WAVE THEORY

WAVE → It is disturbance wich is create in medium & transfered energy from one place to another place without any transportation of matter.

classification of waves →

|1|→ A/c to Medium →

[A] → **Mechanical wave** → If medium is necessory for wave propagation of wave. A/R AIIMS

Ex → Sound wave, wave develop in a string.

property of medium for mechanical wave propagation :→

|i|→ Elasticity → due to elasticity medium partide regain its initial position.

|ii|→ Inertia → due to inertia medium particle transfered energy.

|iii|→ Resistance & density of medium is min & Low.

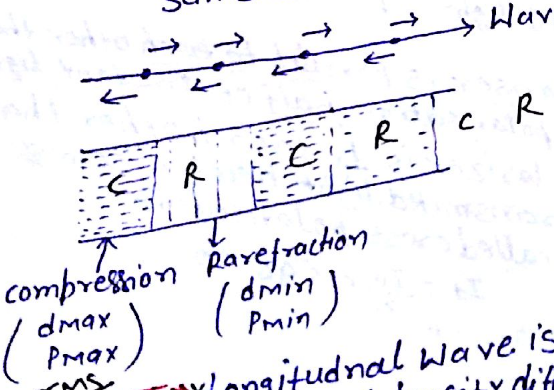
[B] → **NON-mechanical wave** → If medium is not necessory for wave propagation.

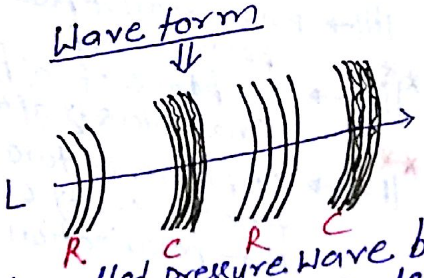
Excemplar
Ex → Light wave, EM wave (γ-ray, x-ray, U.V, visible, I.R, M.W, R.W)

2002 BHU ***
NOTE → Non-mechanical wave propagate in a vaccum as well as in medium but mechanical wave propagate only in medium. (Not in vaccum)

|2|→ A/c to Medium particle vibration →

[A] → **Longitudnal wave** :→ If medium particle vibrate in the same direction of wave propagation.



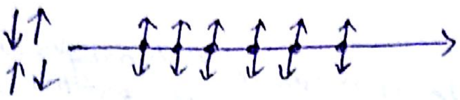


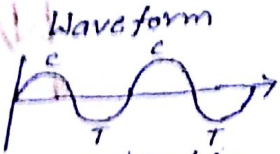
AIIMS
NOTE → *Longitudnal wave is also called pressure wave bcoz it produce pressure & density difference in a medium, Boyles law is not obeyed, bulk Modulus of air oscilate (same)

Exemplar *
A sound wave is passing through air column in the form of compression & Rarefaction → There is no transfer of Heat bcoz we can assume Adiabatic process.

EX → sound wave, wave in a spring.*

[B] → **Transverse Wave** → Medium particle vibrate in the $\perp$r direction of Wave propagation.





2014 AIIMS

NOTE → Transverse mechanical Wave (T.M.W) is also called Elastic wave. → It will propagate only in solid medium $ at surface of liq. It can't propagate in gaseous medium.
↳ due to surface tension.

* Transverce Wave produce crust $ Truf in a medium & it will change periodically w.r.t time.

Ex → Light Wave, E M Wave, Wave in string.
(Light Wave, E M Wave: non mechanical; Wave in string: mechanical)

[C] → **Transverse-Non-Mechanical Wave** → propagate in all medium.

* Longitudnal Wave represent only Mechanical Wave /Nature.
* To detect the nature by polarisation.

NOTE → Polarisation is possible only in transverse nature Wave.
AMU 2007

POLARISATION

* In a EM. Wave electric field, magnetic field $ velocity is $\perp$r to each other $ Electric field, M.F change periodically w.r.t time.

* Light Wich has ∞ $\perp$r component of E. field is called unpolarised light $ Wich has only one component of E. field is called polarised light $ process of conversion unpolarised light in a polarised light is called polarisation $ device is called polariser or poloroid.

$$\boxed{E.M.W = \vec{E} \perp \vec{B} \perp \vec{C}}$$

$$\boxed{\begin{matrix} E = f(t) \\ B = f(t) \end{matrix}}$$

BCECE 2014

Malus Law →

Polariser transmit only parallel component of Electric field $ Block the $\perp$r component.

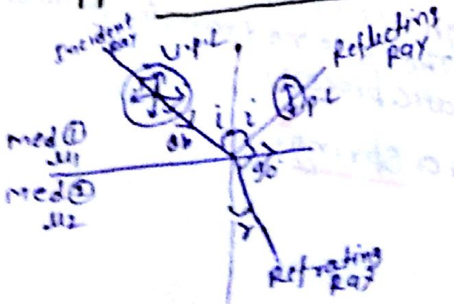
* $\boxed{I_0 = ka^2}$ * $\boxed{I_t = I_0 \cos^2\theta}$

** NOTE →
(i) → AIIMS 2016 Intensity of polarised light is half of unpolarised. * $(I = I_0/2)$
(ii) → Polarisation of polarised light is possible $ Intensity after polarisation ↓.
**(iii) → If plane of 'n' polariser is parellel to each other then final intensity after polarisation half of Incident light.
**(iv) → If plane of two polarizer is $\perp$r to each other than final intensity of transmited light become zero $ that polarization is called cross polarisation.

$$I_t = \frac{I_0}{2} \cos^2 90° = 0$$

** BCECE

Polarisation from Reflection →



$$\boxed{\tan i = \frac{\mu_2}{\mu_1}}$$

$$\boxed{i = \tan^{-1}\left(\frac{\mu_2}{\mu_1}\right) = \theta b}$$

$\mu = 1$ (air) *

$$\boxed{\theta b = i = \tan^{-1}(\mu_2)}$$

$$\boxed{\begin{matrix} i \leq \theta b \rightarrow \text{polarisation possible} \\ i > \theta b \rightarrow \text{not possible} \end{matrix}}$$

~~Ex Intensity~~

If reflecting ray is ⊥r to the refracting ray them reflecting light behave as a polarised light & angle of incident at that condition is called Brewster angle. (polarising angle).

Use of polarisation →

- * To identify nature of Wave b/c polarisation is possible only in transverse nature.
- * To identify optical Isomerism (Nical prism use as a polariserm).
- Jipmer 2015 * In a front glass of vehile.

|3| → A/c to Energy transfer →

[A] → Progressive Wave → If Energy propagate in the direction of Wave.
Exemplar
* Wave velo. depend on nature of med.

Ex → Sound wave, Light wave.

[B] → Standing Wave / stationary Wave → If energy remain bounded in Specific Region.

EX → Waves in a streach string (Gitar, sitar).
→ Wave develop in a organ pipe.
→ Wave develop in a Rod.

|4| → A/c to Direction →

1D → Wave in a String
2D → Wave develop at surface of Water.
3D → Sound wave, light wave.

Ripple Waves → Mix. of transverse & longitudnal wave.

Ex → * Sesmic Wave
* Wave in a long spring.
AIIMS Exemplar Wave develop at surface of water when boat moves in a River. (both longitudnal & transverse)

NOTE → Longitudnal wave velocity is always greater than from transverse Wave velocity in a same medium.

$$\boxed{V_T = V_L\sqrt{(strain)}}$$

V_T ⇒ Transverse wave velo.
V_L ⇒ Longitudnal wave velo.

Strain<1
$V_T < V_T$

* At surface of Water / liq longitudnal & Transverse both will propagate but at depth of liq only Transverse non-mechanical wave propagate.
* In Wire only Transverse but in Rod Transverse + Longitudnal both.
* Transverse non-mechanical wave propagate in solid, liq & gas.

2.→ Plane progressive wave equation :→

$$\boxed{y = \pm a f(\underbrace{\pm bx \pm ct})}$$

Med particle direction & position of medium particle.

A/R Periodic function (sin/cos) ↓ Bcoz its value never ∞

Wave propagate direction $(\pm bx \pm ct = 0)$ $x = \mp c/b\, t$

→ Same sign (+,+/−,−) → Wave propagate in ⊖ve direction.

→ opposite sign (+,−/−,+) → Wave propagate in ⊕ve direction.

**
***

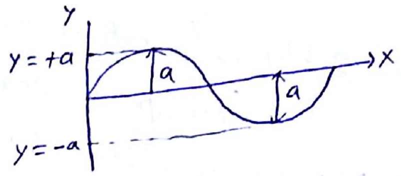
3.→ Basic terms Related to Wave →

[A]→ **Amplitude (A/a)** → Max. disp. of Medium particle from mean position.

EX→

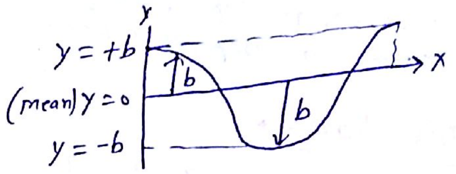
|i|→ $y = a\sin(\omega t - kx)$

$\boxed{\text{Amplitude} = a}$



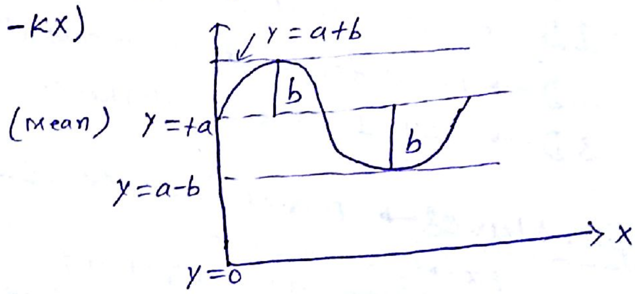
|ii|→ $y = b\cos(\omega t - kx)$

Amplitude = b



|iii|→ $y = a + b\sin(\omega t - kx)$

Amplitude = b

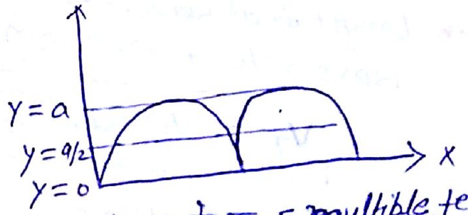


|iv|→ $y = a \pm ⓑ\cos(\omega t - kx)$

$\boxed{\text{Amplitude} = b}$

|V|→ $y = a\sin^2(\omega t - kx)$

$\boxed{\text{Amplitude} = a/2}$



NOTE→ * If sin & cos term हो तो Amp sin & cos के साथ multiple term होगा!
* If $\sin^2$ & $\cos^2$ term हो तो Amp. multiple term का Half होगा!

