WAVES

- Wave is a design or pattern which requires energy to travel from one location to another in a medium.
- Elasticity and mass (inertia) are necessary for the formation of a wave

Elasticity ki vajah se doosra particle bhi upar aya.

Types of Waves

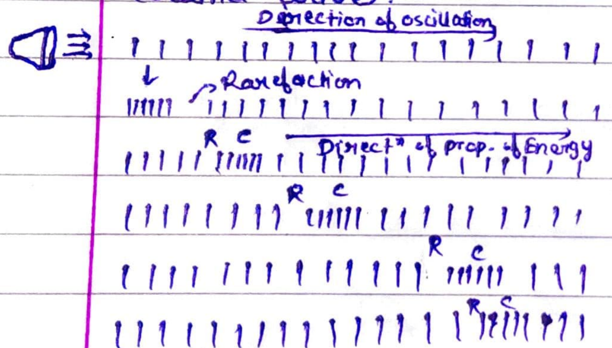
1. Material waves (Medium wave) :- which requires medium to travel.
2. EM waves :- which do not require medium to travel.
3. Matter waves

Material Waves

Longitudinal waves

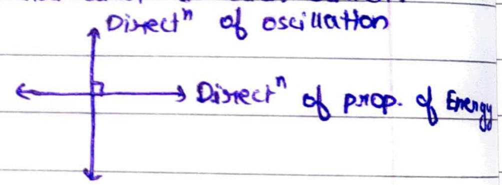
Direction of oscillation of particle and direction of propagation of energy are same

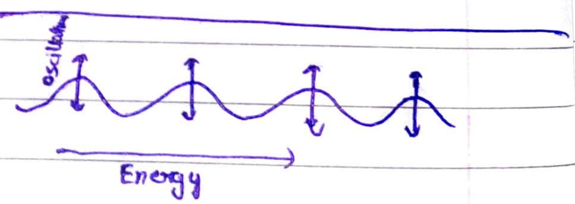
(sound wave):-



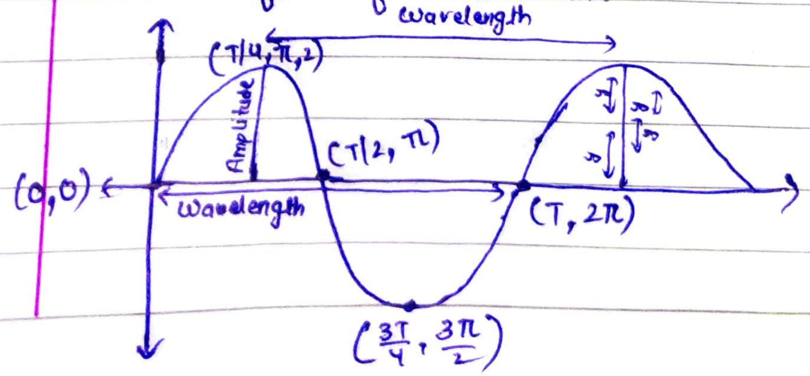
Transversal waves

Direction of oscillation of particle and propagation of energy are perpendicular to each other.





- Longitudinal waves are also called Pressure waves. They travel inside the medium.
- Transversal waves are also called Surface waves. They travel on the outer surface of the medium.



Constant quantities

$\lambda \rightarrow$ wavelength (Distance b/w crust and crust or Trough and Trough or constant phase to constant phase)

$\nu \rightarrow$ Frequency $(1/T)$

Crest

Trough

T - Time period (period to complete one oscillation)

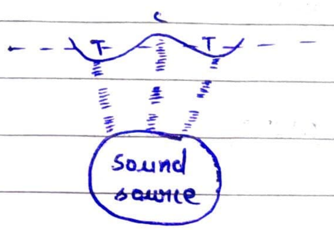
ω - Angular velocity $\left(\frac{2\pi}{T}\right)$

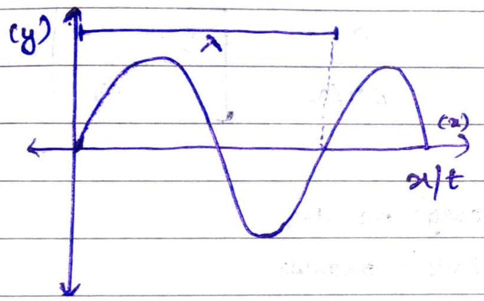
k - Propagation constant $\left(\frac{2\pi}{\lambda}\right) \rightarrow 1\lambda$ cover karne mein 2π phase travel hua
1 unit cover karne mein $\frac{2\pi}{\lambda}$

Variables

$y \rightarrow$ Displacement $\qquad t \rightarrow$ instantaneous time

$x \rightarrow$ Propagation distance





- Jab humne time constant kiya matlab kisi particular time par x distance par ja jakar wave ki position dekhi (crust/trough)
- Jab humne x distance ko constant kiya to time ke saath wave upar neeche ja rahi hai.

