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Chapter – 11

SOUND

Sound is a form of energy which produces a sensation of hearing in our ears. There are also other forms of energy like mechanical energy, light energy, etc.

Production of Sound

we have produced sound by striking the tuning fork. the objects vibrating and produce sound. Vibration means a kind of rapid to and fro motion of an object.

Propagation of Sound

Sound is produced by vibrating objects. The matter or substance through which sound is transmitted is called a medium.

When an object vibrates, it sets the particles of the medium around it vibrating. The particles do not travel all the way from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is first displaced from its equilibrium position. It then exerts a force on the adjacent particle.

As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues in the medium till the sound reaches your ear.

Wave

A wave is a disturbance that moves through a medium when the particles of the medium set neighbouring particles into motion.

They in turn produce similar motion in others. The particles of the medium do not move forward themselves, but the disturbance is carried forward.

This is what happens during propagation of sound in a medium, hence sound can be visualised as a wave. Sound waves are characterised by the motion of particles in the medium and are called mechanical waves.

Compression & Rarefaction

Air is the most common medium through which sound travels. When a vibrating object moves forward, it pushes and compresses the air in front of it creating a region of high pressure. This region is called a compression (C) .

This compression starts to move away from the vibrating object. When the vibrating object moves backwards, it creates a region of low pressure called rarefaction (R).

Compression is the region of high pressure and rarefaction is the region of low pressure. Pressure is related to the number of particles of a medium in a given volume. More density of the particles in the medium gives more pressure and vice versa. Thus, propagation of sound can be visualised as propagation of density variations or pressure variations in the medium.

SOUND NEEDS A MEDIUM TO TRAVEL

Sound is a mechanical wave and needs a material medium like air, water, steel etc. for its propagation. It cannot travel through vacuum.

SOUND WAVES ARE LONGITUDINAL WAVES

Take a slinky. Now stretch the slinky, move your hand pushing and pulling the slinky alternatively. mark a dot on the slinky, you will observe that the dot on the slinky will move back and forth parallel to the direction of the propagation of the disturbance.

The regions where the coils become closer are called compressions (C) and the regions where the coils are further apart are called rarefactions (R).

compare the propagation of disturbance in a slinky with the sound propagation in the medium. These waves are called longitudinal waves. In these waves the individual particles of the medium move in a direction parallel to the direction of propagation of the disturbance. The particles do not move from one place to another but they simply oscillate back and forth about their position of rest. This is exactly how a sound wave propagates, hence sound waves are longitudinal waves.

In a transverse wave particle do not oscillate along the direction of wave propagation but oscillate up and down about their mean position as the wave travels. Thus, a transverse wave is the one in which the individual particles of the medium move about their mean positions

in a direction perpendicular to the direction of wave propagation.

CHARACTERISTICS OF A SOUND WAVE

Frequency tells us how frequently an event occurs.

when sound is propagated through a medium, the density of the medium oscillates between a maximum value and a minimum value. The change in density from the maximum value to the minimum value, then again to the maximum value, makes one complete oscillation.

The number of such oscillations per unit time is the frequency of the sound wave. If we can count the number of the compressions or rarefactions that cross us per unit time, we will get the frequency of the sound wave. It is usually represented by v

SI unit is hertz (symbol, Hz).

t the time taken for one complete oscillation is called the time period of the sound wave. It is represented by the symbol T. Its SI unit is second (s).

Frequency and time period are related as $v = \frac{1}{T}$

Amplitude of the wave

Objects of different sizes and conditions vibrate at different frequencies to produce sounds of different pitch.

The magnitude of the maximum disturbance in the medium on either side of the mean value is called the amplitude of the wave. It is usually represented by the letter A.

The loudness or softness of a sound is determined basically by its amplitude. The amplitude of the sound wave depends upon the force with which an object is made to vibrate

The speed of sound is defined as the distance which a point on a wave, such as a compression or a rarefaction, travels per unit time.

speed, v = distance / time

$$= \frac{\lambda}{T}$$

Here λ is the wavelength of the sound wave. It is the distance travelled by the sound wave in one time period (T) of the wave. Thus

or v = λ ν

That is, speed = wavelength × frequency. The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

SPEED OF SOUND IN DIFFERENT MEDIA

Sound propagates through a medium at a finite speed. The speed of sound depends on the properties of the medium through which it travels.

The speed of sound in a medium depends on temperature of the medium. The speed of sound decreases when we go from solid to gaseous state. In any medium as we increase the temperature, the speed of sound increases

Reflection of Sound

The directions in which the sound is incident and is reflected make equal angles with the normal to the reflecting surface at the point of incidence, and the three are in the same plane.

ECHO

Echo is a reflection of sound that arrives at the listener with a delay after the direct sound. The delay is proportional to the distance of the reflecting surface from the source and the listener.

The sensation of sound persists in our brain for about 0.1 s. To hear a distinct echo the time interval between the original sound and the reflected one must be at least 0.1s.

e, the total distance covered by the sound from the point of generation to the reflecting surface and back should be at least (344 m/s) × 0.1 s = 34.4 m. Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance, that is, 17.2 m.

REVERBERATION

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation.

Range of Hearing

The audible range of sound for human beings extends from about 20 Hz to 20000 Hz (one Hz = one cycle/s).

Sounds of frequencies below 20 Hz are called infrasonic sound or infrasound.

Earthquakes produce low-frequency infrasound before the main shock waves begin which possibly alert the animals

Frequencies higher than 20 kHz are called ultrasonic sound or ultrasound. Ultrasound is produced by animals such as dolphins, bats and porpoises

Ultrasounds are high frequency waves. Ultrasounds are able to travel along welldefined paths even in the presence of obstacles. Ultrasounds are used extensively in industries and for medical purposes.

SONAR

Sonar is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects.

SONAR stands for SOund Navigation And Ranging.

Sonar consists of a transmitter and a detector and is installed in a boat or a ship, The transmitter produces and transmits ultrasonic waves. These waves travel through water and after striking the object on the seabed, get reflected and are sensed by the detector. The detector converts the ultrasonic waves into electrical signals which are appropriately interpreted.

The distance of the object that reflected the sound wave can be calculated by knowing the speed of sound in water

and the time interval between transmission and reception of the ultrasound.

Let the time interval between transmission and reception of ultrasound signal be t and the speed of sound through seawater be v. The total distance, 2d travelled by the ultrasound is then, 2d = v × t. The above method is called echo-ranging.

Structure of Human Ear

The outer ear is called 'pinna'. It collects the sound from the surroundings. The collected sound passes through the auditory canal.

At the end of the auditory canal there is a thin membrane called the ear drum or tympanic membrane. When a compression of the medium reaches the eardrum the pressure on the outside of the membrane increases and forces the eardrum inward.

The eardrum moves outward when a rarefaction reaches it. In this way the eardrum vibrates. The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear.

The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear. In the inner ear, the pressure variations are turned into electrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve, and the brain interprets them as sound.