Section 2 Properties of Sound

Objectives

After this lesson, students will be able to

O.2.2.1 Identify factors that affect the loudness of sound.

O.2.2.2 State what the pitch of a sound depends on.

O.2.2.3 Explain what causes the Doppler effect.

Target Reading Skill

Outlining Explain that using an outline format helps students organize information by main topic, subtopic, and details.

Answers

Properties of Sound

- I. Loudness
  - A. Energy of a sound source
  - B. Distance from a sound source
  - C. Measuring loudness
- II. Pitch
  - A. Pitch and frequency
  - B. Changing pitch
- III. Doppler effect
  - A. What causes the Doppler effect?
  - B. What causes shock waves?

All in One Teaching Resources

- Transparency O19

Preteach

Build Background Knowledge L2

Experience With Loudness

Ask: **Which is louder, the sound of a whisper in your ear or the sound of a distant airplane in the sky?** *(Students may say the whisper is louder.)* Explain that distance from the sound source is one factor that affects the loudness of sound. State that loudness is one of the properties of sound students will learn about in this section.

Section 2 Properties of Sound

Reading Preview

Key Concepts

- What factors affect the loudness of a sound?
- What does the pitch of a sound depend on?
- What causes the Doppler effect?

Key Terms

- loudness • intensity
- decibel (dB) • pitch
- ultrasound • infrasound
- larynx • Doppler effect

Target Reading Skill

Outlining An outline shows the relationship between main ideas and supporting ideas. As you read, make an outline about the properties of sound. Use the red headings for the main ideas and the blue headings for the supporting ideas.

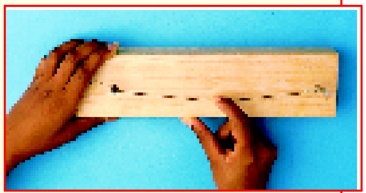
Properties of Sound

I. Loudness
  A. Energy of a sound source
  B.
  C.
II. Pitch
  A.

Lab zone Discover Activity

How Does Amplitude Affect Loudness?

1. Your teacher will give you a wooden board with two nails in it. Attach a guitar string to the nails by wrapping each end tightly around a nail and tying a knot.
2. Hold the string near the middle. Pull it about 1 cm to one side. This distance is the amplitude of vibration. Let it go. How far does the string move to the other side? Describe the sound you hear.



3. Repeat Step 2 four more times. Each time, pull the string back a greater distance. Describe how the sound changes each time.

Think It Over

Forming Operational Definitions How would you define the amplitude of the vibration? What effect did changing the amplitude have on the sound?

Suppose that you and a friend are talking on a sidewalk and a noisy truck pulls up next to you and stops, leaving its motor running. What would you do? You might talk louder, almost shout, so your friend can hear you. You might lean closer and speak into your friend's ear so you don't have to raise your voice. Or you might walk away from the noisy truck so it's not as loud.

Loudness

Loudness is an important property of sound. **Loudness** describes your perception of the energy of a sound. In other words, loudness describes what you hear. You probably already know a lot about loudness. For example, you know that your voice is much louder when you shout than when you speak softly. The closer you are to a sound, the louder it is. Also, a whisper in your ear can be just as loud as a shout from a block away. **The loudness of a sound depends on two factors: the amount of energy it takes to make the sound and the distance from the source of the sound.**

Lab zone Discover Activity

Skills Focus Forming operational definitions

Materials wooden board, two nails, guitar string

Time 10 minutes

Tips Pound two nails into the board and wrap the guitar string tightly and securely around them, as shown in the picture.

L2 Have students use graph paper or a metric ruler to measure amplitude.

Expected Outcome The farther the string is pulled, the louder the sound.

Think It Over The amplitude of a vibration is the distance that the string moves to either side of its resting position. As amplitude increased, the sound became louder.