When x is constant $\boxed{y = A \sin kx}$

When time is constant $\boxed{y = A \sin \omega t}$

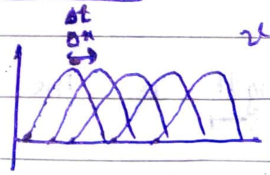
Combining equations, $y(x,t) = A \sin (kx \pm \omega t)$

$+$ → Direction of wave is ←

$-$ → Direction of wave is →

Agar wave upar se start hui toh

$$\boxed{\therefore \; y(x,t) = A \sin (kx \pm \omega t \pm \phi)}$$



$v = \frac{x}{t}$

$y(x,t) = A \sin (kx - \omega t \pm \phi)$

$y(x,t) = A \sin (\underbrace{kx - \omega t}_{\text{Phase}})$

$\because$ Phase is constant

$\therefore \; (kx - \omega t) = \text{constant}$

Differentiating $k\Delta x - \omega \Delta t = 0$

$k\Delta x = \omega \Delta t \quad \Rightarrow \quad \frac{\Delta x}{\Delta t} = \frac{\omega}{k}$ and $\frac{\Delta x}{\Delta t} = v$ $\qquad \boxed{v = \frac{\omega}{k}}$

$T \longrightarrow \lambda$

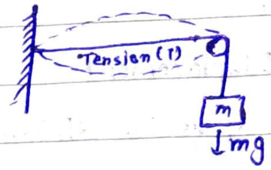
$1\,sec \longrightarrow \frac{\lambda}{T}$ $\left(\omega = \frac{2\pi}{T} \text{ and } k = \frac{2\pi}{\lambda} \right)$

$\frac{\lambda}{T} = \frac{2\pi}{k} \Big/ \frac{2\pi}{\omega} = \frac{\omega}{k} = v$

$$\boxed{v = \frac{\lambda}{T}} \qquad \boxed{v = \lambda . \nu}$$

Velocity of wave in Transversal wave

$(v \propto T)$ $\left(v \propto \frac{1}{m}\right)$



$m \rightarrow$ mass of wire per unit length

$$\boxed{v = \sqrt{\frac{T}{m}}}$$

under root dimensions same karne ke liye lagaya hai

Velocity of wave in Longitudinal wave

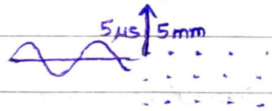
$v = \frac{\text{Restoring force per unit area}}{\text{change in volume}} = \frac{P}{\Delta V / V}$ $\boxed{v = \frac{PV}{\Delta V}}$

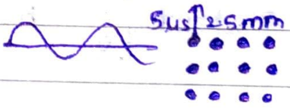
$v = \sqrt{\frac{Y}{\rho}}$

Y = Young's modulus

In liquids, $v = \sqrt{\frac{\beta}{\rho}}$ β = Bulk's modulus

- Frequency is the characterstic of source

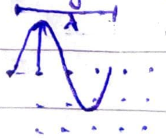


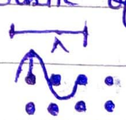


Air (Rarer medium) Water (Denser medium)

Air mein wave ne particle ko 5µs mein 5mm upar uthaya aur water mein 5µs mein 2.5mm upar uthaya. Uska amplitude change hua. Time period to same raha $\left(\nu = \frac{1}{T}\right)$

- Wavelength is the characteristic of medium





Water (Denser)

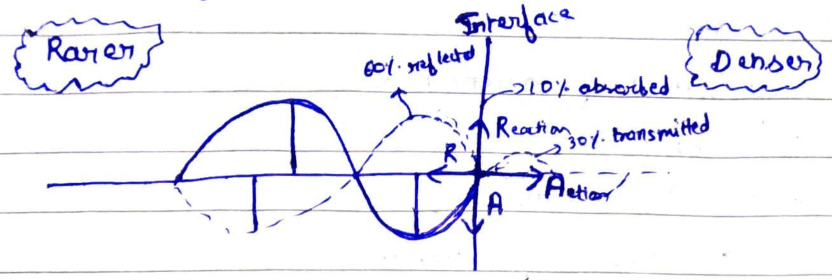
Air (Rarer)

