a less dense medium?

7-6 What is the Doppler effect?

Objective ▸ Explain what is meant by the Doppler effect.

TechTerm

- **Doppler effect:** apparent change in the frequency of waves

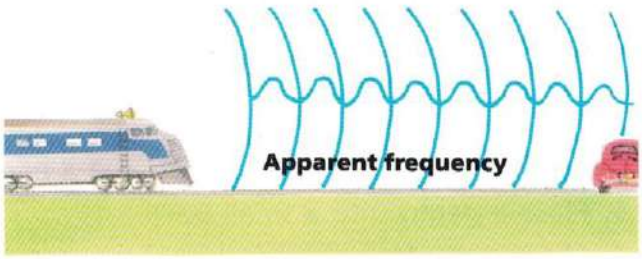
Changing Frequency The frequency of a wave can sometimes appear to change. Remember that frequency is the number of complete waves that pass a point each second. Frequency seems to change when a wave source moves toward you or away from you. Imagine you are sitting on a dock. You can count the number of waves hitting the dock. As a motorboat comes toward you, many waves hit the dock. The frequency of the waves is high. As the boat heads away from the dock, fewer waves hit the dock. The frequency of the waves is low.

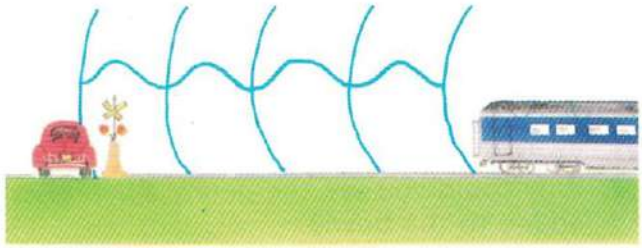
Compare: Will you be able to count more waves when a boat is approaching or heading away from a dock?

Doppler Effect An apparent change in the frequency of waves is called the **Doppler effect.** The Doppler effect occurs when there is relative motion between the source of the waves and an observer. The frequency of waves appears to change when the observer is moving toward or away from the source of the waves. The frequency also seems to change when the source of the waves is moving and the observer is standing still. For the Doppler effect to take place, either the source or the observer must be moving.

Define: What is the Doppler effect?

Doppler Effect and Sound You are probably most familiar with the Doppler effect in sound waves. The frequency of sound waves changes as the source of the waves moves toward or away from you. Suppose you are waiting for a train to pass a crossing. You can hear the train whistle as the train approaches the crossing. The waves are pushed close together by the moving train. Many waves per second reach your ears. The sound waves appear to have a high frequency. As the train passes you, the sound waves spread out. Fewer waves reach your ears each second. The frequency of the waves appears to be lower.





Compare: Is the frequency of sound waves from a train whistle high or low as the train comes toward you?

LESSON SUMMARY

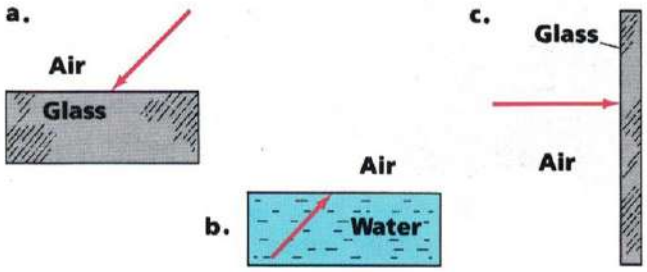
- Waves are bent when they move at an angle from one medium to another.
- The bending, or refraction, of waves is caused by a change in wave speed.
- The laws of refraction describe how waves are refracted when they move from one medium to another.

CHECK *Complete the following.*

1. Waves travel through a medium in- _____ lines.
2. When a wave moves from one medium to another at an angle, it _____ .
3. The bending of a wave is called _____ .
4. Refraction is caused by a change in _____ .
5. The speed of a light wave _____ when it moves from water into air.
6. When a wave moves at an angle from a less dense medium to a more dense medium, it is bent _____ the normal.

APPLY *Complete the following.*

7. **Analyze:** Copy the diagrams onto a separate sheet of paper. Draw arrows to show how the light waves will be refracted in each example.



8. **Hypothesize:** Have you ever tried to pick up a seashell under water? Why do you think the seashell appeared closer to the surface of the water than it really was?

InfoSearch

Read the passage. Ask two questions about the topic that you cannot answer from the information in the passage.

Ocean Waves Ocean waves change direction as they come close to a shoreline. Waves almost always approach the shore at an angle. However, they usually hit the shore straight on. The speed of waves is slower in shallow water. As waves approach the shallow water near shore, they slow down. This change in speed causes the waves to change direction.

SEARCH: Use library references to find answers to your questions.

ACTIVITY

OBSERVING THE EFFECTS OF REFRACTION

You will need a small bowl, water, and a penny.

1. Place a penny into a small bowl.
2. Move away from the bowl until you can no longer see the penny.
3. Without changing your position, have a partner add water to the bowl until you can see the penny again.

Questions

1. Why could you not see the penny when you moved away from the bowl?
2. Why could you see the penny again after water was added to the bowl?
3. Draw a diagram showing how light waves reflected from the penny were refracted as they moved from the water into the air.