|vi|→ $y = b\cos^2(\omega t - kx)$
Amplitude = b/2

|vii|→ $y = a\sin(\omega t - kx)\cos(\omega t - kx)$
$y = \frac{a}{2}(\sin(\omega t - kx)\cos(\omega t - kx)$
Amp = a/2

|viii| → $y = a\sin(\omega t - Kx) + b\sin(\omega t - Kx + b)$

$$\boxed{y_R = A\sin(\omega t - Kx + \theta)}$$

$$\boxed{A = \sqrt{a^2 + b^2 + 2ab\cos\phi}}$$

$$\boxed{\theta = \tan^{-1}\left(\frac{b\sin\phi}{a + b\cos\phi}\right)}$$

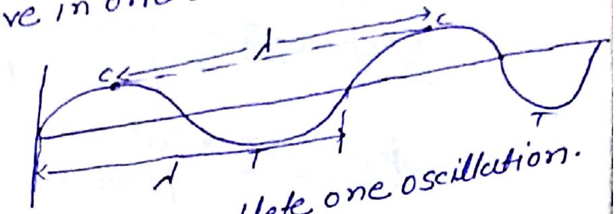
|ix| → $y = \pm a\sin(\omega t - Kx) \pm b\cos(\omega t - Kx)$

$$\boxed{A = \sqrt{a^2 + b^2}}$$

$\cos 90 = 0$

$$\boxed{\theta = \tan^{-1}(b/a)}$$

[B] → **Wavelength (λ)** → Distance cover by Wave in one onsscilation.



* Transverse → C to C, T to T → distance $= \lambda$

* Longitudnal → comp. to comp., Rare. to Rare → distance $= \lambda$

[C] → **Time period (T)** → Time taken by Medium particle to complete one oscillation.

[D] → **Frequency (n)** → No. of oscillation complete per unit time.

*one oscillation = T time

*1 time $= \frac{1}{T}$ oscillation.

$$\boxed{n = \frac{1}{T}}$$

*unit → c.p.s, R.p.s, o.p.s

S.I unit = Hertz (Hz)

$$\boxed{1\ Hz = 1\ c.p.s}$$

$1\ Hz = 1\ \frac{vib}{sec}$

AMU 2016

NOTE → Frequency of Wave depend on Nature of source it is independent from Medium.

[E] → **Phase, Initial phase & phase difference** →

Term in a Wave equation Which is decide direction & position of Med. particle at any instant called phase.

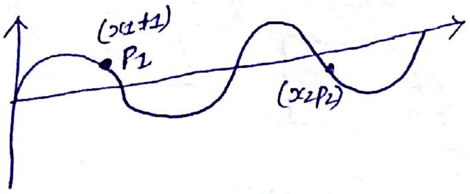
Ex → $y = a\sin(\omega t - Kx + \phi)$

|a| → Phase $= \omega t - Kx + \phi$

|b| → Initial phase (phase at $t = 0, x = 0$) $= \phi$

|c| → phase diff ($\Delta\phi = \phi_f - \phi_i$

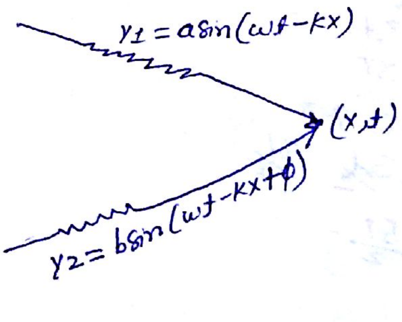
|a| →



$$\left.\begin{aligned}\phi_1 &= \omega t_1 - Kx_1 + \phi \\ \phi_2 &= \omega t_2 - Kx_2 + \phi\end{aligned}\right\} \Delta\phi = \phi_2 - \phi_1$$

$$\boxed{\Delta\phi = \omega(t_2 - t_1) - K(x_2 - x_1)}$$

|b| →



$\phi_1 = (\omega t - Kx)$

$\phi_2 = \omega t - Kx + \phi$

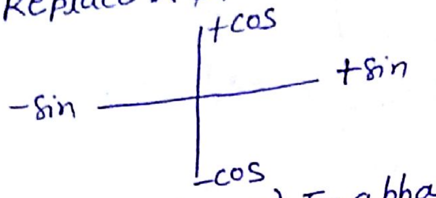
$$\boxed{\Delta\phi = \phi_2 - \phi_1 = \phi}$$

**

NOTE → When two Waves reached at same point simultaneously then phase difference of Wave is equal to difference of there angle (Wave fun same).

Phase diagram method

Step No-I → Replace x & y axis from sin & cos function.



Step No-II → Put ($t=0$ & $x=0$) In a phase of given Wave eqn.

Step No-III → Measure ⊕ve angle (↺ A.C.W) & ⊖ve angle (↻ C.W) from Respective angle.

Step No-IV → cal. Min. angle b/w displacement vector Wich Represent phase diff b/w Wave.

Relation b/w phase difference ($\Delta\phi$)
path difference (Δx)
& time difference (ΔT)

$t_1 = 0$
$x_1 = 0$
$\phi_1 = 0$

$t_2 = T = \Delta T \Rightarrow t_2 - t_1 = T$
$x_2 = \lambda \Rightarrow \Delta x = x_2 - x_1 = \lambda$
$\phi_2 = 2\pi \Rightarrow \Delta\phi = \phi_2 - \phi_1 = 2\pi$

$\boxed{T = \lambda \equiv 2\pi}$

|a| → Δx and $\Delta\phi$

$\lambda = 2\pi$
$1 = \frac{2\pi}{\lambda}$

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

|b| → Δx & ΔT

$\lambda \equiv T$
$1 = T/\lambda$

$\Delta x = \boxed{\frac{T}{\lambda}\Delta x = \Delta T} \Rightarrow \boxed{\frac{\Delta x}{\lambda} = \frac{\Delta T}{T}}$

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

* Same phase →
$\Delta\phi = 0, 2\pi, 4\pi, 6\pi$----
$\Delta x = 0, \lambda, 2\lambda, 3\lambda$----
$\Delta T = 0, T, 2T, 3T$---

* opp. phase →
$\Delta\phi = \pi, 3\pi, 5\pi, 7\pi$---
$\Delta x = \lambda/2, \frac{3\lambda}{2}, 3\lambda/2, \frac{5\lambda}{2}$---
$\Delta T = \frac{T}{2}, \frac{3T}{2}, \frac{5T}{2}$----

|F|→ Wave velocity (V), Angular freq. (ω), Propagation const (K)

$\boxed{\lambda = T = 2\pi}$

Wave velocity →

$\boxed{v = \frac{\lambda}{T} = n\lambda}$

λ ← Wavelength

n → Frequency (only depend on source)

v → velocity → depend on medium & Nature of Wave.

Angular frequency (ω) →

$\boxed{\omega = \frac{d\theta}{dt} = \frac{2\pi}{T} = 2\pi n}$

ω = rad./sec
n = Hertz
* unit → Rad/sec.

Propagation const. (K) →

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

AIPMT 2008

$$\boxed{\begin{aligned} K &= \frac{\omega}{v} = \frac{2\pi}{\lambda} \\ v &= \frac{\omega}{K} = n\lambda \\ \omega &= vK = 2\pi n = \frac{2\pi}{T} \end{aligned}}$$

→ Relation

$\boxed{n = \frac{2\pi}{\omega}}$

|G|→ Particle velo (Vpa) & Particle Accln (Apa) →

* Wave velocity = $\boxed{v = \frac{dx}{dt} = \lambda/T = n\lambda = \omega/K}$

* particle velocity $\boxed{V_{pa} = \frac{dy}{dt}}$

***

$$\boxed{\begin{aligned} &*V_{pa} = \omega\sqrt{a^2 - y^2} \\ &*A_{pa} = -\omega^2 y \\ &*(V_{pa})_{max} = a\omega \\ &*(A_{pa})_{max} = \omega^2 a \end{aligned}}$$

*

$$\boxed{\begin{aligned} &* y = 0 \text{ (Mean position)} \\ &(V_{pa})_{max} = \pm a\omega \\ &(A_{pa})_{min} = 0 \end{aligned}}$$

*

$$\boxed{\begin{aligned} &* y = \pm a \text{ (Extreme position)} \\ &(V_{pa})_{min} = 0 \\ &(A_{pa})_{max} = I\omega^2 a \end{aligned}}$$

NOTE → particle velo. max at mean point & min at extreme point but particle ~~aa~~ accleration max extreme point & min at mean point.

