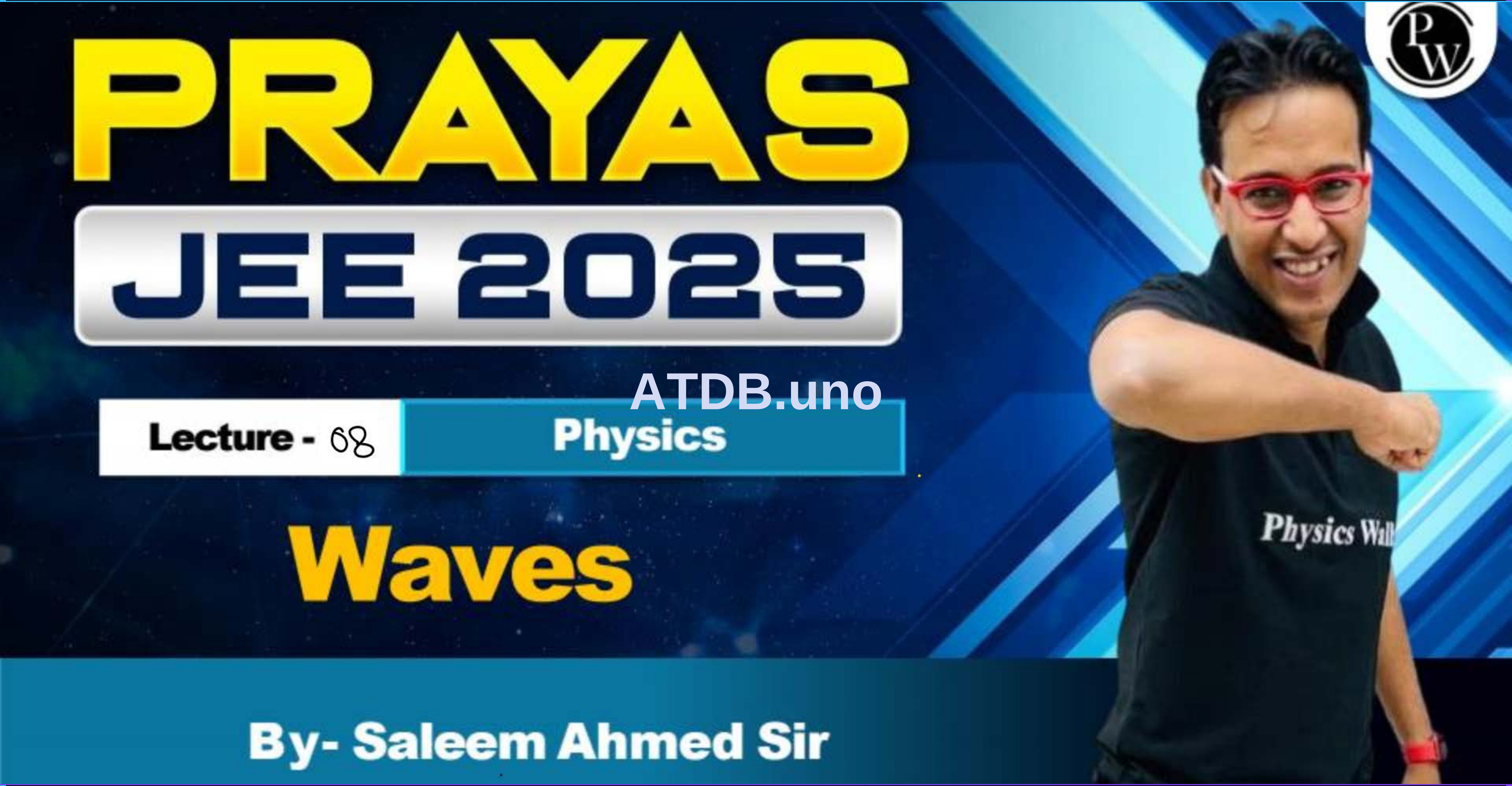

PRAYAS
JEE 2025
Lecture - 08
Physics
Waves
By- Saleem Ahmed Sir

Topics *to be covered*

1. Sound wave, velocity of sound wave
2. Characteristics of sound
3. Loudness
4.

Sound wave.

- Longitudenal Wave
- Particle viberates in the dir^n of wave motion (parallel/Antiparallel)
- As sound travel through air, the elements of air viberates to produce change in density and pressure along the direction of motion of the wave.

when no sound wave

when sound wave travel

Eq^n of sound wave

$$S = S_0 \sin(\omega t - Kx + \phi)$$

Displacement of particle (S)

Amplitude (S_0)

$$V_w = \frac{\omega}{K}$$

ω, K Sign opposite ⇒ $+x$ dir^n "
ω, k " same ⇒ $-x$ " "

$$\frac{\partial s}{\partial t} = V_p$$

$$\frac{\partial^2 s}{\partial t^2} = a_p$$

$$V_p = -V_w \frac{\partial s}{\partial x}$$

Variation of excess pressure in gas due to propagation of longitudinal wave.

