13/02 L-1 12-92

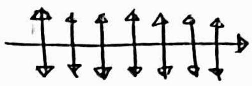
WAVE THEORY

(sound waves)

* **Wave:-** wave is disturbance that propogates in space, transport energy + momentum from one place to another without actual transport of matter.

Classification

- **Necessity of medium**
  - medium required ⇒ Mechanical waves
  - No medium req. ⇒ Non-mech. waves
- **Propogat^n of energy**
  - Propogat^n occurs ⇒ Progressive waves.
  - Redistribut^n at same place ⇒ standing or stationary waves.
- **Direct^n**
  - 1D ⇒ waves on string
  - 2D ⇒ waves on surface
  - 3D ⇒ EMW
- **Vibration of Particles**
  - → Transverse

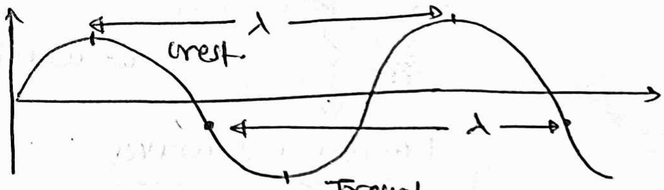


  - → longitudinal

★ **Transverse:-**

* oscillation of particle ⊥ar to direc^n of propogat^n of wave

* ⇒  ⇒



wave length = dist. b/w two particles / 2 points oscillating in same phase (same phase = $\Delta\phi = 0, 2\pi, 4\pi, 6\pi ....$)

* AKA "displacement waves".

$$y = A\sin(\omega t + \phi)$$

★ **Longitudinal:-**

* when oscillation of particle is along direction of propogat^n waves.

* due to pressure change. + variation of density of medium. (molecular)

$$P = P_0 \sin\left(\omega t - kx \pm \frac{\pi}{2}\right)$$

$$\boxed{P = \pm P_0 \cos(\omega t - kx)}$$

C R C R C

C → compression

R → Rarefraction

$\underbrace{P \to \text{more},\ y \to \text{less}}_{\text{Node (N)}}$

$\underbrace{P \to \text{less},\ y \to \text{More}}_{\text{Anti node (AN)}}$

Examples! -

1) Light waves are Transverse progessive

2) sound waves are longitudinal progressive

2) In sonometer experiment, Transverse stationary

In organ pipe / Resonance tube longitudinal stationary.

3) water waves :- Ripple = Transverse + longitudinal

motion of particle = elliptical

4) seismic waves :- (भूकम्प) → P waves + S-waves

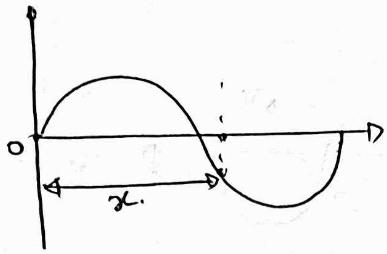
P-waves (Pressure waves) → longitudinal

S-waves (shear waves) → Transverse

PROGRESSIVE WAVES

* Medium is required for propogation
* Elasticity and inertia of medium is most essential properties for mechanical wave propogat^n

* Equation P. W



* wave velocity ⇒ V – spd of wave in a medium

* x dist. travel करने में wave को time लगा $t = \frac{x}{V}$

'O' के लिए eq.

P का oscillation $y = A\sin\omega t$

$$\boxed{y = A\omega\sin\left(t - \frac{x}{V}\right)}$$

Disturbance "start" कब हुआ : $\frac{x}{V}$ time पहले

* $y = A\sin\left[\omega\left(t - \frac{x}{V}\right)\right]$

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

K = Propogat^n const.

$$\boxed{K = \frac{\omega}{V}}$$

wave spd

$$\boxed{V = \frac{\omega}{K}}$$

* $y = A\sin K(Vt - x)$

$$\boxed{y = f(Vt \pm x)}$$

* $$\boxed{y = A\sin\left[2\pi\left[\frac{t}{T} - \frac{x}{\lambda}\right]\right]}$$

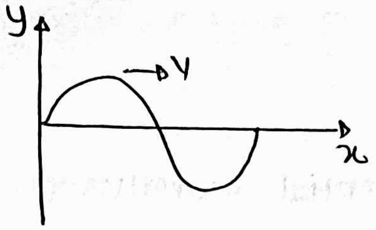
K = Angular wave No.

$K = 2\pi\left(\frac{1}{\lambda}\right)$

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

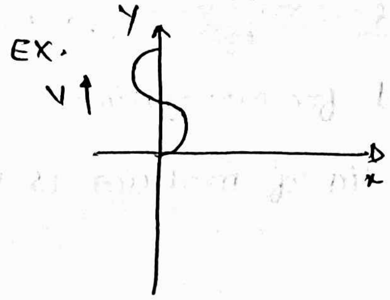
$$\boxed{\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda} = \frac{\Delta t}{T}}$$

Ex.



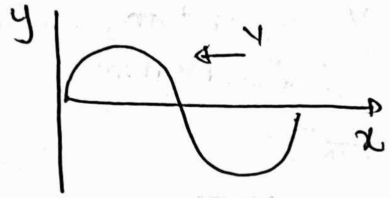
$y = A\sin(\omega t - kx)$

Ex.



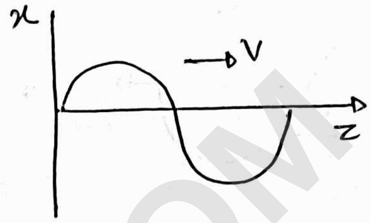
$x = A\sin(\omega t - ky)$

Ex.



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

Ex.



