14. WAVES

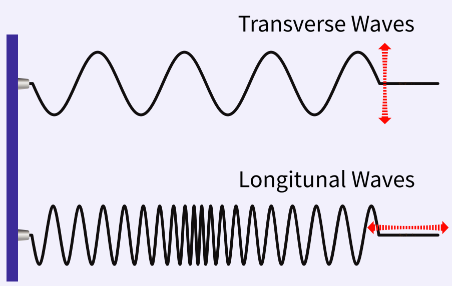
Mechanical Wave

Wave which require a material medium For propagation and to transfer energy continually are said to be mechanical wave. Example:- Water waves, Sound Waves

Non-Mechanical Wave

Waves which do not require any material medium for propagation and to transfer of energy. Example:- Electromagnetic waves (X – rays, radio waves)

Vibration of Particles



Matter Wave

Waves associated with Constituents of matter i.e, electrons, protons, neutrons, atoms and molecules are called matter waves.

Longitudinal waves
Waves in which the direction of disturbance of wave particle is along the direction of propagation of wave.

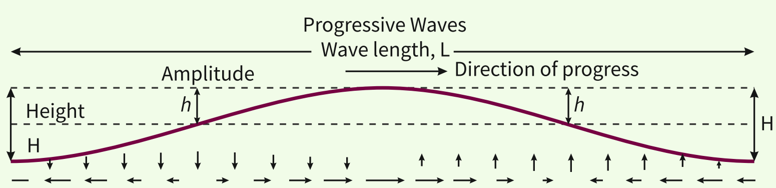
Transverse Waves
In which the direction of disturbance is perpendicular to the direction of propagation of wave.

Transfer of energy

Progressive Wave
Which travels continuously in a medium in same direction without changing its amplitude. Example: Longitudinal wave, Transverse Waves

Stationary Wave
Which seems to be at rest due to superposition of two waves having same amplitude, wavelength travelling in straight line in opposite direction.

DISPLACEMENT RELATION IN A PROGRESSIVE WAVE



Progressive wave travels continuously in a medium without changing its amplitude.

$y(x,t) = a\sin(kx \pm \omega t \pm \phi)$
x = Position of the constituents particles
y(x,t) = displacement of particles

AMPLITUDE

Amplitude is maximum displacement of vibrating particles from their equilibrium position.

Time Period

Time to Complete one vibration (or) oscillation,

$$T = \frac{2\pi}{\omega}$$

S.I. unit is sec (s)

Wavelength

minimum distance between two points having same phase.
- S.I. unit = metre (m)

Frequency

Frequency is number of oscillations per second.

$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$

f = frequency
ω = angular frequency.
- Unit = Hertz (Hz)

Angular Frequency

Angular frequency is angular displacement of any element per unit time.

$$\omega = \frac{2\pi}{T} = 2\pi f$$

Unit = rad/sec.

Wave number

Wave number is defined as the number of waves per unit length.

$$\bar{\nu} = \frac{1}{\lambda}$$

S.I. unit = 1/m

Relation between particle velocity and wave velocity

$V_p = a\omega\cos(\omega t - kx + \phi)$

$$v_\omega = \frac{\omega}{k}$$

$$v_p = -v\left(\frac{dy}{dx}\right)$$

SPEED OF LONGITUDINAL WAVE (SOUND WAVE)

Speed of sound wave in solids, $V = \sqrt{\frac{Y}{\rho}}$

Y = Young modulus

ρ = density of the solid

NEWTON'S FORMULA

propagation of sound wave is an isothermal process in air

$\Delta T = 0$, $V = \sqrt{\frac{P}{\rho}}$

P = Pressure, ρ = density

LAPLACE CORRECTION

Propagation of sound is not an isothermal process. It is an adiabatic process

$V = \sqrt{\frac{\gamma . P}{\rho}}$ $\gamma = \frac{C_P}{C_V}$

SPEED OF TRANSVERSE WAVE

Speed of sound wave in a stretched string

$V = \sqrt{\frac{T}{\mu}}$

T = Tension in the string

μ = linear mass density.

RESONANCE

Phenomenon of increased amplitude when the frequency of periodically applied force is equal to the natural frequency of system on which it acts.

NATURAL FREQUENCY

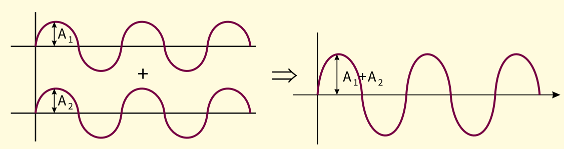
Frequency at which system tends to oscillate in the absence of any damping Force.

PRINCIPLE OF SUPERPOSITION OF WAVES

Phenomenon of mixing of two or more waves to produce a new wave.

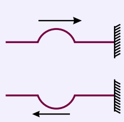
$y(x,t) = 2a\cos\frac{\phi}{2}\sin(kx - \omega t + \frac{\phi}{2})$ $A_{net} = 2a\cos\frac{\phi}{2}$

If $\phi = o$, $A_{net} = 2a$ (amplified wave). If $\phi = \pi$, $A_{net} = O$ (Standing wave)



REFLECTION OF WAVES

Reflection from rigid boundary



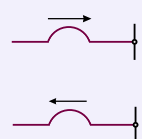
$-Y_{incident} = a\sin(wt - kx)$ (in +ve x- direction)

$-Y_{reflected} = -a\sin(wt + kx)$ (in – ve x – direction)

Reflection from Free End

$-Y_{incident} =$ a sin (wt – kx)

$-Y_{reflected} =$ a sin (wt + kx)



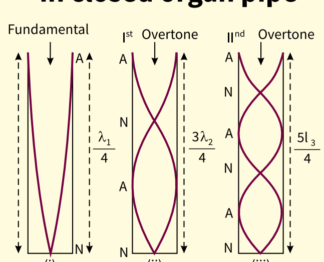
Beats

Beats is the phenomenon caused by superposition of two waves of same amplitude and slightly different angular frequency.

$y_{net} = 2\cos(\frac{\omega_1 - \omega_2}{2})\cos(\frac{\omega_1 + \omega_2}{2})$

Beat frequency $\Delta f = f_1 \sim f_2$

Vibration of air column in closed organ pipe



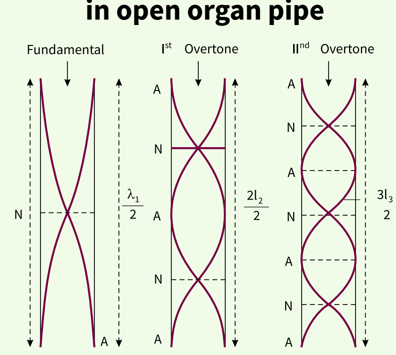
For nth harmonic, frequency of vibration

$$f_n = \frac{V}{\lambda} = \frac{(2n+1)V}{4L}$$

n = 0, 1, 2, 3,......

L = Length of the tube

Vibration of air column in open organ pipe



For nth harmonic, frequency of vibration

$$f_n = \frac{V}{\lambda} = \frac{(n+1)V}{2L}$$

n = 0, 1, 2, 3,.....

L = Length of the tube