Let s is displacement of particle at x

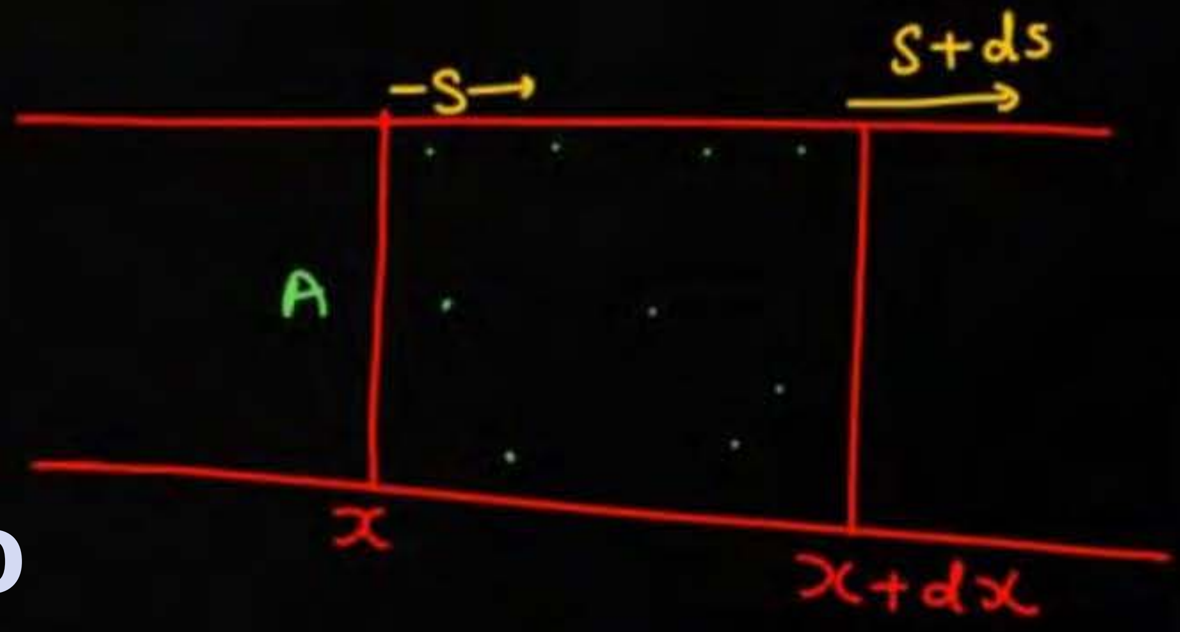
$s+ds$ is displacement of particle at $x+dx$

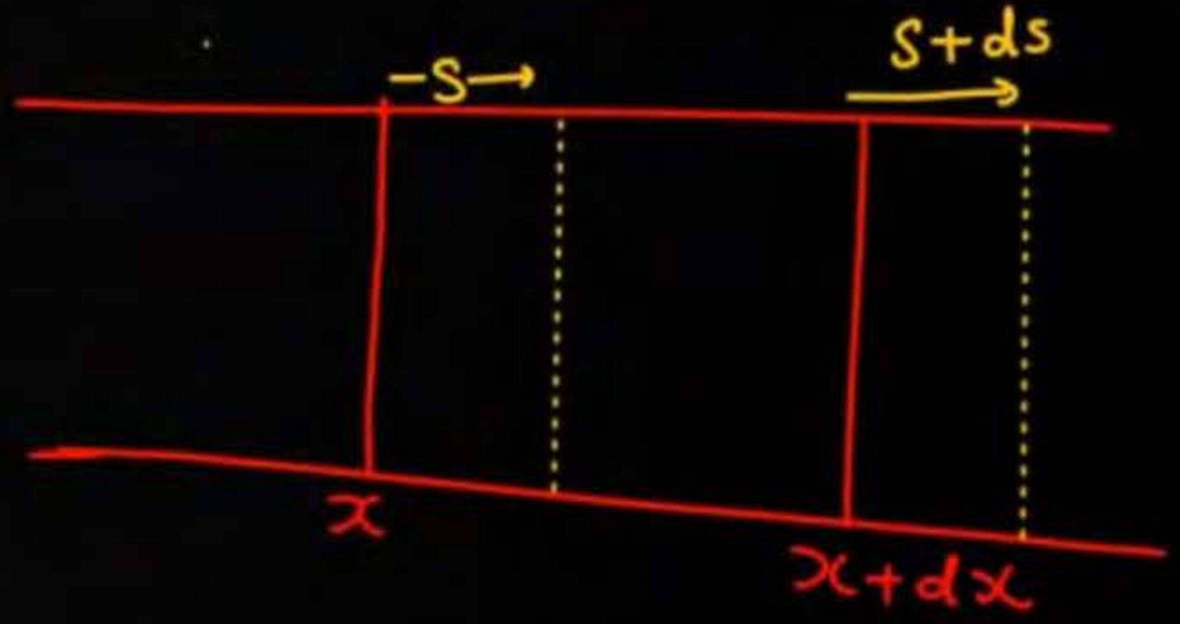
Change in volume of elements $= \Delta V$