$x = A\sin(\omega t - kz)$

★ For wave Equation

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

$V = \frac{\omega}{k}$ = wave velocity = const. in a particular medium

$\boxed{V = f\lambda}$

velocity of oscillating particle

$$V_p = \frac{dy}{dt}$$

$\boxed{V_p = A\omega\cos(\omega t - kx)}$ $\quad (V_p)_{max} = A\omega$

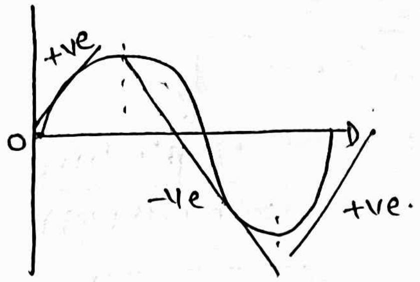
* slope of wave at a position

$$\boxed{\frac{dy}{dx} = -kA\cos(\omega t - kx)}$$

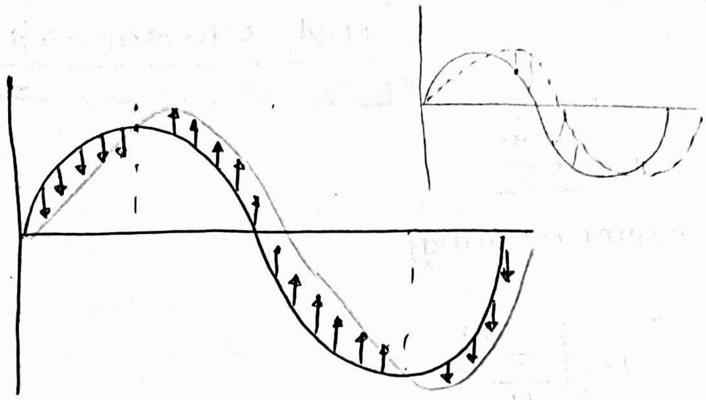
$$\boxed{\frac{\text{Particle velocity}}{\omega} = \frac{\text{slope}}{-k}}$$

$\boxed{V_p = -(\text{slope})(\text{speed of wave})}$

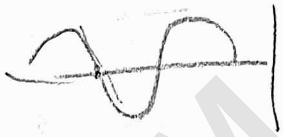
velocity ⇒ dirc^n.



$\Rightarrow$



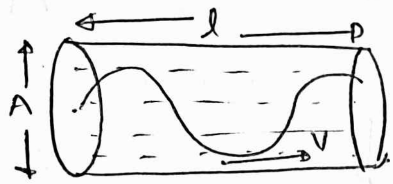
$$\boxed{\frac{\partial y}{\partial t} = -v\left(\frac{\partial y}{\partial x}\right)}$$



condition of a progressive wave

$$\boxed{\frac{\partial^2 y}{\partial t^2} = v^2\left(\frac{\partial^2 y}{\partial x^2}\right)}$$

Intensity of wave :-



$$I = \frac{E}{A \times t} = \frac{\text{Max. K.E of oscillating particle}}{A \times t}$$

$M = \rho A l$

$l = vt$

Max K.E of med. particle

$$K_{max} = \frac{1}{2} M (V_p)_m^2$$

$$= \frac{1}{2}(\rho A l)(a^2 \omega^2)$$

$$= \frac{1}{2} \rho A (vt)(a^2 \omega^2)$$

$$\boxed{I = \frac{1}{2} \rho v (a^2 \omega^2)}$$

$$\boxed{I \propto a^2 \omega^2}$$

$$\Updownarrow$$

$$\boxed{I = 2\pi^2 (\rho v a^2 f^2)}$$

$$\boxed{I \propto a^2 f^2}$$

Speed of the mechanical waves

Transverse
(waves on string)

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

longitudinal
(sound waves)

$$\boxed{V = \sqrt{\frac{E}{\rho}}}$$

E = coeff. of elasticity

ρ = density

Gas

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

isothermal

$B = P$

Newton's $V = \sqrt{\frac{P}{\rho}} = \sqrt{\frac{RT}{M_w}}$

Adiabatic

$B = \gamma P$

$$V = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M_w}}$$ → Kelvin.

laplace's correctⁿ

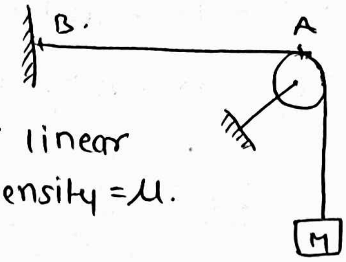
Liquid

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

solids

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

Ques.



spd of wave from A to B

string की linear mass density $= \mu$.

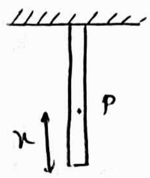
Sol

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

$$\boxed{v = \sqrt{\frac{Mg}{\mu}}}$$

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

Q. A rope of mass $= m$, length $= L$



$$\sqrt{\frac{M \lambda x}{\mu}}$$

1) Spd. at a point P at a dist. x from lower end
2) Time taken to cover complete length.

Sol.

① $v = \sqrt{\frac{\frac{M x}{L}}{\frac{M}{L}}}$ $\quad (v = \sqrt{xg})$

① $$v = \sqrt{\frac{\left(\frac{M}{L}x\right)g}{M/L}} = \sqrt{xg}.$$

② $$\frac{dx}{dt} = \sqrt{g}\, x^{1/2} \Rightarrow \int_0^L x^{-1/2}\, dx = \int_0^t \sqrt{g}\, dt$$

$$\boxed{T = \frac{2\sqrt{L}}{\sqrt{g}} = t}$$

$x \to v$
$1 \to \frac{v}{x}L$

$D = S \times t$

$\frac{x}{v} = 1$

$\left(t = \sqrt{\frac{x}{g}}\right)$

Q. Young's modulus of wire is $Y = 2 \times 10^{11}\ N/m^2$ & $\rho = 8 \times 10^3\ kg/m^3$ find spd of ~~Transverse~~ longitudinal wave in wire = ?

$$\frac{2 \times 10^{11}}{8 \times 10^3}$$

$$\frac{1}{4} \times 10^8$$

$$\frac{1}{2} \times 10^4$$

$5000\ m/s$

Q. spd. of sound in Alcohol = 1280 m/s , $\rho_{alcohol}$ = 0.8 gm/cm³ find change in vol. of 6L of Alcohol if pressure is ↓sed from 200 cm of Hg to 75 cm of Hg

Sol.