LESSON SUMMARY

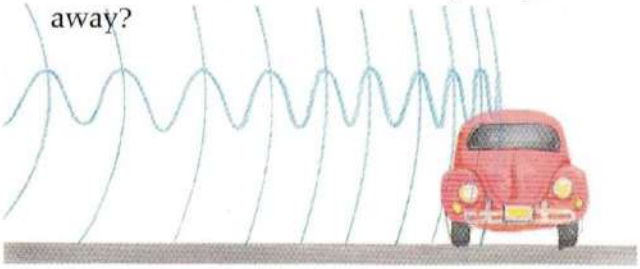
- The frequency of waves can sometimes appear to change.
- The Doppler effect is caused by motion of the observer or the source of the waves.
- The frequency of sound waves changes as the source of the waves moves toward or away from you.

CHECK *Complete the following.*

1. The apparent change in the frequency of waves is called the _____ .
2. Waves hit a dock more often when a boat is moving _____ the dock.
3. The Doppler effect is caused by _____ .
4. The frequency of waves appears to change when either the source of the waves or the _____ is moving.
5. The frequency of sound waves is _____ when the source of the waves is moving away from you.
6. As a boat comes toward you, the frequency of the water waves appears _____ than if the boat was moving away from you.

APPLY *Complete the following.*

7. Describe how the sound of a car horn changes as the car approaches and then passes you.
8. **Predict:** Suppose you are driving by a fire station. An alarm is ringing at the station. How will the alarm sound as you approach the station? How will the sound change as you drive away?



Ideas in Action

IDEA: Many police forces use Doppler radar to measure the speed of passing cars.

ACTION: Visit your local police station. Find out how Doppler radar works. How do radar detectors in cars work? How is Doppler radar used to track the path of fast-moving storms? What are other uses of Doppler radar? Describe your findings to the class.

SCIENCE CONNECTION

RED SHIFT

Astronomers study the wavelength of light from the stars to find out about the universe. The wavelength of light determines the color of the light. Red light has a long wavelength. Blue light has a short wavelength.

The Doppler effect causes an apparent change in the frequency of a wave. It also causes an apparent change in wavelength. If a light source is moving away from an observer, the wavelength of the light appears to change. The light appears redder than it would if the source were not moving. This change in wavelength is called the red shift.

Astronomers studied the red shifts of many different galaxies. They found that all of the galaxies are moving away from the earth. Each galaxy is also moving away from every other galaxy. This means that the universe is expanding, or getting bigger. Think of a raisin in a cake. As the cake bakes, it expands. Each raisin moves away from every other raisin.

UNIT 7 Challenges

STUDY HINT Before you begin the Unit Challenges, review the TechTerms and Lesson Summary for each lesson in this unit.

TechTerms

amplitude (118)
compression (116)
crest (116)
Doppler effect (124)
frequency (118)
hertz (118)
incident wave (120)
longitudinal wave (116)
medium (114)
normal (120)
rarefaction (116)
reflected wave (120)
reflection (120)
refraction (122)
transverse wave (116)
trough (116)
wavelength (118)
waves (114)

TechTerm Challenges

Matching *Write the TechTerm that matches each description.*

1. substance through which waves can travel
2. high point of a wave
3. height of a wave
4. unit used to measure frequency
5. wave that strikes a barrier
6. apparent change in frequency
7. line at 90° to a barrier
8. disturbances in a medium

Applying Definitions *Explain the difference between the words in each pair. Write your answers in complete sentences.*

1. compression, rarefaction
2. longitudinal wave, transverse wave
3. crest, trough
4. frequency, wavelength
5. reflected wave, incident wave
6. reflection, refraction

Content Challenges

Multiple Choice *Write the letter of the term or phrase that best completes each statement.*

1. Waves are caused by
   a. potential energy. **b.** kinetic energy. **c.** heat energy. **d.** nuclear energy.
2. Sound waves cannot travel through
   a. air. **b.** water. **c.** metal. **d.** space.
3. When a transverse wave moves through a medium, the particles of the medium move
   a. in circles. **b.** up and down. **c.** forward. **d.** backward.
4. The two kinds of waves are transverse and
   a. circular. **b.** normal. **c.** longitudinal. **d.** compression.
5. The crest of a wave is the wave's
   a. low point. **b.** length. **c.** speed. **d.** high point.
6. In a transverse wave, the particles of the medium move
   a. up and down. **b.** back and forth. **c.** forward. **d.** backward.

7. In a rarefaction, the particles are
   a. squeezed together. **b.** lined up. **c.** spread apart. **d.** not moving.
8. Wavelength can be measured in
   a. meters. **b.** hertz. **c.** angles. **d.** number of waves.
9. The speed of a wave is equal to the frequency of the wave times the
   a. amplitude. **b.** wavelength. **c.** height. **d.** medium.
10. The angle between the normal and a barrier is equal to
    a. 45°. **b.** 90°. **c.** 180°. **d.** 360°.
11. The angle of incidence is equal to the angle of
    a. refraction. **b.** compression. **c.** rarefaction. **d.** reflection.
12. When a wave is refracted it is
    a. bent. **b.** bounced back. **c.** compressed. **d.** spread apart.
13. A wave is refracted when its
    a. amplitude changes. **b.** frequency changes. **c.** speed changes. **d.** wavelength changes.
14. The Doppler effect is an apparent change in a wave's
    a. speed. **b.** medium. **c.** amplitude. **d.** frequency.