V_i = Initial Vol^n $= A\,dx$

ΔV = Change in Vol^n $= A\,ds$

$$\frac{\Delta V}{V_i} = \frac{A\,ds}{A\,dx} = \frac{\partial s}{\partial x}$$





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

ΔP → Excess pressure

$$\Delta P = -B\frac{\Delta V}{V} = -B\frac{\partial s}{\partial x}$$

$$\boxed{\Delta P = -B\frac{\partial s}{\partial x}}$$

ΔP → Excess pressure

$$S = S_0 \sin(\omega t - kx + \phi)$$

$$\Delta P = -B\frac{\partial s}{\partial x}$$

$$\Delta P = +\boxed{BS_0K}\cos(\omega t - kx + \phi)$$

$$\Delta P = \Delta P_0 \cos(\omega t - kx + \phi)$$

$\equiv$ 90° phase diff

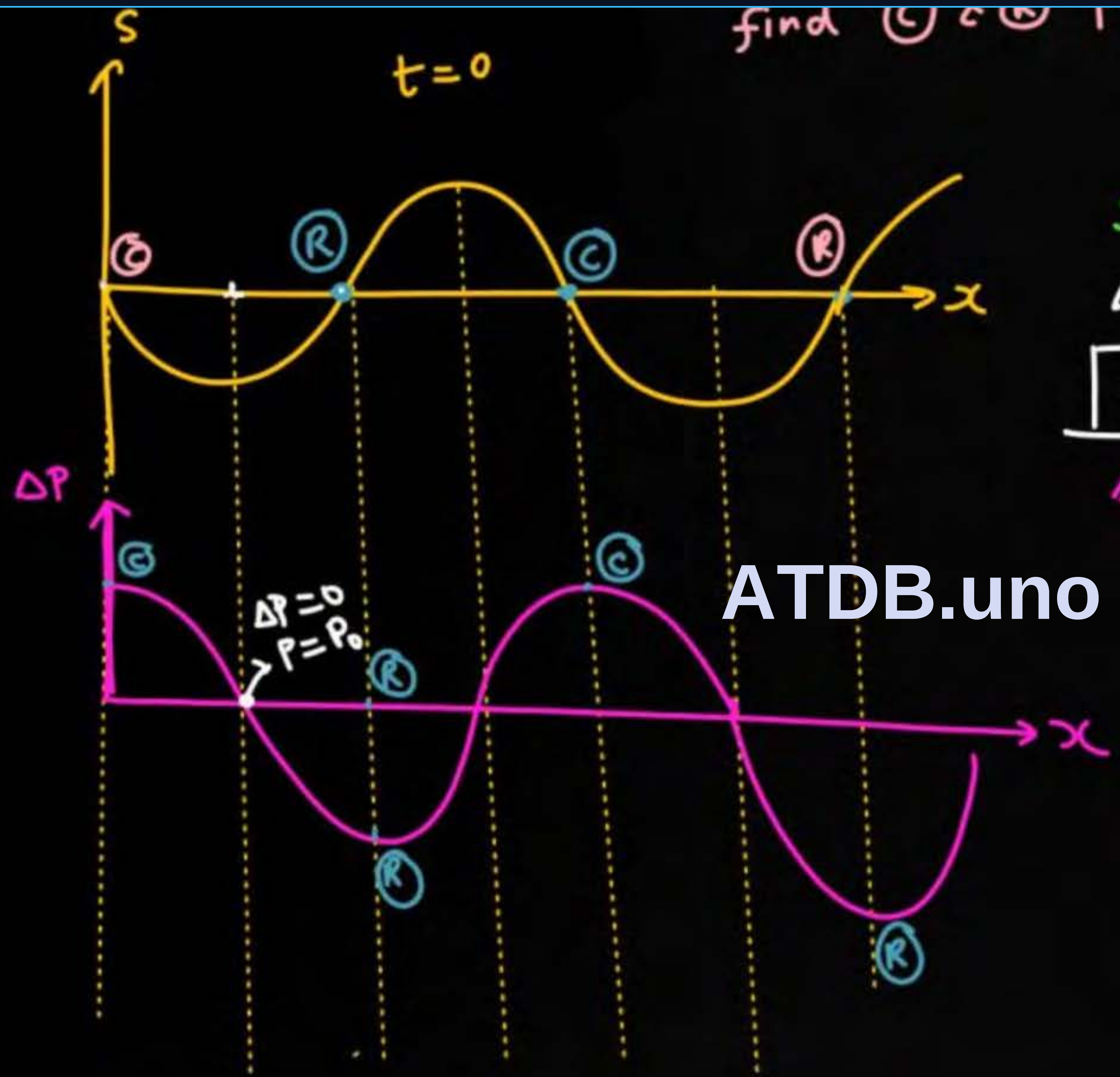
ΔP → excess pressure

ΔP_0 → excess press Amplitude

$$\boxed{\Delta P_0 = BS_0K}$$

At most compressed $vol^n \equiv P = P_0 + \Delta P_0 = P_0 + BS_0K$

" Varifies Ⓡ $\equiv P = P_0 - BS_0K$



$S = -S_0 \sin kx$

$\Delta P = -B \frac{ds}{dx}$

$\boxed{\Delta P = +B S_0 K \cos kx}$

$\Delta P = \Delta P_0 \cos kx$

Q A sound wave of wavelength 40 cm travel in air. If the difference b/w maximum & minimum pressure at a point is $4.0 \times 10^{-3}\ N/m^2$, find the amplitude of vibration of particle of medium. Bulk modulus of air $= 1.4 \times 10^5\ \frac{N}{m^2}$