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

1280

32 = V 0.2

$$B = \rho v^2.$$

$$\frac{\Delta P}{-\left(\frac{\Delta V}{V}\right)} = \rho v^2$$

$$\Delta V = -\frac{V_0(\Delta P)}{\rho v^2}$$

$$\Delta V = -\frac{6\,(-125)}{0.8 \times 1280 \times 128}$$

$$\Delta V =$$

25

$$B = \frac{P}{\Delta V/V}$$

$$32 \times 0.8 = \frac{125}{x}$$

$$x = \frac{125 \times \frac{5}{10}}{32 \times 8.2}$$

$$\frac{150}{32} = 3.$$

Spd. of sound in a gaseous mixture

$$V = \sqrt{\frac{\gamma RT}{M_w}}$$

V_0 = spd. at 0°C $\quad V_0 \propto \sqrt{273}$

V_t = spd. at t°C $\quad V_t \propto \sqrt{t+273}$

$$\boxed{\frac{V_t}{V_o} = \left(\frac{t+273}{273}\right)^{1/2}}$$

$$\boxed{V_t = V_0\left(1 + \frac{t}{273}\right)^{1/2}}$$

$$V_t = V_0\left(1 + \frac{t}{576}\right)$$

$$\boxed{V_t = V_0 + 0.61\,t}$$

per°C ↑es spd ↑es by 0.61 m/s.

Super position of waves

when two or more waves are travelling in a same medium & they overlap on each other, then resultant disp. of a particle at any point of medium at any time is the vector sum of displacement caused ~~to~~ to the particle by individual

$$\boxed{\vec{y} = \vec{y_1} + \vec{y_2} + \vec{y_3}}$$

$$\boxed{\vec{y_r} = \vec{y_1} + \vec{y_2}}$$

* Interference

i) coherent sources

ii) $f_1 = f_2$

iii) $\Delta\phi = *$

iv) Amplitude may / or may not be same.

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1 A \cos(\Delta\phi)}$$

$$I = \sqrt{I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(\Delta\phi)}$$

$A_1 = A_2$.

$$\boxed{A = 2A_0 \cos\left(\frac{\Delta\phi}{2}\right)}$$

$I_1 = I_2$

$$\boxed{I = 4I_0 \cos\left(\frac{\Delta\phi}{2}\right)}$$

* constructive $\Delta\phi = 0, 2\pi, 4\pi, 6\pi \ldots\ldots$ = same phase.

$$A_{max} = A_1 + A_2$$

$$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$$

* Destructive $\Delta\phi = \pi, 3\pi, 5\pi, 7\pi \ldots$ = opp. phase

$$A_{min} = A_1 \sim A_2$$

$$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2.$$

* Degree of interference

$$\boxed{\beta = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}}$$

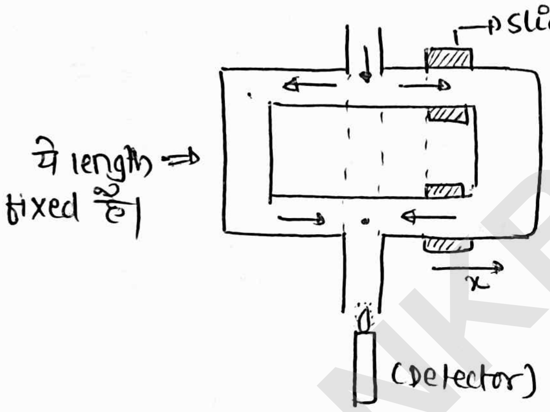
* For sustained interference => Perfect Interference

- $A_1 = A_2 = a$ $\quad A_{max} = 2a \quad I_{max} = 4I$
- $I_1 = I_2 = I.$ $\quad A_{min} = 0 \quad I_{min} = 0.$

* DoI = 100% in this case.

* Quincke's Tube :-

* it is practical approach to calculate spd. of sound in gaseous medium.
* it explains interference of sound
*



if x moved

$\Delta\phi = 2x$ then.

* Vibrations in flame become

→ Maximum to maximum
OR
minimum to minimum

$$\boxed{\Delta x = 2x = \lambda}$$

→ Maximum to ~~maximum~~ Min.
OR
Minimum to ~~minimum~~ Max.

$$\boxed{\Delta x = 2x = \frac{\lambda}{2}}$$

Q. In a Quincke's tube experiment to find maximum to maximum, tube is slided by 30cm.

if spd of sound in tube is 330 m/s. find wave length & frequency.

Sol.