wavelength change hui

Wavelength decreases from rarer to denser

- ## Reflection of waves

Rarer to Denser



Reflection
Trasmission
Absorbtion

$$y = A \sin (kx - \omega t)$$

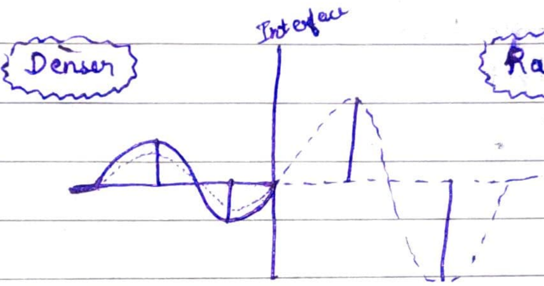
After 100% reflection,

$$\boxed{y = -A \sin (kx + \omega t)}$$

$y = A \sin (kx + \omega t + \pi)$ Phase difference

$(\because \sin(\pi + \theta) = -\sin \theta)$

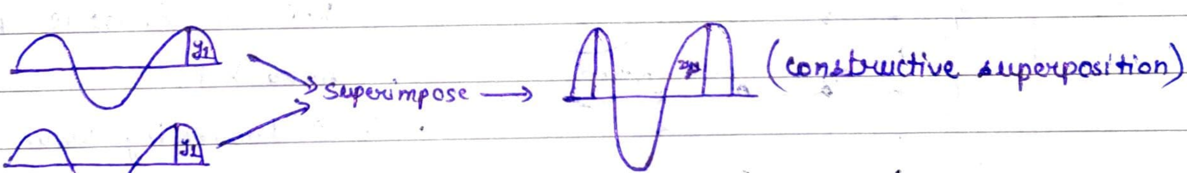
Denser to Rarer



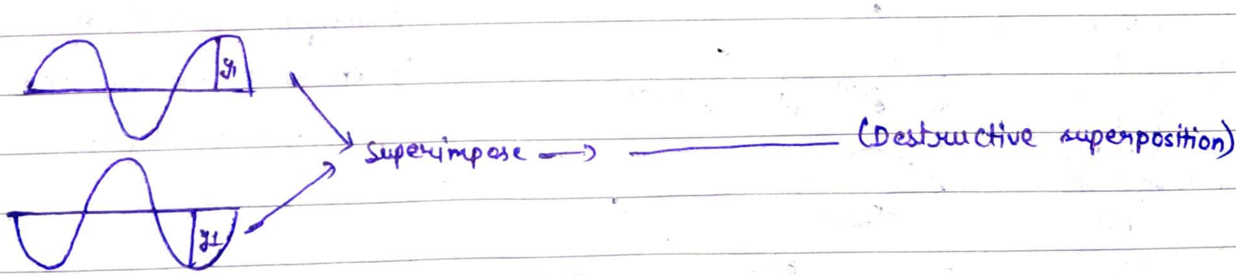
$$y = A \sin (kx - \omega t)$$

After 100% reflection, $\boxed{y = A \sin (kx + \omega t)}$

- ## Superposition of sound waves



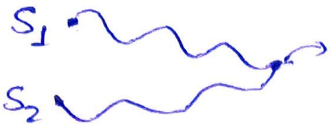
$$\boxed{y = y_1 + y_1 = 2y_1}$$



- ## Application of Superposition

→ Interference :- ~~Joing~~ Joining of two waves which have same frequency, constant phase difference and same direction.

The source which emit waves of same frequency and of constant phase difference are coherent soures.



may be contructive or destructive.

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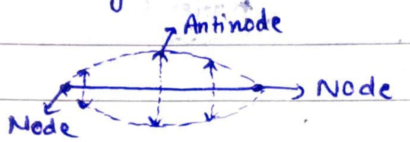
→ Beats :- Two waves of :-

