Summary

THE BIG IDEA **Waves transmit energy through space and time.**

25.1 Vibration of a Pendulum

The period of a pendulum depends on only the length of the pendulum and the acceleration of gravity.

- A repeating back-and-forth motion about an equilibrium position is a **vibration.**
- The time a pendulum takes to swing back and forth through small angles depends on the length of the pendulum—the mass has no effect.
- The time of a back-and-forth swing of a pendulum is called the **period.**
- A long pendulum has a longer period than a shorter pendulum. The longer pendulum swings back and forth more slowly—less frequently—than a short pendulum.

25.2 Wave Description

The source of all waves is something that vibrates.

- A disturbance that is transmitted progressively from one place to the next with no actual transport of matter is a **wave.**
- The back-and-forth vibratory motion (often called oscillatory motion) of a swinging pendulum is called **simple harmonic motion.**
- A **sine curve** is a pictorial representation of a wave.
- The high points on a wave are called **crests.**
- Low points on a wave are called **troughs.**
- The term **amplitude** refers to the distance from the midpoint to the crest (or trough) of the wave.
- The **wavelength** of a wave is the distance from the top of one crest to the top of the next one. Or, equivalently, the wavelength is the distance between successive identical parts of the wave.
- The number of vibrations an object makes in a unit of time is an object's **frequency.**
- The unit of frequency is called the **hertz** (Hz). A frequency of one cycle per second is 1 hertz.
- Frequency and period are inverses of each other:

$$\text{Frequency} = \frac{1}{\text{period}} \quad \text{or} \quad \text{Period} = \frac{1}{\text{frequency}}$$

25.3 Wave Motion

The energy transferred by a wave from a vibrating source to a receiver is carried by a disturbance in a medium.

- When energy is transferred by a wave from a vibrating source to a distant receiver, there is no transfer of matter between the two points.
- When someone talks to you from across the room, the sound wave is a disturbance in the air that travels across the room.

25.4 Wave Speed

You can calculate the speed of a wave by multiplying the wavelength by the frequency.

- The speed of a wave depends on the medium through which the wave moves.
- Sound waves move at speeds of about 330 m/s to 350 m/s in air.
- Whatever the medium, the speed, wavelength, and frequency of the wave are related.
- In equation form, the relationship for wave speed is as follows:

$$v = \lambda f$$

  where v is wave speed, λ (Greek letter lambda) is the wavelength, and f is wave frequency.
- Wavelength and frequency vary inversely to produce the same wave speed for all sounds.

25.5 Transverse Waves

Waves in the stretched strings of musical instruments and the electromagnetic waves that make up radio waves and light are transverse.

- Whenever the motion of the medium is at right angles to the direction in which a wave travels, the wave is a **transverse wave.**

25.6 Longitudinal Waves

Sound waves are longitudinal waves.

- When the particles in the medium oscillate parallel to or *along* the direction of the wave rather than at right angles to it, the wave is a **longitudinal wave.**

25.7 Interference

Interference patterns occur when waves from different sources arrive at the same point—at the same time.

- An **interference pattern** is a regular arrangement of places where wave effects are increased, decreased, or neutralized.
- In **constructive interference,** the crest of one wave overlaps the crest of another and their individual effects add together.

- The result of constructive interference is a wave of increased amplitude.
- In **destructive interference,** the crest of one wave overlaps the trough of another and their individual effects are reduced.
- Destructive interference is also called cancellation.
- When waves are **out of phase,** the crests of one wave overlap the troughs of another to produce regions of zero amplitude.
- When waves are **in phase,** the crests of one wave overlap the crests of another, and the troughs overlap as well.
- Interference is characteristic of all wave motion, whether the waves are water waves, sound waves, or light waves.

25.8 Standing Waves

A standing wave forms only if half a wavelength or a multiple of half a wavelength fits exactly into the length of the vibrating medium.

- A **standing wave** is a wave that appears to stay in one place—it does not seem to move through the medium.
- **Nodes** are the stationary points on a standing wave.
- The positions on a standing wave with the largest amplitudes are known as **antinodes.**
- Standing waves are the result of interference. Standing waves can be produced in either transverse or longitudinal waves.

25.9 The Doppler Effect

As a wave source approaches, an observer encounters waves at a higher frequency. As the wave source moves away, an observer encounters waves with a lower frequency.

- The apparent change in frequency due to the motion of the source (or receiver) is called the **Doppler effect.** The greater the speed of the source, the greater the Doppler effect.
- The Doppler effect is evident when you hear the changing pitch of a siren as a firetruck passes you. Police make use of the Doppler effect of radar waves in measuring the speeds of cars on the highway.
- The Doppler effect also occurs for light.
- An increase in the frequency of light is called a **blue shift,** because the increase is toward the high-frequency, or blue, end of the color spectrum.
- A decrease in the frequency of light is called a **red shift,** referring to the low-frequency, or red, end of the color spectrum.

25.10 Bow Waves

A bow wave occurs when a wave source moves faster than the wave it produces.

- When wave crests overlap at the edges and the pattern made by these overlapping crests is a V shape, the wave is called a **bow wave.**
- The familiar bow wave generated by a speedboat knifing through the water is produced by the overlapping of many circular wave crests.
- After the speed of the source exceeds the wave speed, increased speed produces a bow wave with a narrower V shape.

25.11 Shock Waves

A shock wave occurs when an object moves faster than the speed of sound.

- A **shock wave** is a three-dimensional wave that consists of overlapping spheres that form a cone.
- The sharp crack heard when the shock wave that sweeps behind a supersonic aircraft reaches the listener is called a **sonic boom.**
- It is not necessary that the moving source emit sound for it to produce a shock wave.