Relation b/w Wave velocity & particle velocity →

$y = a\sin(\omega t - Kx)$

|a|→ $V_{Wave} = \frac{dx}{dt} = \lambda/T = n\lambda = \frac{\omega}{K}$

|b|→ $V_{pa} = \frac{dy}{dt} = a\omega\cos(\omega t - Kx)$ —①

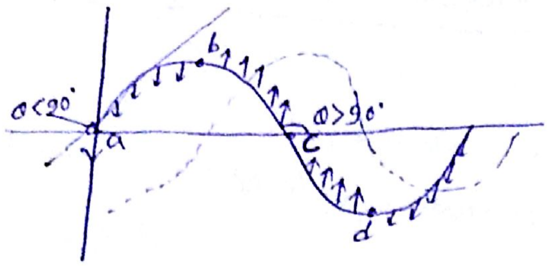
|c|→ strain $= \frac{dy}{dx} = a\cos(\omega t - Kx)\frac{d}{dx}(\underset{0}{\omega t} - \underset{1}{Kx})$

$= -aK\cos(\omega t - Kx)$ —②

$\frac{dy}{dx} = -aK\cos(\omega t - Kx)$

**

$$\boxed{\begin{aligned} V_{pa} &= -V_{Wave}\left(\frac{dy}{dx}\right) \\ V_{pa} &= -V_{Wave}\,(\text{slope of curve}) \\ V_{pa} &= -V_{Wave}(\tan\theta) \end{aligned}}$$



* a-b ⇒ slope ⇒ $\oplus$ve $V_{pa} = \ominus$ve ⇒ Downward
* b-d ⇒ slope ⇒ $\ominus$ve ⇒ $V_{pa} = \oplus$ve ⇒ upward
* d-e ⇒ slope ⇒ $\oplus$ve ⇒ $V_{pa} = \ominus$ve ⇒ Downward

|H| → Intensity of Wave (I) →

$$\boxed{I = \frac{E}{At} = P/A}$$

*

$$\boxed{I = 2\pi^2 n^2 a^2 \rho v}$$

Wave velo.
density of Medium
Freq.
Amplitude

* Medium & source same (n = const, v = const, ρ = const) → $\boxed{I \propto a^2}$
* Medium same (v = c, ρ = ~~a~~ = c) → $\boxed{I \propto n^2 a^2}$

WAVE VELOCITY

|1| → Transverse Wave velocity →

|a| → Non-Mechanical Wave → Eg → EM Wave, Light Wave = velo. of light)

$$\boxed{C_m = \frac{C_o}{\mu_m}} \quad C_o \rightarrow 3\times10^8 \text{ m/sec.}$$

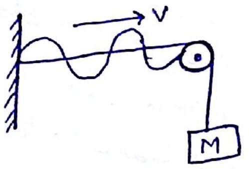
2014 AIIMS

|b| → Mechanical T.W velocity →

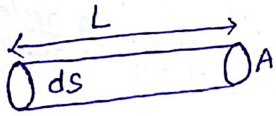
*

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

T → Tension in string.
m → Linear mass density or, Mass per unit length.



$$\boxed{m = \frac{M_{string}}{L_{string}}}$$ *



$$\boxed{m = Ad = (\pi r^2)d = (\pi/4 D^2)d}$$

A → Cross-Section Area
d → density
D → Dimeter of wire
d → density of wire.

**

$$\boxed{V = \sqrt{\frac{T}{m}} = \sqrt{\frac{T}{Ad}} = \sqrt{\frac{T}{\pi r^2 d}} = \sqrt{\frac{T}{\pi/4\, D^2 d}} = \sqrt{\frac{Y}{d}(\alpha \Delta T)}} = \boxed{\sqrt{\frac{S}{d}}}$$

* $\frac{T}{A}$ = Longitudnal stress (S)

$$\boxed{V = \sqrt{\frac{T}{Ad}} = \sqrt{\frac{S}{d}}}$$

* Thermal strain

$$\frac{\Delta L}{L} = \frac{L_2 - L_1}{L_1} = \frac{L_1(1 \alpha \Delta T) - L_1}{L_1}$$

Exemplar → **

$$\boxed{\frac{\Delta L}{L} = \alpha \Delta T}$$

ΔT → change in temp.
α → Linear Expansion const.

* Y = young Modulus of Elasticity.

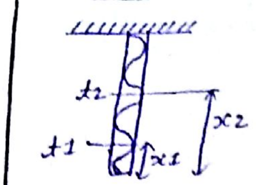
$$\boxed{Y = \frac{Stress}{Strain} = \frac{S}{\frac{\Delta L}{L}}} \qquad \boxed{S = Y\left(\frac{\Delta L}{L}\right)}$$

*

$$\boxed{V = \sqrt{\frac{S}{d}} = \sqrt{\frac{Y}{d}\left(\frac{\Delta L}{L}\right)}}$$

Scanned by CamScanner

** # Standard Result

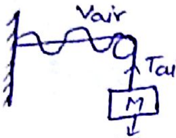


*
$$t_1 = 2\sqrt{\frac{x_1}{g}}$$
$$t_2 = 2\sqrt{\frac{x_2}{g}}$$

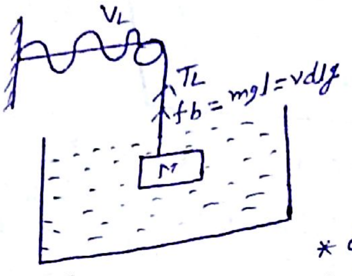
*
$$\Delta t = t_2 - t_1 = \frac{2}{\sqrt{g}}\left(\sqrt{x_2} - \sqrt{x_1}\right)$$

*** **NOTE** → Wave velocity, accl^n & time taken by Wave is independent from Nature of Material.

Imp concept ** # Relation b/w Wave velocity in a string when it is suspenderd in a liq. & Air.



$$V_{air} = \sqrt{\frac{T_{air}}{m}} = \sqrt{\frac{Mg}{m}}$$



$$\boxed{T_L = mg - F_b}$$

* $d_l \Rightarrow$ density of liq.
* $d_b \Rightarrow$ density of body

** $$T_L = Mg\left(1 - \frac{d_l}{d_b}\right)$$

$$\boxed{d_b > d_l}$$

12 → Longitudnal Wave velocity :→ EX → Sound Wave.

velo. of sound → * $V = \sqrt{\frac{E}{d}}$; E → Elasticity coff. of medium. ; d → density of med.

*
* $\overset{10^9 N/m^2}{E_{solid}} > \overset{10^9 N/m^2}{E_{liq.}} > \overset{10^5 N/m^2}{E_{gas}}$
* $d_{solid} > d_{liq} > d_{gas}$.
* $\frac{E}{d} \Rightarrow$ solid > liq. > Gas

Eg → * $V_{Fe} = 5000$ m/sec (solid)
* $V_{H_2O} =$ 1500 m/sec
* $V_{air} =$ 330 m/sec
* AIIMS $V_{quartz} = 6000$ m/sec (max)

NOTE → * If Wave goes from one Medium to another medium & Its speed ↑ then second Medium rarer to Ist Medium. & Its speed ↓ then it is denser w.r.t Ist Medium.

* If Ray's goes from Denser to Rarer Medium it will daviate away from normal. & If It is goes from Rarer to denser, It move towards Normal.

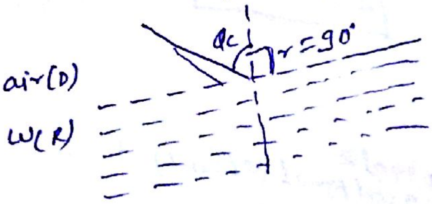
** AIIMS 2003, 2007, 2015, 2016.

T.I.R → When ray's goes from denser to Rarer medium it will deviate away from normal. When angle of Incident is ↑. & angle of Refraction is also ↑ When refracting ray become ∥ to reflecting surface. Angle of Incidence is called critical angle. & When angle of Incidence become more than criticle angle of reflecting ray come to same medium It is called T.I.R.

$$\sin\theta_c = \left(\frac{\mu_R}{\mu_D}\right) \quad \Big| \quad \mu \propto \frac{1}{V}$$

$$\boxed{\sin\theta_c = \frac{1}{5}} \qquad \boxed{\theta_c = 15^\circ}$$

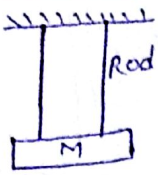
$i \geq \theta_c \Rightarrow$ T.I.R
$i < \theta_c \Rightarrow$ Refraction



AIIMS EX → Mirage, Lumming, *Brillions of Diamond, optical fibre.

[A]→

Velocity of sound in solid medium :→



$\boxed{V_L = \sqrt{\frac{Y}{d}}}$

$\boxed{V_T \sqrt{\frac{Y}{d}}}$

$\boxed{V_T = V_L\sqrt{strain}}$

$\boxed{V_T < V_L}$

$\boxed{Strain < 1}$ (In Homogenous medium)

[B]→ Velocity of sound in liq: Medium →

$$K = -\frac{\Delta P}{\left(\frac{\Delta V}{V}\right)} = \cancel{V}\left(\frac{\Delta P}{\Delta V}\right)$$

(minus)

$$\boxed{V = \sqrt{\frac{E}{d}} = \sqrt{\frac{K}{d}} = \sqrt{\frac{\frac{T\Delta P}{\Delta V/V}}{d}}}$$

K = volume Elasticity coff.
or,
β = Bulk Modulus of Elasticity

$$K = \frac{\text{volumetric stress}}{\text{volumetric strain}} = \frac{F_L/A}{\Delta V/V} = \frac{\Delta P}{\Delta V/V}$$

To humne extra press. diya.

[C]→ Velo. of sound in Gases medium :→

NOTE→ Solid & liq. has single value of volume elasticity coff but Gases has ∞ value of volume elasticity cofficient. It depend on thermodynamic process.

* I.T → $\boxed{PV = K}$

$K_{I.P} = P$

$\boxed{\frac{dP}{dV} = -P/V}$

$$\boxed{V = \sqrt{\frac{K}{d}} = \sqrt{\frac{P}{d}}}$$

Newton statement
↓
propagation of sound in a gaseous medium is a Isothermal process. compression & Rarefraction changes slowly.

* At N.T.P in a air.

$P = 1\ atm = 10^5 N/m^2$

$d_{air} = 1.3\ kgN/m^3$

$$V = \sqrt{\frac{10^5}{1.3}} = \boxed{280\ m/sec < 330\ m/sec.}$$

Here Newton's wrong !!

Laplace Statement/correction → propagation of sound in a gaseous medium is adiabatic process compression & Rarefraction change very fast.

