14

WAVE PHENOMENA

WAVE PROPAGATION

Propagation of Transverse Waves

λIn a wave motion, the distance between the two nearest particles vibrating in the same phase is called a wavelength. It is denoted by λ.

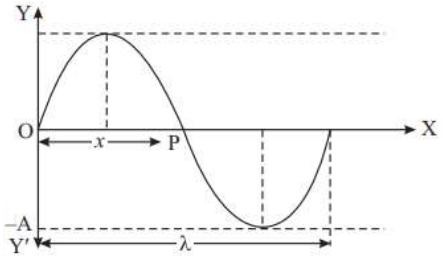
Velocity of wave = distance / time

=λ/T

the wave moves along the string, all particles of the string are oscillating up and down about their respective equilibrium positions with the same period (T) and amplitude (A).

v = vλ

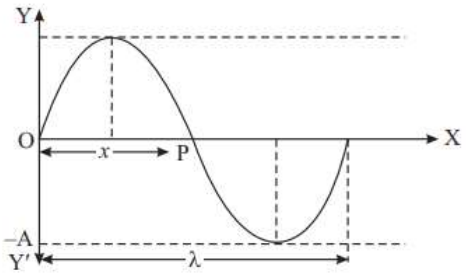
ω = T/2π = 2πv



Propagation of a Longitudinal Wave

Equation of a Simple Harmonic Wave in One Dimension

y = a sin ωt



y = a sin (ωt – φ)

y(x, t) = a sin (ωt – kx)

y(x, t) = a sin 2π (t/T-x/λ)

y (x,t) = a sin [(ωt – kx) + φ_0]

Phase difference between two points on a wave

y = a sin (ωt – kx)

and y = a sin [ωt – k (x + Δx)]

Phase difference between them

$$\Delta\varphi = k\Delta x = \frac{2\pi}{\lambda}\Delta x = -\frac{2\pi}{\lambda}(x2 - x1)$$

Phase difference at the same position over a time interval Δt :

$$\Delta\varphi = \varphi_2 - \varphi_1 = \frac{2\pi}{\lambda}(T_2 - T_1)$$

Transverse and Longitudinal Waves

Transverse waves	Longitudinal waves
(i) Displacements of the particles are perpendicular to the direction of propagation of the wave.	(i) Displacements of the particles are along the direction of propagation of the wave.
(ii) Transverse waves look as crests and troughs propagating in the medium.	(ii) Longitudinal waves give the appearance of alternate compressions and rarefaction moving forward.
(iii) Transverse waves can only be transmitted in solids or on the surface of the liquids.	(iii) Longitudinal waves can travel in solids, liquids and gases.
(iv) In case of a transverse wave, the displacement - distance graph gives the actual picture of the wave itself.	(iv) In case of longitudinal waves, the graph only represents the displacement of the particles at different points at a given time.

Essential properties of the medium

propagation of longitudinal and transverse mechanical waves are:

(i) the particles of the medium must possess mass,

(ii) (ii) the medium must possess elasticity. Longitudinal waves for propagation in a medium require volume elasticity but transverse waves need modulus of rigidity

VELOCITY OF LONGITUDINAL AND TRANSVERSE WAVES IN AN ELASTIC MEDIUM

Newton's Formula for velocity of sound in Gas

A relation for the velocity of sound in a gaseous medium.

$v = \sqrt{\frac{P}{\rho}}$

Laplace's Correction

The change in pressure of air layer caused bypassage of sound takeplace under adiabatic condition

Air is bad conductor of heat

Compression and rarefaction caused by the sound are too rapid to permit heat to flow out during compression and flow in during rarefraction

$E = \gamma P$,

Where $\gamma = \frac{C_p}{C_v}$

Factors affecting velocity of sound in a gas

(i)Effect of Temperature

$$v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{m}}$$

~ 333 + 0.61t

Effect of pressure

When we increase pressure on a gas, it gets compressed but its density increases in the same proportion as the pressure i.e. P/ρ remains constant. It means that, pressure has no effect on the velocity of sound in a gas.

Effect of density

$v \propto \frac{1}{\sqrt{\rho}}$

Effect of humidity on velocity of sound in air

As humidity in air increases (keeping conditions of temperature and pressure constant), its density decreases and hence velocity of sound in air increases.

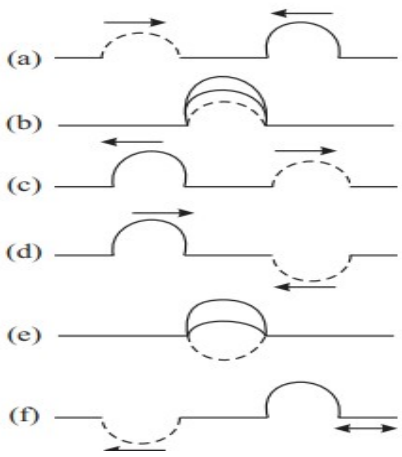
Velocity of Waves in Stretched Strings

$v = \sqrt{E/\rho}$

Velocity of longitudinal wave

$$v_g < v_l < v_s$$

SUPERPOSITION OF WAVES



: At the points where the two pulses overlap, the resultant displacement is the vector sum of the displacements due to each of the two wave pulses. This is called the principle of superposition.

Reflection and Transmission of Waves

when reflection takes place from a denser medium, the wave undergoes a phase change of π, that is, it suffers a phase reversal.

Thus on reflection from a rarer medium, no phase change takes place

Thus, when reflection takes place from a denser medium, the longitudinal waves are reflected without change of type but with change in sign. And on reflection from a rare medium, a longitudinal wave is reflected back without change of sign but with change of type.

