SECTION 2

Properties of Sound

Imagine that you are swimming in a neighborhood pool. You can hear the high, loud laughter of small children and the soft splashing of the waves at the edge of the pool.

What You Will Learn

- Compare the speed of sound in different media.
- Explain how frequency and pitch are related.
- Describe the Doppler effect, and give examples of it.
- Explain how amplitude and loudness are related.
- Describe how amplitude and frequency can be "seen" on an oscilloscope.

Vocabulary

pitch
Doppler effect
loudness
decibel

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Table 1 Speed of Sound in Different Media	
Medium	**Speed (m/s)**
Air (0°C)	331
Air (20°C)	343
Air (100°C)	366
Water (20°C)	1,482
Steel (20°C)	5,200

Why are some sounds loud, soft, high, or low? The differences between sounds depend on the properties of the sound waves. In this section, you will learn about properties of sound.

The Speed of Sound

Suppose you are standing at one end of a pool and two people from the opposite end of the pool yell at the same time. You would hear their voices at the same time. The reason is that the speed of sound depends only on the medium in which the sound is traveling. So, you would hear them at the same time—even if one person yelled louder!

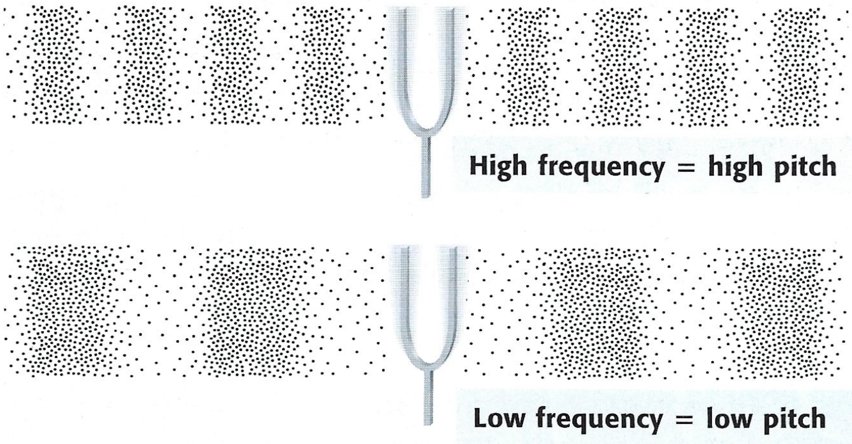
How the Speed of Sound Can Change

Table 1 shows how the speed of sound varies in different media. Sound travels quickly through air, but it travels even faster in liquids and even faster in solids.

Temperature also affects the speed of sound. In general, the cooler the medium is, the slower the speed of sound. Particles of cool materials move more slowly and transmit energy more slowly than particles do in warmer materials. In 1947, pilot Chuck Yeager became the first person to travel faster than the speed of sound. Yeager flew the airplane shown in **Figure 1** at 293 m/s (about 480 mi/h) at 12,000 m above sea level. At that altitude, the temperature of the air is so low that the speed of sound is only 290 m/s.

Figure 1 *The* X-1 *airplane was the first vehicle to move faster than the speed of sound.*

Figure 2 Frequency and Pitch



Pitch and Frequency

How low or high a sound seems to be is the **pitch** of that sound. The *frequency* of a wave is the number of crests or troughs that are made in a given time. The pitch of a sound is related to the frequency of the sound wave, as shown in **Figure 2.** Frequency is expressed in hertz (Hz), where 1 Hz = 1 wave per second. For example, the lowest note on a piano is about 40 Hz. The screech of a bat is 10,000 Hz or higher.

pitch a measure of how high or low a sound is perceived to be, depending on the frequency of the sound wave

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

Frequency and Hearing

If you see someone blow a dog whistle, the whistle seems silent to you. The reason is that the frequency of the sound wave is out of the range of human hearing. But the dog hears the whistle and comes running! **Table 2** compares the range of frequencies that humans and animals can hear. Sounds that have a frequency too high for people to hear are called *ultrasonic.*