Sol^n

$\lambda = .40$

$K = \frac{2\pi}{\lambda} = \frac{2\pi}{.40}$

$= 5\pi$

$4 \times 10^{-3} = (P_0 + BS_0K) - (P_0 - BS_0K)$

$4 \times 10^{-3} = 2BS_0K$

$S_0 = \frac{4 \times 10^{-3}}{2 \cdot B \cdot K} = \frac{4 \times 10^{-3}}{2 \times 1.4 \times 10^5 \ 5 \times \frac{22}{7}}$

Q Equation of sound wave in air is given by

$P = .2 \sin(3000t - 9x)$ where all variables are in S.I. Unit.

① find λ, frequency, speed of sound

$\omega = 2000 = 2\pi f$ $\quad K = 9 = \frac{2\pi}{\lambda}$ $\quad V_w = \frac{\omega}{K} = \frac{3000}{9} = \frac{1000}{3}$

$f = \frac{2000}{2\pi}$ $\quad \lambda = 2\pi/9$

② If the equilibrium pressure of air is 1.0×10^5 N/m what are max & min pressure at a point as wave pass through the points.

$\boxed{P_0 = 1.0 \times 10^5}$

$P_{max} = P_0 + .2$

$P_{min} = P_0 - .2$

③ $B = 1.4 \times 10^5$ ✓ $\quad S_0 = \frac{\Delta P_0}{BK}$

Velocity of Sound in Longitudinal wave

$$v_w = \sqrt{\frac{E}{\rho}}$$

E → modulus of rigidity.
ρ → density

① Solid E = Y (young's modulus)

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

② Fluid / gas E = B

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

Velocity of sound in air

Newton → isothermal process

B = P   PM = ρRT

$$V_w = \sqrt{\frac{P}{\rho}} = \sqrt{\frac{RT}{M}} \approx 280 \text{ m/s}$$

15-17%

Lapalace Correction

propagation of sound in air → Adiabatic process

$$B = \gamma P$$

$$V_w = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$$

Q If velocity of sound in oxygen gas is V_0 find velocity of sound in nitrogen gas at same temp.

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

$\gamma \rightarrow$ same

$T \rightarrow$ same

$$\frac{V_1}{V_2} = \sqrt{\frac{m_2}{m_1}}$$

$$\frac{V_{N_2}}{V_0} = \sqrt{\frac{32}{28}}$$

Q find velocity of sound in oxygen at 20°C is V_0 find velocity of sound in He at 40°C

He ≡ $\gamma_{mono} = \frac{5}{3} = \gamma_2$

$O_2 \equiv \gamma_{dia} = \frac{7}{5} = \gamma_1$

oxygen ⇒ $V_0 = V_1 = \sqrt{\frac{\gamma_1 R(273+20)}{m_1}}$

He

$V_2 = \sqrt{\frac{\gamma_2 R(273+40)}{m_2}}$

$\frac{V_1}{V_2} = \sqrt{\frac{\gamma_1}{\gamma_2}\,\frac{293}{313}\,\frac{m_2}{m_1}}$

Q If pressure of gas is increase to four times at const temp. velocity of sound will become

$$V_w = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{m}} \longrightarrow \text{Same}$$

