WAVES

Harmonic Progression	$y = A\sin(kx - \omega t + \phi)$
Acceleration	$a_k = -\omega^2 y$ $(a_k)_{max} = A\omega^2$
Speed of Wave	$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$
Speed of Particle	$V_P = A\omega\cos(\omega t + kx)$ $(V_P)_{max} = Akv$ v=speed of wave

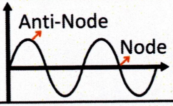
Energy

$K_\lambda = \frac{1}{4}\mu\omega^2A^2\lambda$	$U_\lambda = \frac{1}{4}\mu\omega^2A^2\lambda$

$$E = K + U = \frac{1}{2}\mu\omega^2A^2\lambda$$

Power

$P = \frac{E}{T} = \frac{1}{2}\mu\omega^2A^2v$	$I = \frac{1}{2}\rho\omega^2A^2v$
Velocity of particle & Wave relation	$v_{particle} = -(\text{slope}) \times v_{wave}$

Nodes & Antinodes	
The Wave Equation	$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{dt^2}$
Intensity of wave	
$I = 2\pi^2 n^2 A^2 \rho v$	ρ = density of medium v=Wave velocity A=amplitude n=Wave frequency
Energy Density	$E = \frac{\text{Energy Intensity}}{\text{Energy Velocity}}$ $E = 2\pi^2 n^2 a^2 \rho$
Velocity of Propagation of Mechanical Waves	
Transverse wave on string	$c = \sqrt{T/m}$
Transverse ripples on a pond	$c = \sqrt{2\pi\sigma/\rho\lambda}$
Longitudinal wave on spring	$c = \sqrt{kl/m}$
Longitudinal wave on a rod	$c = \sqrt{E/\rho}$
Sound wave in a gas	$c = \sqrt{\gamma p/\rho}$

Speed of non-mechanical Electromagnetic wave in vacuum	$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ μ_0 = absolute permeability ε_0 = absolute permittivity of air
Speed of Longitudinal Wave in gas	
T=Temperature ρ=Density	$v = \sqrt{\frac{\gamma p}{\rho}} = \sqrt{\frac{RT}{M}}$
Speed of Transverse Wave	
T=Tension in String μ=mass per unit length η=modulus of Rigidity	$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{\eta}{\rho}}$
Speed of Transverse Wave at a point x	$v_x = \sqrt{gx}$
Accelerating of a Transverse Wave going up Vertical Plane	$a_{wave} = \frac{g}{2}$
Relation b/w Phase diff., Path diff. and Time diff.	$\frac{2\pi}{\Delta\phi} = \frac{\lambda}{\Delta x} = \frac{T}{\Delta t}$

Speed of Transverse Wave			
Newton's Formula	$v = \sqrt{\frac{P}{\rho}}$	**Laplace's Correction (longitudinal)**	$v = \sqrt{\frac{\gamma P}{\rho}}$

Effect of Temperature on Speed of Sound	$v_t = v_0 + 0.61t$
Principal of Superposition of Wave	
Two or more progressive waves can travel simultaneously in the medium without effecting the motion of one another	
Equation of Stationary Wave	$y = 2a \sin\frac{2\pi t}{T} \cos\frac{2\pi x}{\lambda}$
Position of Nodes	$x = \frac{n\lambda}{2}$
Speed of Sound	Vsound $\propto$ humidity It depends on T
Sound level	
I=sound intensity I_0=Threshold of hearing P_0=Pressure amplitude ρ = density of medium	$\beta = 10\log\left(\frac{I}{I_0}\right)$dB $I = \frac{P_0^2}{2\rho V}$

Properties	Reflected	Refracted/ Transmitted
Velocity	Same	Same
Wavelength	Same	$V = \lambda f$(f is same)
Phase	from Denser there is phase difference of π	No change

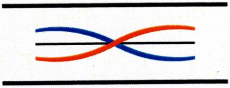
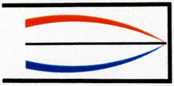
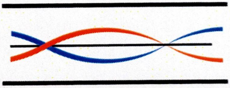
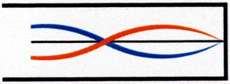
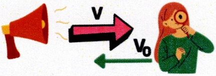
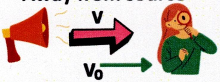
Sonometer Wire/Open Organpipe	$f = \frac{nV}{2L} = \frac{n}{2L}\sqrt{\frac{T}{\mu}} = \frac{n}{2L}\sqrt{\frac{\gamma P}{\rho}}$