$\boxed{PV^{\gamma} = K}$

$$\boxed{V = \sqrt{\frac{K}{d}} = \sqrt{\frac{\gamma P}{d}}}$$

At N.T.P in air

$P = 1\ atm = 10^5 N/m^2$, $V_{air} = 1.9$

$d_{air} = 1.3\ kg/m^3$

$$V = \sqrt{\frac{1.9 \times 10^5}{1.3}} = \boxed{330\ m/sec}$$

Gas equation →

$$\boxed{PV = \mu RT}$$

Press. → P

Vol. → V

T → Temp

R → Gas const. = 8.31 mol K
= 1.9 cal/mol K (2cal)

μ → No. of Mole = $\frac{m}{M_W} = \frac{N}{N_A}$

$N_A = 6.023 \times 10^{23}$

$$\boxed{\frac{P}{d}=\frac{RT}{mw}}$$

$K = R/N_A =$ Boltzman const $= 1.38\times10^{-23}$ J/K

$$\boxed{\frac{P}{d}=\frac{RT}{mw}=\frac{KT}{m}}$$

**

$$\boxed{\begin{aligned}
V_{sound} &= \sqrt{\frac{\gamma P}{d}}=\sqrt{\frac{\gamma RT}{mw}}=\sqrt{\frac{\gamma KT}{m}}=\sqrt{\frac{\gamma PV}{m}}\\
V_{R.MS} &= \sqrt{\frac{3P}{d}}=\sqrt{\frac{3RT}{MW}}=\sqrt{\frac{3KT}{m}}=\sqrt{\frac{3PV}{m}}\\
V_{Avg} &= \sqrt{\frac{8P}{\pi d}}=\sqrt{\frac{8}{\pi}\frac{RT}{mw}}=\sqrt{\frac{8}{\pi}\frac{KT}{m}}=\sqrt{\frac{8}{\pi}\frac{PV}{m}}\\
V_{M.P} &= \sqrt{\frac{2P}{d}}=\sqrt{\frac{2RT}{mw}}=\sqrt{\frac{2KT}{m}}=\sqrt{\frac{2PV}{m}}
\end{aligned}}$$

* At const 'T' for same gas → $\boxed{V_{R.M.S} > V_{avg} > V_{M.P} > V_{sound}}$

Effecting factor →

|1| → Effect of temp :→

$$\boxed{V_{sound}=\sqrt{\frac{\gamma RT}{Mw}}=\sqrt{\frac{\gamma KT}{m}}}$$

|a| → Gas Fix :→ $\gamma = c$, $Mw = c$, mc

$\boxed{V \propto \sqrt{T}}$ $\boxed{\begin{matrix}T\uparrow & V\uparrow\\ T\downarrow & V\downarrow\end{matrix}}$

Graph :→

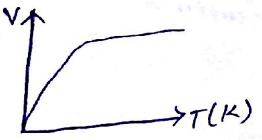
|i| → V v/s T

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

$V^2 = \frac{\gamma R}{mw} T$

$\underset{Y}{\downarrow}$ $\underset{X}{\downarrow}$

$\boxed{Y^2 \propto X}$

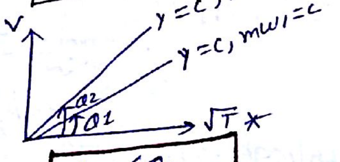


|ii| → V v/s $\sqrt{T}$

$V = \sqrt{\frac{\gamma R}{mw}}\sqrt{T}$

$\underset{Y}{\downarrow}$ $\underset{X}{\downarrow}$

$\boxed{Y = mX}$



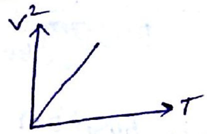
$$\boxed{\begin{matrix}\theta_1 < \theta_2\\ mw_1 > mw_2\end{matrix}}$$

O_2 H_2

AIIMS

|iii| → V^2 v/s T

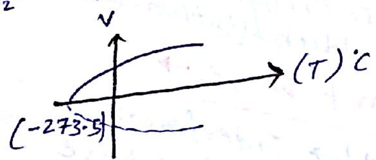
$\boxed{\underset{Y}{V^2} = \frac{\gamma R}{mw}\,\underset{mX}{T}}$



* Graph b/w $V^2 \propto T + 273.5$

$\underset{Y}{\downarrow}$ $\underset{X}{\downarrow}$

$Y^2 \propto X + C$



|b| → Gass different

$$\boxed{V \propto \sqrt{\frac{\gamma R}{mW}}}$$

→ $T = c \Rightarrow \boxed{V \propto \sqrt{V/mw}}$

→ $\gamma = c \Rightarrow \boxed{V \propto \sqrt{T/mw}}$

|2|→ **Effect of pressor** :→ $V = \sqrt{\frac{\gamma P}{d}}$

* T = c, Gas same, γ = same

$$\frac{P}{d} = \frac{RT}{M_W} = \text{const} \Rightarrow P \propto d$$

V_{sound} = const $\left[\begin{matrix} P\uparrow \Rightarrow d\uparrow \\ R\uparrow \Rightarrow d\downarrow \end{matrix}\right]$

* At const. Temp. velo of Sound remain unchange With press.

* If temp. is change on changing P velo. of Sound change with T.

Gas same ⇒ $\gamma = c$, $P = c$ $\boxed{V \propto \frac{1}{\sqrt{d}}}$

|3.|→ **Effect of density**→ $\boxed{V = \sqrt{\frac{\gamma P}{d}}}$

***

AIIMS

Exemplar

BCECE

\# Gas ⇒ 18 gm से कम Mol. wt हो तो $V_{dry} > V_{Moist}$.

$d_{Dry air} > d_{moist air}$

M_W ⇒ dry air > moist air

\# Gas ⇒ If 18 gm से ज्यादा mol. wt हो तो $V_{dry} < V_{moist}$

$d_{dry air} < d_{moist air}$ → Eg → $\boxed{V_{dry\ H_2} > V_{moist\ H_2}}$

T↑, V↑, D to R, Dry↓

|4|→ **Effect of medium**:→

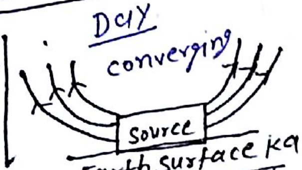
Ex→ ① →

T↓

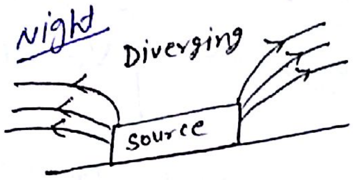
V↓

Dry air↑

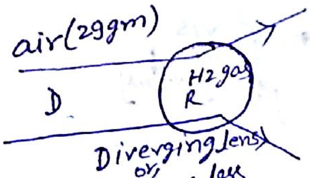
R to D



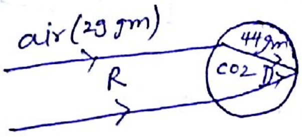
* Earth surface ka temp. ज्यादा कम → Temp↓



Ex→ AIIMS



Diverging lens or, concave lens



converging or, convex lens.

|5|→ **Superposition principle** If two or, more than two superimpose at same point Net disp. of medium particle is a vector Resultant of Indivisual wave.

$\boxed{\vec{y} = \vec{y_1} + \vec{y_2} --- \vec{y_N}}$

Limitation * It is applicable on Low Amplitude Wave like Sound Wave & Light wave

* It is not applicable of High Amplitude wave (Sesmic wave, Laserbeam).

* It is applicable on Same nature Wave. Means Light superimpose With Lightwave & sound superimpose with sound.

Resultant Wave→

|1|→ Interference

|2|→ Standing Wave

|3|→ Beat (only in sound Wave)

|4|→ Lissageous figure.

|1| → **Interference** → When two wave of same freq. same velocity goes in a same direction same speed & superimpose. In this process Redistribution of energy takeplace.

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

$y_2 = b\sin(\omega t - kx + \phi)$

* cohorent source → n, v, direction same.

phase diff. $\boxed{\Delta\phi = \phi} \propto t^\circ$

* Resultant wave eqn → $y A\sin(\omega t - kx + \theta)$

NOTE → In a interference n, v, direction of Resultant wave is similar to the superimpose wave.

|a| → Resultant Amplitude (A) $\boxed{A = \sqrt{a^2 + b^2 + 2ab\cos\phi}}$

|b| → Initial phase (θ) $\boxed{\theta = \tan^{-1}\left(\frac{b\sin\phi}{a + b\cos\phi}\right)}$

|c| → Resultant Intensity (I_R) $\boxed{I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi}$

NOTE → In a Interference Intensity change w.r.t path but It is Independent w.r.t time.

Type of Interference

|a| → **constructive Interference** → Point where Intensty & Amplitude is max.

* $\boxed{\phi, \lambda \to \text{even multiple}}$

$\boxed{A = \sqrt{a^2 + b^2 + 2ab\cos\phi}}$

$\boxed{I_{max} = A_{max} = (\cos\phi)_{max} = 1}$

* phase diff ⇒ $\phi = 0°, 2\pi, 4\pi, 6\pi - - - 2\pi n$ $(n = 0, 1, 2, 3 - - -)$
* ~~phat~~ path dif ⇒ $\Delta x = \frac{\lambda}{2\pi}(\Delta\phi) = \underset{\text{Ist max}}{0}, \underset{\text{2nd max}}{\lambda}, \underset{\text{3rd max}}{2\lambda}, 3\lambda - - - - n\lambda$

* $\boxed{A_{max} = a + b}$

* $\boxed{I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = K(a + b)^2}$

|b| → **Distructive Interference** → ϕ, λ → odd multiple

$\boxed{I_{min} \Rightarrow A_{min} = (\cos\phi)_{min} = -1}$

$\phi = \pi, 3\pi, 5\pi, 7\pi - - - - - - (2n + 1)\pi$ $n = 0, 1, 2 - - -$

$\Delta x = \frac{\lambda}{2\pi}(\Delta\phi) = \underset{\text{Ist Min}}{\frac{\lambda}{2}}, \underset{\text{2nd Min}}{\frac{3\lambda}{2}}, \underset{\text{3rd Min}}{\frac{5\lambda}{2}} - - - - \frac{(2n+1)\lambda}{2}$

$\boxed{A_{min} = (a - b)}$

$\boxed{I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2 = K(a - b)^2}$

NOTE → |i| → AIR When wave superimpose in same phase type of Interference constructive & when superimpose in opp. phase it is distructive.

|ii| → point where path diff. is even multiple of λ is constructive.
" " " " odd " " $\lambda/2$ " distructive.

|iii| → If phase diff is even multiple of π - constructive.
" " " " odd " " π - "

|iv|→ Distance b/w consicute max & consicutive min position is→λ;
,, ,, ,, ,, ,, ,, , ,,→$\lambda/2$

AMU 2009

Degree of Hearing [H] →

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

*

$$\boxed{H = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{2\sqrt{I_1 I_2}}{I_1 I_2} = \frac{2\sqrt{\frac{I_1}{I_2}}}{\frac{I_1}{I_2}+1}}$$

$\frac{I_1}{I_2} \Rightarrow \uparrow \Rightarrow H\downarrow$

* If Intensity ratio ↑ then H↓.

AIPMT 1992

AIIMS 2009

NOTE→ |i|→ Around the cohrent source min path difference is zero & max path difference is equal to distance b/w source.

* min at bisecterline & max on axis.

|ii|→ At bisector line of coherent source is always constructive Interference. It is independent from distance b/w source.