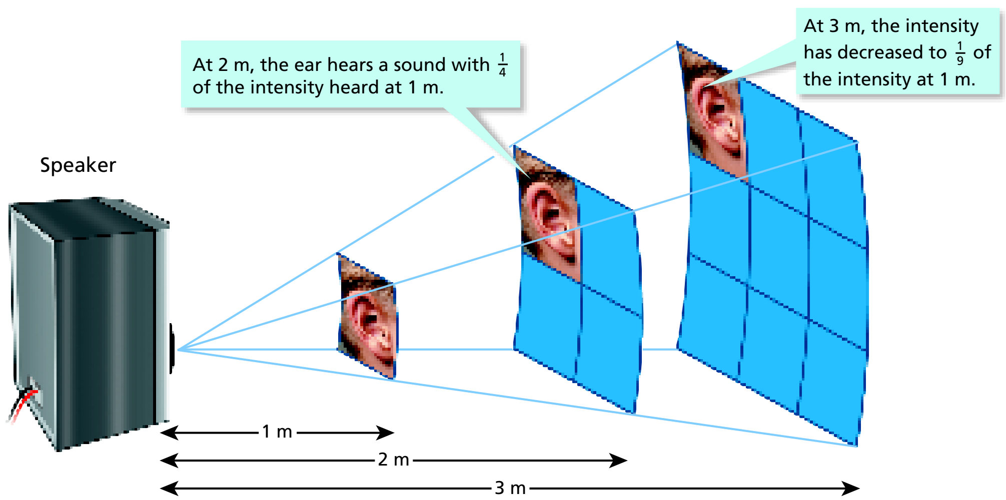
Energy of a Sound Source In general, the greater the energy used to make a sound, the louder the sound. If you did the Discover activity, you may have noticed this. The more energy you used to pull the guitar string back, the louder the sound when you let the string go. This happened because the more energy you used to pull the string, the greater the amplitude of the string's vibration. A string vibrating with a large amplitude produces a sound wave with a large amplitude. Recall that the greater the amplitude of a wave, the more energy the wave has. So, the larger the amplitude of the sound wave, the more energy it has and the louder it sounds.

Distance From a Sound Source If your friend is speaking in a normal voice and you lean in closer, your friend's voice sounds louder. Loudness increases the closer you are to a sound source. But why?

Imagine ripples spreading out in circles after you toss a pebble into a pond. In a similar way, a sound wave spreads out from its source. Close to the sound source, the sound wave covers a small area, as you can see in Figure 8. As the wave travels away from its source, it covers more area. The total energy of the wave, however, stays the same whether it is close to the source or far from it. Therefore, the closer the sound wave is to its source, the more energy it has in a given area. The amount of energy a sound wave carries per second through a unit area is its **intensity.** A sound wave of greater intensity sounds louder. As you move away from a sound source, loudness decreases because the intensity decreases.

Go Online PHSchool.com
For: More on the properties of sound
Visit: PHSchool.com
Web Code: cgd-5022

FIGURE 8
Intensity and Distance
Because sound waves spread out, intensity decreases with distance from the source.
Interpreting Diagrams *How does the intensity at 3 meters compare to the intensity at 2 meters?*



Instruct

Loudness

Teach Key Concepts L2

Loudness and Energy

Focus Introduce loudness as the perception of the energy in sound.

Teach Ask: **What are some things that sound loud?** *(Sample answer: Fans shouting at a basketball game)* **What are some things that sound soft?** *(Sample answer: Falling leaves)* Point out how the loud sounds are associated with more energy.

Apply Ask: **How are loudness and energy related?** *(The greater the energy of the sound source, the louder the sound.)* **learning modality: verbal**

Go Online PHSchool.com
For: More on the properties of sound
Visit: PHSchool.com
Web Code: cgd-5022
Students can review properties of sound in an online interactivity.