$\lambda = 60cm$

$v = 3 \cdot 0$

$\frac{330}{6 \times 10^{-2}} = v$

5.5

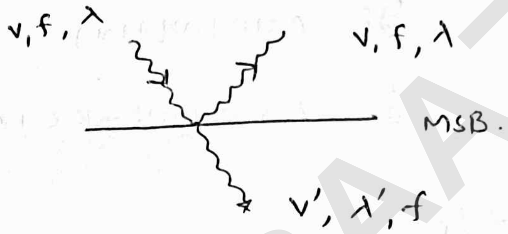
$6 \overline{)33}$

30

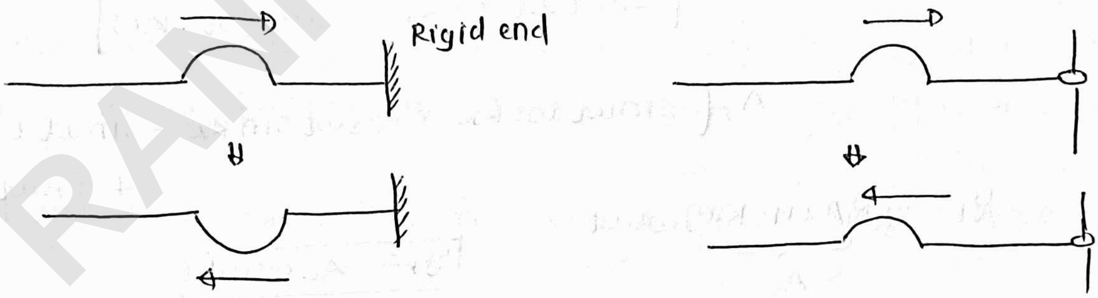
30

$5.6 \times 10^2 = v$

REFLECTION OF ~~SOUND~~ MECH. WAVES :-



* string wave



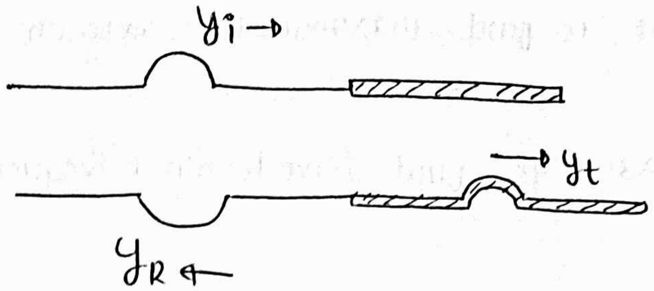
$y_i = A\sin(\omega t - Kx)$

$y_R = A\sin(\omega t + Kx + \pi)$

$y_i = A\sin(\omega t - Kx)$

$y_R = A\sin(\omega t + Kx)$.

*

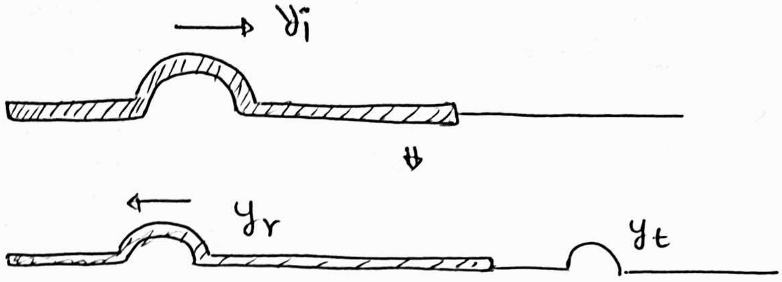


$y_i = A\sin(\omega t - Kx)$

$y_r = A\sin(\omega t + Kx + \pi)$

$y_t = A'\sin(\omega t - K_1 x)$

*



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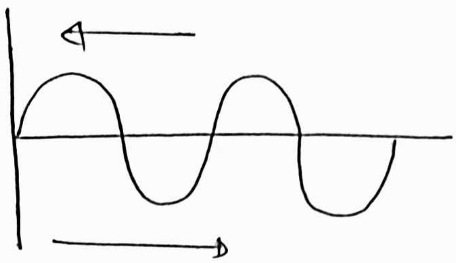


$y_i = A\sin(\omega t + Kx)$

$y_r = A\sin(\omega t - Kx + \pi)$

$$y_R = y_i + y_R.$$

$$y_R = A\sin(\omega t + Kx) + A\sin(\omega t - Kx + \pi)$$

$$= A\left[\sin(\omega t + Kx) - \sin(\omega t - Kx)\right]$$

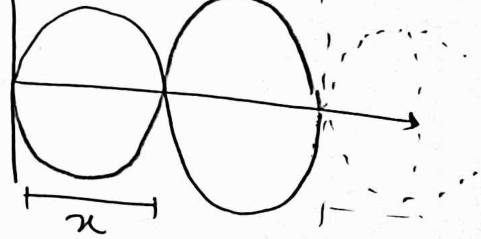
$$A\left[\sin\omega t\cos Kx + \cos\omega t\sin Kx - \sin\omega t\cos Kx + \cos\omega t\sin Kx\right]$$

$$y_R = \underbrace{(2A\sin Kx)}_{A_0}\cos\omega t$$

$$\boxed{y_R = A_0\cos\omega t}$$

each particle performs its own SHM.

$$A_0 = 2A\sin\left(\frac{2\pi}{\lambda}x\right)$$



$x = 0$ — $A_0 = 0$

$x = \frac{\lambda}{2}$ — $A_0 = 0$ — NODE

$x = \lambda$ — $A_0 = 0$

$x = \lambda/4$

$x = \frac{3\lambda}{4}$ — A.N $\boxed{A_0 = 2A}$

$x = \frac{5\lambda}{4}$

Ex.

$y_i = A\sin(\omega t + Kx)$ ←

open end → $y_R = A\sin(\omega t - Kx)$

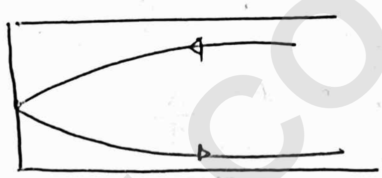
$$y_R = y_i + y_R = A\,[2\sin\omega t\cos Kx]$$

$$\boxed{y_R = \underbrace{(2A\cos Kx)}_{A_0}\sin\omega t} \qquad y_R = (A_0)\sin\omega t$$

$x = 0 \Rightarrow$ Antinode

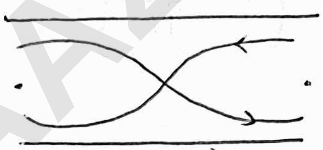
Note :-

closed end organ pipe



close end पर Node
open end पर antinode

open end organ pipe



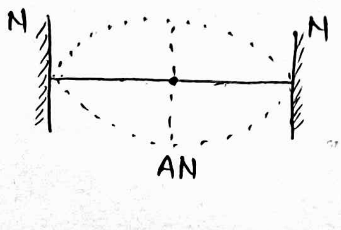
Both open ends पर Antinode.