1st Harmonic Fundamental Freq.	2nd Harmonic 1st Overtone	3rd Harmonic 2nd Overtone
$f_1 = \frac{V}{2L}$	$f_1 = \frac{V}{L}$	$f_1 = \frac{3V}{2L}$

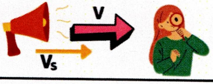
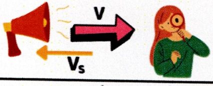
Closed Organpipe	$f_1 = \frac{(2n-1)V}{4L}$

n=1 1st Harmonic	Fundamental Frequency $f_1 = \frac{V}{4L}$	n=2 3rd Harmonic	1st Overtone $f_1 = \frac{3V}{4L}$

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

Velocity of Sound	$n = \frac{V}{2(l_2 - l_1)}$
Wavelength of Sound	$\lambda = 2(l_2 - l_1)$
Resonance Tube	If, $l_1 = l$; Then, $l_2 = 3l$
Open Organpipe	**Closed Organpipe**
Fundamental 	**Fundamental/First Harmonic** 
Second Harmonic 	**Third Harmonic** 
Doppler Effect	
Source at rest, observer moves	
Towards source 	**Away from source** 
$f = f_0\left(\frac{v + v_0}{v}\right)$	$f = f_0\left(\frac{v - v_0}{v}\right)$

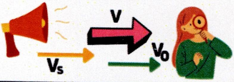
Source at rest, observer moves

Towards Observer	Away from Observer
	
$f = f_0\left(\dfrac{v}{v - v_s}\right)$	$f = f_0\left(\dfrac{v}{v + v_s}\right)$

When source and observer both are moving

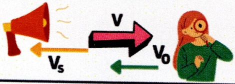
Both moving in direction of sound

$$f = f_o\left(\frac{v - v_o}{v - v_s}\right)$$



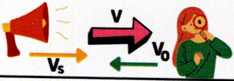
Both moving opposite direction of sound

$$f = f_o\left(\frac{v + v_o}{v + v_s}\right)$$



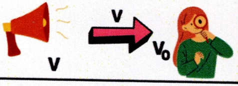
Both moving towards each other

$$f = f_o\left(\frac{v + v_o}{v - v_s}\right)$$



Both moving opposite to each other

$$f = f_o\left(\frac{v - v_o}{v + v_s}\right)$$

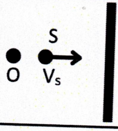


Kundt's Tube	$\dfrac{V_{air}}{V_{rod}} = \dfrac{\lambda_{air}}{\lambda_{rod}} = \dfrac{l_{air}}{l_{rod}}$

Beats

Arising from interference of waves	$f_{beat} = \lvert f_1 - f_2 \rvert$

Case 1



Cliff/Wall at rest

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

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

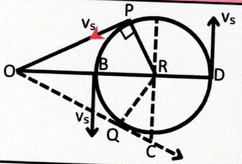
Beat frequency

$$f'' - f' = \left(\frac{v}{v - v_s} - \frac{v}{v + v_s}\right) f = \left(\frac{v \times 2v_s}{v^2 - v_s^2}\right) f$$

Case 2

A source of frequency 'f' is resolving in a circle of radius R with speed V_s.

At 'P' frequency is maximum as $OP \perp PR$, i.e.,

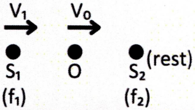


$$f' = \left(\frac{v}{v - v_s}\right) f \qquad OP = \sqrt{OR^2 - PR^2} = \sqrt{x^2 - R^2}$$

At Q frequency is minimum as $OQ \perp QR$, i.e.,

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

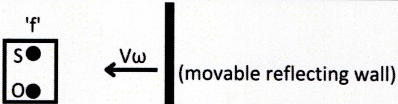
Case 3



$$f_1' = \left(\frac{v - v_0}{v - v_1}\right) f_1$$

$$f_2' = \left(\frac{v + v_0}{v}\right) f_2$$

Case 4



Reflected frequency $= \left(\frac{v + v_\omega}{v - v_\omega}\right) f$

Beat frequency $= f\left(\frac{v + v_\omega}{v - v_\omega} - 1\right) = f\left(\frac{2v_\omega}{v - v_\omega}\right)$