All in One Teaching Resources
- Transparency O20

Independent Practice L2

All in One Teaching Resources
- Guided Reading and Study Worksheet: *Properties of Sound*

Student Edition on Audio CD

Differentiated Instruction

Less Proficient Readers L1
Identifying Supporting Ideas Have students listen to this section on the **Student Edition on Audio CD.** As they listen, they can identify supporting ideas and add them under the appropriate headings and subheadings in their section outline. **learning modality: verbal**

Gifted and Talented L3
Researching Decibel Ratings Challenge students to research the decibel ratings of several sounds other than those listed in Figure 9. Examples might include tornado sirens and car horns. Tell students to add the sounds and their decibel ratings to an expanded table, based on Figure 9. Make copies of the table to share with the class. **learning modality: visual**

Monitor Progress L2

Writing Have students describe how energy and distance are related to the loudness of sound.

Answer
Figure 8 The intensity at 3 m is a little less than half the intensity at 2 m.

Build Inquiry L2

Modeling Sound Intensity and Distance

Materials 14 index cards, 108 grains of rice

Time 15 minutes

Focus Point out how sound intensity and distance are related in Figure 8.

Teach Have students use the materials to model the relationship shown in the figure. *(Sets of 1, 4, and 9 index cards can represent the area the sound waves cover at increasing distances from the sound source. An equal number of grains of rice (36) spread out over each set of cards can represent the energy of sound, which stays the same at each distance from the source but becomes more spread out.)*

Apply Ask students to explain which parts of their model represent energy and which parts represent area. **learning modality: kinesthetic**

Integrating Health Science L2

Many students use headphones to listen to music. Tell them that using headphones at high volume can be as damaging to their ears as listening to the roar of a chain saw. Add that a common symptom of hearing damage is ringing in the ears, which is called *tinnitus*. Tinnitus is thought to be due to signals from the brain that are sent out in response to damage to the nerves and structures of the ear. **learning modality: verbal**

Pitch

Teach Key Concepts L2

Pitch and Frequency

Focus Remind students that the frequency of a wave is the number of vibrations that occur per second.

Teach State that the frequency of a sound wave determines how high or low it is. Ask: **What do you call how high or low a sound is?** *(Its pitch)* Explain that high frequencies produce high-pitch sounds and low frequencies produce low-pitch sounds.

Apply Have a volunteer sing a high note followed by a low note. Ask: **Which note was caused by a higher frequency sound wave?** *(The higher-pitch note)* **learning modality: verbal**

Measuring Loudness

Sound	Loudness (dB)
Rustling leaves	10
Whisper	15–20
Very soft music	20–30
Normal conversation	40–50
Heavy street traffic	60–70
Loud music	90–100
Rock concert	110–120
Jackhammer	120
Jet plane at takeoff	120–160

FIGURE 9
Some sounds are so soft that you can barely hear them. Others are so loud that they can damage your ears. **Interpreting Data** *Which sounds louder, a rock concert or a jet plane at takeoff?*

Measuring Loudness The loudness of different sounds is compared using a unit called the **decibel (dB).** Figure 9 shows the loudness of some familiar sounds. The loudness of a sound you can barely hear is about 0 dB. Each 10-dB increase in loudness represents a tenfold increase in the intensity of the sound. For example, soft music at 30 dB sounds ten times louder than a 20-dB whisper. The 30-dB music is 100 times louder than the 10-dB sound of rustling leaves. Sounds louder than 100 dB can cause damage to your ears, especially if you listen to those sounds for long periods of time.

Reading Checkpoint **What is a decibel?**

Pitch

Pitch is another property of sound you may already know a lot about. Have you ever described someone's voice as "high-pitched" or "low-pitched?" The **pitch** of a sound is a description of how high or low the sound seems to a person. **The pitch of a sound that you hear depends on the frequency of the sound wave.**

Pitch and Frequency Sound waves with a high frequency have a high pitch. Sound waves with a low frequency have a low pitch. Frequency is measured in hertz (Hz). For example, a frequency of 50 Hz means 50 vibrations per second. Look at Figure 10. A bass singer can produce frequencies lower than 80 Hz. A trained soprano voice can produce frequencies higher than 1,000 Hz.

