23. SOUND WAVES

(i) Longitudinal displacement of sound wave

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

(ii) Pressure excess during travelling sound wave

$P_{ex} = -B\dfrac{\partial \xi}{\partial x}$ (it is true for travelling

$= (BAk)\cos(\omega t - kx)$

wave as well as standing waves)

Amplitude of pressure excess = BAk

(iii) Speed of sound $C = \sqrt{\dfrac{E}{\rho}}$

Where E = Ellastic modulus for the medium

ρ = density of medium

for solid $C = \sqrt{\dfrac{Y}{\rho}}$

where Y = young's modulus for the solid

for liquid $C = \sqrt{\dfrac{B}{\rho}}$

where B = Bulk modulus for the liquid

for gases $C = \sqrt{\dfrac{B}{\rho}} = \sqrt{\dfrac{\gamma P}{\rho}} = \sqrt{\dfrac{\gamma RT}{M_0}}$

where M_0 is molecular wt. of the gas in (kg/mole)

Intensity of sound wave :

$\langle I \rangle = 2\pi^2 f^2 A^2 \rho v = \dfrac{P_m^2}{2\rho v}$ $\qquad \langle I \rangle \propto P_m^2$

(iv) Loudness of sound : $L = 10\log_{10}\dfrac{I}{I_0}$ dB

where $I_0 = 10^{-12}$ W/m^2 (This the minimum intensity human ears can listen)

Intensity at a distance r from a point source = $I = \dfrac{P}{4\pi r^2}$

Interference of Sound Wave

if $P_1 = p_{m1}\sin(\omega t - kx_1 + \theta_1)$

$P_2 = p_{m2}\sin(\omega t - kx_2 + \theta_2)$

resultant excess pressure at point O is

$p = P_1 + P_2$

$p = p_0 \sin(\omega t - kx + \theta)$

$p_0 = \sqrt{p_{m_1}^2 + p_{m_2}^2 + 2p_{m_1}p_{m_2}\cos\phi}$

where $\phi = [k(x_1 - x_2) + (\theta_1 - \theta_2)]$

and $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

(i) For constructive interference

$\phi = 2n\pi$ and $p_0 = p_{m1} + p_{m2}$ (constructive interference)

(ii) For destructive interfrence

$\phi = (2n+1)\pi$ and $p_0 = |p_{m1} - p_{m2}|$ (destructive interference)

If ϕ is due to path difference only then $\phi = \frac{2\pi}{\lambda}\Delta x$.

Condition for constructive interference : $\Delta x = n\lambda$

Condition for destructive interference : $\Delta x = (2n+1)\frac{\lambda}{2}$.

(a) If $p_{m1} = p_{m2}$ and $\theta = \pi, 3\pi, \ldots$
resultant $p = 0$ i.e. no sound

(b) If $p_{m1} = p_{m2}$ and $\phi = 0, 2\pi, 4\pi, \ldots$
$p_0 = 2p_m$ & $I_0 = 4I_1$
$p_0 = 2p_{m1}$

Close organ pipe :

$$f = \frac{v}{4\ell}, \frac{3v}{4\ell}, \frac{5v}{4\ell}, \ldots\ldots\ldots \frac{(2n+1)v}{4\ell}$$ n = overtone

Open organ pipe :

$$f = \frac{v}{2\ell}, \frac{2v}{2\ell}, \frac{3v}{2\ell}, \ldots\ldots\ldots \frac{nV}{2\ell}$$

Beats : Beatsfrequency = $|f_1 - f_2|$.

Doppler s Effect

The observed frequency, $f = f\left(\frac{v - v_0}{v - v_s}\right)$

and Apparent wavelength $\lambda = \lambda\left(\frac{v - v_s}{v}\right)$