Chapter:- 6 :- Oscillation And Waves

Simple Harmonic Motion (S.H.M):-

Simple Harmonic motion is the motion in which the restoring force is proportional to displacement from the mean position and opposes its increase. When an object moves to and fro along a line the motion is called simple harmonic motion.

Examples of S.H.M:-

(i) Simple pendulum:-

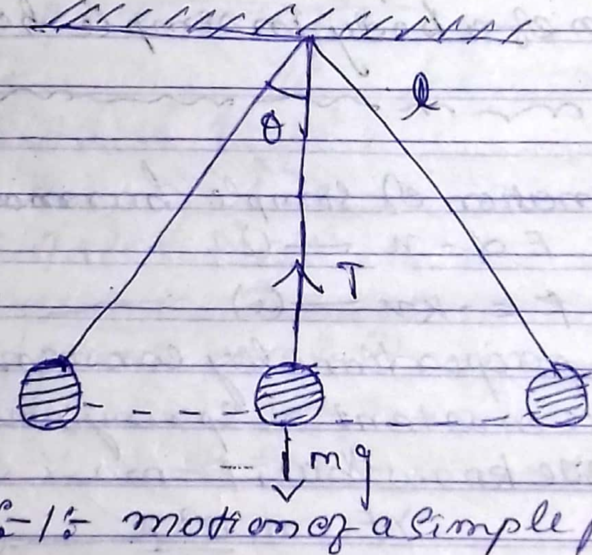


Fig:-1:- motion of a simple pendulum.

(ii) Spring-Mass System:-

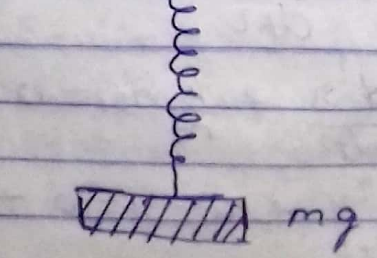
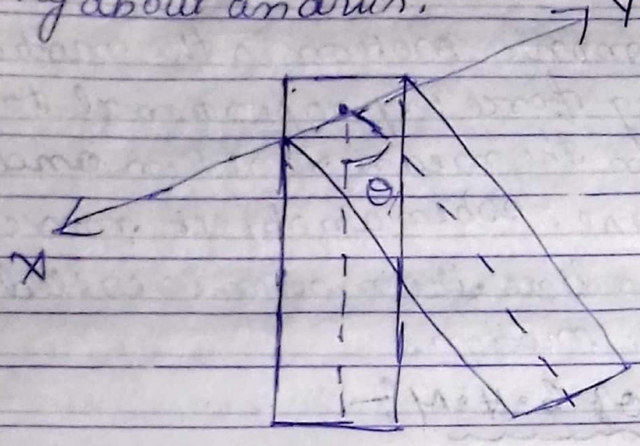


Fig:-2:- Vibration of a spring mass system.

(iii) Bar pendulum:-

It consists of a rectangular bar capable of rotating about an axis.



(iv) A steel Ball rolling on a curved dish.

Imp
Expression for displacement, velocity, acceleration of a body in simple harmonic motion:-

From defination of simple harmonic motion

$$F \propto -x \quad \text{—— (i)}$$

$$\Rightarrow F = -kx \quad \text{—— (ii)}$$

Where the proportionality constant 'k' is called force constant or spring constant.

We know that, $F = ma$

$$\Rightarrow F = m\frac{d^2x}{dt^2} \quad \text{—— (iii)}$$

From eq^n (ii) and (iii) we have,

$$m\frac{d^2x}{dt^2} = -kx$$

$$\Rightarrow m\frac{d^2x}{dt^2} + kx = 0$$

$$\Rightarrow \frac{d^2x}{dt^2} + \frac{k}{m}x = 0$$

$$\Rightarrow \frac{d^2x}{dt^2} + \omega^2 x = 0 \quad \text{—— (iv)}$$

where $\omega = \sqrt{\frac{K}{m}}$ is the angular frequency of oscillation.

