SUPERPOSITION OF WAVES

Mechanical wave

→ wave which require a material medium for propagation and to transfer energy continually are said to be mechanised wave.
→ Example:- (1) water waves. (2) Sound waves

Non- Mechanical wave

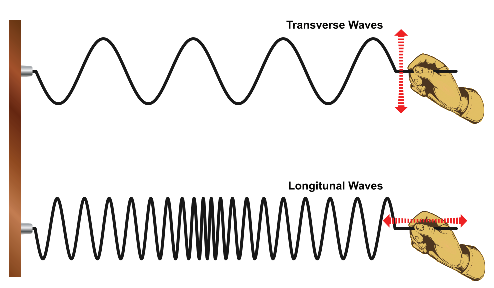
waves associated with constituents of matter i.e. electrons, protons, neutrons, atoms and molecular are called matter waves

Matter 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

Transfer of energy



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.

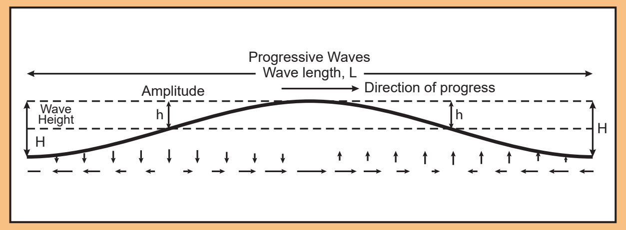
Stationary wave

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

Progressive wave

which travels continuously in a medium in same direction without changing its amplitude.
Example: (1) longitudinal wave.
(2) Transverse waves

DISPLACEMENT RELATION IN A PROGRESSIVE WAVE



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

AMPLITUDE

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

Time Period

Time to complete one revolution of oscillation.
- S.I. unit is sec (S)

wavelength

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

Frequency

Frequency is number of oscillations per second.

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

N = No. of oscillations
w = 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.

Relation between particle velocity and wave velocity

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

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

$$\upsilon_w = -\tan\theta.\ \upsilon_p$$

wavenumber

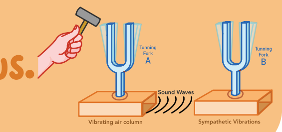
wavenumber is defined as 2π times the number of waves per unit length

$$K = \frac{2\pi}{\lambda}$$

- S.I. unit = rad/m

SPEED OF LONGITUDINAL WAVE (SOUND WAVE)

Speed of sound wave $\upsilon = C\sqrt{\frac{B}{\rho}}$
B = Bulk modulus.
ρ = density. For solids.
y = young modulus.



LAPLACE CORRECTION

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

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

- $\gamma = \frac{C_p}{C_v}$

NEWTON'S FORMULA

Propagation of sound wave is an isothermal process

$\Delta T = 0.$

$$v = \sqrt{\frac{P}{\rho}} = 228\ \text{m/s}$$

P = Pressure, ρ = density

SPEED OF TRANSVERSE WAVE

Speed of sound wave in tight string

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

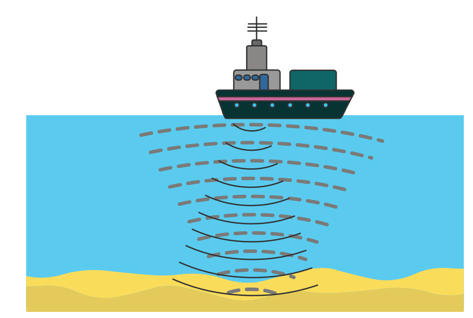
T = Tension in the string
μ = linear mass density.

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.



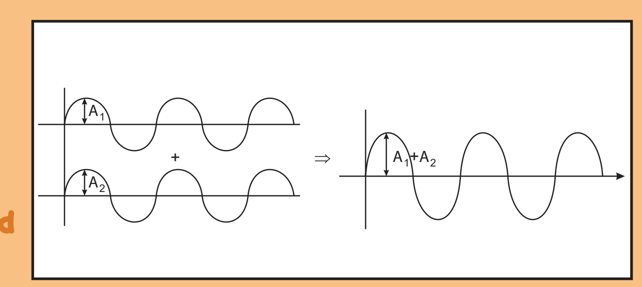
PRINCIPLE OF SUPERPOSITION OF WAVES

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

$$y(x,t) = 2a\cos\frac{\phi}{2}\sin\left(kx - wt + \frac{\phi}{2}\right)$$

$$A_{net} = 2a\cos\frac{\phi}{2}$$

If $\varphi = 0$, Anet = 2a (amplified wave)
If $\varphi = \pi$, Anet = 0 (Standing wave)



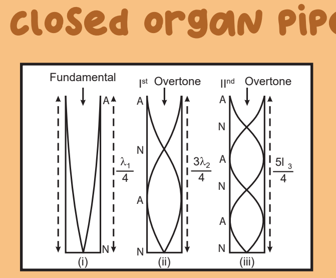
BEATS

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

$$Y_{net} = 2\cos\left(\frac{W_1 - W_2}{2}\right)\cos\left(\frac{W_1 + W_2}{2}\right)$$