★ **stationary waves (standing waves)**

(*) when two waves are identical & travelling in opp. dir^n in a confined region then by superposition they can produce a resultant stationary wave

(*) stationary wave format^n is in bounded region only in this wave velocity $= 0$.
b/coz energy is redistributed in that limited region.

(*) in this all particle perform own SHM with diff amplitudes (depends upon the position of particle) and same time period.
i.e all particles crosses the mean position simultaneously but with diff. spds.



Pluck = AN (Antinode)
Touch / press = Node

(*) In this pattern of node + Antinodes are fixed.

Distance b/w two nodes $\longrightarrow \lambda/2$

two antinodes $\longrightarrow \lambda/2$

Node - AN $\longrightarrow \lambda/4$

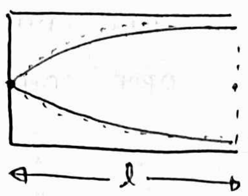
★ **Application of longitudinal stationary waves:-**

(organ pipe + resonance tube)

(*) **closed organ pipe:-**

open end पर Antinode बनेगा ।

*



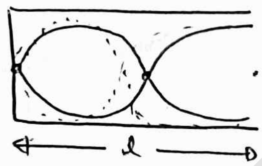
- $l = \frac{\lambda}{4}$

$\lambda = 4l$

- $\boxed{f_c = \frac{v}{4l}}$

4, 6, 8, 10, 12
14, 16, 18, 20
Min → fundamen…
overtone
1st O.T = 6
2nd O.T = 8
3rd O.T = 10
Harmonic
8 = 4 × (2) 2nd Har…
16 = 4 × (4) 4th …

*

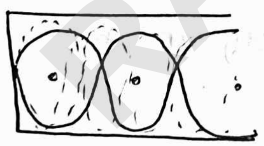


- $l = \frac{3\lambda}{4}$

$\lambda = 4l/3$

- $f_1 = 1^{st}\ OT = \frac{3v}{4l} = 3f_c = 3^{rd}$ Harmonic

*



- $l = \frac{5\lambda}{4}$ $\lambda = \frac{4l}{5}$

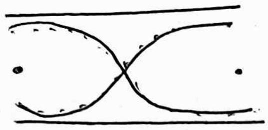
- $f_2 = 2^{nd}\ O.T = \frac{5v}{4l} = 5F_c = 5^{th}$ Harmonic

(*) $F_c : f_1 : f_2 : f_3 = 1:3:5:7$

(*) only odd Harmonic are int.

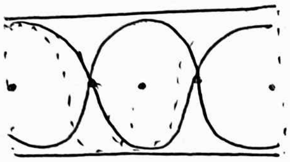
* open organ Pipe

open end पर Antinode

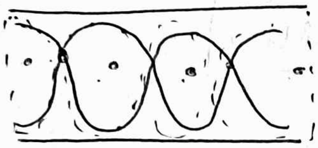


- $l = \frac{\lambda}{2}$ $\boxed{\lambda = 2l}$

$$\boxed{f_0 = \frac{V}{2l}}$$



- $l = \frac{4\lambda}{4}$ $\boxed{l = \lambda}$
- $f_1 = \frac{V}{l} = 1^{st}$ O.T $= 2f_1 = 2^{nd}$ Harmonic



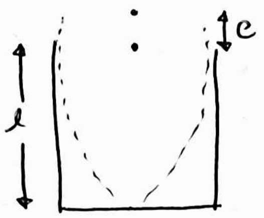
- $l = \frac{6\lambda}{4}$ $\boxed{\lambda = \frac{2}{3}l}$
- $f_2 = \frac{3V}{2l} = 2^{nd}$ O.T $= 3^{rd}$ Harmonic

⊛ $f_0 : f_1 : f_2 : f_3 = 1 : 2 : 3 : 4$

⊛ All Harmonics are int.

* End correction:-

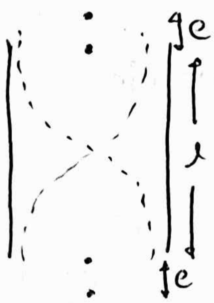
due to inertia of medium particles, Antinode is formed "not exactly at the open end" but a bit outside.



- $\frac{\lambda}{4} = l + e$

$$\boxed{\lambda = 4(l+e)}$$

$$\boxed{f_c = \frac{v}{4(l+e)}}$$



$\frac{\lambda}{2} = l + 2e$

$$\boxed{\lambda = 2(l+2e)}$$

$$\boxed{f_o = \frac{v}{2(l+2e)}}$$

" experimentally $\boxed{e = 0.6r}$." r = radius.

for Questions

① For COP →

f_n = n^{th} overtone.

$= \frac{(2n+1)v}{4l}$.

$$\boxed{f_n = (2n+1) f_c \quad = (2n+1)^{th} \text{ Harmonic}}$$

nodes = $n+1$ Antinodes = $n+1$

② for OOP →

f_n = n^{th} overtone

$\cancel{f_n} = \frac{2(n+1)v}{2l}$

$$\boxed{f_n = (n+1) f_o \quad = (n+1)^{th} \text{ Harmonic}}$$

Nodes = $n+1$ A.N = $n+2$

★ Resonance Tube experiment:-

An organ pipe is converted to a close organ pipe by filling water in it.

