Sound

Properties of Sound Waves

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	3. Sound waves from different sources can affect one another when they meet.	
	4. You can tell whether an ambulance is moving toward or away from you by listening to changes in the sound of the siren.	

Read to Learn

Energy of Sound Waves

How is a yell different from a whisper? The energy a sound wave carries depends on the amount of energy that caused the vibration. To speak softly, just use less energy!

Amplitude

The more energy you put into your voice, the farther the air particles move as they vibrate back and forth. *For a longitudinal wave,* **amplitude** *is the maximum distance the particles in a medium move from their rest positions as the wave passes through the medium.* As the energy in a sound wave increases, its amplitude increases.

Amplitude, Intensity, and Loudness

Sound waves leave a source, like a horn, with a certain amount of energy and, therefore, a certain amplitude. Loudness is how you perceive the energy of a sound wave. A wave with a greater amplitude will produce a louder sound. Sounds are quieter farther from their source. As sound waves travel away from a horn, the air particles vibrate back and forth, collide with, and transfer energy to other air particles. As the energy spreads out among more and more particles, the intensity of the wave decreases. **Intensity** *is the amount of energy that passes through a square meter of space in one second.*

Key Concepts

- How are amplitude and intensity related to energy?
- What is the relationship among frequency, pitch, and wavelength?
- How can you recognize sounds from different sources?
- In what ways are musical sounds produced?

Mark the Text

Building Vocabulary Skim this lesson and circle any words you do not know. If you still do not understand a word after reading the lesson, look it up in a dictionary. Keep a list of these words and definitions to refer to when you study other chapters.

Key Concept Check

1. Analyze How is the amplitude of a sound wave related to energy?

Key Concept Check

2. Infer How is the intensity of sound related to energy?

Intensity and Loudness As a sound wave travels farther from a horn, the area of particles sharing the energy that left the horn is larger. Therefore, as distance from the horn increases, the energy passing through one square meter decreases. The wave is less intense. As intensity decreases, amplitude decreases, and loudness decreases.

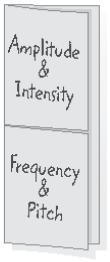
The Decibel Scale

The decibel (dB) is the unit of measure that describes the intensity or loudness of sound. Decibel levels of common sounds are shown in the figure below.

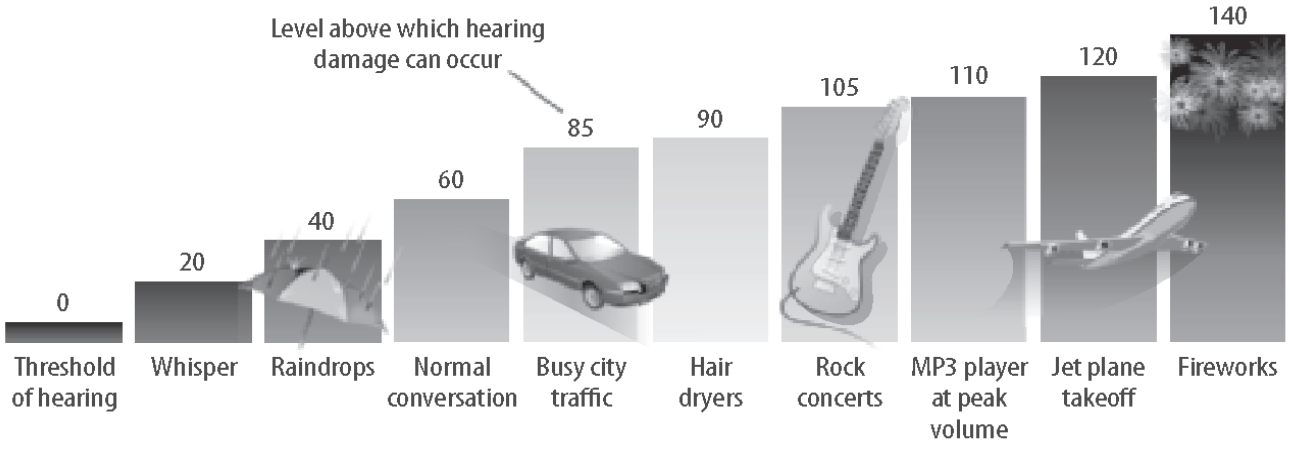
Each increase of 10 dB indicates that the sound is about twice as loud and has about 10 times more energy. For example, the decibel level of city traffic is about 85 dB. The level of a rock concert is about 105 dB. This means a concert, which is 20 dB higher, has about 10 × 10, or 100 times, more energy than traffic. Recall that a loud sound can make the eardrum vibrate so hard that it tears. As sounds get louder, the amount of time you can listen without hearing loss gets shorter.