MATH PRACTICE

The Speed of Sound

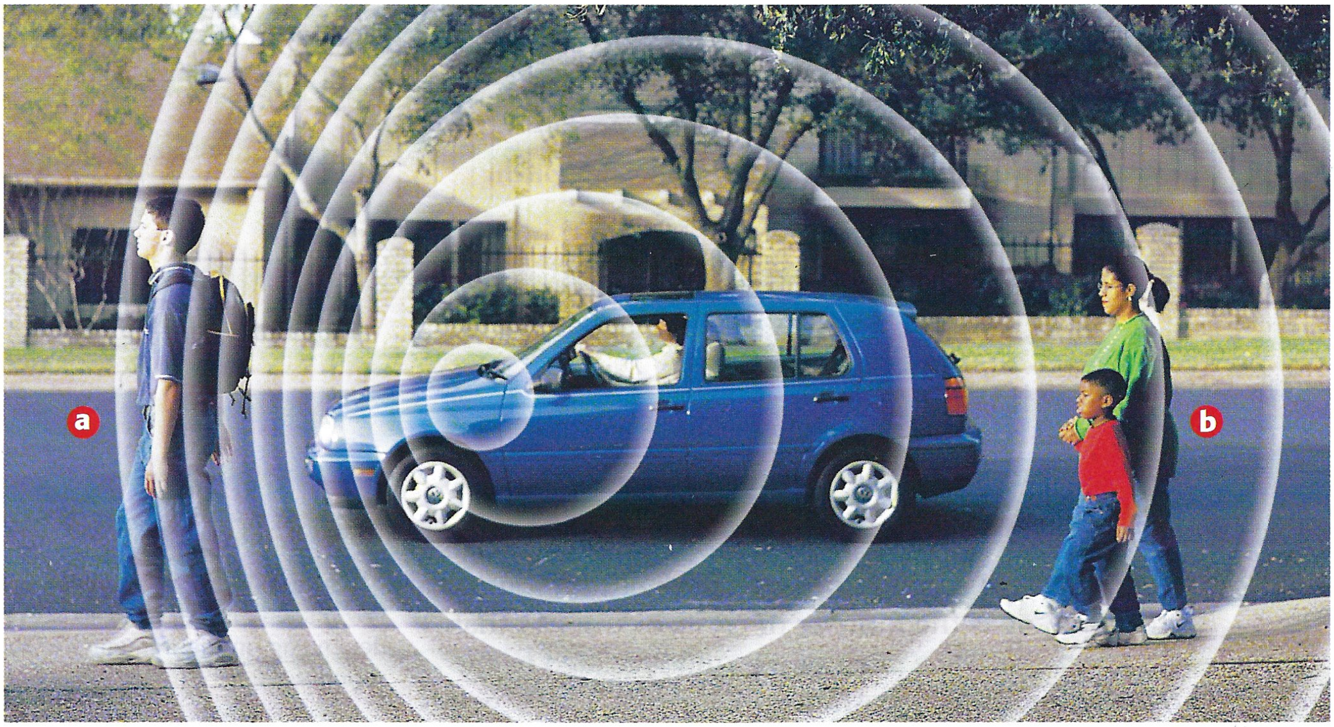
The speed of sound depends on the medium through which sound is traveling and the medium's temperature. Sound travels at 343 m/s through air at a temperature of 20°C. How far will sound travel in 20°C air in 5 s?

The speed of sound in steel at 20°C is 5,200 m/s. How far can sound travel in 5 s through steel at 20°C?

Table 2 **Frequencies Heard by Different Animals**

Animal	Frequency range (Hz)
Bat	2,000 to 110,000
Porpoise	75 to 150,000
Cat	45 to 64,000
Beluga whale	1,000 to 123,000
Elephant	16 to 12,000
Human	20 to 20,000
Dog	67 to 45,000

Figure 3 The Doppler Effect



a A car with its horn honking moves toward the sound waves going in the same direction. A person in front of the car hears sound waves that are closer together.

b The car moves away from the sound waves going in the opposite direction. A person behind the car hears sound waves that are farther apart and have a lower frequency.

Doppler effect an observed change in the frequency of a wave when the source or observer is moving

The Doppler Effect

Have you ever been passed by a car with its horn honking? If so, you probably noticed the sudden change in pitch—sort of an *EEEEEOOoooowwn* sound—as the car went past you. The pitch you heard was higher as the car moved toward you than it was after the car passed. This higher pitch was a result of the Doppler effect. For sound waves, the **Doppler effect** is the apparent change in the frequency of a sound caused by the motion of either the listener or the source of the sound. **Figure 3** shows how the Doppler effect works.