* without end correction

- 1st Resonance length $l_1 = \frac{\lambda}{4}$

  2nd " " $l_2 = \frac{3\lambda}{4}$

  3rd " " $l_3 = \frac{5l}{4}$

$l_1 : l_2 : l_3 = 1:3:5$

$$\boxed{l_2 - l_1 = l_3 - l_2 = l_4 - l_3 = \frac{\lambda}{2}}$$

$$\boxed{\lambda = 2(l_2 - l_1)}$$

with end correction

- 1st R.L $l_1 + e = \frac{\lambda}{4}$

  2nd R.L $l_2 + e = \frac{3\lambda}{4}$

  3rd R.L $l_3 + e = \frac{5\lambda}{4}$

$l_2 > 3l_1$, $l_3 > 5l_1$, $l_4 > 7l_1$

$$\boxed{l_2 - l_1 = l_3 - l_2 = l_4 - l_3 = \frac{\lambda}{2}}$$

$$\boxed{\lambda = 2(l_2 - l_1)}$$

$$\boxed{e = \frac{l_2 - 3l_1}{2}}$$

Q. In COP 7th O.T = 600 Hz then 3rd O.T = ?

Sol. $f_7 = 15f_c$

$600 = 15(f_c)$

$f_c = 40$

$f_3 = 7f_c = 280\,Hz.$

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

$\frac{600}{x} = \frac{7}{3}$

$x = \frac{1800}{7}$

Q. In COP 7th O.T = 900 then 1st O.T of OOP of same length.

$f_7 = 15f_c$

$900 = 15f_c$

$f_c = 60 = \frac{v}{4l}$

$f_1 = 2f_0 = 2\left(\frac{v}{2l}\right)$

$= 240\,Hz.$

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

$f_n =$

$\frac{900}{x} = \frac{7}{1}$ $\frac{v}{4l}$ $\frac{12}{24}$

$x = \frac{1600}{7}$

Q. $v = 300\,m/s$ $f = 500\,Hz$ $L = 125\,cm$ of Resonance Tube?

i) maximum & minimum water level.

ii) Max no. of resonance.

Sol.

$$\lambda = \frac{300}{500} \times 100 = 60\,cm.$$

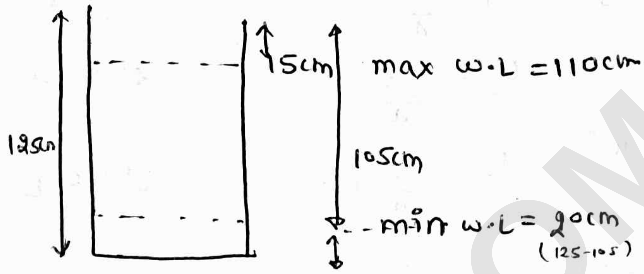
$l_1 = \frac{\lambda}{4} = 15\,cm$

$l_2 = \frac{3\lambda}{4} = 45\,cm$

$l_3 = \frac{5\lambda}{4} = 75\,cm.$

$l_4 = 7\lambda/4 = 105\,cm$

$l_5 = 9\lambda/4 = 135\,cm$



Q. 1^{st} R.L = 17cm & 2^{nd} R.L = 55cm the radius of R.T

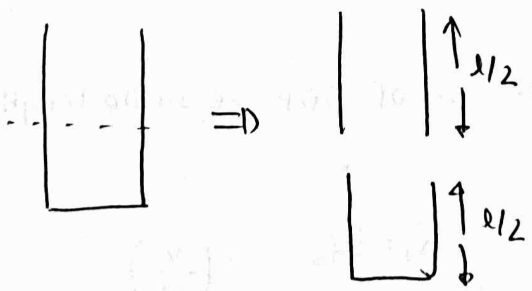
$$e = 0.6r = \frac{l_2 - 3l_1}{2}$$

$$0.6r = \frac{55-51}{2}$$

$$\boxed{r = \frac{2}{0.6}\,cm}$$

Q. if COP is cut in 2 equal parts, then ratio of their ~~length~~ fundamental frequencies.

Sol.



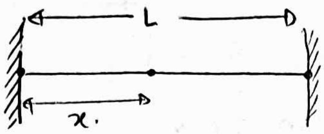
$f_1 = \frac{v}{2l}$

$= \frac{v}{2(l/2)}$

$f_2 = \frac{v}{4(l/2)}$

$$\boxed{\frac{F_1}{F_2} = \frac{2}{1}}$$

* Stationary wave in streched string : (SONOMETER)



Standing wave ⇒ $y = \underbrace{(2A \sin kx)}_{\text{Amplitude of oscillating particle at } x} \cos \omega t$

$\sin kx = 0 = \sin(n\pi)$

$\boxed{x = \frac{n\pi}{k}}$ ⇒ Node

$x = \frac{n\pi}{2\pi}\lambda$

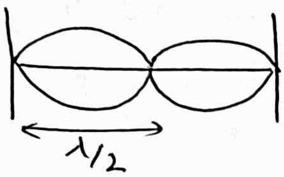
$\boxed{x = \frac{n\lambda}{2}}$

$L = \frac{\lambda}{2}.$

$\boxed{\lambda = \frac{2L}{n}}$

$\boxed{l = \frac{L}{2}}$

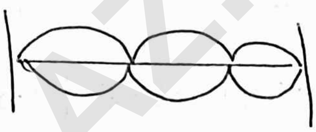
* $n = 2$



$L = 2(\lambda/2)$

$\boxed{\lambda = L}$

$n = 3$ ⇒ No. of loops.



$\boxed{L = \frac{3\lambda}{2}}$ $\boxed{\lambda = \frac{2L}{3}}$

* Spd. of Transverse wave in string $\boxed{V = \sqrt{\frac{T}{\mu}}}$

freq $f = \frac{V}{\lambda} = \frac{nV}{2L}$

$n = 1$ fundmental freq. $f = \frac{V}{2L}$

$n = 2$ 1st O.T $\boxed{f_1 = \frac{2V}{2L}}$

$n = 3$ 2nd O.T $\boxed{f_2 = \frac{3V}{2L}}$

↓

No. of loops

↓

Plucking dist. $\boxed{l = \frac{L}{2n}}$

$$f = \frac{nv}{2L} = \frac{n}{2L}\sqrt{\frac{T}{\mu}} = \frac{n}{2L}\sqrt{\frac{TL}{M}}$$

$$f = n\sqrt{\frac{T}{mL}}$$

- $f \propto \sqrt{T} \rightarrow m + L *$
- $f \propto 1/\sqrt{m} \rightarrow T + L *$
- $f \propto \frac{1}{\sqrt{L}} \rightarrow T + m *$

17/02

BEATS

When two waves of equal amplitude + nearly equal freq. travelling in same dirc^n superimpose on each other then variat^n of intensity occurs periodically w.r.t time this phenomenon is cld "beat format^n"

- only for nearly equal freq.

