Class XI: Physics
Waves

Key Learning:

1. Waves carry energy from one place to another.

2. The amplitude is the magnitude of the maximum displacement of the elements from their equilibrium positions as the wave passes through them.

3. The wavelength λ of a wave is the distance between repetitions of the shape of the wave. In a stationary wave, it is twice the distance between two consecutive nodes or anti nodes.

4. The period T of oscillation of a wave is the time any string element takes to move through one full oscillation.

5. A mechanical wave travels in some material called the medium. Mechanical waves are governed by Newton's Laws.

6. The speed of the wave depends on the type of wave and the properties of the medium.

7. The product of wavelength and frequency equals the wave speed.

8. $y = A\sin(kx - \omega t)$ is an equation that describes a traveling wave

9. In transverse waves the particles of the medium oscillate perpendicular to the direction of wave propagation.

10. In longitudinal waves the particles of the medium oscillate along the direction of wave propagation.

11. Progressive wave is a wave that moves from one point of medium to another.

12. The speed of a transverse wave on a stretched string is set by the properties of the string. The speed on a string with tension T and linear mass density μ is $v = \sqrt{\frac{T}{\mu}}$.

11. Sound waves are longitudinal mechanical waves that can travel through solids, liquids, or gases. The speed v of sound wave in a fluid having bulk modulus B and density ρ is

$$v = \sqrt{\frac{B}{\rho}}$$

The speed of longitudinal waves in a metallic bar of Young's modulus Y and density ρ is

$$v = \sqrt{\frac{Y}{\rho}}$$

For gases, since $B = \gamma P$, the speed of sound is

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

12. When two or more waves traverse the same medium, the displacement of any element of the medium is the algebraic sum of the displacements due to each wave. This is known as the principle of superposition of waves

13. Two sinusoidal waves on the same string exhibit interference, adding or canceling according to the principle of superposition.

14. A traveling wave, at a rigid boundary or a closed end, is reflected with a phase reversal but the reflection at an open boundary takes place without any phase change.

For an incident wave

$$y_i\ (x, t) = a \sin (kx - \omega t)$$

The reflected wave at a rigid boundary is

$$y_r\ (x, t) = - a \sin (kx + \omega t)$$

For reflection at an open boundary

$$y_r\ (x,t) = a \sin (kx + \omega t)$$

15. The interference of two identical waves moving in opposite directions produces standing waves. For a string with fixed ends, the standing wave is given by

$$y\ (x, t) = [2a \sin kx] \cos \omega t$$

16. Standing waves are characterized by fixed locations of zero displacement called nodes and fixed locations of maximum displacements called antinodes. The separation between two consecutive nodes or antinodes is $\lambda/2$.

17. A stretched string of length L fixed at both the ends vibrates with frequencies given by

$$\upsilon = \frac{1}{2}\frac{v}{2L}, \quad n = 1, 2, 3.....$$

The set of frequencies given by the above relation are called the normal modes of oscillation of the system. The oscillation mode with lowest frequency is called the fundamental mode or the first harmonic. The second harmonic is the oscillation mode with n = 2 and so on.

16. A string of length L fixed at both ends or an air column closed at one end and open at the other end, vibrates with frequencies called its normal modes. Each of these frequencies is a resonant frequency of the system.

17. Beats arise when two waves having slightly different frequencies, v_1 and v_2 and comparable amplitudes, are superposed.
The beat frequency, $v_{beat} = v_1 \sim v_2$

18. The Doppler's effect is a change in the observed frequency of a wave when the source and the observer move relative to the medium.

5. The velocity of sound changes with change in pressure, provided temperature remains constant.

16. The plus/minus sign is decided by loading/filling any of the prongs of either tuning fork.

17. on loading a fork, its frequency decrease and on filling its frequency increases.

Top Formulae

1. Velocity of wave motion, $v = \upsilon \lambda = \lambda / T$, where λ is wavelength, T is period, υ is frequency.

2. Angular wave number $k = \frac{2\pi}{\lambda}$

3. Angular frequency $\omega = \frac{2\pi}{T}$

4. Newton's formula (corrected) for velocity of sound in air is

$$\upsilon = \sqrt{\frac{B_a}{\rho}} = \sqrt{\frac{\gamma P}{\rho}},$$

Where B_a is coefficient of volume elasticity of air under adiabatic conditions, P is pressure and ρ is density of air.

5. Velocity of transverse waves in stretched string, $\upsilon = \sqrt{T/m}$, where T is tension in string and m is mass/ length of string.

6. Phase difference between two points separated by distance $\lambda = 2\pi$ radian.

7. Equation of a plane progressive harmonic wave traveling along positive direction of X – axis is

$$y = r\sin\frac{2\pi}{\lambda}(vt - x)$$

Where, y = displacement of particle at time t, r = amplitude of vibration of particle, v = velocity of wave, λ = wavelength of wave,

x = distance of starting point (or wave) from the origin.

8. Velocity of particle at time t = dy/dt

9. Acceleration of particle at time $t = \frac{d^2y}{dt^2}$

10. Acceleration of wave = 0.

11. Equation of a stationary wave is

$$y = 2r\sin\frac{2\pi}{\lambda}x\cos\frac{2\pi}{\lambda}\upsilon t$$

12. Fundamental frequency

$$\nu_1 = \frac{\upsilon}{2L} = \frac{1}{2L}\sqrt{\frac{T}{m}} = \frac{1}{\ell D}\sqrt{\frac{T}{\pi\rho}}$$

13. Second harmonic or 1st overtone $v_2 = 2v_1$

14. Third harmonic or 2nd overtone $v_3 = 3v_1$ and so on.

15. Closed organ pipes.

i. Fundamental note $\nu_1 = \frac{\upsilon}{4L}$

ii. First overtone or 3rd harmonic $v_2 = 3v_1$.

iii. Second overtone or 5th harmonic $v_3 = 5v_1$

16. Open organ pipes.

i. Fundamental note $\nu_1 = \frac{\nu}{2L}$

ii. First overtone or 2nd harmonic $v_2 = 2v_1$

iii. Second overtone or 3rd harmonic $v_3 = 3v_1$

17. Beat frequency, $m = (n_1 - n_2)$ or $(n_2 - n_1)$

18. Doppler's effect

$$\upsilon' = \frac{[(v + v_m) - v_L]}{(v + v_m) - v_s}\upsilon$$

Where, υ = actual frequency of sound emitted by the source,

υ' = apparent frequency of sound heard,

v = velocity of sound in air,

v_m = velocity of medium (air) in the direction of sound,

v_s = velocity of source, along SL

v_L = velocity of listener, along SL