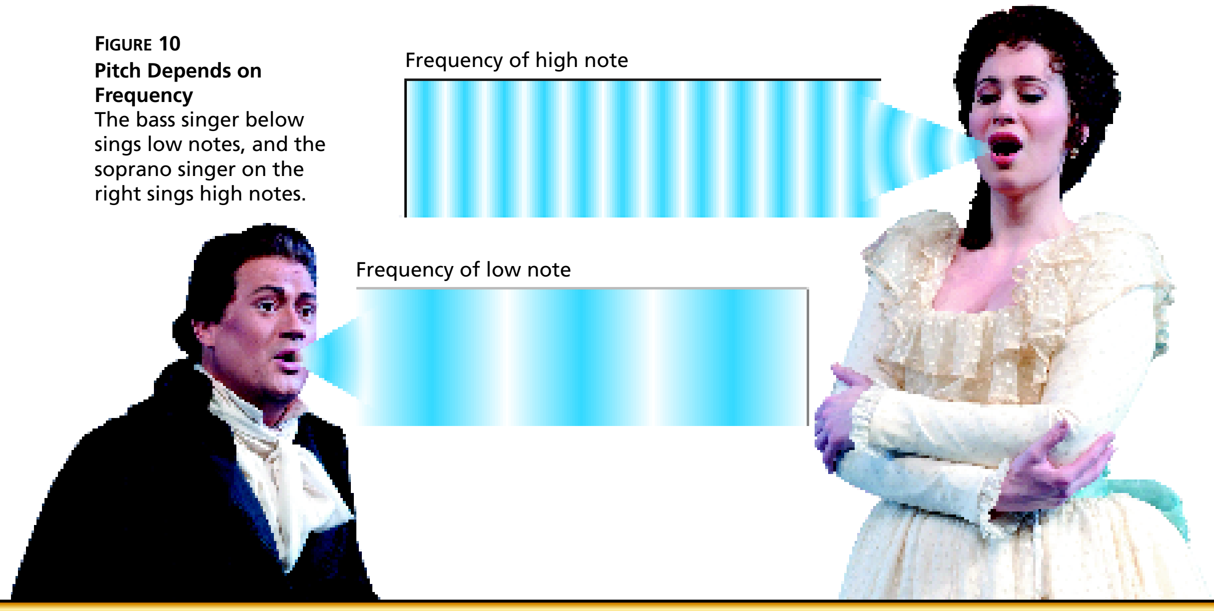


FIGURE 10
Pitch Depends on Frequency
The bass singer below sings low notes, and the soprano singer on the right sings high notes.

Most people can hear sounds with frequencies between 20 Hz and 20,000 Hz. Sound waves with frequencies above the normal human range of hearing are called **ultrasound.** The prefix *ultra-* means "beyond." Sounds with frequencies below the human range of hearing are called **infrasound.** The prefix *infra-* means "below." People cannot hear either ultrasound waves or infrasound waves.

Changing Pitch Pitch is an important property of music because music usually uses specific pitches called notes. To sing or play a musical instrument, you must change pitch often.

When you sing, you change pitch using your vocal cords. Your vocal cords are located in your voice box, or **larynx,** as shown in Figure 11. When you speak or sing, air from your lungs is forced up the trachea, or windpipe. Air then rushes past your vocal cords, making them vibrate. This produces sound waves. Your vocal cords are able to vibrate more than 1,000 times per second!

To sing different notes, you use muscles in your throat to stretch and relax your vocal cords. When your vocal cords stretch, they vibrate more quickly as the air rushes by them. This creates higher-frequency sound waves that have higher pitches. When your vocal cords relax, lower-frequency sound waves with lower pitches are produced.

With musical instruments, you change pitch in different ways depending on the instrument. For example, you can change the pitch of a guitar string by turning a knob to loosen or tighten the string. A tighter guitar string produces a higher frequency, which you hear as a note with higher pitch.

Reading Checkpoint Where are your vocal cords located?