* on axis of chorent source type of Interference dippend on distance b/w source.

Quenkey tube Exp →

AIPMT

* In this exp. we practically demostrate Interference pattern in sound wave.

* Practically calculate value of freq. of unknown source velo. of sound in gases medium.

It shift $= x$ then path diff $= \Delta x = 2X$

|a|→ Ist Max shift in Nth max →

$\Delta X = (N-1)\lambda = 2X$

$$\boxed{\lambda = \frac{2X}{\lambda - 1}} \quad \boxed{V = n\left(\frac{2X}{N-1}\right)}$$

|b|→ Ist Max shift in Nth min →

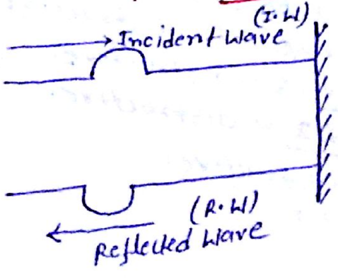
$\Delta x = \frac{(2N-1)\lambda}{2} = 2X$

$$\boxed{\lambda = \frac{4X}{2N-1}}$$

|2|→ Standing Wave / Stationary Wave → When two wave of same freq. same velo. moves in a opposite direction & superimpose result of superposition called Standing Wave.

Reflection of Wave :→

|a|→ Rigid end → $2\pi = \lambda = T$



* Direction change
* Phase difference $= \pi$
* path difference $= \lambda/2$
* Time difference $= T/2$

|a|→ $y_{I.W} = a\sin(\omega t - kx)$

$y_{S.W} = A\cos\omega t$

|b|→ $y_{I.W} = a\cos(\omega t - kx)$

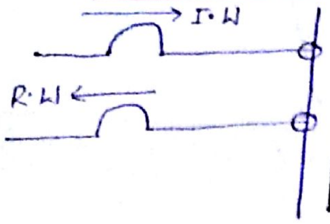
$y_{S.W} = A\sin\omega t$

$A = 2a\sin kx$

* If Incidence $\begin{cases} \overset{I.W}{\sin} \rightarrow \overset{R.W}{\cos} \\ \cos \rightarrow \sin \end{cases}$

Scanned by CamScanner

|b| → Wave Reflected from free end →



**
- * Direction change
- * Phase difference = 0
- * Path difference = 0
- * Time difference = 0

**
(a) → $Y_{I \cdot W} = a\sin(\omega t - kx)$

$Y_{S \cdot W} = A\sin\omega t$.

|b| → $Y_{I \cdot W} = a\cos(\omega t - kx)$

$Y_{S \cdot W} = A\cos kx$

$A = 2a\cos kx$

**

* Reflection of Wave
- → Rigid End
  - → Incidence Wave = sin → cos] S·W
  - → " " = cos → sin
- → Free End
  - → " " = sin → sin] S·W
  - → " " = cos → cos

	Progressive Wave	Standing Wave
|i| → Wave eqn	$y = \pm a\sin(\pm\omega t \pm (kx)$ $y = \pm b\cos(\pm\omega t \pm kx)$	$Y_{SW} = 2a\sin kx \sin\omega t$ $= 2a\sin kx \cos\omega t$] Rigid End. $= 2a\cos kx \cos\omega t$ $2a\cos kx \sin\omega t$] Free end. $A_{S \cdot W} = 2a\sin kx$ or, $2a\cos kx$
|ii| → Amplitude	a/b const	
|iii| → Freq	$n = \frac{\omega}{2\pi}$	* $n = \frac{\omega}{2\pi}$
|iv| → Wavelength	* $\lambda = \frac{2\pi}{k}$	* $\lambda = 2\pi/k$
|v| → Wave velo.	* $v = n\lambda = \frac{\omega}{k}$	$V_{S \cdot W} = 0$ or, Not difine.

* **NODE (N)** → point where Amplitude & particle velo. energy is min but strain & change in presser max.

* **Antinode (AN)** → point where Amp. & particle velo. max. but strain & change in press min.

*
N − N → $\lambda/2$
A − A → $\lambda/2$
NA → $\lambda/4$

[A] Rigid End (Node form) →

$Y_{I \cdot W} = a\sin(\omega t - kx)$

$\boxed{Y_{S \cdot W} = 2a\sin kx \cos\omega t}$

|i| → $A = 2a\sin kx$

|ii| → $V_{pa} = \frac{dv}{dt} = 2a\omega \sin kx \sin\omega t$

|iii| → Strain $= \frac{dy}{dx} = 2ak\cos kx \cos\omega t$

|iv| → chang in press. $= E = \frac{Stress}{Strain} = \frac{F1/A}{dy/dt} = \frac{\Delta P}{dy/dx}$

* $\boxed{\Delta P = E = 2aE\cos kx \cos\omega t}$

|I| → Nodeposition (Reflected from Riegidend)

$A_{min} = \sin kx = 0$

$kx = 0, \pi, 2\pi ---- n\pi$

$kx = 0, \pi, 2\pi --- n\pi$

$\frac{2\pi}{\lambda} x = 0, \pi, 2\pi --- n\pi$

$x = 0, \lambda/2, \frac{2\lambda}{2}, \frac{3\lambda}{2} --- \frac{n\lambda}{2}$

↑ Ist node ↑ 2nd node ↑ 3rd N

|II| → Antinode position (Rigidend)

$A_{max} = (\sin kx)_{max} = \pm 1$

$kx = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, --- \frac{(2n-1)\pi}{2}$

$n = 1, 2, 3$

$X = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$

↑ Ist AN ↑ 2nd A·N

Scanned by CamScanner

[B] → Free End [Antinode form] →

Trick

FATOO → $\boxed{n = 1, 2, 3}$

Free end · Anti node · $x = \frac{n\lambda}{2}$

$Y_{I.W} = a\sin(\omega t - kx)$

$Y_{S.W} = 2a\cos kx \sin\omega t$

|i| → $A = 2a\cos kx$

|ii| → $|V_{pa}| = \frac{dy}{dt} = 2a\omega\cos kx \cos\omega t$

|iii| → $|\text{Strain}| = \frac{dy}{dx} = 2a\sin kx \sin\omega t$

|iv| → change in press. $\boxed{\Delta P = E\frac{dy}{dx} = 2akE\sin kx \sin\omega t}$

|I| → Antinode position

$A_{max} = (\cos kx)_{max} = \pm 1$

$kx = 0, \pi, 2\pi, 3\pi \cdots n\pi$

$\frac{2\pi}{\lambda} = 0, \pi, 2\pi \cdots n\pi$

$x = 0, \lambda/2, \frac{2\lambda}{2}, \frac{3\lambda}{2} \cdots \frac{n\lambda}{2}$

↑ Ist AN, ↑ 2nd AN, ↑ 3rd AN

|II| → Node position.

$A_{min} = (\cos kx)_{min} = 0$

$kx = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2} \cdots \frac{(2n-1)\pi}{2}$ $n = 1, 2, 3$

$x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4} \cdots$

↑ Ist N, ↑ 2nd N

***

NOTE → |i| → When Wave Reflected from Rigid end Node are form at Rigid end & When Reflected from free end Antinode are form at free end.

|ii| → In a standing Wave Node & Antinode change periodically w.r.t position.

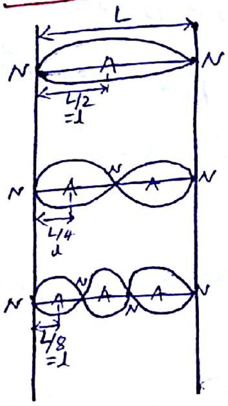
|iii| → Distance b/w consicutive Node & consicutive A·N ⇒ λ/2

〃 〃 〃 〃 ⇒ λ/4

〃 〃 〃

*|iv| → B/w two Node medium particle vibrate in same phase & Either side of Node medium particle vibrate in opposite phase.

Transverse standing Wave →



$L = \frac{\lambda_1}{2}$ $\boxed{\lambda_1 = 2L}$ ⇒ $\boxed{n_1 = \frac{V}{\lambda} = \frac{1}{2L}\sqrt{\frac{T}{m}}}$

- * Fundamental freq.
- * Ist Harmonic
- * 0th overtone.

$L = \frac{2\lambda_2}{2}$ $\boxed{\lambda_2 = \frac{2L}{2}}$ ⇒ $\boxed{n_2 = \frac{V}{\lambda_2} = \frac{2}{2L}\sqrt{\frac{T}{m}}}$

- * 2nd Harmonic
- * Ist overtone

$L = \frac{3\lambda_3}{2}$ = $\boxed{\lambda_3 = \frac{2L}{3}}$ ⇒ $\boxed{n_3 = \frac{V}{\lambda_3} = \frac{3}{2L}\sqrt{\frac{T}{m}}}$

- * Fundamental / Basic freq → Min freq. of Instrument.
- * Harmonic / Harmonic freq → complete multiple of fundamental freq.
- * overtone → Freq. of Instrument after fundamental freq.
- * octave → freq. ratio 1:2 or, 2:1
- * octave higher → freq. double
- * octave lower → freq. half.
- * Unison / Resonance condn. : → ($n_1 : n_2 = 1 : 1$) Freq. ratio.

NOTE →
- * Even & odd all harmonic are developed in a streached string.
- * Harmonic freq. ratio (1:2:3:4 ‒ ‒)
- * overtone freq. ratio (2:3:4 ‒ ‒ ‒)
- * No. of Antinode = No. of Harmonic = No. of loope.
- * No. of Node (N) = $\boxed{A+1}$
- * No. of overtone = No. of Harmonic ‒ 1.

**

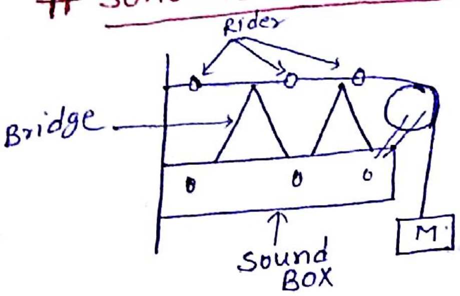
* 'P' harmonic
  - → $n = \frac{P}{2L}\sqrt{\frac{T}{m}}$
  - → $\lambda = \frac{2L}{P}$
  - → $N = P+1$
  - → $A = P$

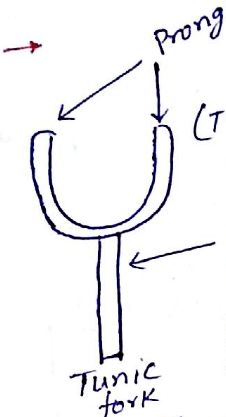
* 'P' overtone
  - → $n = \frac{(P+1)}{2L}\sqrt{\frac{T}{m}}$
  - → $\lambda = \frac{2}{P+1}$
  - → $A = P+1$
  - → $N = P+2$

Plucking distance or, Jerk distance → Distance of Ist Antinode from Left & Right end of Wire.