Completion *Write the term that best completes each statement.*

1. Waves transfer _____ from place to place.
2. Most waves travel through a substance called a _____ .
3. There are _____ kinds of waves.
4. In a transverse wave, the particles of the medium move _____ .
5. In a longitudinal wave, the particles of the medium move _____ .
6. The two parts of a longitudinal wave are the _____ and the rarefaction.
7. A thunder clap is an example of a _____ wave.
8. The basic features of all waves are _____ , wavelength, and frequency.
9. Frequency is measured in waves per second, or _____ .
10. A wave is refracted when a barrier does not _____ all of its energy.
11. The angle at which a wave strikes a barrier is the angle of _____ .
12. Waves are refracted when they move from one _____ into another.
13. There are _____ laws of refraction.
14. Frequency is the number of complete _____ that pass a point each second.

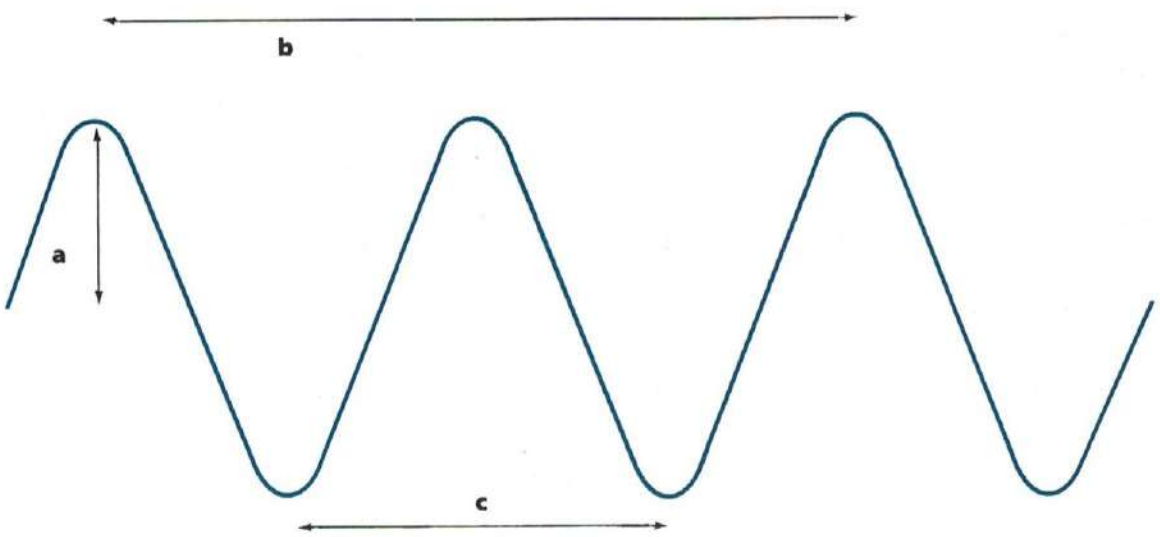
Understanding the Features

Reading Critically *Use the feature reading selections to answer the following. Page numbers for the features are shown in parentheses.*

1. **Infer:** Why must surfers be good swimmers in addition to having good balance and quick reflexes? (113)
2. What did astronomers learn by studying the red shifts of different galaxies? (123)
3. How many different kinds of earthquake waves are there? What are they called? (115)

Concept Challenges

Interpreting a Diagram *Use the diagram to answer the following.*



1. Which letter represents the wavelength of the wave?
2. Which letter represents the amplitude?
3. Which letter represents the frequency?
4. What is the relationship between speed, wavelength, and frequency?
5. If the frequency of a wave increases, and the speed stays the same, what happens to the wavelength?
6. If the speed of a wave does not change, but the wavelength increases, what happens to the frequency?

Critical Thinking *Answer each of the following in complete sentences.*

1. **Hypothesize:** You can make transverse waves in a rope tied to a doorknob. What happens to the waves when they reach the door?
2. **Compare:** How are the crests and troughs of a transverse wave like the compressions and rarefactions of a longitudinal wave?
3. **Hypothesize:** Suppose that light waves needed a medium to travel through. How do you think the world would be different?

Finding Out More

1. Try this at home. Fill a fish tank with water. Add some food coloring to the water. Cut a thin slit in a piece of cardboard. Tape the cardboard over the front end of a flashlight. Shine a beam of light at an angle into the water. Then shine the beam of light straight down into the water. Describe what happens to the beam of light in each case. Explain your observations based on what you learned in this unit.
2. Use library references to find out about the three types of earthquake waves. What kind of waves are they? How does studying earthquake waves help scientists learn more about earthquakes? Write a report of your findings.