Lab zone Skills Activity

Predicting

1. Flatten one end of a drinking straw and cut the end to form a point.
2. Blow through the straw. Describe what you hear.
3. Predict what changes you would hear if you shortened the straw by cutting off some of the straight end. Test your prediction by making two new straws of different lengths.

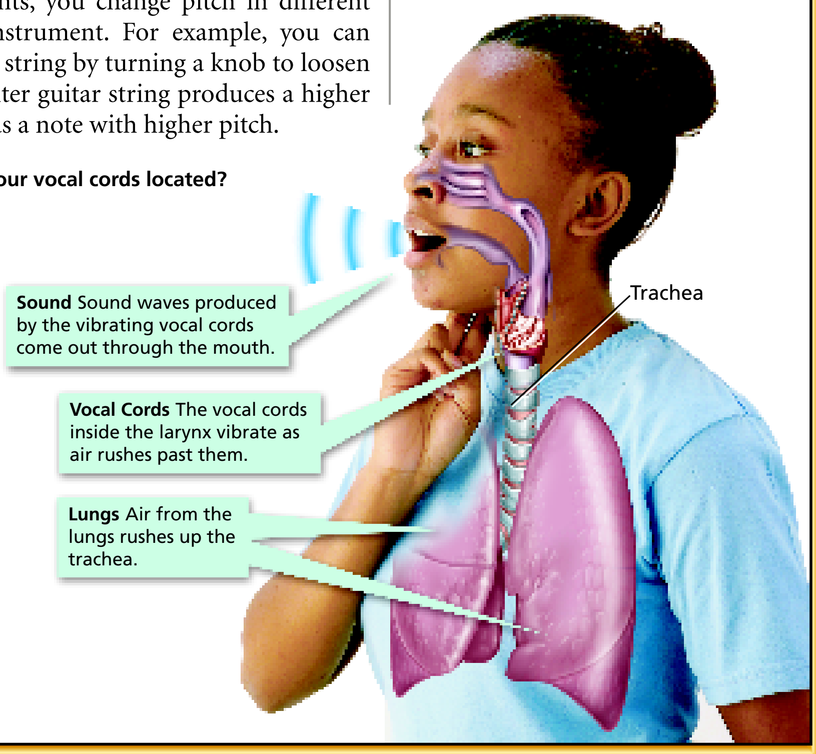


FIGURE 11
The Human Voice
When a person speaks or sings, the vocal cords vibrate. The vibrations produce sound waves in the air.

Address Misconceptions L2

Two Different Frequencies

Focus Students may confuse the frequency of vibrations in a guitar string with the frequency at which the string is plucked.

Teach Ask volunteers to take turns plucking a guitar string at different rates. Have the class listen to the sounds produced.

Apply Ask: **Why can't you make a guitar string produce a higher-pitch sound by plucking it faster?** *(Because the string still vibrates at the same frequency)* **learning modality: kinesthetic**

Use Visuals: Figure 11 L1

Vocal Cords

Focus Point out the location of the larynx in the figure. Explain that the larynx contains the vocal cords, which vibrate to produce sound waves.

Teach Have students place their fingers on their neck, as the girl in the photograph is doing. Then, tell students to hum. Ask: **What do you feel moving in your neck?** *(Vibrations of the vocal cords)* Tell students to hum at a low pitch and then a high pitch. Then, ask: **What difference do you feel in your vocal cords when you change the pitch?** *(Sample answer: The vibrations feel like they are coming from a different part of the vocal cords.)*

Extend Ask: **How do you think you raise the pitch of sounds produced by the vocal cords?** *(Some students may correctly infer that pitch is raised by increasing the tension of the vocal cords.)* **learning modality: kinesthetic**

Lab zone Skills Activity

Skills Focus Predicting L2

Materials drinking straw, scissors

Time 10 minutes

Tips Caution students to use care when handling the scissors. Do not allow them to share straws, and have them dispose of straws in a trash can following the activity. Students must make at least two cuts to test their prediction.

Predicting Students may predict correctly that the sound produced by a shorter straw has a higher pitch than the sound produced by a longer straw.

