

Chapter 17 Mechanical Waves and Sound

Summary**17.1 Mechanical Waves**

A mechanical wave is a movement of matter. It carries energy from place to place. Mechanical waves need matter to travel through. The matter a wave travels through is called its medium (plural, media). Solids, liquids, and gases can act as media for mechanical waves.

A mechanical wave is created when a source of energy causes a vibration in a medium. A vibration is a repeating back-and-forth motion. For example, when you shake one end of a rope up and down, you create a vibration in that end of the rope. The vibration travels through the rope as a wave. The wave carries energy from your hand to the other end of the rope.

Scientists classify mechanical waves by the way they move through a medium. There are three main types of mechanical waves:

- transverse waves,
- longitudinal waves, and
- surface waves.

In a transverse wave, the medium moves at right angles to the direction of the wave. A wave in a rope is a transverse wave. The rope moves up and down. The wave travels from one end of the rope to the other. As the wave moves through each particle in the rope, the particle moves a short distance up and down. The highest point the medium reaches is called a crest. The lowest point the medium reaches is called a trough.

In a longitudinal wave, the medium moves in the same direction as the wave. A wave in a spring toy is a longitudinal wave. When you push on one end of the spring, a few coils bunch up. This area is called a compression. Behind the compression, the coils are spread apart. This area is called a rarefaction. The compression and rarefaction travel

through the spring. As the wave passes each coil in the spring, the coil moves a short distance back and forth.

A surface wave travels along the surface between two media. Ocean waves are surface waves. They travel along the surface between water and air. In a surface wave, particles of medium move up and down, like particles in a transverse wave. The particles also move back and forth, like particles in a longitudinal wave. When these two motions are combined, the particles move in circles.

17.2 Properties of Mechanical Waves

Several properties of mechanical waves help describe the waves. The properties are

- period,
- frequency,
- wavelength,
- speed, and
- amplitude.

Period is a measure of time. The period of a transverse wave is the time between one crest or trough and the next. The period of a longitudinal wave is the time between one compression or rarefaction and the next. Period is usually measured in seconds (s).

Frequency is a count, or number. The frequency of a transverse wave is the number of crests or troughs that pass a point in a given time. The frequency of a longitudinal wave is the number of compressions or rarefactions that pass a point in a given time. The unit of frequency is the hertz (Hz), or number per second. The frequency of a wave is determined by the frequency of the vibrations producing the wave.

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Wavelength is a measure of distance, or length. The wavelength of a transverse wave is the distance from one crest or trough to the next. The wavelength of a longitudinal wave is the distance from one compression or rarefaction to the next. Wavelength is often measured in meters. Increasing the frequency of a wave decreases its wavelength.

Speed is a measure of how fast something is moving. You can calculate the speed of a wave by multiplying wavelength by frequency:

$$\text{Speed} = \text{Wavelength} \times \text{Frequency}$$

A common unit of speed is meters per second. Two waves can have different wavelengths and frequencies and still have the same speed. Their speed will be the same as long as the product of wavelength and frequency is the same for both waves.

Amplitude is a measure of distance. The amplitude of a mechanical wave is the maximum distance the medium moves from its position at rest. For example, the amplitude of a transverse wave is the distance from the rest position to a crest or a trough. It takes more energy to produce a wave with higher crests and lower troughs. Therefore, the greater the amplitude of a wave, the greater its energy is.

17.3 Behavior of Waves

Waves meet and interact with surfaces and with other waves. Types of wave interactions include

- reflection,
- refraction,
- diffraction, and
- interference.

Reflection is the bouncing back of a wave from a surface that it cannot pass through. Reflection of a wave from a surface is like a ball bouncing off a wall. Reflection does not change the speed or frequency of a wave, but the wave can be flipped upside down.

Refraction is the bending of a wave as it enters a new medium at an angle. If the wave travels more slowly in the new medium, one side of the wave will slow down before the other side. This causes the wave to bend.

Diffraction is the bending of a wave as it moves around an obstacle or passes through a narrow opening. How much a wave bends depends on the wavelength and the size of the opening or obstacle. The bigger the wavelength compared to the size of the opening or obstacle, the more the wave bends.

The interaction of two or more waves is called interference. Two types of interference are constructive interference and destructive interference.

- In constructive interference, the crests of one wave overlap the crests of another wave. This results in a combined wave with larger amplitude.
- In destructive interference, the crests of one wave overlap the troughs of another wave. This results in a combined wave with smaller amplitude.

Sometimes a wave and its reflected wave interact to produce a standing wave. A standing wave is a wave that appears to stay in one place. It does not seem to move through the medium. A standing wave forms only if half a wavelength (or a multiple of half a wavelength) fits exactly within the length of the vibrating rope or other medium.