FOLDABLES

Make a two-tab book to explain the relationships between sound properties and energy.



Decibel Scale



Visual Check

3. Explain Why do you think workers who load baggage on departing jets wear ear protection?

Describing Sound Waves

Sounds depend on the properties of the sound waves that enter your ear. Loudness or softness depends on the wave's amplitude. You also might describe sound according to how frequently the waves occur or how long the waves are.

Wavelength

One property of a sound wave is its wavelength. *The distance between a point on one wave and the nearest point just like it is called* **wavelength.** You could measure a wavelength as the distance between the midpoint of one compression and the midpoint of the next compression, as the next page shows.

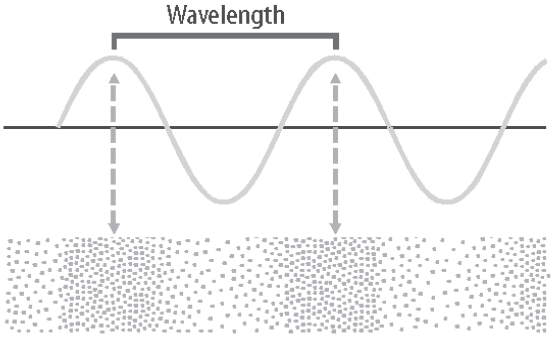
Frequency and Pitch

Suppose you could count sound waves produced by playing middle C on a piano. You would find that 262 wavelengths pass you each second. *The* **frequency** *of sound is the number of wavelengths that pass by a point each second*. Notice in the figure below, that as the wavelength of a sound wave decreases, its frequency increases. Frequency is measured in hertz. The frequency of one vibration, or wavelength, per second is 1 hertz (Hz). The frequency of middle C on a piano is 262 Hz.

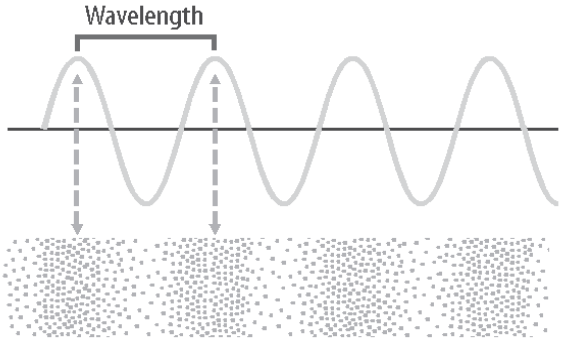
The perception of how high or low a sound seems is **pitch.** A higher frequency produces a higher pitch. For example, an adult male voice ranges from 85 Hz to 155 Hz. An adult female voice ranges from 165 Hz to 255 Hz.

The human ear can detect sounds with frequencies between about 20 Hz and 20,000 Hz. Frequencies above this range are called ultrasound. Many animals can hear sounds outside the range of human hearing.

Frequency and Wavelength



Low frequency; long wavelength



High frequency; short wavelength

Reading Check

4. Name What unit is used to measure frequency?

Key Concept Check

5. Analyze What is the relationship among frequency, pitch, and wavelength?

Visual Check

6. Recognize How can you tell that the sounds have the same intensity?

The Doppler Effect

You might have heard the high pitch of a train whistle as the train approaches. As the train passes, the pitch drops. Sound frequency depends on the motions of the sound source and the listener.

Compare the wave frequencies in front of and behind the moving train in the figure below. The frequency increases if the distance between the listener and the source is decreasing. The frequency decreases if the distance between the listener and the source increases. *The change of pitch when a sound source is moving in relation to an observer is the* **Doppler effect.**