$\therefore$ $\boxed{f_1 - f_2 = 10}$ तक

- Beat freq. $\Rightarrow$ $\boxed{b = f_1 - f_2}$ No. of beat/sec.

- freq. of amplitude variation $= \frac{f_1 - f_2}{2}$

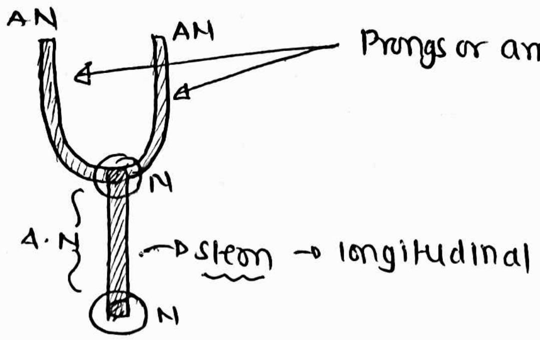
- freq. of Resultant wave $= \frac{f_1 + f_2}{2}$

- Time interval b/w the beats $\Rightarrow$ Amp. Maximum

$$\boxed{\Delta t = \frac{1}{f_1 - f_2}}$$

- instant when beat is heard $\Rightarrow t = \frac{1}{f_1 - f_2}, \frac{2}{f_1 - f_2}, \frac{3}{f_1 - f_2} \ldots\ldots$

TUNING FORK:-



* Forced variation ⇒ Prong → hit ⇒ Driver

  other one ⇒ Driven

(*) can't produced overtones ⇒ fundamental Always.

⇓ (Given)

(*) Prongs are loaded (wax / string / paper) ⇒ freq. ↓

Prongs are filed → (घिसना) ⇒ freq. (↑)

Q. Two tuning forks of 500 Hz & 504 Hz are sounded together. No. of beats produced =?, & the instants.

Sol.

$$\text{beats} = f_1 - f_2 = 504 - 500 = 4$$

$$\text{instant} = \frac{1}{4}, \frac{2}{4}, \frac{3}{4}, \frac{4}{4}$$

Que. 500 Hz, 502, 504 are sounded together

No. of ~~Heart~~ beats heard = ?

Sol.

500 → 502: 2 — $\frac{1}{2}, \frac{2}{2}$

502 → 504: 2 — $\frac{1}{2}, \frac{2}{2}$

500 → 504: 2. — $\frac{1}{4}, \frac{2}{4}, \frac{3}{4}, \frac{4}{4}$

No. of beats = 4

Quen. 500 Hz, 504 Hz, 506 Hz No. of beats Heard = ?

Sol. Beats = 8

14 4 2 6

$\frac{1}{4}, \frac{2}{4}, \frac{3}{4}, \frac{4}{4}$ $\frac{1}{2}, \frac{2}{2}$ $\frac{1}{6}, \frac{2}{6}, \frac{3}{6}, \frac{4}{6}, \frac{5}{6}, \frac{6}{6}$

Quen A T.F can be produced 5 beats/sec. with a T.F of freq. = 500 Hz. freq. of 1st T.F = ?

$5 = f_2 -$

$x > 505$

495

Quen. A T.F can be produce 3 beats/sec. with a T.F of freq. 300 Hz. If some wax is applied to arms of known T.F then beat freq. ~~of unknown tuning fork can be~~ ↑es., Freq. of unknown T.F = ?

$3 = f_1 - f_2$

297 303

If large amount of wax applied then 297 & 303 can be the answer.

Quen A T.F produces 4 beats/sec with T.F of freq. 256 Hz if we file the arms of unknown T.F beat freq. ↑es. Freq. of unknown T.F

Sol.

$$252 \leftarrow 256 \rightarrow 260.$$

$$252 \leftarrow 256 \rightarrow 260$$

Q. Two T.F of freq. n_1 + n_2 can produce two beats per sec. , n_1 with 15 cm COP + n_2 with 30.5 COP find freq. n_1 + n_2 ?

Sol.

$n_1 = 15$ cm COP $f_c^1 = V/4l_1$

$n_2 = 30.5$ cm COP $f_c^2 = V/4l_2$

$$\frac{f_{c_2}}{f_{c_1}} = \frac{l_1}{l_2} = \frac{15}{30.5} = \frac{30}{61}$$

$n_1 - f_{c_1}$ OR $f_{c_1} - n_1$ $= 2$ / $n_2 - f_{c_2}$ $f_{c_2} - n_2$ $= 2$

$2 = n_1 - n_2$

$n_1 = \frac{V}{4l}$

$n_1 = \frac{V}{4(15)}$ $n_2 = \frac{V}{120}$

$n_1 = \frac{V}{60}$

$n_1 = 2n_2$

$2 = 2n_2 - n_2$

$n_2 = 2$

Q. 41 T.F are arranged to produce 3 beats/s with nearest T.F if freq of last T.F is 3 times the freq. of 1st T.F then freq. of 21st T.F = ?

$f_1 = 3f_{41}$

Sol.

* unison ⟹ same freq. OR resonance

* octave ⟹ Double freq.

f_1 f_2 f_3 . . . . f_{41}

x $x+3$ $x+6$ $3x$.

↓ (02 freq. is term)

1st term of A.P ⟹ $a = x$

nth term of A.P ⟹ $a_n = a + (n-1)d$

$3x = x + (41-1)3$

$2x = 120$

$\boxed{x = 60 = a}$

$a_{21} = 60 + (20)(3) = 120$ Hz

DOPPLER'S EFFECT

⇒ Apparent change in freq. of sound when source of sound, observer + medium are in relative motion is c/a "Doppler's effect".

(*) In this foll. assumpt^{n} are to be made:-

① velocity of source, observer + medium are taken along line joining the source + observer.