17.4 Sound and Hearing

Sound is carried by longitudinal waves. Properties of sound include speed, intensity, loudness, frequency, and pitch. These properties explain the behavior of sound.

- Speed is how fast sound travels. In dry air at 20°C, sound waves travel at a speed of 342 meters per second.

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Sound waves travel fastest in solids, slower in liquids, and slowest in gases.

- Intensity is a measure of the energy of sound in a given area. Intensity depends on the amplitude (energy) of the sound waves and the distance from the sound source. A nearby whisper could have the same intensity as a distant shout.
- Loudness is a measure of how intense a sound seems to a listener. High-intensity sounds generally sound loud. However, loudness also depends on factors such as the sharpness of the listener's hearing.
- Frequency is the number of sound waves that occur in a given time. It depends on how fast the sound source is vibrating.
- Pitch is how high or low a sound seems to a listener. Pitch depends mostly on the frequency of the sound waves. High-frequency sounds have a high pitch. Low-frequency sounds have a low pitch.

People cannot hear sounds with very low or very high frequencies. Infrasound is sound at frequencies lower than most people can hear. Ultrasound is sound at frequencies higher than most people can hear. Ultrasound is used for sonar and ultrasound imaging. Sonar is used to find the distance of objects under water.

Ultrasound imaging is used to make maps of structures inside the body.

When a siren passes you, it may sound like it changes pitch. This is called the Doppler effect. As a source of sound approaches, an observer hears a higher frequency. This occurs because the sound waves get closer together when the sound source moves in the same direction as the sound. As the sound source moves away, the observer hears a lower frequency. This occurs because the sound waves get farther apart when the sound source moves in the opposite direction from the sound.

The ear is the organ that responds to sound. The ear has three main regions: the outer ear, the middle ear, and the inner ear.

- The outer ear gathers and focuses sound into the middle ear.
- The middle ear receives the vibrations and increases their amplitude.
- The inner ear senses the vibrations and sends signals to the brain.

Sound is recorded by changing sound waves into electronic signals. The signals are stored on tapes or disks. Sound is reproduced by changing the stored electronic signals back into sound waves. Musical instruments can make sounds of different pitches. They change pitch by changing the frequency of the sound waves.

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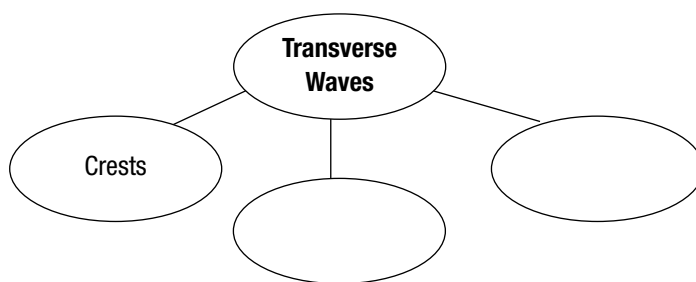
Section 17.1 Mechanical Waves

(pages 500–503)

This section explains what mechanical waves are, how they form, and how they travel. Three main types of mechanical waves—transverse, longitudinal, and surface waves—are discussed and examples are given for each type.

Reading Strategy (page 500)

Previewing As you read this section, use Figure 2 on page 501 to complete the web diagram. Then use Figures 3 and 4 to make similar diagrams for longitudinal waves and surface waves on a separate sheet of paper. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.



What Are Mechanical Waves? (page 500)

1. A disturbance in matter that carries energy from one place to another is called a(n) _____.
2. Is the following sentence true or false? Mechanical waves can travel through empty space. _____
3. The material through which a wave travels is called a(n) _____.
4. Is the following sentence true or false? Solids, liquids, and gases all can act as mediums for waves. _____
5. What creates a mechanical wave? _____

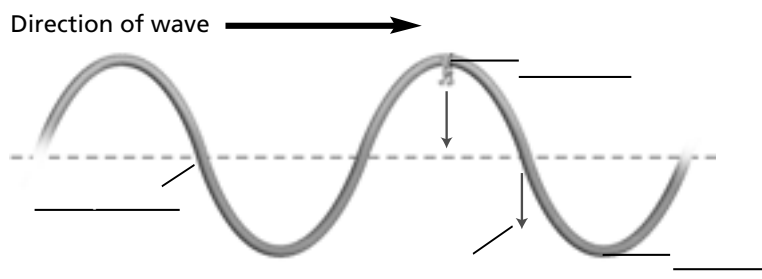
Types of Mechanical Waves (pages 501–503)

6. Is the following sentence true or false? The three main types of mechanical waves are water waves, longitudinal waves, and surface waves. _____
7. Circle the letter of the characteristic used to classify a mechanical wave.
 - a. the height of its crest
 - b. the depth of its trough
 - c. the way it travels through a medium
 - d. the type of medium through which it travels

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8. The highest point of a wave above the rest position is the _____ and the lowest point below the rest position is the _____.
9. What is a transverse wave? _____
- _____

10. Look at the figure below. Label the missing aspects of the wave in the rope.



11. A wave in which the vibration of the medium is parallel to, or in the same direction as, the direction in which the wave travels is called a(n) _____.
12. When a longitudinal wave carries energy through a spring, the area where the coils of a spring are closer together than they would be in the rest position is called a(n) _____.
13. Is the following sentence true or false? A rarefaction is a region in a longitudinal wave where particles of a medium spread out.