Eq. (iv) is a second order linear homogenous differential equation whose solution gives us the displacement.

$$x = A\sin(\omega t + \alpha) \text{ —— (v)}$$

Velocity of the particle is given by ;

$\frac{d}{d\theta}(\sin\theta) = \cos\theta$

$$v = \frac{dx}{dt} = \frac{d}{dt}\left[A\sin(\omega t + \alpha)\right]$$

$\frac{d}{d\theta}(\cos\theta) = \sin\theta$

$$V = A\omega\cos(\omega t + \alpha) \text{ —— (vi)}$$

From eq^n - (vi) we can write

$$V = A\omega\sqrt{1 - \sin^2(\omega t + \alpha)} \quad [\sin^2\theta + \cos^2\theta = 1]$$

$$= A\omega\sqrt{1 - \left(\frac{x}{A}\right)^2}$$

$$= A\omega\sqrt{1 - \frac{x^2}{A^2}}$$

$$= A\omega\sqrt{\frac{A^2 - x^2}{A^2}}$$

$$= A\omega\frac{\sqrt{A^2 - x^2}}{A}$$

$$V = \omega\sqrt{A^2 - x^2} \text{ —— (vii)}$$

Case-1 :- at mean pos^n, $x = 0$

$$\Rightarrow V_{max} = \omega A \text{ —— (viii)}$$

Case-2 :-

at extreme pos^n, $x = \pm A$

$$\Rightarrow V_{min} = 0 \text{ —— (ix)}$$

Acceleration of the particle is given by ;

$$a = \frac{dv}{dt} = \frac{d}{dt}\left[A\omega\cos(\omega t + \alpha)\right]$$

$$= A\omega - \sin(\omega t + \alpha)\,\omega$$

$$\Rightarrow a = -A\omega^2\sin(\omega t + \alpha)$$

$$\Rightarrow a = -\omega^2 x \text{ —— (xi)}$$

Case :- (i) :- at mean pos^n, $x = 0$

$\Rightarrow a_{min} = 0$ —— (x ii)

Case :- (ii) :- at extreme pos^n, $x = \pm A$

$\Rightarrow a_{max} = \mp \omega^2 A$ —— (x iii)

Wave motion :-

(i) Transverse wave motion.
(ii) Longitudinal wave motion.

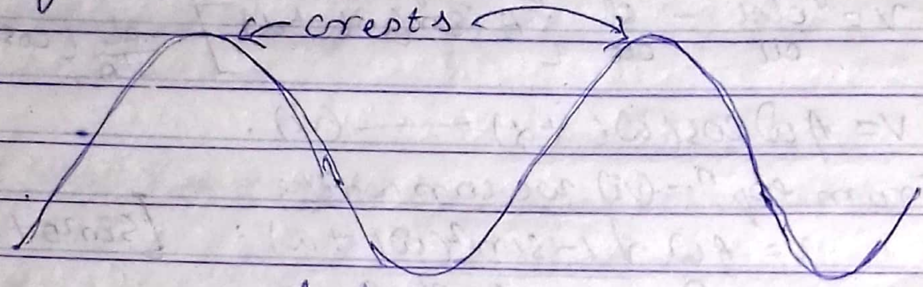


fig :- 4.

(i) Transverse wave motion :-

Ex :- Light wave.

(ii) Longitudinal wave motion :-

It is the type of wave motion in which the particles of the medium vibrate in the direction of propagation of wave.

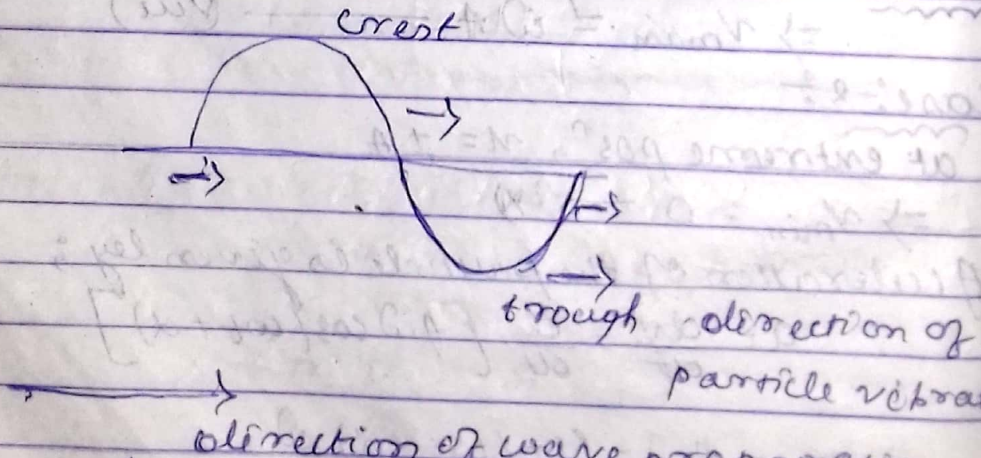


fig :- 5 :- Longitudinal wave motion

Ex :- Sound wave.