In a moving sound source, such as a car with its horn honking, sound waves that are moving forward are going the same direction the car is moving. As a result, the compressions and rarefactions of the sound wave will be closer together than they would be if the sound source was not moving. To a person in front of the car, the frequency and pitch of the sound seem high. After the car passes, it is moving in the opposite direction that the sound waves are moving. To a person behind the car, the frequency and pitch of the sound seem low. The driver always hears the same pitch because the driver is moving with the car.

Loudness and Amplitude

If you gently tap a drum, you will hear a soft rumbling. But if you strike the drum with a large force, you will hear a much louder sound! By changing the force you use to strike the drum, you change the loudness of the sound that is created. **Loudness** is a measure of how well a sound can be heard.

Energy and Vibration

Look at **Figure 4.** The harder you strike a drum, the louder the boom. As you strike the drum harder, you transfer more energy to the drum. The drum moves with a larger vibration and transfers more energy to the air around it. This increase in energy causes air particles to vibrate farther from their rest positions.

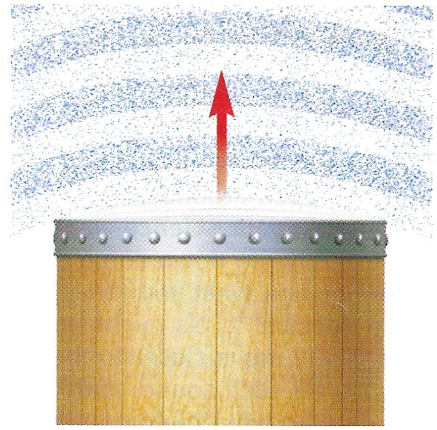


Figure 4 *When a drum is struck hard, it vibrates with a lot of energy, making a loud sound.*

Increasing Amplitude

When you strike a drum harder, you are increasing the amplitude of the sound waves being made. The *amplitude* of a wave is the largest distance the particles in a wave vibrate from their rest positions. The larger the amplitude, the louder the sound. And the smaller the amplitude, the softer the sound. One way to increase the loudness of a sound is to use an amplifier, shown in **Figure 5.** An amplifier receives sound signals in the form of electric current. The amplifier then increases the energy and makes the sound louder.

loudness the extent to which a sound can be heard

Reading Check **What is the relationship between the amplitude of a sound and its energy of vibration?**

Figure 5 *An amplifier increases the amplitude of the sound generated by an electric guitar.*

Quick Lab

Sounding Board

1. With one hand, hold a **ruler** on your **desk** so that one end of it hangs over the edge.
2. With your other hand, pull the free end of the ruler up a few centimeters, and let go.
3. Try pulling the ruler up different distances. How does the distance affect the sounds you hear? What property of the sound wave are you changing?
4. Change the length of the part that hangs over the edge. What property of the sound wave is affected? Record your answers and observations.

SCHOOL to HOME

WRITING SKILL **Decibel Levels**

With an adult, listen for the normal sounds that happen around your house. In your **science journal,** write down some sounds and what you think their decibel levels might be. Then, move closer to the source of each sound, and write what you think the new decibel level of each is.

ACTIVITY

Table 3 Decibel Levels of Common Sounds

Decibel level	Sound
0	the softest sounds you can hear
20	whisper
25	purring cat
60	normal conversation
80	lawn mower, vacuum cleaner, truck traffic
100	chain saw, snowmobile
115	sandblaster, loud rock concert, automobile horn
120	threshold of pain
140	jet engine 30 m away
200	rocket engine 50 m away

decibel the most common unit used to measure loudness (symbol, dB)

Measuring Loudness

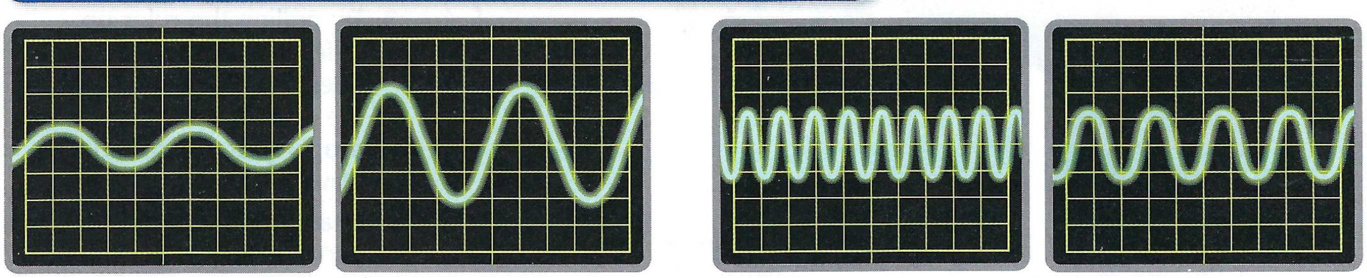
The most common unit used to express loudness is the **decibel** (dB). The softest sounds an average human can hear are at a level of 0 dB. Sounds that are at 120 dB or higher can be painful. **Table 3** shows some common sounds and their decibel levels.