14. Why is an ocean wave classified as a surface wave? _____
- _____
15. Why do ocean waves transport objects on the surface of the water as they approach shore? _____
- _____

Match the type of wave to each description below. The type of wave may be used more than once.

Description	Type of Wave
_____ 16. P wave	a. transverse wave
_____ 17. Direction of travel is perpendicular to vibration direction	b. longitudinal wave
_____ 18. Rarefactions with particles that are spread out	c. surface wave
_____ 19. A wave that travels along a boundary separating two mediums	
_____ 20. An ocean wave	

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Section 17.2 Properties of Mechanical Waves

(pages 504–507)

This section introduces measurable properties used to describe mechanical waves, including frequency, period, wavelength, speed, and amplitude.

Reading Strategy (page 504)

Build Vocabulary As you read, write a definition in your own words for each term in the table below. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.

Properties of Waves	
Vocabulary Term	Definition
Period	
Frequency	
Wavelength	
Amplitude	

Frequency and Period (page 504)

1. Is the following sentence true or false? A periodic motion repeats at regular time intervals. _____
2. The time required for one cycle, a complete motion that returns to its starting point, is called the _____.
3. The number of complete cycles in a given period of time is the _____ of a periodic motion.
4. Circle the letter of each sentence that is true about frequency.
 - a. Frequency is measured in cycles per second, or hertz.
 - b. A wave's frequency equals the frequency of the vibrating source producing it.
 - c. Five cycles per minute is a frequency of five hertz.
 - d. Any periodic motion has a frequency.

Wavelength (page 505)

5. The distance between a point on one wave and the same point on the next cycle of the wave is called _____.
6. How is wavelength determined for a longitudinal wave?

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Wave Speed (pages 505–506)

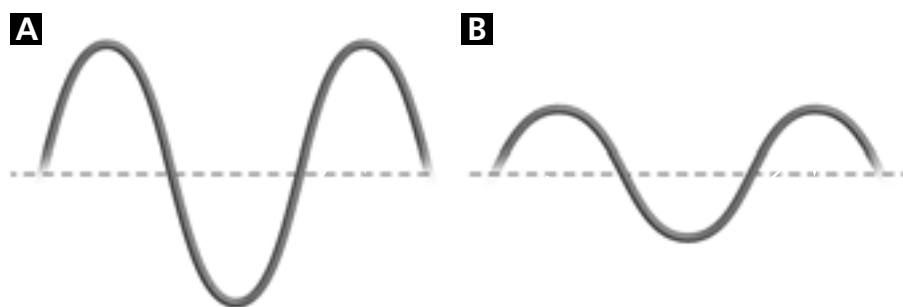
7. Write a formula you can use to determine the speed of a wave.

8. Is the following sentence true or false? The speed of a wave equals its wavelength divided by its period. _____
9. What variables can cause the speed of a wave to change? _____
10. Circle the letter of the sentence that tells how wavelength is related to frequency for a wave traveling at a constant speed.
 - a. Wavelength is equal to frequency.
 - b. Wavelength is directly proportional to frequency.
 - c. Wavelength is inversely proportional to frequency.
 - d. A wave with a higher frequency will have a longer wavelength.

Amplitude (page 507)

11. What is the amplitude of a wave? _____
12. It takes more energy to produce a wave with higher crests and deeper troughs, so the more energy a wave has, the _____ its amplitude.

Questions 13 through 17 refer to the figure below.



13. The type of waves shown are _____.
14. Label the rest position for waves A and B.
15. Add arrows to the figure to indicate the amplitude of each wave. Which wave has the greater amplitude? _____
16. Which wave shown has more energy? _____
17. Add an arrow to indicate one wavelength on wave B.

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Section 17.3 Behavior of Waves**(pages 508–512)**

This section describes different interactions that can occur when a mechanical wave encounters an obstacle, a change in medium, or another wave. These interactions include reflection, refraction, diffraction, and interference.

Reading Strategy (page 508)

Identifying Main Ideas Complete the table below. As you read, write the main idea of each topic. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.

Wave Interactions	
Topic	Main Idea
Reflection	
Refraction	
Diffraction	
Interference	
Standing waves	

Reflection (page 508)

1. Is the following sentence true or false? Reflection occurs when a wave bounces off a surface that it cannot pass through.