Beat frequency $\Delta f = F_{max} - F_{min}$

Vibration of air column in closed organ pipe

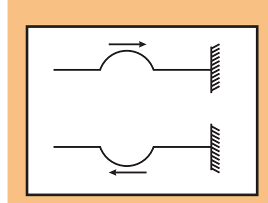


For nth harmonic. frequency of vibration

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

(N = 0, 1, 2.......)
L = Length of the tube

REFLECTION OF WAVES ((Reflection from rigid boundary)

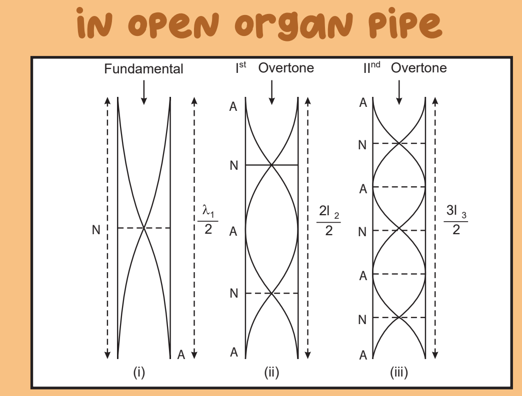


- $y_{incident} = a\sin(wt - kx)$ (in +ve x- direction)
- $y_{reflected} = -a\sin(wt + kx)$ (in – ve x – direction)

REFLECTION FROM FREE END

- $y_{incident} = a\sin(wt - kx)$
- $y_{reflected} = a\sin(wt + kx)$

Vibration of air column in open organ pipe

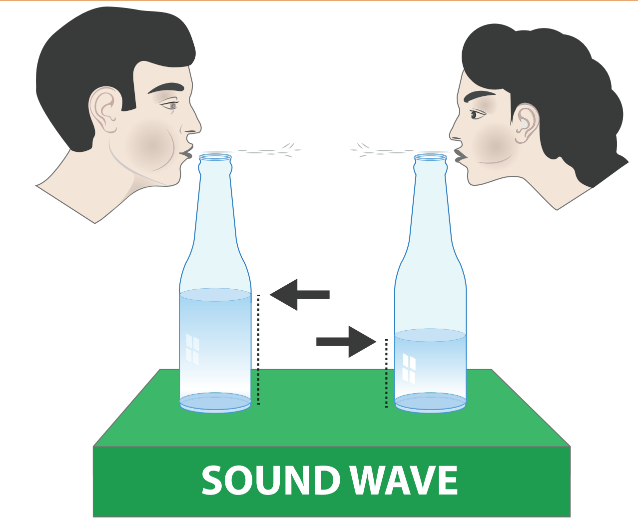


For nth harmonic. frequency of vibration

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

N = (0,1,2,3.....)
L = Length of tube

Doppler effect in sound wave



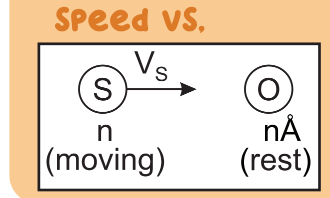
Doppler effect refer to the change in wave frequency due to relative motion between a wave source and its observer.

→ $f_o = \left(\frac{v \pm v_o}{v \pm v_s}\right) f_s$, fS = frequency emitted by source

fo = frequency heared by observer
V = Speed of sound
Vo = Speed of observer
VS = Speed of source

Case - 1

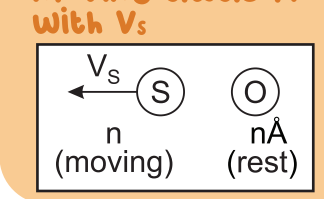
- $V_o$observe= 0 m/S and source moving towards observer with speed VS.



$$f_o = \left(\frac{v}{v - v_s}\right) f_s$$

Case - 2

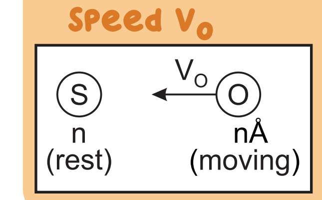
Vobserve= 0 m/s and source moving away from observer with V_S



$$f_o = \left(\frac{v}{v + v_s}\right) f_s$$

Case - 3

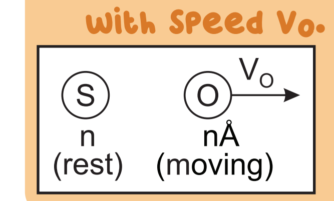
Vobserve= 0 m/s and observe is moving towards source with speed V_o



$$f_o = \left(\frac{v + v_o}{v}\right) f_s$$

Case - 4

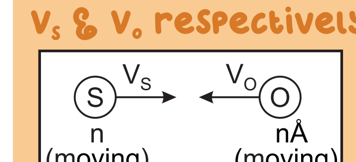
Vobserve= 0 m/s and observe is moving away from source with speed Vo.



$$f_o = \left(\frac{v - v_o}{v}\right) f_s$$

Case - 5

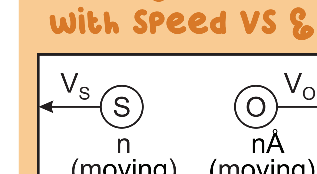
Source and observe both moving towards each other with speed V_s & V_o respectively.



$$f_o = \left(\frac{v + v_o}{v - v_s}\right) f_s$$

Case - 6

Source and observer both moving away from each other with speed VS & Vo respectively.



$$f_o = \left(\frac{v - v_o}{v + v}\right) f_s$$