Visual Check

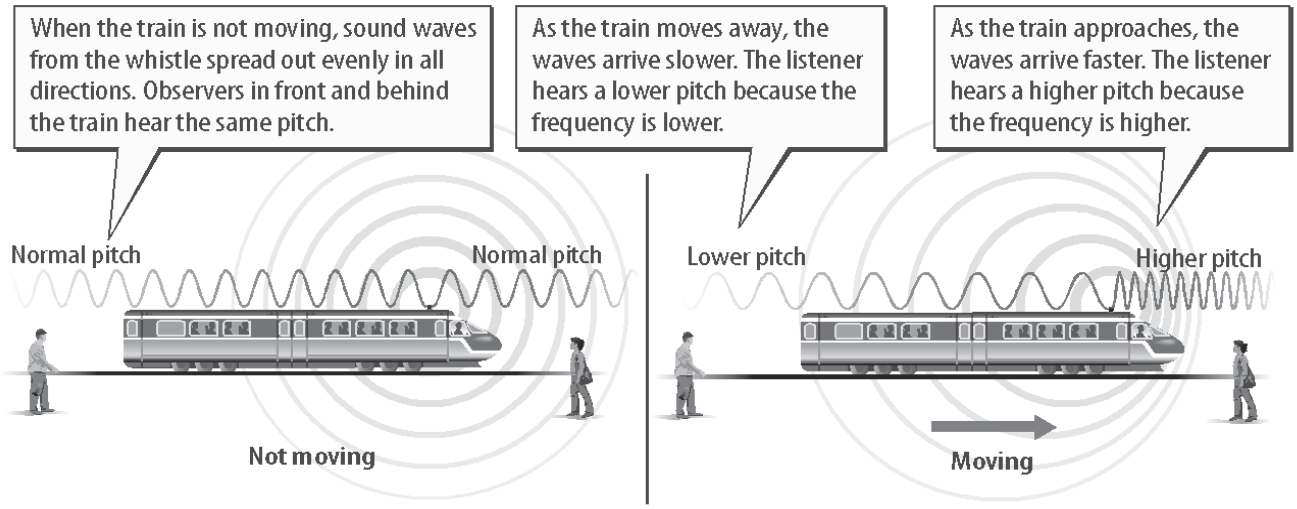
7. Contrast How are the waves in front of the moving train different from the waves in the back of the train?

_____

_____

_____

The Doppler Effect



Sound Interference

If you walk through a room with stereo speakers at each end, the sound might seem louder in some places and softer in others. The waves from each speaker interact with one another.

Interference *occurs when waves that overlap combine, forming a new wave*. The figure at the top of the next page shows why this happens.

When compressions meet, they join and form a wave with higher intensity and greater amplitude. This is called constructive interference. However, when a compression meets a rarefaction, the intensity and amplitude decrease. This is destructive interference.

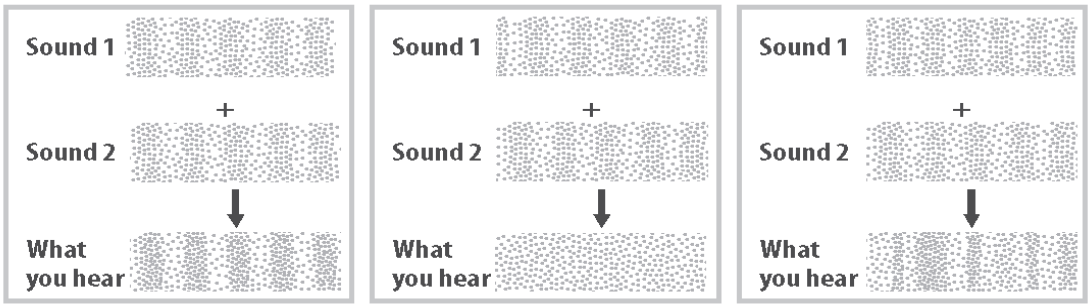
Reading Check

8. Describe What happens to intensity and amplitude when a compression meets a rarefaction?

_____

_____

Sound Interference and Sound Beats



Constructive Interference
When the compressions and rarefactions of waves overlap, the combined compressions have greater intensity.

Destructive Interference
When the compressions of one wave overlap the rarefactions of another wave, the waves cancel and the result is no sound.

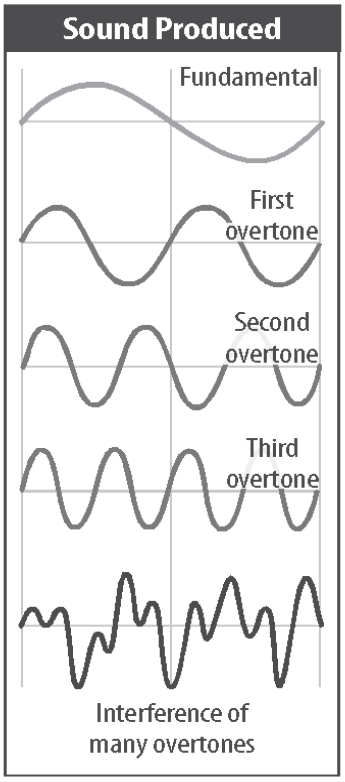
Beats
When the compressions of two waves are slightly offset, a pattern of increasing and decreasing compressions, called beats, occurs.

Beats

A group of musicians usually start a concert by playing the same note to check the pitches of their notes. If the pitches are slightly different, the sounds will interfere. The audience might hear the notes get louder and softer several times a second. The repeating increases and decreases in amplitude are beats. Look at the figure above. The difference in frequencies determines how often beats occur. If one musician plays a note with a pitch of 392 Hz and another plays a note with a pitch of 395 Hz, the difference is 3 Hz. Beats will occur 3 times each second. Musicians can avoid beats by playing notes at the correct pitch on their instruments.