*
$$\boxed{l = \frac{L}{2P}}$$
Jerk distance → l
L → Length of Wire
P → No. of Harmonic = No. of loop.

Sonometer Experiment :→





*
$$\boxed{n \propto \frac{t}{l^2}\sqrt{\frac{E}{d}}}$$
⇓ For prongs.

Imp * By Sonometer Exp. We practically calculate freq. of unknown tuning fork.

* vibration of tuning fork stem is transfered in sonometer wire.

* Resonance condn →

*
$$\boxed{n_{driver} = n_{driven} = I_{max}}$$
करने वाला / करवाने वाला (Intensity max)

*
$$\boxed{n_{\text{Tunik fork}} = n_{wire} = \frac{1}{2l}\sqrt{\frac{T}{m}}}$$

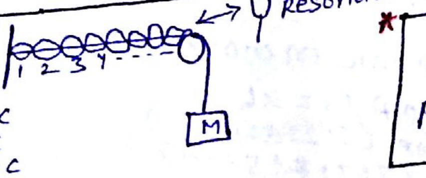
$$\boxed{n = \frac{1}{2l}\sqrt{\frac{T}{m}} = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 d}}}$$

Law of String :→

LAW OF

- Length: $n \propto \frac{1}{l}$; $T = c$, $m = c$
- Tension: $n \propto \sqrt{T}$; $m = c$, $l = c$
- Radius: $n \propto \frac{1}{r}$; $l = c$, $T = c$, $d = c$
- Density: $n \propto \frac{1}{\sqrt{d}}$; $l = c$, $T = c$, $r = c$
- Mass: $n \propto \frac{1}{\sqrt{m}}$ → string mass; $l = c$, $T = c$

** # Melde's Exp →



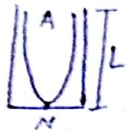
*
$$\boxed{n = \frac{P}{2l}\sqrt{\frac{T}{m}}}$$
$n = c$
$l = c$
$m = c$

*
$$\boxed{P\sqrt{T} = const \qquad P_1\sqrt{T_1} = P_2\sqrt{T_2}}$$

Longitudinal Standing Wave

organ pipe → C·O·P ; O·O·P

[A] → CLOSE ORGAN PIPE [C·O·P] →



$L = \frac{\lambda_1}{4}$

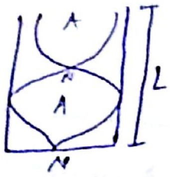
* $\lambda_1 = 4L$ *

$n_1 = \frac{V}{\lambda} = \frac{V}{4L}$

*Fundamental freq

Ist Harmonic

0th overtone



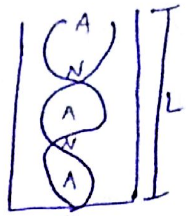
$L = \frac{3\lambda_2}{4}$

$\lambda_2 = \frac{4}{3}L$

$n_2 = \frac{V}{\lambda_2} = \frac{3V}{4L}$

3rd Harmonic

Ist overtone



$L = \frac{5\lambda_3}{4}$

$\lambda_3 = \frac{4L}{5}$

$n_3 = \frac{V}{\lambda_3} = \frac{5V}{4L}$

5th Harmonic

2nd overtone.

NOTE → * only odd harmonic is developed in c·o·p·

* Max Wavelength develop in c·o·p = 4L

* $\boxed{V = \sqrt{\frac{\gamma RT}{MW}}}$ velo· of Gas

* Harmonic freq· ratio = 1:3:5: 7 ---

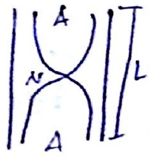
* overtone freq· ratio = 3:5:7:9----

*

'p' harmonic (P=1,2,3--) → $n = \frac{PV}{4L}$; $\lambda = \frac{4L}{P}$

'p' overtone ⇓ (2P+1) harmonic → $n = \frac{(2P+1)V}{4L}$; $\lambda = \frac{4L}{2P+1}$; N = A = P+1

[B] → OPEN ORGAN PIPE [O·O·P] : →



$L = \frac{\lambda_1}{2}$

* $\lambda_1 = 2L$

$n_1 = \frac{V}{\lambda_1} = \frac{V}{2L}$

*Fundamental freq·

Ist harmonic

0th overtone·

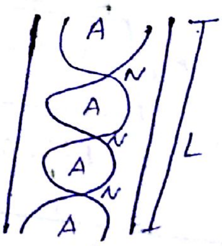
$L = \frac{2\lambda_2}{2}$

$\lambda_2 = \frac{2L}{2}$

$n_2 = \frac{V}{\lambda_2} = \frac{2V}{2L}$

2nd Harmonic

Ist overtone



$L = \frac{3\lambda_3}{2}$

$\lambda_3 = \frac{2L}{3}$

$n_3 = \frac{V}{\lambda_3} = \frac{3V}{2L}$

3rd Harmonic

2nd overtone

NOTE → * Even & odd all harmonic in o·o·p

* max wavelength in o·o·p is = 2L

* Harmonic freq· ratio (1:2:3:4---)

* overtone freq· ratio (2:3:4:5---)

'P' harmonic
- $n = \frac{pv}{2L}$
- $\lambda = \frac{2L}{p}$
- $N = p, A = p+1$

'P' overtone
- $n = \frac{(p+1)v}{2L}$
- $\lambda = \frac{2L}{p+1}$
- $N = p+1, A = p+2$

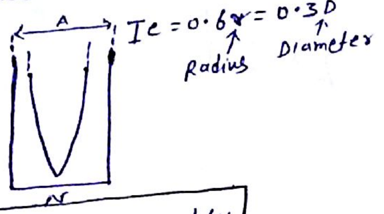
* No. of Node = No. of Harmonic

* If $\overset{4L}{L_{c.o.p}} = \overset{2L}{L_{o.o.p}} \Rightarrow n_{o.o.p} = 2n_{c.o.p}$

* If $n_{c.o.p} = n_{o.o.p} \Rightarrow L_{o.o.p} = 2L_{c.o.p}$

End correction :→ Due to inertia Med. particle does not Reflect from free end that's Why antinode is formed the outside of the free end $ effective length of organ pipe is more than length of organ pipe that correction in length is called end correction.

|a|→

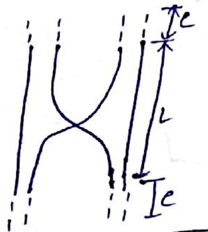


$L_{cop} = L + e = \lambda/4$

$\lambda = 4(L \pm e)$

$n_{c.o.p} = \frac{v}{\lambda} \left(\frac{v}{4(L+e)}\right)$

|b|→



$L_{eff} = L + 2e = \lambda/2$

$\lambda = 2(L+2e)$

$n_{o.op} = \frac{v}{\lambda} = \frac{v}{2(L+2e)}$

$e \neq 0$, $L_{cop} = L_{oop}$

$\frac{L+2e}{L+e} > 1$

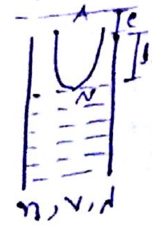
$n_{cop} \underset{e=0}{\overset{e\neq 0}{\gtrless}} \frac{1}{2} n_{oop}$

$n_{oop} \underset{e=0}{\overset{e\neq 0}{\lessgtr}} 2n_{cop}$

Resonance tube Exp: → * Work as a variable length c.o.p.

* In a Resonance tube variation of tuning fork prong is transmit $ position of prong w.r.t resonance tube is verticle.

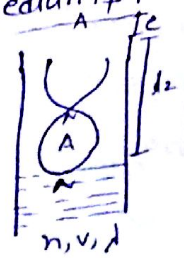
* By this exp. we practically calculate value of endcorrection, velocity of sound in gaseous medium $ freq of unknown tuning fork.



n, v, λ

Imax1

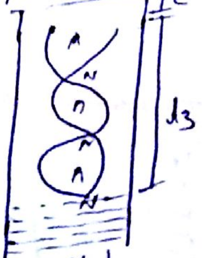
$l_1 + e = \frac{\lambda}{4}$ ①



n, v, λ

Imax2

$l_2 + e = \frac{3\lambda}{4}$ ②



n, v, λ

Imax3

$l_3 + e = \frac{5\lambda}{4}$ ③

* $I_{max} \propto \frac{1}{l} \Rightarrow$ Resonance length ↑ Imax ↓

|a| → End correction (e) →

$\frac{eq②}{eqn①}$ $\boxed{e = \frac{\ell_2 - 3\ell_1}{2}}$ $\frac{eqn③}{eqn.①} =$ $\boxed{e = \frac{\ell_3 - 5\ell_1}{4}}$

L.P

* $e = 0 \Rightarrow$ AMU $\boxed{\begin{matrix}\ell_2 = 3\ell_1 \\ \ell_3 = 5\ell_1\end{matrix}}$
* $e \neq 0$ $\boxed{\begin{matrix}\ell_2 > 3\ell_1 \\ \ell_3 > 5\ell_1\end{matrix}}$

$\ell_1 : \ell_2 : \ell_3 --- = 1 : 3 : 5 : 7 ---$

|b| → velo. of sound → $V = n\lambda$

$\boxed{V = 2n(\ell_2 - \ell_1)}$

|c| → Frequency → $n = V/\lambda$

$\boxed{n = \frac{V}{2(\ell_2 - \ell_1)}}$

ℓ_1 = Ist R. length
ℓ_2 = 2nd R. ''
ℓ_3 = 3rd R ''

$\boxed{\lambda = 2(\ell_2 - \ell_1)}$ → $V = n\lambda$ → $n = \frac{V}{\lambda}$

Possible Resonce condition: →

* $\boxed{\ell \leq L}$ → R. possible ← Length of tube

Resonance length

$\boxed{\ell > L}$ → not possible.

