WAVE MOTION IN AN ELASTIC MEDIUM:

The motion of a particle under different conditions has been considered. But when we have got a number of particles linked together by elastic chains, it is not possible to displace any one of them without disturbing the other. The motion imparted to one is communicated through the chains to others and they in turn are set into motion. An elastic medium consists of very fine particles with elastic connection between them. If we impart periodic motion to any particle, its energy of motion will be communicated to the adjacent particles surrounding it, which will thus execute similar periodic motions and in doing so will in their turn transfer their energy to the neighbouring particles surrounding them and so on. The motion imparted to the particle will move uniformly to all directions from particle to particle with a definite velocity. The propagation of a disturbance of this kind due to transfer of energy from particle to particle is called wave motion.

There are two types of wave motion ***(i) Transverse wave motion***

(ii) Longitudinal wave motion.

- In a transverse wave motion the particles of a medium vibrate at right angles about the mean position to the direction of propagation of the wave.
- Longitudinal wave motion is that wave motion in which the particles of the medium vibrate about their mean position in the same direction in which the wave is propagated.
- There are waves in which no material medium is necessary viz. radio waves, light waves, heat radiation, x-rays, γ-rays and in general all these waves are called electromagnetic waves. Now we shall discuss ourselves to elastic waves in material media.

Wavelength of a wave is the minimum distance along the line of propagation between two particles of the medium vibrating in the same phase. The phase difference between two particles separated by a distance of one wavelength is 2π. It is the distance through which the energy transference advances through the medium in the interval when the source completes one oscillation. If the distance through which the energy is propagated i.e., wave is propagated in unit time 'c', the velocity of propagation of the wave and n be the frequency of vibration of the source, then the wavelength $\lambda = c/n$ or $c = n\lambda$ where the frequency of the wave is the number of waves passing through a point in one second. The time period (T) of a wave is the time taken by a single wave to pass over a point in the medium. The frequency of the wave is given by $n = 1/T$. The S.I. unit of wavelength is meter, frequency is Hertz (Hz) and time period is second.

DIFFERENT TYPES OF PROGRESSIVE WAVES

There are two types of waves:

(i) Progressive longitudinal wave in which every particle vibrates along the direction of propagation of the wave. They are same in amplitude but differ in phase with distance.

Example: The motion by smart push at one end of a spiral spring, suspended from a wooden frame horizontally by bifilar suspension is an example of longitudinal wave. The rims move to and fro along the axis of the spring producing compressions (C) and rare-fraction (R) which will travel along the length of the spring. Here the motion of individual turns is along the direction of propagation. So, the wave is called longitudinal wave.

(ii) Progressive transverse wave in which every particle vibrates in a direction perpendicular to the direction of propagation of the wave. They have the same in amplitude but differ in phase with distance.

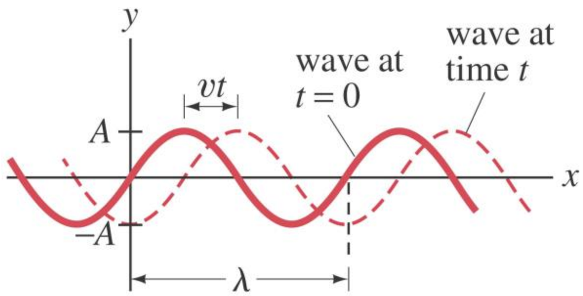
Examples: 1. Water waves and rope waves are transverse. Alternate dipping and rising of a small rod at any point on the surface of still water will generate ripples which propagates onwards uniformly in all directions in form of circles of alternate crests and troughs of gradually increasing radius. Every particle of water executes S.H.M. about their mean position of rest at right angles to the line of advance. A cork floating on water which was at rest originally, will rise and fall as waves advance through it.

2. A thick rope says a rubber tubing suspended from one end, the other end of which is moved a little at right angles to the length with given horizontal periodic motion will cause the disturbance in the form of sinusoidal wave to travel along the length upwards. Every particle of the rope will execute to and fro motion perpendicular to the length of the rope without advancing in the forward direction.

3. The motion of stringed musical instruments is the example of transverse waves. The total length of a crest and a trough, is called the wavelength of the transverse wave. The distance he tween two consecutive crests or consecutive trough is called the wavelength of the transverse wave.

MATHEMATICAL REPRESENTATION OF A TRAVELING WAVE:

Suppose the shape of a wave is given by, $D(\mathrm{x}) = A\sin\frac{2\pi}{\lambda}x$



After a time t, the wave crest has traveled a distance vt, so we write: $D(\mathrm{x},\mathrm{t}) = A\sin\left[\frac{2\pi}{\lambda}(x - vt)\right]$

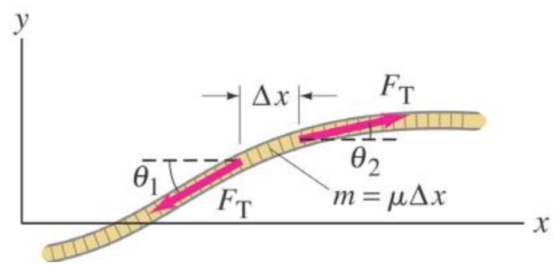
$$D(\mathrm{x},\mathrm{t}) = A\sin\left[\mathrm{k}\,x - \omega t\right]$$

The Wave Equation for a segment of string under tension:

Newton's second law gives:

$$\sum F_y = ma_y$$

$$F_T \sin\theta_2 - F_T \sin\theta_1 = (\mu.\Delta\,\mathrm{x})\frac{\partial^2 D}{\partial t^2}$$



Assuming small angles, and taking the limit Δx → 0, gives

$$\frac{\partial^2 D}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 D}{\partial t^2}$$

PROPAGATION OF SOUND WAVE THROUGH AIR:

The source of sound is always a vibrating body. All vibrating bodies do not perform a single S.H.M. A tuning fork is ordinarily the only source which produces sound by performing a single S.H.M. of a fixed frequency.

When a fork vibrates and motion of one of the prongs is outwardly for the first time at the beginning will compress the layer of air immediately in front of it. When the prong moves back to the extreme opposite position, the compressed layer expands and in doing so, pushes the layer in front of it and comes backwards in the space in which pressure has been released due to motion backwards. The compression will successively travel outwards from layer to layer from the prong.

By this time, the prong swing back and start a journey leftward. As such, it creates a partial vacuum behind causing a rarefaction of the layer in contact with it. This rarefied layer tends to return to its normal condition and causes a rarefaction of the adjoining layer. Thus, a pulse of single rarefaction travels outwards. During the vibration of the prong alternate compression (condensation) and rarefaction are created in the medium which travels outwards from the source. A compression and rarefaction constitute a longitudinal wave progressive in the outward direction. The distance between successive compression or rarefaction is called a wavelength of longitudinal sound wave.