SUPERPOSITION OF WAVES TRAVELLING IN THE SAME DIRECTION

Superposition of waves travelling in the same direction give rise to two different phenomenon

$y1 = a1 \sin(\omega t - kx)$ and

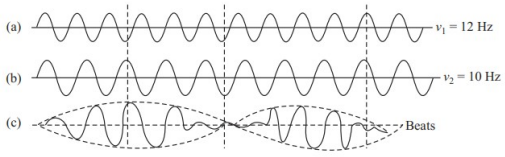
$y2 = a2 \sin[(\omega t - kx) + \varphi]$

Interference of waves

$$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$$

Beats

the number of beats heard in one second equals the difference in the frequencies of the two tuning forks.



Superposition of two identical collinear waves travelling with the same speed in opposite directions leads to formation of stationary waves. They are called stationary waves, because the wave form does not move forward, but alternately shrinks and dilates. The energy merely surges back and forth and on an average, there is no net flow of energy past a point

CHARACTERISTICS OF MUSICAL SOUND

Pitch

The term pitch is the characteristic of musical notes that enables us to classify a note as 'high' or 'low'.

Loudness

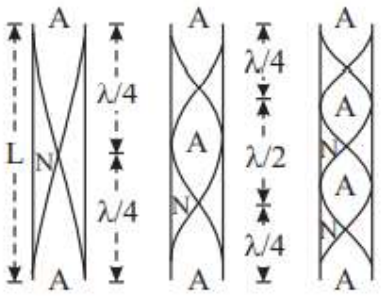
The loudness of sound is a subjective effect of intensity of sound received by listeners ear. The intensity of waves is the average amount of energy transported by the wave per unit area per second normally across a surface at a given point.

Organ Pipes

Awooden or metalpipe producing musical sound is lnown as organ pipe.

If both the end of pipe are open called open pipe

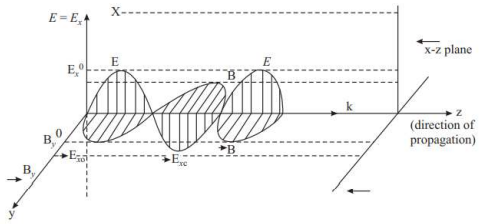
If one end is closed called close pipe



ELECTROMAGNETIC WAVES

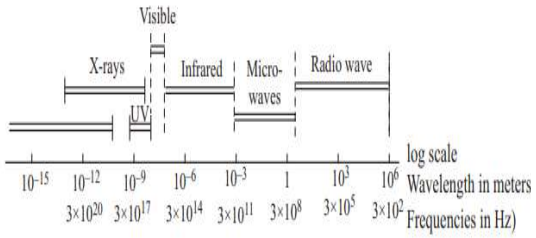
(i) E.M. waves are transverse in nature

(ii) They consist of electric (E) and magnetic fields (B) oscillating at right angles to each other and perpendicular to the direction of propagation (k).



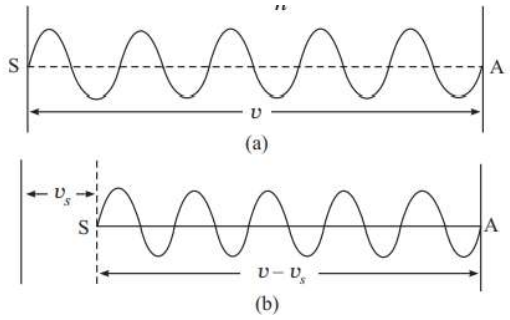
Electromagnetic Spectrum

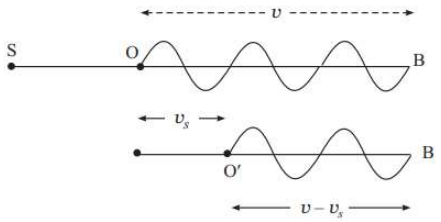
The physical properties of e.m. waves are determined by the frequencies or wavelengths and not by the method of their generation



DOPPLER EFFECT

Apparent change of frequency observed due to the relative motion of the observer and the source is known as Doppler effect.





$$\frac{v - v_0}{v - v_s} n$$

Check Your Self

1 Transverse waves can be transmitted in

a) solid
b) surface of liquid
c) gases
d) a&b

2 Relation between phase difference and path difference is

a) $\theta = 2\pi P/\lambda$
b) $P = 2\pi\lambda/P$
c) $P = 2\pi\theta/\lambda$
d) $\theta = 2\pi P/\lambda$

3 Velocity of sound in air increased by …… with every degree Celsius rise in temperature

a) 0.5 ms^{-1}
b) 0.61 ms^{-1}

c) 0.55 ms^{-1}
d) 0.65 ms^{-1}

4 A tunning fork of unknown frequency gives 5 beats per second with another tunning of 500 Hz. Frequency of unknown fork in Hz

a) 495,505
b) 490,510
c) 500,505
d) 495,500

5 The point where amplitude is maximum but the strain is minimum called

a) nodes
b) antinodes
c) successive node
d) none of the above

Stretch Your Self

1. Write Newton's formula for the velocity of sound in a gas and explain Laplace's correction
2. Derive the equation of a stationary wave and show that displacement nodes are pressure antinodes and displacement antinodes are pressure nodes?
3. Describe an experiment to demonstrate existence of nodes and antinodes in an organ pipes?
4. How does the velocity of e.m. waves depend upon the permeability μ and permittivity ε of the medium through which they pass?