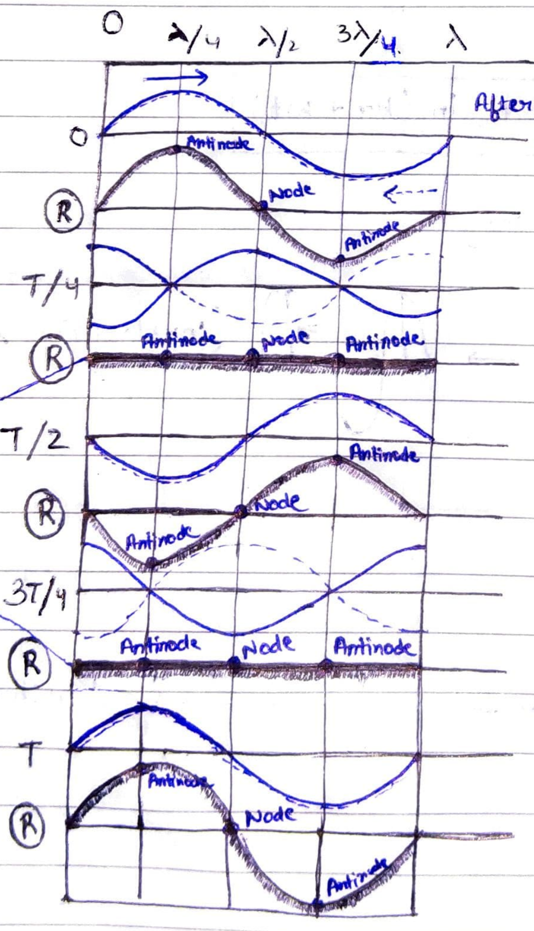
* very small frequency difference
* Same direction

→ Stationary wave:- Two waves of :-

* Same frequency
* opposite direction

* Energy ek hi jagah par rahegi (stationary rahegi)
* Stationary wave mein ek hi particle maximum peak tak ja sakta hai jabki travelling wave mein saare particle crust and trough bante hain.





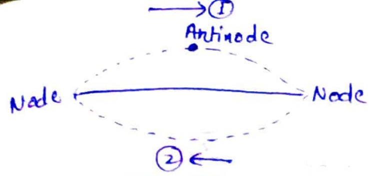
After reflection, direction opposite ho gayi

R = Resultant wave/ Stationary wave

Yaha ki energy 0 hai kyunki iski energy upar wale R ne le li jiski vajah se uska amplitude badh gaya (Redistribution of energy)

Node hamesha ruka hua hai aur antinode chal raha hai.

* To 2 travelling wave ne milkar 1 stationary wave banayi
* Stationary wave mein energy transfer nahi hoti. Agar hoti to node energy lekar upar neeche chalta.
* Node par pressure zyada hota hai antinode se.
* Node par pressure constant rehta hai antinode par change hota rehta hai.



$y_1 = A\sin(kx-\omega t)$

$y_2 = A\sin(kx+\omega t)$

(Stationary wave ⟺ 2 Transverse wave)

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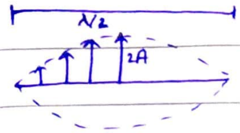
$$y_{net} = y_1 + y_2$$

$$y_{net} = A\sin(kx-\omega t) + A\sin(kx+\omega t)$$

$$\left(\because \sin A + \sin B = 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)\right)$$

$$\boxed{y_{net} = \underbrace{2A\sin kx}_{\text{Amplitude}}\ \underbrace{\cos}_{\text{Periodic function}}\ \underbrace{\omega t}_{\text{phase}}}$$

- 2A sin kx amplitude kaise hai..



$x \to \frac{\lambda}{2}$ $\quad 1 \to \frac{\lambda}{2x}$ $\quad \frac{x}{2} \to \frac{\lambda}{2\cancel{x}} \times \frac{\cancel{x}}{2} = \frac{\lambda}{4}$

x/2

λ/4

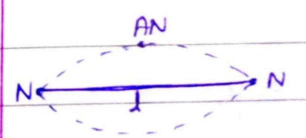
$$2A\sin kx = \text{Amplitude}$$

$$2A\sin\frac{2\pi}{\cancel{\lambda}}\times\frac{\cancel{\lambda}}{4_2} = \text{Amplitude}$$

$$\text{Amplitude} = 2A\sin\frac{\pi}{2} = 2A\times 1 = 2A$$

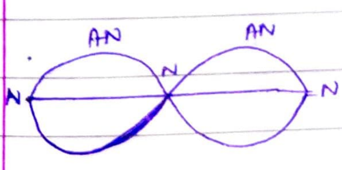
- Aur x ke respect mein Amplitude 0 se badhta ja raha hai aur fir ghat raha hai. Aur sin hi aisa periodic function hai jo 0 se badhta hai aur fir kam hota hai.

