Chapter 2

Wave Motion & Velocity

2.1 Introduction

Wave in medium might be characterized as the disturbance traveling through tl medium without the difference in structure, for instance, swell in water shap because of dropping a stone in water. At the point when a stone in dropped water, it moves some portion of its kinetic energy to the particles of water wi which it comes to contact. These particles are set into vibration. Presently the vibrating particles give their energy to the neighboring particles. Hen neighboring particles are set into vibrations. Therefore every molecule ge energy from past molecule and passes it to the following molecule. Subsequent wave move energy from one point to the next.

A wave motion can be defined as a disturbance which travels in the materi medium and is due to the repeated motion of the medium particle about the mean position, the motion being holded on from one particle to the next aft regular interval of time.

Characteristics of Wave motion:

i) The particles of the medium are not carried along the waves
ii) It is the disturbance which moves and forms the wave
iii) All the particles of the medium perform Simple Harmonic Motion about their mean positions, with the same amplitude and period.
iv) As the disturbance reaches different particles successively, each succeeding particle lags behind the previous particle in a phase
v) Wave motion is both periodic in space and periodic in time. Hence, it is a double periodic phenomenon.
i) The wave velocity is different from particle velocity. The velocity of a wave is constant in a given medium, whereas the velocity of the particles changes, being maximum in the mean position and maximum at the extreme position.

i) The wave travels from one medium to another, the wave speed and wave change but the frequency remains the same because the frequency is determi the source.

Terminology of wave motion:

i) Period of wave: Time taken to compete one cycle or oscillation is called period of the wave. It is denoted by 'T'. Its S.I unit is second.

ii) Frequency of wave: The number of cycles or oscillations performed by a w one second is called the frequency of the wave. It is denoted by 'f' or 'n'. Its : is hertz (Hz)

iii) Amplitude of wave: The maximum displacement of medium particles fron mean positions is called amplitude of a wave. It is denoted by 'a'. Its SI meter.

iv) Velocity of wave: The distance travelled by a wave in one second is call velocity of the wave. It is denoted by 'v'. Its SI unit is m/s.

v) Wave Length of wave: The distance between two successive particles of a w the same phase is constant. It is denoted by 'λ'. It SI unit is meter.

vi) Wave Number of wave: The number of waves passing through a distance is ca wave number of the wave. Reciprocal of wavelength is called as the wave nun wave. It is denoted by 'v'. Its SI unit is m^{-1}.

2.2 Classification of waves

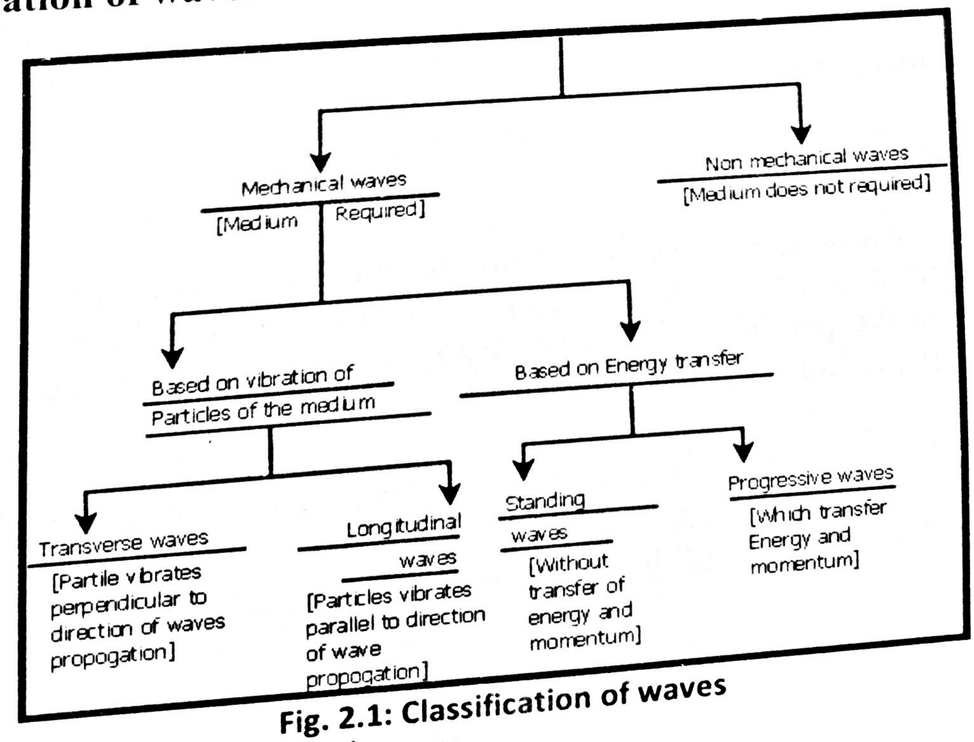

Fig. 2.1: Classification of waves

- On the basis of necessity of medium required
    - Mechanical Waves
    - Electromagnetic Waves
- On the basis of mode of vibration of the particle
    - Transverse Waves
    - Longitudinal Waves
  - Surface Waves

2.3 Mechanical Waves

Mechanical Waves behave as a propagation of a particular disturbance traveling through a material medium as a result of the steady periodic motion of particles. Under this, the disturbance is moved from one particle to the next.