Fundamental and Overtones

All objects tend to vibrate with a certain frequency that depends on the object's properties. The lowest frequency at which a material naturally vibrates is called its fundamental tone or fundamental. Higher frequencies at which the material vibrates are called overtones. Objects vibrate with both a fundamental and overtones, as shown in the figure on the right. A fundamental and overtones combine to produce interference, which is the sound you hear.



Visual Check

9. Define What are beats?

Visual Check

10. Identify Highlight the wave in the figure that has the lowest frequency.

Reading Check

11. Contrast What is the difference between a fundamental and overtones?

Music

How are music and noise different? Unlike noise, music is sound with a pleasing pattern.

Sound Quality

The unique sound of a musical instrument is a mix of its fundamental and overtones. These waves interact to form a distinct sound, or timbre. Suppose, for example, a clarinet player and a piano player play the same note. The fundamental of both instruments is the same. The number and intensity of the overtones, however, differ. Overtones produce the complex sound waves that let you distinguish the unique sound quality of each instrument.

Key Concept Check

12. Differentiate How can you recognize sounds from different sources?

Resonance

If you hold a guitar string at each end and have someone pluck it, the sound is almost too low to hear. Instruments use resonance to amplify sound. **Resonance** *is an increase in amplitude that occurs when an object vibrating at its natural frequency absorbs energy from a nearby object vibrating at the same frequency.*

A vibrating guitar string causes the back of a guitar and the air inside to vibrate by resonance. The sound is then much louder.

Types of Musical Instruments

The sound quality of a musical instrument depends on many factors. Different types of instruments control the pitch and the loudness of sound in different ways.

String Instruments Musical instruments that have strings, such as a guitar, a violin, a harp, and a piano, produce sound when the string vibrates. A player plucks the strings of a guitar or a harp. The motion of a bow vibrates the strings of a violin. Pressing a piano key causes a felt-covered hammer to strike a particular string inside the piano. When the string inside the piano vibrates, you hear a tone. The pitch a string makes depends on its length and its thickness. Shortening a string produces a higher pitch.

The material that makes up the string and how tightly it is stretched also affect pitch. You can hear sounds a stringed instrument makes because of resonance between the string and the instrument's hollow body. Plucking or pressing the strings harder increases the loudness.

Think it Over

13. Apply A male ruffed grouse makes a drumming sound with his wings to attract a mate. He does his drumming while standing on a hollow log. Why?

Reading Check

14. Describe how a string instrument makes musical sounds.

Wind Instruments The vibrating medium in a wind instrument, such as a saxophone or a trumpet, is air. Either your lips vibrate or a thin piece of wood, called a reed, vibrates. This causes an air column to vibrate by resonance. The length of the air column determines pitch. On a trombone, pulling the slide back shortens the air column and makes a higher note. Blowing harder increases the loudness.

Percussion Instruments You make sound with a percussion instrument by striking it. Examples of a percussion instrument are a drum, cymbals, and a bell. A percussion instrument's pitch depends on the instrument's size, its thickness, and the material from which it is made. A smaller drum makes a higher-pitched sound than a larger drum. Resonance can make the sound of a percussion instrument louder.

Voice The source of sound in your voice is vocal cords. Muscles in your throat enable you to increase the pitch of your voice by pulling the cords tighter. The vocal cords become thinner as they stretch, making your voice higher. Other parts of your mouth and throat also affect the sounds your voice makes. You can make your voice louder by pushing out the air with a greater force.

Reading Check

15. State What is the function of a reed in a wind instrument?

Key Concept Check

16. Describe In what ways are musical sounds produced?

After You Read

Mini Glossary

amplitude: for a longitudinal wave, the maximum distance the particles in a medium move from their rest positions as the wave passes through the medium

Doppler effect: the change of pitch when a sound source is moving in relation to an observer

frequency: the number of wavelengths that pass by a point each second

intensity: in a wave, the amount of energy that passes through a square meter of space in one second

interference: occurs when waves that overlap combine, forming a new wave

pitch: the perception of how high or low a sound seems

resonance: an increase in amplitude that occurs when an object vibrating at its natural frequency absorbs energy from a nearby object vibrating at the same frequency

wavelength: the distance between a point on one wave and the nearest point just like it

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how resonance helps a musician produce music on a guitar.

2. Identify each property of sound described in the table below. Use these terms to complete the table: *frequency, wavelength, intensity, pitch*.

Description	Properties of Sound
measured in hertz	
can be measured at the distance between the top of a compression and the top of the next compression	
perceived as loudness	amplitude
measured in decibels	
how high or low a sound seems	

3. Why does constructive interference increase intensity?

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Connect ED

Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

END OF LESSON