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Waves

- Waves is a form of disturbance which travels through a material medium due to the repeated periodic motion of the particles of medium about their mean positions without any actual transportation of matter.

Characteristics of wave

- The particles of the medium traversed by a wave execute relatively small vibrations about their mean positions but the particles are not permanently displaced in the direction of propagation of the wave.

- Each successive particle of the medium executes a motion quite similar to its predecessors along perpendicular to the line of travel of the wave.
During wave motion only transfer of energy takes place but not that of a portion of the medium.

- Waves are mainly of three types :

1) Mechanical waves - Produced or propagated only in a material medium. These waves are governed by Newton's law of motion. Ex - waves on water surface, waves on strings, sound waves etc.

2) Electromagnetic waves - Require no material medium for their production and propagation. Ex - visible light, ultra violet light, radiowaves, microwaves etc.

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3) Matter waves - These waves are associated with moving particles of matter, like electrons, protons, neutrons etc. I

Mechanical waves are of two types :-

(i) Transverse wave motion

Particles of the medium vibrate at right angles to the direction in which the wave propagates.

Ex - waves on strings, surface water waves and electromagnetic waves.

NOTE :- In electromagnetic waves the disturbance that travels is not a result of vibrations of particles but it is the oscillation of electric and magnetic fields which takes place at right angles to the direction in which the wave travels.

(ii) Longitudinal wave motion

In these type of waves, particles of the medium vibrate to and fro about their mean position along the direction of propagation of energy.

These are also called pressure waves.

Ex - Sound waves

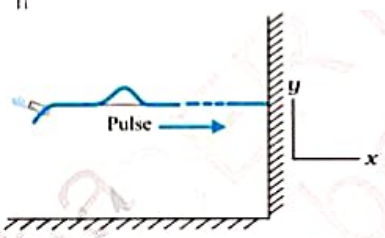

Fig. 15.2 When a pulse travels along the length of a stretched string (x-direction), the elements of the string oscillate up and down (y-direction)

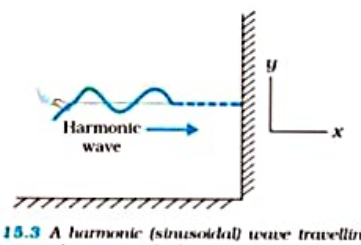

Fig. 15.3 A harmonic (sinusoidal) wave travelling along a stretched string is an example of a transverse wave. An element of the string in the region of the wave oscillates about its equilibrium position perpendicular to the direction of wave propagation.

Longitudinal waves (sound) generated in a pipe filled with air by moving the piston up and down. A volume element of air oscillates in the direction parallel to the direction of wave propagation.

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Displacement relation in a progressive wave:

- A progressive wave is one which travels in a given direction with constant amplitude.
As in wave motion, the displacement is a function of position as well as time, hence displacement relation is expressed as a combined function of position and time as:

$$y(x,t) = a \sin(kx - \omega t + \phi)$$

- The term ϕ in the argument of sine function means equivalently that we are considering a linear combination of sine and cosine functions :-

$$y(x,t) = A \sin(kx - \omega t) + B \cos(kx - \omega t)$$

- From both equation -

$$a = \sqrt{A^2 + B^2} \quad \text{and} \quad \phi = \tan^{-1}\left(\frac{B}{A}\right)$$

where,

$y(x,t)$: displacement as a function of position x & time t
a : amplitude of a wave
ω : angular frequency of the wave
k : angular wave number.
$kx - \omega t + \phi$: Initial phase angle ($a + x = 0, t = 0^\circ$)

- For a wave travelling in the negative direction of x-axis

$$y(x,t) = a \sin(kx + \omega t + \phi)$$