Height of Water column: →

$$\boxed{\begin{matrix} h_w = L - \ell \\ (h_w)_{max} = L - \ell_1 \\ (h_w)_{min} = L - \ell_{max} \end{matrix}}$$

***BEATS

When two Wave of different freq. goes in a same direction with same velocity. Result of superposition called beats.

$y_1 = a\sin(\omega_1 t - k_1 x)$
$y_2 = b\sin(\omega_2 t - k_2 x)$

* $+x$ direction ⇒ same
* velo. $V = \frac{\omega_1}{K_1} = \frac{\omega_2}{K_2}$
* $\omega_1 \neq \omega_2$
* $\Delta\phi = (\omega_2 - \omega_1)t - (K_2 - K_1)x$

$\boxed{\Delta\phi = f(x, t)}$

* Interference
V, n, direction] same
$\boxed{I = f(x)}$

* St. Wave
V, n] same
direction opposite

* Beats
V, direction] same
n ⇒ change
$\boxed{I = f(x, t)}$
* Beats ⇒ also called 'Dynamic Interference'
AFMC

|a| → $\omega_R = \frac{\omega_1 + \omega_2}{2}$ ⇒ Resulting freq.

$n_R = \frac{\omega_1 \omega_2}{4\pi} = \frac{n_1 + n_2}{2}$

|b|→ No. of beats = beat freq.

$$\boxed{\Delta n = n_1 - n_2}$$

|c|→ Beat time period →

$$\boxed{\Delta t = \frac{1}{\Delta n} = \frac{1}{(n_1 - n_2)}}$$

$$\boxed{\Delta t_{Max \leftrightarrow Min} = \frac{1}{2(n_1 - n_2)}}$$

Max ⟷ Max
Min ⟷ Min

BCECE

* For hearing & seeing We differenciate only When time lag is → $\boxed{1/10 \text{ sec.}}$
or, Time lag b/w two sound wave to clearly observed → $\geq \boxed{1/10 \text{ sec}}$

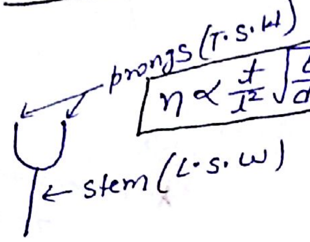
$$\boxed{\Delta t \geq \frac{1}{\text{sec}}} \quad \boxed{\Delta n \leq 10 \text{ beats/sec}}$$

AIIMS

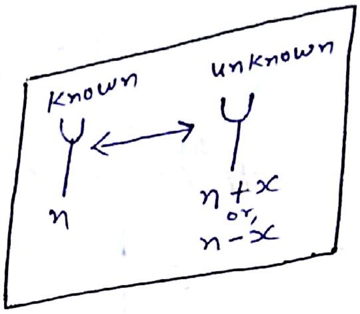
\# calculate min distance b/w person & Reflector It we clearly observed Eco of It sound → $d = \underline{\overset{*}{16.5}\,m} \simeq 17m$

Application of Beats :→

|1|→ Tuning fork →



$$\boxed{n \propto \frac{t}{l^2}\sqrt{\frac{E}{d}}}$$



Prong → Waxing/Loading ⇒ n↓
→ on Filing ⇒ n↑
→ Temp.↑, l↑ ⇒ n↓

Case I → Waxing of known/Filing of unknown) →
|a|→ $x' > x \Rightarrow n_{unknown} (n+1)$
|b|→ $x' < x$
|c|→ $x' = x$] ⇒ $n - x$

Case-II → Waxing of unkown/Filing of Known →
|a|→ $x' < x \Rightarrow n - x$
|b|→ $x' > x$
|c|→ $x' = x$] ⇒ $n + x$

* NOTE → If More than two tuning fork sounded together no. of beats is equal to max. freq. difference.

** Imp *

$$\boxed{n_N = n_1 \pm (N-1)x}$$

↑ order, ↓ order
→ No. of beat
freq. of Nth tuning fork.
Ist tuning fork

Charestistic of sound :→

* Loundnes → It is depend on Energy, Intensity & Amplitude.
* unit → bel (b), decibel (db), (1 b = 10 db)

$$* \boxed{L = \log_{10}(I/I_0)\text{ bel} = 10\log_{10}(I/I_0)\text{ db}}$$

L = Louness, I = Intensity of sound, I_0 = thresold of Hearing (min) $= 10^{-12}\, w/m^2$

NOTE → Loudness never depend on frequency.

$I_1 \to L_1$
$I_2 \to L_2$

$$\boxed{\begin{aligned} &{}^*\Delta L = L_2 - L_1 = 10\log_{10}(I_2/I_1)\text{ ab} \\ &{}^*I = \frac{E}{At} = \frac{P}{A} = \frac{P}{4\pi r^2} \propto \frac{1}{r^2} \\ &{}^*\Delta L = L_2 - L_2 = 10\log_{10}\left(\frac{r_1}{r_2}\right)^2 = 20\log_{10}\left(\frac{r_1}{r_2}\right)\text{dB} \end{aligned}}$$

pitch : → *depend on frequency.

*pitch ∝ freq

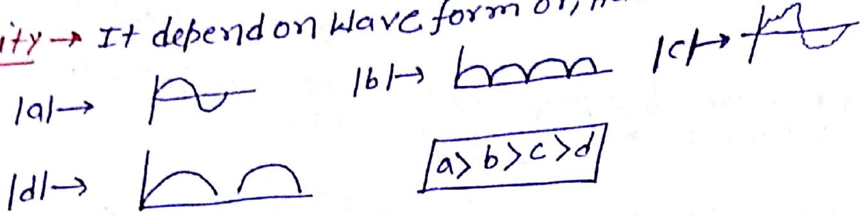
*High shrill voice ⇒ pitch high ⇒ ♀

* High grove voice ⇒ pitch low ⇒ ♂

EX→ * Freq of Male sound < Woman ∝ pitch.

BCECE 2015 * pitch of Mosquito sound > Lion.
but Loudnes of Lion > Mosquito.

* Quality → It depend on Wave form or, Harmonics.

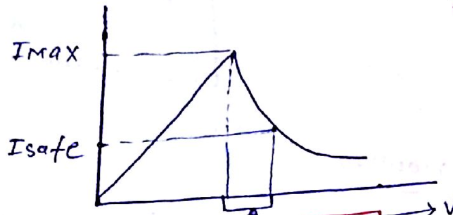


$\boxed{a > b > c > d}$

AIIMS Accousting of Building →

A/R

Imp * Intensity of sound in a room ↑ Linearly due to reflection & ↓ Exponentialy w.r.t time.

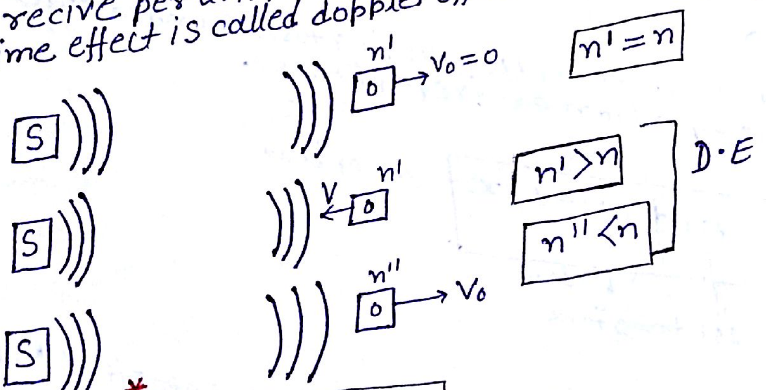


* $t \propto \frac{V}{aS}$ → vol. → surface area → absorbing cap.

Reverbasition time

DOPPLER EFFECT

Due to relative motion b/w source & observer No. of Wave recive per unit time is different form No. of Wave emitted per unit time effect is called doppler effect.



**

$\boxed{\begin{array}{l} r\cdot d \uparrow \Rightarrow n' < n \\ r\cdot d \downarrow \Rightarrow n'' > n \\ r\cdot d \text{ same} \Rightarrow n' = n \end{array}}$

Dopper effect of sound :→ Relative velo concept not applicable for velo. compared to light.

$\boxed{n \propto \frac{1}{\lambda}}$

$$\boxed{\begin{array}{l} n' = n\left(\frac{V \pm V_0}{V \pm V_s}\right) \\ \lambda' = \lambda\left(\frac{V \pm V_s}{V \pm V_0}\right) \end{array}}$$

V_0 → officer

V_s → servent

V ⇒ Resultant velo. of sound

V₀ = velo. of observer.

Vs = velo of source

[$n \Rightarrow$ Actual Frequency $n' \Rightarrow$ App. Frequency
$\lambda \Rightarrow$ Actual Wavelength $\lambda' \Rightarrow$ App. Wavelength]

* **Limitation** → velocity of obserber, source & Medium is less than from velo. of sound.

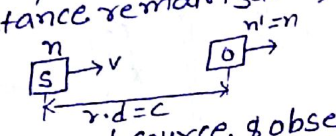
Mech no. → $M = \frac{V_{obs}}{V_{sound}}$

* $V_{obs} > V_{sound} \Rightarrow M > 1 \Rightarrow$ shock Wave.

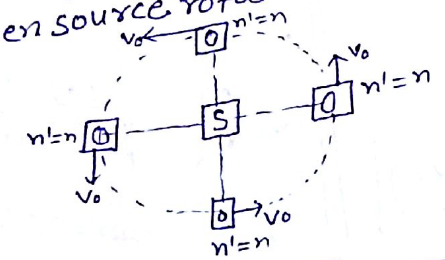
* $V_{obs} < V_{sound} \Rightarrow M < 1 \Rightarrow$ D.E applicable.

condn → When doppler effect Will be not observed.