$$B = -\frac{dP}{\frac{dV}{V}}$$

isothermal

$$PV = \text{Const}$$

$$P + V\frac{dP}{dV} = 0$$

$$P = -\frac{dP}{\left(\frac{dV}{V}\right)}$$

Adeba

$$PV^{\gamma} = \text{Const}$$

$$P\gamma V^{\gamma-1} + V^{\gamma}\frac{dP}{dV} = 0$$

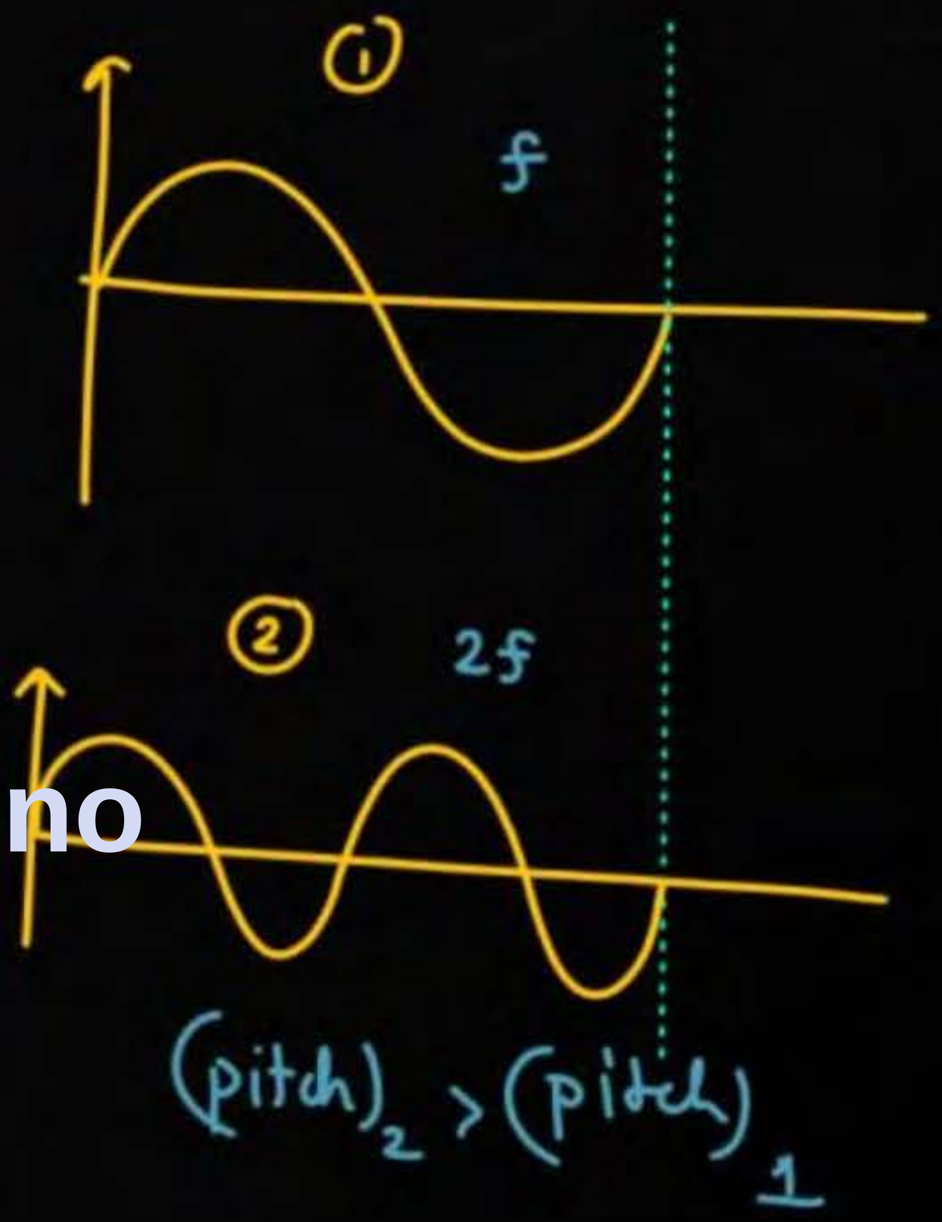
$$\gamma\frac{P}{V}V^{\gamma} + \frac{dP}{dV}\cdot V^{\gamma} = 0$$