② velocity of source + observer must be less than velocity of sound.

$$\boxed{n' = n\left[\frac{(v \pm v_m) \pm v_o}{(v \pm v_m) \pm v_s}\right]}$$

Medium at Rest.

$$\boxed{n' = n\left[\frac{v \pm v_o}{v \pm v_s}\right]}$$

medium in mot^{n}

in dirc^{n} of sound.

$$n' = n\left[\frac{(v + v_m) \pm v_o}{(v + v_m) \pm v_s}\right]$$

in opp. dirc^{n} of sound

$$n' = n\left[\frac{(v - v_m) \pm v_o}{(v - v_m) \pm v_s}\right]$$

$$n' = n\left[\frac{v \pm v_o}{v \pm v_s}\right]$$

① $\left.\begin{array}{l} v_o = 0 \\ v_s = 0 \end{array}\right\}$ Both are at rest

$\boxed{n' = n}$

no Doppler effect

② S (Rest) ← O

$$n' = n\left[\frac{v + v_o}{v}\right]$$

③ S (Rest) O →

$$n' = n\left[\frac{v - v_o}{v}\right]$$

④ S → O (Rest)

$$\boxed{n' = n\left[\frac{v}{v - v_s}\right]}$$

⑤ ← S O (Rest)

$$n' = n\left[\frac{v}{v + v_s}\right]$$

⑥ S → O →

$$n' = n\left[\frac{v - v_o}{v - v_s}\right]$$

⑦ ← S ← O

$$n' = n\left[\frac{v + v_o}{v + v_s}\right]$$

⑧ ← S O →

$$n' = n\left[\frac{v - v_o}{v + v_s}\right]$$

⑨ S → ← O

$$n' = n\left[\frac{v + v_o}{v - v_s}\right]$$

* Doppler effect in light:-

⊛ Distance b/w 'S' & O

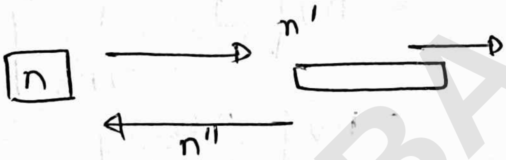
- increases ⇒ $n' < n$ → $\lambda' > \lambda$ → Red shift
- Decreases. $n' > n$, $\lambda' < \lambda$ ⇒ Blue light.

⊛ $$\boxed{n' = n\left(\frac{1 \pm v/c}{1 \pm v/c}\right)^{1/2}}$$

⊛ Distance +es ⇒ $n' = n\left(\frac{1+v/c}{1-v/c}\right)^{1/2}$ ⇒ $n' = n\left(1+\frac{v}{c}\right)$ $v <<c$

⊛ Distance +es = $n' = n\left(\frac{1-v/c}{1+v/c}\right)^{1/2}$ ⇒ $n' = n\left(1-\frac{v}{c}\right)$ $v<<c.$

⊛ RADAR / star



$$n' = n\left(1-\frac{v}{c}\right)$$

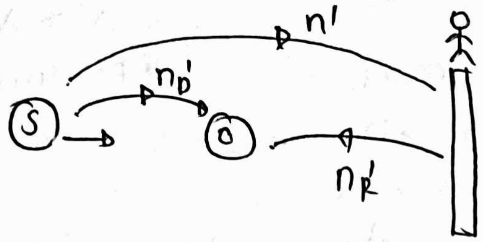
$$n'' = n\left(1+\frac{v}{c}\right)$$

$$\Delta n = n'' - n' = n\left(1+\frac{v}{c}\right) - n\left(1-\frac{v}{c}\right)$$

$$\Delta n = n\left(\frac{2v}{c}\right) \qquad \boxed{\frac{\Delta n}{n} = \frac{2v}{c}}$$

* Reflection of sound

(1)

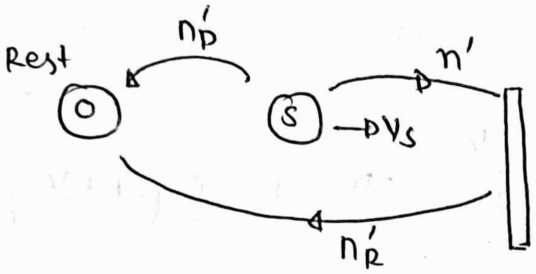


$$n' = n\left(\frac{v}{v-v_s}\right)$$

$$n_D' = n\left(\frac{v}{v-v_s}\right)$$

$$n_R' = n'\left(\frac{v-0}{v-0}\right) = n' = n\left(\frac{v}{v-v_s}\right)$$

(2)



$$n' = n\left(\frac{v}{v-v_s}\right)$$

$$n_D' = n\left(\frac{v}{v+v_s}\right)$$

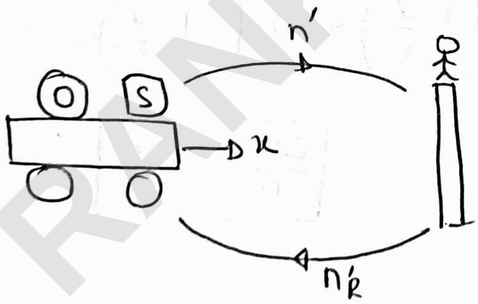
$$n_R' = n' = n\left(\frac{v}{v-v_s}\right)$$

Beats $= n_R' - n_D'$

$$= nv\left[\frac{1}{v-v_s} - \frac{1}{v+v_s}\right]$$

$$= nv\left[\frac{2v_s}{v^2-v_s^2}\right]$$

(3)



$$n' = n\left(\frac{v}{v-x}\right)$$

$$n_D' = n$$

$$n_R' = n'\left(\frac{v+x}{v}\right) = n\left(\frac{v+x}{v-x}\right)$$

Beats $= n_R' - n_D'$

$$= n\left(\frac{v+x}{v-x} - 1\right) = n\left(\frac{2x}{v-x}\right)$$