"Seeing" Amplitude and Frequency

Sound waves are invisible. However, technology can provide a way to "see" sound waves. A device called an *oscilloscope* (uh SIL uh SKOHP) can graph representations of sound waves, as shown in **Figure 6.** Notice that the graphs look like transverse waves instead of longitudinal waves.

Reading Check What does an oscilloscope do?

Figure 6 **"Seeing" Sounds**



The graph on the right has a **larger amplitude** than the graph on the left. So, the sound represented on the right is **louder** than the one represented on the left.

The graph on the right has a **lower frequency** than the one on the left. So, the sound represented on the right has a **lower pitch** than the one represented on the left.

From Sound to Electrical Signal

An oscilloscope is shown in **Figure 7.** A microphone is attached to the oscilloscope and changes a sound wave into an electrical signal. The electrical signal is graphed on the screen in the form of a wave. The graph shows the sound as if it were a transverse wave. So, the sound's amplitude and frequency are easier to see. The highest points (crests) of these waves represent compressions, and the lowest points (troughs) represent rarefactions. By looking at the displays on the oscilloscope, you can quickly see the differences in amplitude and frequency of different sound waves.

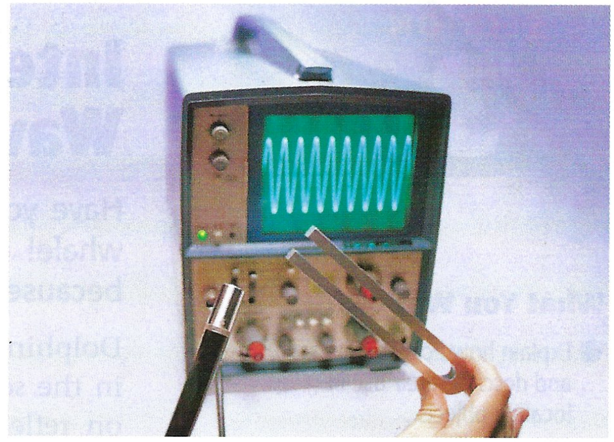


Figure 7 *An oscilloscope can be used to represent sounds.*

SECTION Review

Summary

- The speed of sound depends on the medium and the temperature.
- The pitch of a sound becomes higher as the frequency of the sound wave becomes higher. Frequency is expressed in units of Hertz (Hz), which is equivalent to waves per second.
- The Doppler effect is the apparent change in frequency of a sound caused by the motion of either the listener or the source of the sound.
- Loudness increases with the amplitude of the sound. Loudness is expressed in decibels.
- The amplitude and frequency of a sound can be measured electronically by an oscilloscope.

Using Key Terms

1. In your own words, write a definition for the term *pitch*.
2. Use the following terms in the same sentence: *loudness* and *decibel*.

Understanding Key Ideas

3. At the same temperature, in which medium does sound travel fastest?
   a. air
   b. liquid
   c. solid
   d. It travels at the same speed through all media.
4. In general, how does the temperature of a medium affect the speed of sound through that medium?
5. What property of waves affects the pitch of a sound?
6. How does an oscilloscope allow sound waves to be "seen"?

Math Skills

7. You see a distant flash of lightning, and then you hear a thunderclap 2 s later. The sound of the thunder moves at 343 m/s. How far away was the lightning?
8. In water that is near 0°C, a submarine sends out a sonar signal (a sound wave). The signal travels 1500 m/s and reaches an underwater mountain in 4 s. How far away is the mountain?

Critical Thinking

9. **Analyzing Processes** Will a listener notice the Doppler effect if both the listener and the source of the sound are traveling toward each other? Explain your answer.
10. **Predicting Consequences** A drum is struck gently, then is struck harder. What will be the difference in the amplitude of the sounds made? What will be the difference in the frequency of the sounds made?

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