Unit 6
Mechanical Oscillation and Sound Wave

Introduction

Oscillations are movements back and forth about a fixed point. They are fundamental to many systems, such as a swinging pendulum or a vibrating guitar string. When an object oscillates, it involves force and energy. This motion can sometimes create **waves**.

Waves are disturbances that move away from their source, carrying energy with them. Examples include:

- **Sound waves**: Created by vibrations and can travel through air.
- **Water waves**: Created when you slap the surface of a pool.

Oscillation is also known as **periodic motion** because it repeats over time. Examples include a pendulum swinging or a mass on a spring.

Common Characteristics of Waves

1. Rest Position: The undisturbed position of particles when they are not vibrating.

2. Displacement: The distance a point in the medium has moved from its rest position.

3. Trough: The lowest point of a wave below the rest position.

4. Crest: The highest point of a wave above the rest position.

5. Period (T): The time it takes for one complete cycle of the wave to pass a given point. It is measured in seconds.

6. Frequency (f): The number of complete waves passing a point per unit time. Measured in Hertz (Hz).

- Formula: $f=\frac{1}{T}$

7. Amplitude (A): The maximum displacement from the equilibrium position. It shows the wave's strength and is measured in meters.

8. Wave Speed (v): The distance a wave travels in one second. Measured in meters per second.

- Formula: $v = f \times \lambda$

9. Wavelength (λ): The distance between two consecutive crests or troughs. Measured in meters.

Relationship Between Period, Frequency, Wavelength, and Wave Speed

The period and frequency of a wave are reciprocals:

- $T = \frac{1}{f}$

Wave speed can be calculated using:

- $v = \lambda \times f$

Examples and Applications

Pendulums and Springs: Both exhibit periodic motion.

- **Pendulum**: The time for one complete swing depends on the length of the pendulum and the acceleration due to gravity.
  - Formula: $T = 2\pi\sqrt{\frac{L}{g}}$
- **Spring**: The time for one complete oscillation depends on the mass attached to the spring and the spring constant.
  - Formula: $T = 2\pi\sqrt{\frac{m}{k}}$

Mechanical Waves: Require a medium (e.g., sound waves, water waves).

Electromagnetic Waves: Do not require a medium and can travel through a vacuum (e.g., light, radio waves).

Types of Waves

- **Transverse Waves**: The particle motion is perpendicular to the wave direction (e.g., waves on a string).
- **Longitudinal Waves**: The particle motion is parallel to the wave direction, with regions of compression and rarefaction (e.g., sound waves).

Sound Waves

Have you ever strummed a guitar or struck a tuning fork? The sounds you hear are produced by vibrations. These vibrations travel through a medium as sound waves. In this note, we will explore what sound is, how it is produced and propagated, and its properties.

What is Sound?

Sound is a type of mechanical wave that travels through a medium—like air, water, or solid materials—caused by vibrations of objects. When you strum a guitar string or hit a drum, the object vibrates, and these vibrations set surrounding air particles into motion. These moving air particles carry the sound waves to your ears.

Production and Propagation of Sound

Sound waves are longitudinal waves, meaning the particles of the medium move in the same direction as the wave travels. For example, when you hit a tuning fork, it vibrates back and forth. This vibration creates alternating compressions and rarefactions in the air. These changes in air pressure travel away from the tuning fork as sound waves.

Key Points:

- **Vibration**: The source of sound is always a vibrating object.
- **Medium**: Sound requires a medium (air, water, solids) to travel. It cannot travel through a vacuum because there are no particles to transmit the sound.
- **Energy Transfer**: The energy from the vibrating object is transferred to the surrounding medium, which then propagates the sound.

Speed of Sound

The speed of sound varies depending on the medium through which it travels:

- **In air**: Approximately 331 m/s at 0°C. It increases with temperature. For example, at 20°C, the speed of sound is about 343 m/s.
- **In water**: Approximately 1493 m/s at 25°C.
- **In solids**: Generally faster because the particles are closer together and can transmit vibrations more quickly.

Example Calculation: To find the speed of sound at 20°C, use the formula:

$v = 331\ \text{m/s} \times \left(1 + \frac{Tc}{273}\right)$ Where T_c is the temperature in °C. For 20°C:

$v = 331\ \text{m/s} \times (1 + \frac{20}{273}) \approx 343\ \text{m/s}$

Reflection, Refraction, Diffraction, and Interference of Sound

- **Reflection**: When sound waves bounce off a surface, we hear an echo. Hard surfaces like walls reflect sound well, while soft surfaces absorb more sound.
- **Refraction**: Sound bends when it passes through air of varying temperatures. For example, sound bends downwards at night when the air near the ground is cooler.
- **Diffraction**: Sound waves spread out as they pass through openings or around obstacles. This is why you can hear someone talking from another room.
- **Interference**: When two sound waves meet, they can interfere constructively (amplify) or destructively (diminish) based on their phase relationship.

Characteristics of Sound

1. **Pitch**: Determined by the frequency of the sound waves. Higher frequencies produce higher pitches.
2. **Loudness**: Relates to the amplitude of the sound waves. Greater amplitude means louder sound. Loudness is measured in decibels (dB).
3. **Timbre**: The quality of sound that distinguishes it from other sounds with the same pitch and loudness. It depends on the harmonic content of the sound.

Summary

- **Sound** is a mechanical wave created by vibrations and requires a medium to travel.
- It has properties such as frequency (pitch), amplitude (loudness), and speed, which vary with the medium.
- **Reflection**, **refraction**, **diffraction**, and **interference** are key phenomena that affect how sound behaves in different situations.