Extend Have students compare the pitches of sounds made by blowing through straws that have equal lengths but different diameters, such as a hollow coffee stirrer and a soda straw. **learning modality: kinesthetic**

Monitor Progress L2

Oral Presentation Call on students to explain how pitch and frequency are related.

Answers

Figure 9 A jet plane at takeoff sounds louder than a rock concert.

Reading Checkpoint A decibel is the unit used for loudness of sound.

Reading Checkpoint Your vocal cords are located in your larynx, which is in your throat.

The Doppler Effect

Teach Key Concepts
L2

Visualizing the Doppler Effect

Focus Have students look at Figure 12, which shows the Doppler effect. Say that the Doppler effect occurs when the source of a sound is moving relative to the listener.

Teach Ask: **What is the source of sound in the figure?** *(The siren on the firetruck)* **As the truck moves forward, what happens to the sound waves in front of the truck?** *(They bunch up.)* **How does this affect the frequency of the sound waves in front of the truck?** *(It makes the frequency higher.)* **How does this affect the pitch of the sound for people the truck is approaching?** *(It makes the pitch higher.)* Explain that the opposite occurs in behind the truck.

Apply Ask: **What are other situations in which the Doppler effect might occur?** *(Sample answer: The sound of a car horn as the car moves toward or away from the listener)* **learning modality: visual**

Lab zone Teacher Demo
L1

Modeling the Doppler Effect

Materials large pan, tuning fork, water

Time 10 minutes

Focus Say that you will model the Doppler effect with a tuning fork in water.

Teach Fill the pan with water. Strike a tuning fork and place one prong in the water about 10 cm from the edge of the pan. Slowly bring the prong toward the edge of the pan. Ask: **What happens to the waves as the prong approaches the side of the pan?** *(The waves in front of it get closer together.)*

Apply Ask: **What wave properties change in the Doppler effect?** *(Frequency and wavelength)* **learning modality: visual**

All in One Teaching Resources

- Transparency O21

Lab zone Try This Activity

Pipe Sounds

1. Find an open space without objects or people nearby.
2. Hold the end of a flexible plastic tube firmly (a vacuum cleaner hose works well). Swing the tube in a circle over your head to produce a sound.
3. Keeping the speed steady, listen to the sound. Have a partner stand at a safe distance and listen at the same time.

Observing Describe the sound you heard. How is it different from the sound your partner heard? Explain the difference.

The Doppler Effect

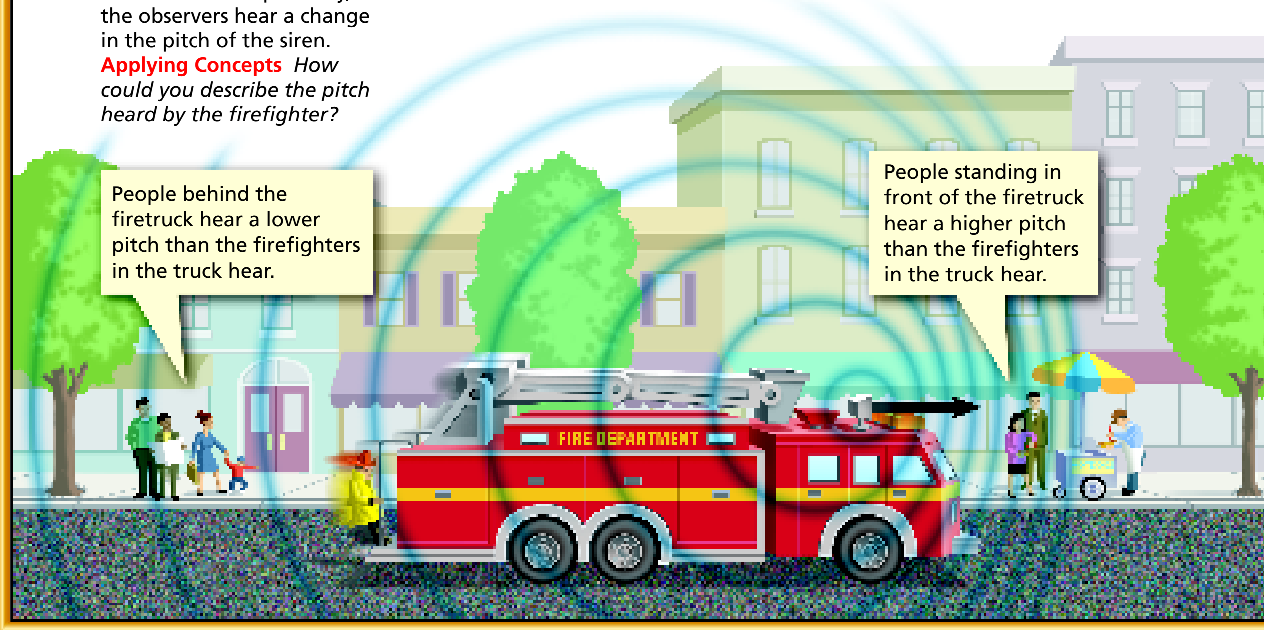
If you listen carefully to the siren of a firetruck on its way to a fire, you will notice something surprising. As the truck goes by you, the pitch of the siren drops. But the pitch of the siren stays constant for the firefighters in the truck. The siren's pitch changes only if it is moving toward or away from a listener.