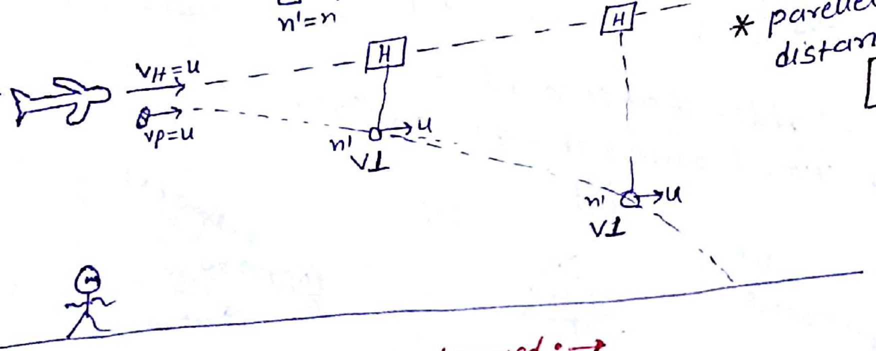
(i) → When source & observer move in same direction With same speed (Relative distance remain same).



(ii) → If line of action of source & obserber is perpendicular. (When source rotate in a circular path & observer ⊕nt at centre).



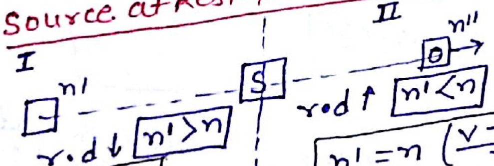
EX →



* parellel direction Relative distance ↑
$\boxed{n' < n}$

condn → Where doppler effect is observed :→

condn (1) → Source at Rest & observer Movable :→



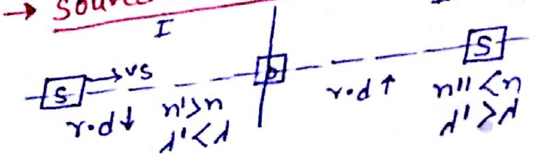
*
$$\boxed{\begin{gathered} n' = n\left(\frac{v+v_0}{v}\right) \\ \lambda' = \lambda \end{gathered}}$$

*
$$\boxed{\begin{gathered} n' = n\left(\frac{v-v_0}{v}\right) \\ \lambda' = \lambda \end{gathered}}$$

NOTE → If observer move With const. Speed Apprent freq. remain unchange with relative distance & observer.

*
$$\boxed{\Delta n = \left(\frac{2v_0}{v}\right) n}$$

condn (2) → Source Movable & observer at Rest :→



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

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

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

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

$n' - n'' = \Delta n$

$$* \boxed{\Delta n = \left(\frac{2V_s V}{V^2 - V_s^2}\right) n}$$

Imp* $V_s << V \Rightarrow \frac{V_s}{V} << 1$ (neglect.

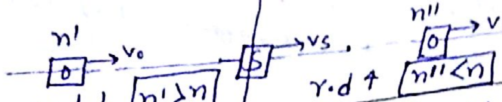
$$* \boxed{\Delta n = \left(\frac{2V_s}{V}\right) n}$$

Condn. |3|→ Both are Movable→

|a|→ Same direction (Same sign)→

$$\boxed{n' = n\left(\frac{V \pm V_o}{V \pm V_s}\right)}$$

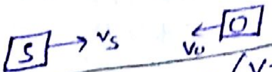
|i|→ $V_o > V_s$→



$$\boxed{n' = n\left(\frac{V+V_o}{V+V_s}\right)}$$

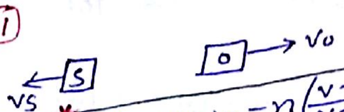
$$\boxed{n' = n\left(\frac{V-V_o}{V-V_s}\right)}$$

**
① →



$$* \boxed{n' = n_{max} = n\left(\frac{V+V_o}{V-V_s}\right)}$$

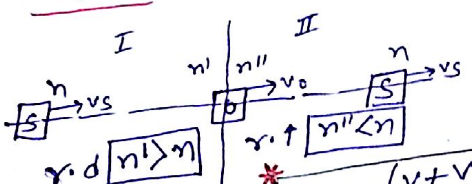
⑪



$$* \boxed{n' = n_{min} = n\left(\frac{V-V_o}{V+V_s}\right)}$$

* opposite direction → opposite sign

|ii|→ $V_s > V_o \Rightarrow$

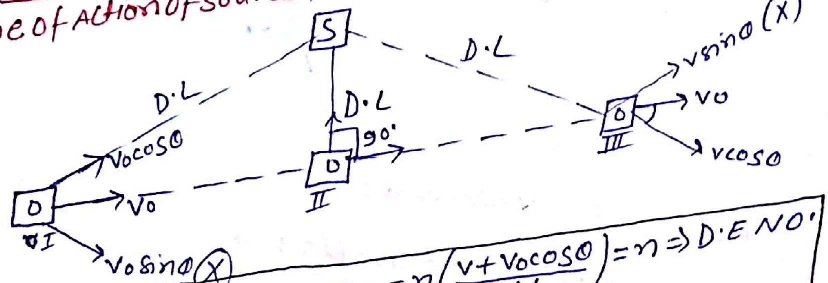


$$* \boxed{n' = n\left(\frac{V-V_o}{V-V_s}\right)}$$

$$* \boxed{n' = n\left(\frac{V+V_o}{V+V_s}\right)}$$

**
***
Special case for Doppler effect of sound:→

Case I→ If line of Action of source & observer is different:→



$$* \boxed{\begin{gathered} n_I = n\left(\frac{V+V_o\cos\theta}{V}\right) \qquad n_{II} = n\left(\frac{V+V_o\cos\theta}{V}\right) = n \Rightarrow D.E\ NO. \\ n_{III} = n\left(\frac{V-V_o\cos\theta}{V}\right) \end{gathered}}$$

2015(m)
BCECE

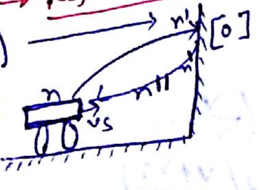
NOTE→ Train move on circular track & engine emit a sound of freq. 'n' then apperant freq. appear to Actual freq. to the person in the train in Any vagon (dabba).

Case II→ Effect of Reflecter → Max → If r.d ↓
→ min → If R.d ↑

|a|→ Reflector at Rest:→

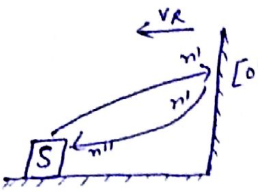
$n' = n\left(\frac{V}{V-V_s}\right)$

$n'' = n'\left(\frac{V+V_s}{V}\right)$



$$\boxed{\begin{aligned} &\text{Reflected freq} \rightarrow n'' = n\left(\frac{V+V_s}{V-V_s}\right) \\ &\text{No. of Beat} = (\Delta n) = n'' - n \end{aligned}}$$

|b|→ Reflector movable :→



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

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

* Reflected freq → $n'' = n'\left(\frac{v+v_R}{v-v_R}\right)$
* Beats $\Delta n = n''-n$

Reflected freq. ** $n'' = n\left(\frac{v+v_S}{v-v_S}\right) \Rightarrow$ max

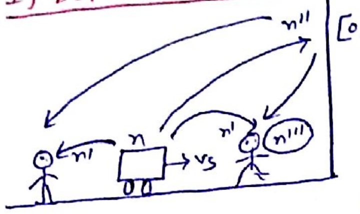
r·d ↓ ⇒ $n'' = n\left(\frac{v+v_S}{v-v_S}\right)$

r·d ↑ ⇒ $n'' = n_{min}$

AIIMS U.K

* Sonar → D·E of sound
* RADAR → D·E of light

|c|→ If both are movable :→



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

calculate No. of Beat a/c to position of observer shown in fig.

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

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

$\boxed{\Delta n = n''' - n' = 0}$

(I) $n' = n\left(\frac{v}{v+v_S}\right)$

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

$\boxed{\Delta n = n''' - n' \neq 0}$

'D·E of light'

$$\boxed{n' = n\left(\frac{c \pm v_o}{c \pm v_S}\right)}$$

condn 1 → Source at Rest & observer movable

I r·d ↓, $\boxed{n'>n}$

II r·d ↑ $\boxed{n''<n}$

* $n' = n\left(1+\frac{v_o}{c}\right)$ ⊕

$\lambda' = \lambda\left(1-\frac{v_o}{c}\right)$ ⊖

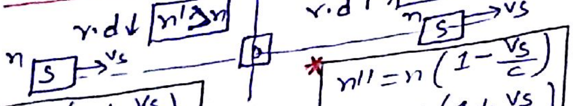
* $n'' = n\left(1-\frac{v_o}{c}\right)$ ⊖

$\lambda'' = \lambda\left(1+\frac{v_o}{c}\right)$ ⊕

condn 2 → Source movable & observer at Rest :→

r·d ↓ $\boxed{n'>n}$

r·d ↑, $\boxed{n''<n}$



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

$\lambda' = \lambda\left(1-\frac{v_s}{c}\right)$

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

$\lambda'' = \lambda\left(1+\frac{v_s}{c}\right)$

Imp.

|a|→ App. freq ⇒ $n' = n\left(1 \pm \frac{v}{c}\right)$

|b|→ App. wavelength ⇒ $\lambda' = \lambda\left(1 \pm \frac{v}{c}\right)$

v_o ⇒ When obs move

v_s ⇒ When source move

$v_{Relative}$ ⇒ When both

* Sign convension → (n) → r·d ↓ ⇒ ⊕ve ; → r·d ↓ ⇒ ⊖ve

(λ) → r·d ↓ ⇒ ⊖ve ; → r·d ↑ ⇒ ⊕ve

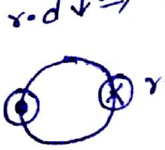
AIIMS

Application of D·E of light →

|i|→ r·d ↑ ⇒ $n'<n \Rightarrow \lambda'>\lambda$ (λ↑) ⇒ Red shift.

|ii|→ r·d ↓ ⇒ $n'>n \Rightarrow \lambda'<\lambda$ (λ↓) ⇒ voilet shift.

|iii|→



r·d ↑ $n'<n$

$\lambda'>\lambda$ (R·shift)

r·d ↓

$n'>n$

$\lambda'<\lambda$

(v·shift)

D·E of light (In case of Reflection) →

Reflected freq.

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

Normal A → V
Refleked A → 2V

Change in freq

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

Reflected wavelength

$\boxed{\lambda' = \lambda\left(1 \pm \frac{2v}{c}\right)}$

change in λ

$\boxed{\Delta\lambda = \lambda' - \lambda = \left(\frac{2v}{c}\right)\lambda}$

NOTE →

Sound	Light
Asymetric	Symetric
Addⁿ & substitution is valid	X