STATIONARY WAVE IN STRING

⇒ 

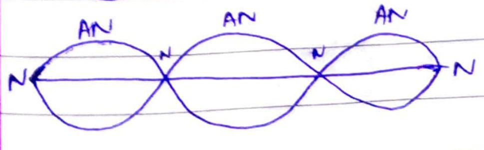
$l = \frac{\lambda}{2}$; $\lambda = 2l$

$\nu = \frac{v}{\lambda} = \frac{v}{2l}$ $\quad \boxed{\nu_1 = \frac{1}{2l}\sqrt{\frac{T}{m}}}$ $\quad \nu_1 \to 1^{st}$ Harmonic

⇒ 

$l = \lambda$ $\quad \nu = \frac{v}{\lambda} = \frac{v}{l}$

$\boxed{\nu_2 = \frac{1}{l}\sqrt{\frac{T}{m}}}$ $\quad \boxed{\nu_2 = 2\nu_1}$ $\quad \nu_2 \to 2^{nd}$ Harmonic

⇒ 

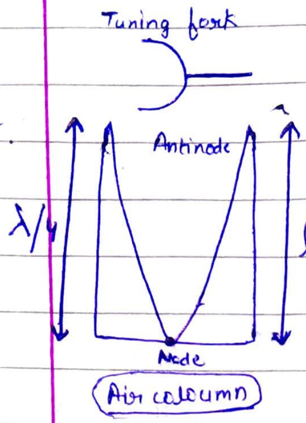
$l = \frac{3\lambda}{2}$; $\lambda = \frac{2l}{3}$

$\nu = \frac{v}{\lambda} = \frac{3v}{2l} = \frac{3}{2l}\sqrt{\frac{T}{m}}$ $\quad \boxed{\nu_3 = \frac{3}{2l}\sqrt{\frac{T}{m}}}$ $\quad \boxed{\nu_3 = 3\nu_1}$

$$\boxed{\nu_1 : \nu_2 : \nu_3 : \nu_4 = 1:2:3:4}$$

STATIONARY WAVE IN ONE END CLOSED PIPE

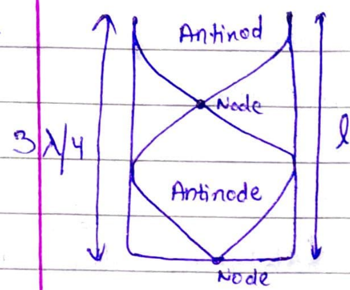
1 node :-



$$l = \frac{\lambda}{4} \; ; \; \lambda = 4l \; ; \; \nu_1 = \frac{v}{\lambda} = \frac{v}{4l} = \frac{1}{4l}\sqrt{\frac{T}{m}}$$

$$\boxed{\nu_1 = \frac{v}{4l} = \frac{1}{4l}\sqrt{\frac{T}{m}}} \rightarrow 1^{st} \text{ Harmonic}$$

2 node :-



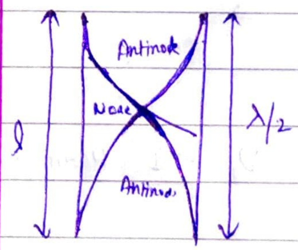
$$l = \frac{3\lambda}{4} \; ; \; \lambda = \frac{4l}{3} \; ; \; \nu_2 = \frac{v}{\lambda} = \frac{3v}{4l} = \frac{3}{4l}\sqrt{\frac{T}{m}}$$

$$\boxed{\nu_2 = \frac{3}{4l}\sqrt{\frac{T}{m}}} \qquad \boxed{\nu_2 = 3\nu_1} \rightarrow 2^{nd} \text{ Harmonic}$$

One end open : $\boxed{\nu_1 : \nu_2 : \nu_3 : \nu_4 = 1:3:5:7}$

WHEN BOTH ENDS ARE CLOSED

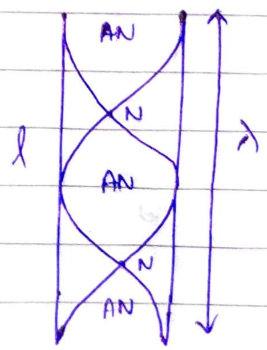
1 node :-



$$l = \frac{\lambda}{2} \; ; \; \lambda = 2l \; ; \; \nu = \frac{v}{\lambda} = \frac{v}{2l}$$

$$\boxed{\nu_1 = \frac{v}{2l}} \rightarrow 1^{st} \text{ Harmonic}$$

2node :-



$$\lambda = l \; ; \; \nu = \frac{v}{\lambda} = \frac{v}{l}$$

$$\boxed{\nu_2 = \frac{v}{l}} \qquad \boxed{\nu_2 = 2\nu_1} \rightarrow 2^{nd} \text{ Harmonic}$$