The change in frequency of a wave as its source moves in relation to an observer is called the **Doppler effect.** If the waves are sound waves, the change in frequency is heard as a change in pitch. The Doppler effect is named after the Austrian scientist Christian Doppler (1803–1853).

What Causes the Doppler Effect? Figure 12 shows how sound waves from a moving source behave. When the source moves toward a listener, the frequency of the waves is higher than it would be if the source were stationary. **When a sound source moves, the frequency of the waves changes because the motion of the source adds to the motion of the waves.**

To understand why the frequency changes, imagine that you are standing still and throwing tennis balls at a wall in front of you. If you throw one ball each second the balls hit the wall at a rate of one per second. Now suppose you walk toward the wall while still throwing one ball per second. Because each ball has a shorter distance to travel than the one before, each takes less time to get there. The balls hit the wall more often than one per second, so the frequency is higher. On the other hand, if you throw balls at the wall as you back away, each ball has farther to travel and the frequency is lower.

FIGURE 12
The Doppler Effect
As the firetruck speeds by, the observers hear a change in the pitch of the siren.
Applying Concepts *How could you describe the pitch heard by the firefighter?*



Lab zone Try This Activity

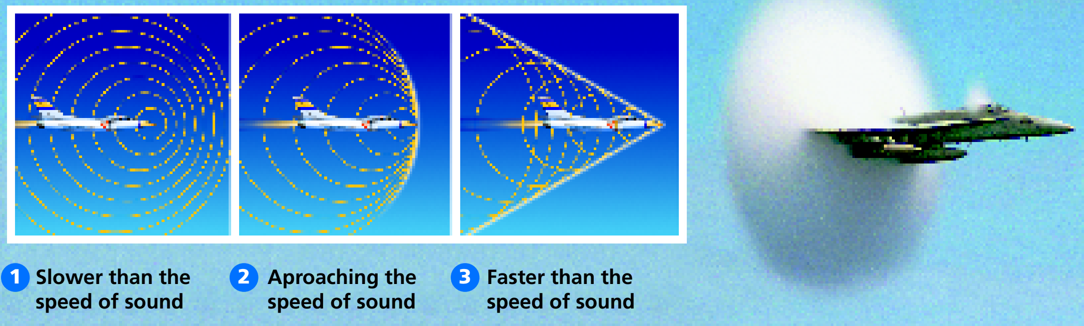
Skills Focus Observing L2

Materials flexible plastic tube or vacuum cleaner hose

Time 10 minutes

Tips Tubes may be found at a vacuum cleaner supply store, or you may use small plastic tubes that are sold as noise-making toys. Warn students to be careful when swinging the tubes.