2. Circle the letter of the results that occur when a wave reflects off a fixed boundary.
 - a. The reflected wave will be turned upside down.
 - b. The amplitude will double as it strikes the surface.
 - c. The speed of the wave will decrease.
 - d. The frequency of the wave will decrease.

Refraction (page 509)

3. Why does refraction occur when a wave enters a new medium at an angle? _____

4. Is the following sentence true or false? Refraction always involves a change in the speed and direction of a wave. _____

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Diffraction (page 510)

5. What is required in order for diffraction to occur? _____

6. Is the following sentence true or false? A wave diffracts more if its wavelength is small compared to the size of an opening or obstacle. _____

Interference (pages 510–511)

7. What causes wave interference? _____

8. Complete the table about interference.

Interference		
Type	Alignment	Displacement Change
Constructive	Crests align with crests; troughs align with troughs	
		Displacements combine to produce a reduced amplitude.

9. Is the following sentence true or false? Destructive interference can result in wave displacements that are above the rest position.

10. How can an increased depth of a trough be considered constructive interference? _____

Standing Waves (page 512)

11. At certain frequencies, interference between a wave and its reflection can produce a(n) _____.
12. Circle each letter of a sentence that is true about standing waves.
 - a. A node is a point that has no displacement from the rest position.
 - b. Standing waves appear to move through a medium, such as a string.
 - c. Complete destructive interference occurs at antinodes.
 - d. A standing wave will form for any wavelength, as long as two ends of a rope or string are stretched tightly between two points.
13. Is the following sentence true or false? If a standing wave occurs in a medium at a given frequency, another standing wave will occur if this frequency is doubled. _____
14. Give an example of a common standing wave. _____

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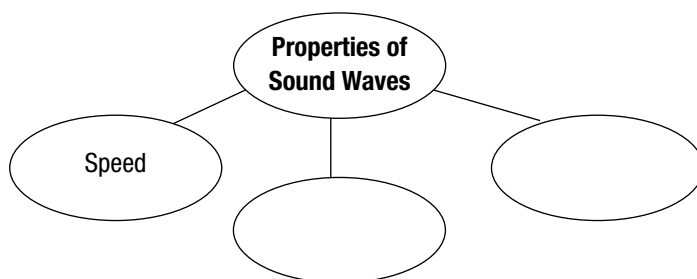
Section 17.4 Sound and Hearing

(pages 514–521)

This section discusses properties of sound waves, how they are produced, and how the ear perceives sound. A description of how music is produced and recorded also is presented.

Reading Strategy (page 514)

Using Prior Knowledge Before you read, add properties you already know about sound waves to the diagram below. Then add details about each property as you read the section. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.



Properties of Sound Waves (pages 514–515)

1. Circle the letter of each sentence that is true about sound.
 - a. Many behaviors of sound can be explained using a few properties.
 - b. Sound waves are compressions and rarefactions that travel through a medium.
 - c. Sound waves usually travel more slowly in solids than in gases.
 - d. The speed of sound in air is about 30 meters per second.

Match each description with one or more sound properties.

Description	Property
_____ 2. This property is measured in units called decibels.	a. loudness
_____ 3. These properties are affected by the length of tubing in a musical instrument.	b. pitch
_____ 4. This property is the frequency of a sound as your ears perceive it.	c. intensity
_____ 5. These properties depend on factors such as your age and the health of your ears.	d. frequency
_____ 6. This property is a physical response to the intensity of sound.	

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Ultrasound (page 516)

7. Is the following sentence true or false? Ultrasound is sound at frequencies that are lower than most people are capable of hearing.

8. Describe some applications of ultrasound. _____

The Doppler Effect (page 516)

9. Is the following sentence true or false? The Doppler effect is a change in sound frequency caused by motion of the sound source, motion of the listener, or both. _____
10. For a stationary observer, as a moving sound source approaches, the observer will first hear a(n) _____ frequency of sound and then a(n) _____ frequency as the source moves away.

Hearing and the Ear (page 517)

Match each description with the appropriate region(s) of the ear.

Description	Region
_____ 11. Sound is gathered and focused here.	a. outer ear
_____ 12. Nerve endings send signals to the brain.	b. middle ear
_____ 13. The eardrum is located at the boundary between these two regions of the ear.	c. inner ear
_____ 14. Hammer, anvil, and stirrup are located here.	
_____ 15. Sound vibrations are amplified.	

How Sound Is Reproduced (pages 518–519)

16. How is sound recorded? _____

17. Sound is reproduced by converting _____ back into sound waves.

Music (page 521)

18. Is the following sentence true or false? Many musical instruments vary pitch by changing the frequency of standing waves.

19. Theaters are designed to prevent “dead spots” where the volume is reduced by _____ of reflected sound waves.
20. The response of a standing wave to another wave of the same frequency is called _____.