$$\gamma P = -\frac{dP}{\left(\frac{dV}{V}\right)} = B$$

Characteristics of sound

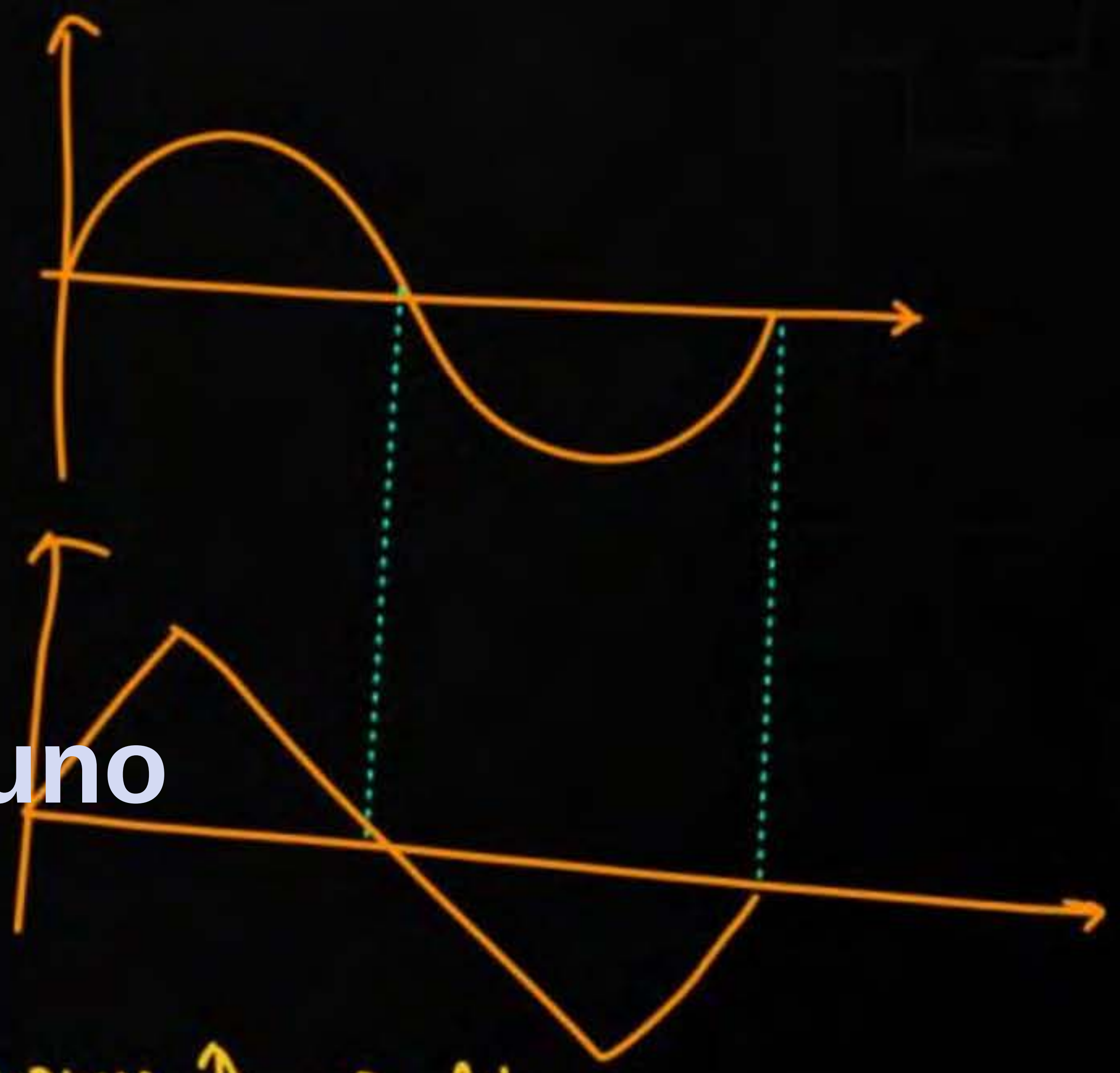
① pitch → depends on freq.

