Nature of Sound

Wave Motion and Medium

Sound is a form of wave motion produced by a vibrating source. It requires a medium such as solids, liquids, or gases to travel and cannot propagate through a vacuum.

Longitudinal Waves

Sound waves are longitudinal waves where particles of the medium vibrate parallel to the direction of wave propagation. These waves consist of successive compressions and rarefactions.

Velocity Dependence

The velocity of sound depends on the nature and temperature of the medium. Sound travels fastest in solids, slower in liquids, and slowest in gases.

Propagation of Sound

Speed in Different Media

Sound travels faster in solids than in liquids and gases due to closer particle spacing, which facilitates quicker transmission of vibrations.

Density and Pressure Variations

Propagation of sound can be visualized as the movement of density or pressure variations through the medium.

Characteristics of Sound Wave

Frequency and Time Period

Frequency is the number of compressions or rarefactions passing a point per second, measured in Hertz (Hz). Time period is the time taken for one complete oscillation and is the reciprocal of frequency.

Amplitude and Wavelength

Amplitude is the maximum disturbance caused by the wave, indicating loudness. Wavelength is the distance between two consecutive compressions or rarefactions.

Speed of Sound

Speed is the distance traveled by a compression or rarefaction per unit time. It is calculated as the product of frequency and wavelength.

Sound Properties

Pitch

Pitch is determined by the frequency of the sound wave; higher frequency corresponds to higher pitch.

Loudness

Loudness depends on the amplitude of the sound wave; greater amplitude means louder sound.

Quality

Quality or timbre is determined by the waveform and distinguishes different sources of sound producing the same pitch and loudness.

Production of Sound

Vibration and Frequency

Objects vibrate at different frequencies to produce sounds of varying pitch. Larger objects generally produce lower frequency sounds.

Loudness and Energy

Louder sounds carry more energy and can travel greater distances. Loudness is influenced by the amplitude of vibrations.

Types of Sounds

A sound of single frequency is called a tone, while a mixture of frequencies produces a note. Noise is unpleasant sound, whereas music is pleasant and of rich quality.

Reflection of Sound

Law of Reflection

Sound reflects off surfaces following the law of reflection: the angle of incidence equals the angle of reflection with respect to the normal.

Reflecting Surfaces

Reflectors should be sufficiently large and can be polished or rough to reflect sound effectively.

Solved Examples

Practice Set

- **Level 1:** Why can sound not travel in a vacuum?
- **Level 2:** Explain why sound travels faster in solids than in gases.
- **Level 3:** A sound wave has a frequency of 500 Hz and a wavelength of 0.68 m. Calculate the speed of sound in the medium.

Answer Key

- **Level 1:** Sound requires a medium to propagate because it travels as vibrations of particles. In a vacuum, there are no particles to vibrate, so sound cannot travel.
- **Level 2:** In solids, particles are closely packed, allowing vibrations to transfer quickly from one particle to another, resulting in faster sound propagation compared to gases where particles are far apart.
- **Level 3:** Speed = Frequency × Wavelength = 500 Hz × 0.68 m = 340 m/s.

Echo, Applications, Range of Hearing

Echo and Reflection

An echo is the repetition of sound caused by reflection from a surface. To hear a distinct echo, the time interval between the original sound and the reflected sound must be at least 0.1 seconds.

Minimum Distance for Echo

The minimum distance between the source and the reflecting surface for a distinct echo is approximately 17.2 meters.

Applications of Sound Reflection

Multiple reflections of sound are used in devices like megaphones, horns, musical instruments, stethoscopes, and in the design of concert halls to enhance sound quality.

Range of Hearing

The audible frequency range for humans is from 20 Hz to 20,000 Hz. Sounds above 20,000 Hz are called ultrasound, and those below 20 Hz are called infrasound.

Applications of Ultrasound

Ultrasound is used for cleaning hard-to-reach parts, detecting cracks in metals, and medical imaging such as sonography.

Solved Examples

Practice Set

- **Level 1:** What is the minimum time interval required between a sound and its echo to hear them distinctly?
- **Level 2:** Why are sound-absorbing materials used in auditoriums?
- **Level 3:** Calculate the minimum distance of a wall from a person to hear a distinct echo if the speed of sound is 340 m/s.

Answer Key

- **Level 1:** The minimum time interval required is 0.1 seconds.
- **Level 2:** Sound-absorbing materials reduce reverberation by absorbing reflected sound waves, improving sound clarity.
- **Level 3:** Minimum distance = (Speed × Time) / 2 = (340 m/s × 0.1 s) / 2 = 17 meters.

Quick Reference Table

Common Mistakes and Misconceptions

Glossary