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 give 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.

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.

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.