Specifically, energy and momentum transmit by the motion of particles in the medium. Mass transfer impossible in this case. It should be noted that mechanical waves cannot propagate through the vacuum. The different examples of mechanical waves are the vibration of a string, the surface wave generated on the surface of a liquid and solid, tsunami waves, ultrasounds, earthquake P-waves, oscillations in spring, and waves in slink, etc.

There are two types of mechanical waves:

1. Transverse Wave
2. Longitudinal Wave

2.4 Transverse Waves

A progressive wave is a wave in which the medium particles are vibrating in the direction perpendicular to the direction of the wave is called a transverse wave, for example, the wave produced in a rope by lying the rope at one end to a rigid wall and jerked at the other end.

The convex part formed by the wave due to upward displacement of the particles of the medium is called ***crest***. The convex part formed by the wave due to downward displacement of the particles of the medium is called ***trough***.

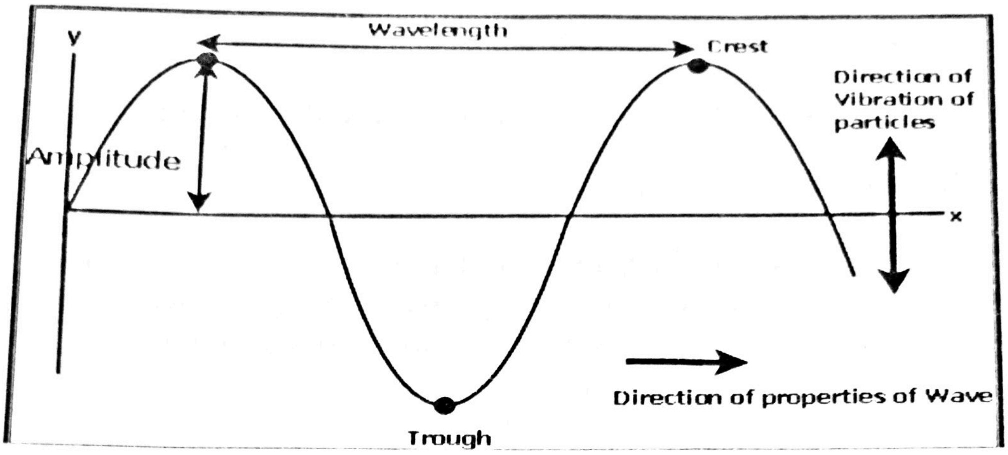

Fig. 2.2: Transverse waves

Characteristics of Transverse Waves:

i) When transverse waves pass through a medium, the medium gets divided into alternate crests and troughs.

ii) A crest and trough form a transverse wave.

iii) The crests and troughs follow each other in rapid succession, i.e., crests and troughs are produced alternatively at the same point of the medium.

iv) Every particle of medium performs SHM of the same amplitude and period.

v) Every particle lags behind the previous particle in a phase.

vi) The distance between two successive particles in the same phase is constant and it is called wavelength of the wave.

vii) Consecutive crest and trough constitute one cycle of a transverse wave.

viii) The transverse waves are produced in a medium, which undergoes a change of shape. Hence transverse waves can be propagated only through solids.

2.4.1 Transverse waves on a string

The speed of transverse waves (v) on a string depends on-

a) linear mass density of the string, i.e., mass per unit length of string (m)

b) tension T in the string

The mas is required so that the vibrating element can have kinetic energy. Further, without tension, no disturbance can be propagated in the string. We can use the method of dimensions to derive the expression for the speed v.

Let

$$v \propto m^a T^b$$

Where a and b are the dimensions.

$\therefore v = km^aT^b$ ......(i)

where k is the dimensionless constant of proportionality.

Now, $v = M^0L^1T^{-1}$

$$m = \frac{mass}{length} = \frac{M}{L} = [M^{-1}L^{-1}]$$

$$T = tension = force = [M^1L^1T^{-2}]$$

Note that in dimensional formulae for v and tension, *T represents time.*

Putting equation (i), we get –

$$[M^0L^1T^{-1}] = [M^1L^{-1}]^a[M^1L^1T^{-2}]^b = M^{a+b}L^{-a+b}T^{-2b}$$

Applying the principle of homogeneity of dimensions, we get

$a + b = 0$ *and* $-a + b = 1$ ......(ii)

$$\therefore\ -2b = -1 \ or\ b = 1/2$$

From equation (ii), we get –

$$v = km^{-1/2}T^{1/2} = k\sqrt{\frac{T}{m}}$$

Using other methods, we can show the dimensionless constant, k = 1.

$$\therefore v = \sqrt{\frac{T}{m}}$$

Thus, speed of a transverse waves along a stretched string depends only on the tension (T) and linear mass density (m) of the string. The speed does not depend upon frequency of the wave. Now that the speed of transverse waves in a solid is given by

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

where η is the modulus of rigidity and ρ is density of material of the solid.

2.4.2 Reflections of Transverse Waves

The way in which a transverse wave reflects is dependent on both ends whether they are fixed or not. First we will look at waves that are fixed at both ends:

Fig 2.3 illustrates an image of a transverse wave that is reflected from a fixed end. When a transverse wave meets at fixed end, the wave is reflected, but inverted. This swaps the peaks with the troughs and the troughs with the peaks.

Fig 2.4 illustrates an image of a transverse wave on a string that meets a free end. The wave is reflected, but unlike a transverse wave with a fixed end, it is not inverted.