Expected Outcome The student swinging the tube hears a humming sound with a constant pitch. The partner hears a humming sound with a pitch that rises and falls as the tube approaches and recedes. Students may say that the source of sound was moving relative to the partner but not relative to the student swinging the tube. **learning modality: kinesthetic**



What Causes Shock Waves? At high speed, the Doppler effect can be spectacular. Look at Figure 13. When the plane travels almost as fast as the speed of sound, the sound waves pile up in front of the plane. This pile-up is the "sound barrier." As the plane flies faster than the speed of sound, it moves through the barrier. A shock wave forms as the sound waves overlap. The shock wave releases a huge amount of energy. People nearby hear a loud noise called a sonic boom when the shock wave passes by them.

FIGURE 13
Breaking the Sound Barrier
When a plane goes faster than the speed of sound, a shock wave is produced. The photo on the right shows how sudden changes in pressure at this speed can cause a small cloud to form.

Reading Checkpoint **What is a shock wave?**

Section 2 Assessment

Target Reading Skill **Outlining** Use the information in your outline about the properties of sound to help you answer the questions below.

Reviewing Key Concepts

1. a. **Identifying** What two factors affect the loudness of a sound?
   b. **Applying Concepts** Why does moving away from a radio affect the loudness you hear?
   c. **Calculating** A band plays music at 60 dB and then changes to a rock song at 80 dB. How many times louder is the rock song?
2. a. **Reviewing** What determines the pitch of a sound?
   b. **Comparing and Contrasting** How are high-pitch sounds different from low-pitch sounds?
   c. **Explaining** How do your vocal cords produce different pitches?
3. a. **Summarizing** What is the Doppler effect?
   b. **Relating Cause and Effect** What causes the Doppler effect?
   c. **Predicting** Would you hear a change in pitch if you are on a moving train and the train's whistle blows? Explain.

Lab zone At-Home Activity

Hum Stopper When listening to a cat's heart, a veterinarian will cover the cat's nostrils to keep the cat from purring. At home, ask family members to hum with their lips closed. Then ask them to cover both of their nostrils while humming. Use Figure 11 to explain what happened.

Monitor Progress L2

Answers
Figure 12 The pitch heard by the firefighter remains constant and is between the pitches heard by observers in front of and behind the truck.

Reading Checkpoint A shock wave is a high-energy wave that forms when sound waves overlap because the sound source is moving faster than the speed of sound.

Assess

Reviewing Key Concepts

1. a. The loudness of a sound depends on the amount of energy it takes to make the sound and the distance from the source of the sound. **b.** The loudness decreases because intensity decreases as you get farther from a sound source. **c.** The rock song is 100 times louder.
2. a. The frequency of the sound wave **b.** Sound waves for high-pitch sounds have a higher frequency than sound waves for low-pitch sounds. **c.** The vocal cords stretch and vibrate more quickly for high-pitch sounds; they relax and vibrate more slowly for low-pitch sounds.
3. a. The Doppler effect is the change in frequency of a wave as its source moves in relation to an observer. **b.** When a sound source moves, the frequency of the waves changes because the motion of the source adds to the motion of the waves. **c.** You would not hear the pitch change because you are not moving relative to the sound source.

Reteach L1

Read the definitions of the key terms, and call on students to identify the terms based on the definitions.

Performance Assessment L2

Skills Check Have students describe how changes in sound wave amplitude and frequency affect loudness and pitch.

All in One Teaching Resources
- Section Summary: *Properties of Sound*
- Review and Reinforcement: *Properties of Sound*
- Enrich: *Properties of Sound*

Lab zone At-Home Activity

Hum Stopper L2 When you hum, your mouth is closed, so air can exit only through your nostrils. If you cover your nostrils, no air can escape. Without air moving past your vocal cords, the humming sound stops.

Lab zone Chapter Project

Keep Students on Track Have students apply section concepts to plan how they can change the pitch of sounds produced by their instruments. Tell them to modify their designs as necessary to allow control of pitch.