freq ↑ , pitch ↑

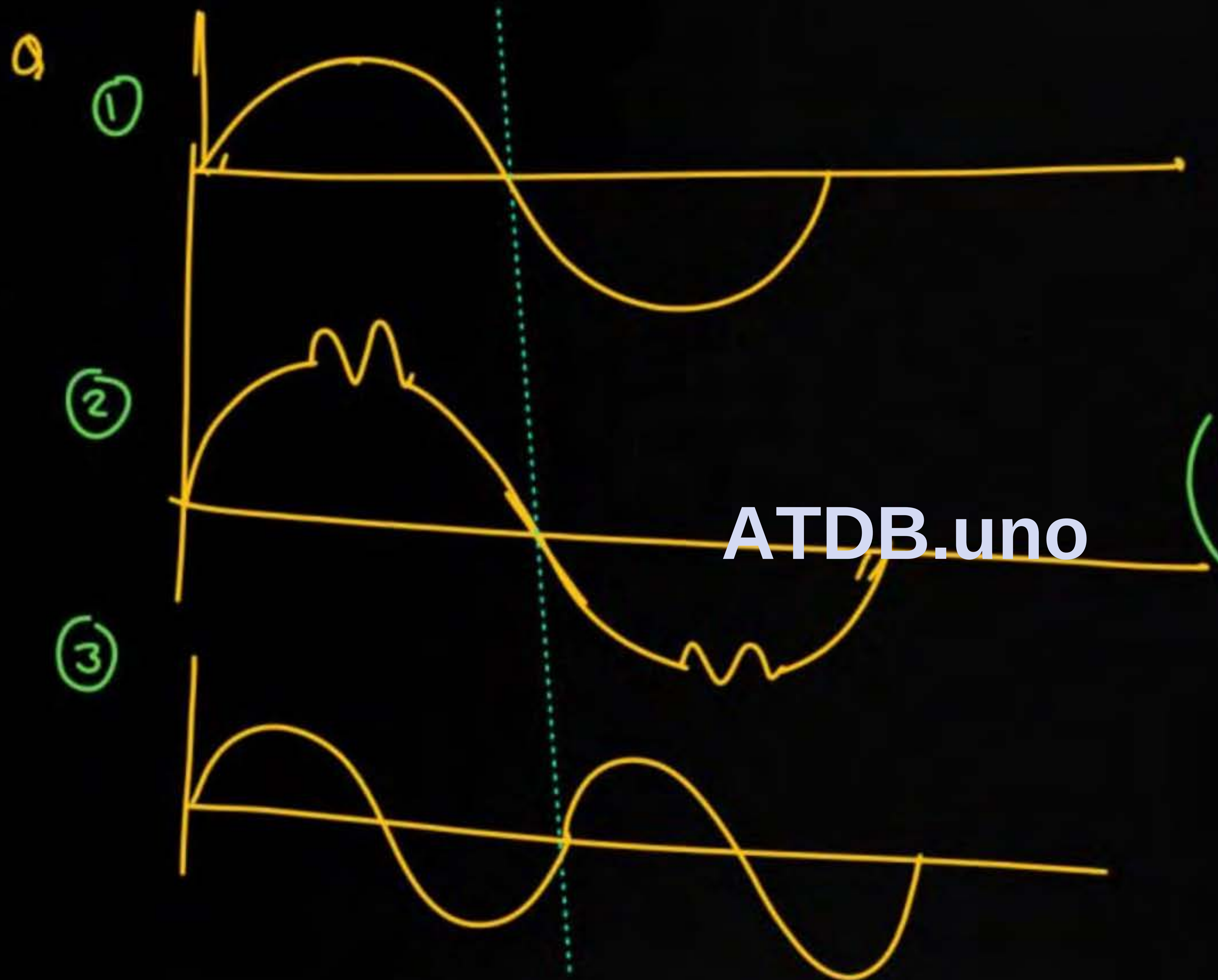


② Quality ⟶ depends on waveform

freq ⟶ Same
pitch ⟶ Same
quality ⟶ diff.



Sharpness ↑ , Quality ↓



1, 3 → same quality
→ diff- freq.

(1, 2 ⇒ freq same
Quality different)

Loudness ⟶ depends on Intensity.

I ⟶ Energy per Unit area per Unit time.

t = 1 sec, A = 1 m

Loudness – It depends on intensity of sound

Loudness of sound is measured in decibel (dB)

$$L = 10 \log_{10}\left(\frac{I}{I_0}\right)$$

$I_0 \rightarrow$ min Intensity that can be heard by normal person.

$= 10^{-12}\ w/m^2$

Q $I = 10^{-10}$ watt/m^2

$$L = 10 \log\left(\frac{10^{-10}}{10^{-12}}\right) = 20\,dB$$

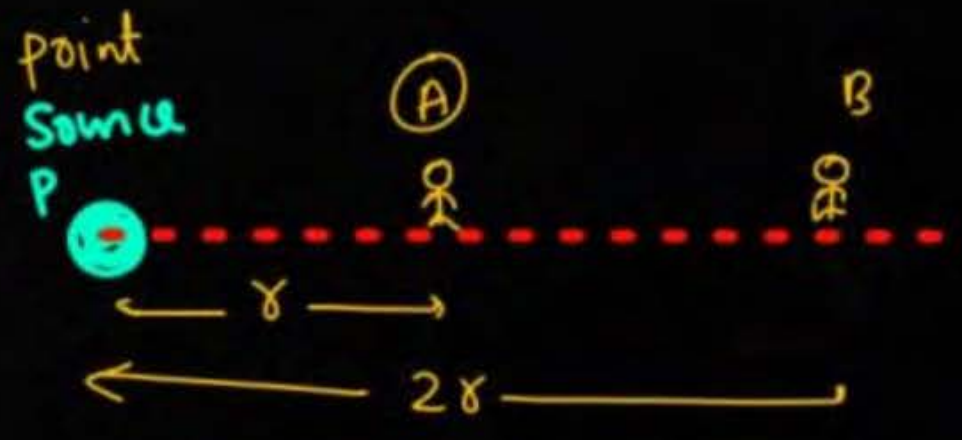
Intensity → Energy per Unit area · per Unit time
power per Unit area

① point source

Intensity at 'A'

