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Sound Production

Sound is produced by vibrating objects. When an object vibrates, it causes the surrounding medium (air, water, or solid) to vibrate as well, creating sound waves. For example, plucking a stretched rubber band or striking a metal object causes vibrations that produce sound. In humans, sound is produced by the vibration of vocal cords located in the larynx. Musical instruments produce sound through vibrating strings, membranes, or air columns.

Sound requires a medium to travel. It can propagate through solids, liquids, and gases but cannot travel through a vacuum. This is why astronauts in space cannot hear sounds directly and use special communication devices.

Sound Waves

Sound waves are longitudinal mechanical waves consisting of alternating compressions and rarefactions in the medium. Compressions are regions of high particle density, and rarefactions are regions of low particle density. The particles of the medium vibrate back and forth parallel to the direction of wave propagation but do not travel with the wave.

Sound waves propagate by transferring energy through the medium. The speed of sound depends on the medium and its properties, traveling fastest in solids, slower in liquids, and slowest in gases. The speed also varies with temperature and humidity in air.

Sound waves can be graphically represented by plotting the variation of air density with distance or time, showing crests (compressions) and troughs (rarefactions).

Sound Characteristics

Key characteristics of sound waves include wavelength, frequency, time period, amplitude, intensity, pitch, and loudness. Wavelength is the distance between two consecutive compressions or rarefactions. Frequency is the number of oscillations per second, measured in hertz (Hz). Time period is the time for one complete oscillation and is the inverse of frequency.

Amplitude relates to the maximum change in air density and determines the loudness of sound. Intensity is the amount of sound energy passing through a unit area per unit time. Pitch is how humans perceive frequency, with higher frequencies perceived as higher pitch.

Humans can hear sounds in the frequency range of 20 Hz to 20,000 Hz. Sounds below 20 Hz are infrasonic, and above 20,000 Hz are ultrasonic. Different animals can hear different frequency ranges.

Sound Reflection

Sound waves reflect off surfaces following the laws of reflection, where the angle of incidence equals the angle of reflection. An echo is a reflected sound heard when the reflected wave returns after a delay of at least 0.1 seconds. Reverberation occurs when multiple reflections cause sound to persist after the source stops emitting.

Echoes are stronger from hard, smooth surfaces and weaker or absent from soft, rough surfaces that absorb or scatter sound.

Ultrasonic and Infrasonic Waves

Ultrasonic waves have frequencies above 20,000 Hz and are used in medical imaging, cleaning, welding, and underwater navigation (sonar). Infrasonic waves have frequencies below 20 Hz and are used to detect natural phenomena like earthquakes and storms.

Echolocation is a biological use of ultrasonic waves by animals like bats and dolphins to locate objects by emitting ultrasonic waves and listening to their echoes.

Sonar technology uses ultrasonic waves to detect underwater objects by sending waves and analyzing their reflections.

Solved Examples

Example 1: Calculate frequency and time period

If there are 10 density oscillations in 2 seconds at a given position, find the frequency and time period of the sound wave.

Solution:

Frequency = Number of oscillations / Time = 10 / 2 s = 5 Hz

Time period = 1 / Frequency = 1 / 5 Hz = 0.2 s

Example 2: Calculate wavelength for given frequencies

Find the wavelength of sound in air for frequencies 20 Hz and 20,000 Hz. Speed of sound in air = 344 m/s.

Solution:

Wavelength, λ = Speed / Frequency

For 20 Hz: λ = 344 / 20 = 17.2 m

For 20,000 Hz: λ = 344 / 20000 = 0.0172 m = 1.72 cm

Example 3: Distance to lightning strike

Lightning is seen before thunder is heard. If the time delay is 5 seconds and speed of sound is 340 m/s, find the distance to the lightning.

Solution:

Distance = Speed × Time = 340 m/s × 5 s = 1700 m = 1.7 km

Example 4: Frequency and time period from wavelength

From a sound wave graph in steel, wavelength is 50 m. Speed of sound in steel = 5000 m/s. Find frequency and time period.

Solution:

Frequency = Speed / Wavelength = 5000 / 50 = 100 Hz

Time period = 1 / Frequency = 1 / 100 = 0.01 s

Example 5: Distance from echo time

Echo heard after 0.5 s. Speed of sound = 340 m/s. Find distance from reflecting surface.

Solution:

Distance = (Speed × Time) / 2 = (340 × 0.5) / 2 = 85 m

Example 6: Sonar distance calculation

Sonar signal returns after 0.90 s. Speed of sound in seawater = 1530 m/s. Find distance to object.

Solution:

Time to object = 0.90 / 2 = 0.45 s

Distance = Speed × Time = 1530 × 0.45 = 688.5 m

Practice Set

- **Level 1:** What causes sound to be produced in a musical instrument?
- **Level 1:** Why can sound not travel through a vacuum?
- **Level 2:** Explain how sound waves propagate through air using compressions and rarefactions.
- **Level 3:** Calculate the frequency of a sound wave if its wavelength is 0.5 m and speed is 340 m/s.

Answer Key

- **Level 1:** Sound is produced by the vibration of parts of the musical instrument, such as strings or air columns.
- **Level 1:** Sound cannot travel through a vacuum because there is no medium (particles) to carry the vibrations.
- **Level 2:** Sound waves propagate as longitudinal waves consisting of compressions (high density) and rarefactions (low density) that move through air by particle vibrations.
- **Level 3:** Frequency = Speed / Wavelength = 340 / 0.5 = 680 Hz.

Quick Reference Table

Common Mistakes and Misconceptions

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