$$I = \frac{P}{4\pi r^2}$$

$I \propto \frac{1}{r^2}$ point source



$$I_A = \frac{P}{4\pi r^2}$$

$$I_B = \frac{P}{4\pi (2r)^2}$$

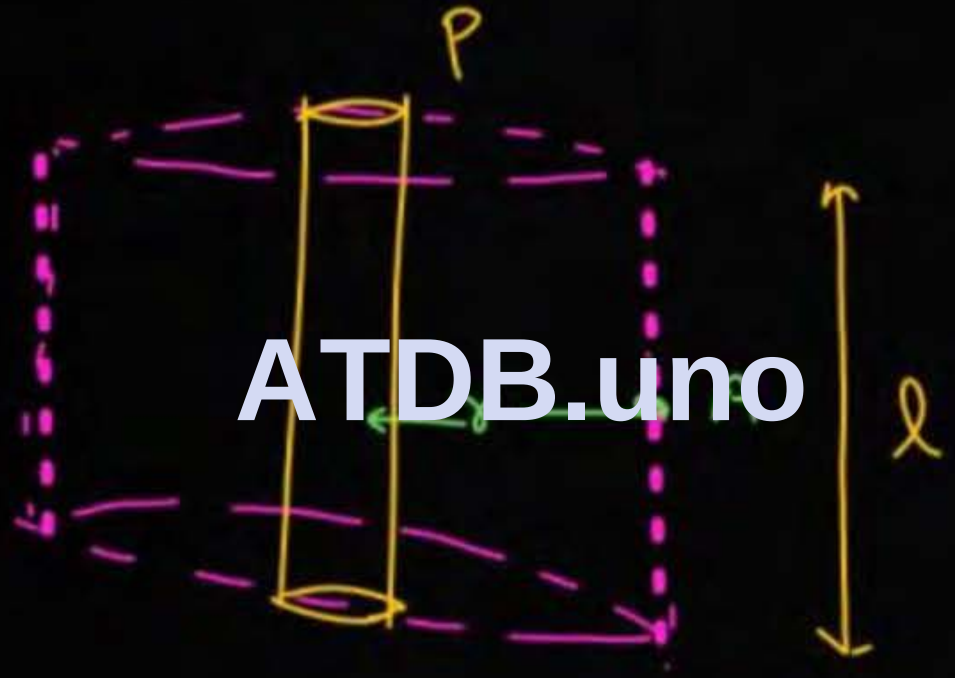
$$I \propto \frac{1}{r^2}$$

$$\frac{I_A}{I_B} = \frac{(2r)^2}{(r)^2}$$

② Linear Source

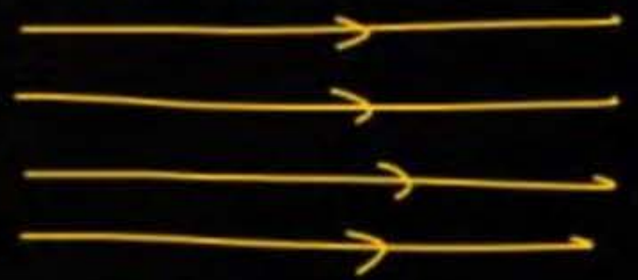
$$I_A = \frac{P}{2\pi r l}$$

$$\boxed{I \propto \frac{1}{r}}$$



point source	$I \propto \frac{1}{r^2}$
linear "	$I \propto \frac{1}{r}$

③ Parallel beam



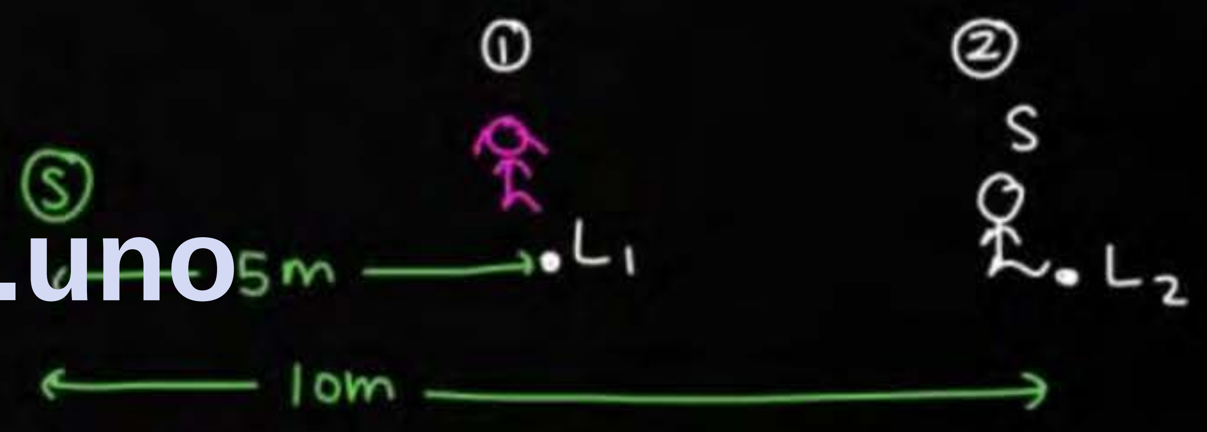
$$I \propto r^0$$

$$I \rightarrow \text{const}$$

Q Consider a point source emitting sound wave, find difference in decibel scale reading, (find difference in Loudness) between two points at a distance 5m and 10m from source respectively.

$$L_1 = 10 \log \frac{I_1}{I_0}$$

$$L_2 = 10 \log \frac{I_2}{I_2}$$



$$L_1 - L_2 = 10\left(\log \frac{I_1}{I_0} - \log \frac{I_2}{I_0}\right)$$

$$= 10 \log\left(\frac{I_1}{I_2}\right) = 10 \log\left(\frac{r_2}{r_1}\right)^2 = 20 \log\left(\frac{10}{5}\right) = 20 \log 2$$

$$I \propto \frac{1}{r^2}$$

$$\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$$

Q A certain Sound level is increased by 20 dB by what multiple its intensity increased. (source is point source)

$$L_2 - L_1 = 20$$

$$10\log\frac{I_f}{I_0} - 10\log\frac{I_i}{I_0} = 20$$

$$10\log\frac{I_f}{I_i} = 20$$

$$\log_{10}\frac{I_f}{I_i} = 2$$

$$\frac{I_f}{I_i} = 100$$

$$\boxed{I_f = 100\, I_i}$$

Home work

- Prarambh ⇒ 22, 20, 23 – 27,

  Prabal ⇒ 14, 15, 17, 18, 19, 20, 29, 30

  HCV → wave on string ⇒ (47 – 52) → Adv level

  Sound wave ⇒ 4, 5, 6, 8, 13, 12, 14, 16, (18 – 23)


THANK
YOU