Imp
Comparision Bet^n Transverse wave & Longitudinal Wave:-

Transverse Wave:- (i) It is the type of wave motion in which the particles of the medium are vibrating in a direction at right angle to the direction of propagation of wave.
(ii) Examples:- Light wave.
(iii) propagation of a transverse wave motion results in the formation of crests and trough.
(iv) The angle bet^n the direction ~~of~~ of propagation and the direction of particle vibration is 90°.

Longitudinal Wave:- (i) It is the type of wave motion in which the particles of the medium vibrates in the direction of propagation of wave.
(ii) Examples:- Sound wave.
(iii) propagation of longitudinal wave motion through a medium results in the formation of compression and rarefractions.
(iv) The angle bet^n the direction of ~~prog~~ propagation and the direction of particle vibration is 0°.

Wave motion:- ~~A~~ Wave motion is the disturbance that travels through the medium and it is due to repeated periodic motion of the particle of the medium, the motion being handed over from particle to particle.

Example of wave Motion:-

1) Let a stone ~~to~~ be ~~draw~~ thrown into a pond of water. It will be observed that water appears to move away from the point where the stone was dropped and travels in the forms of ripples.

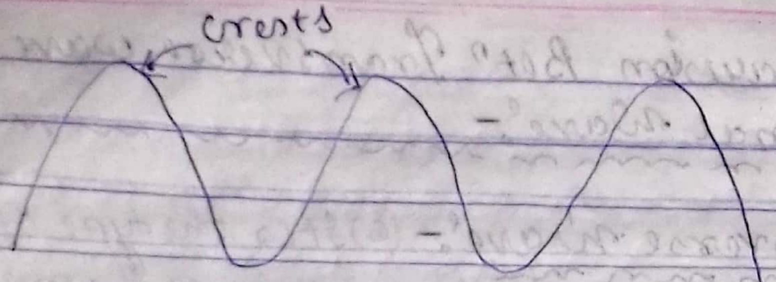


Fig:- 6:- Ripple formation.

Types of wave motion:-

* There are two types of wave motion.
  1) Transverse wave motion.
  2) Longitudinal wave motion.

i) Transverse wave motion:-

* It is the type of wave motion in which the particles of the medium are vibrating in a direction at right angle to the direction of propagation of wave.

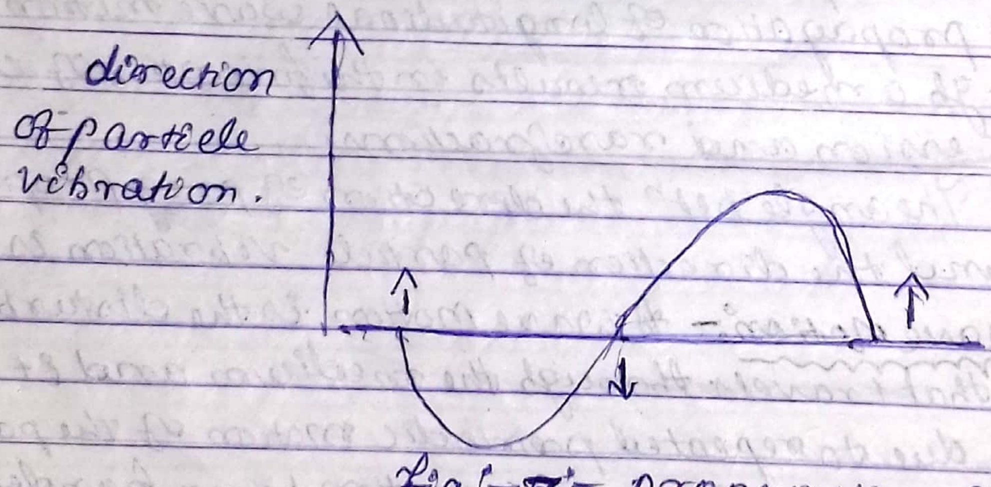


Fig:- 7:- propagation of transverse wave motion.

Example:- Light wave.

Defination of different wave parameters:-

(i) wave length (λ):-

It is defined as the distance travelled by the wave during the time.
Simple harmonic motion amplitude or vibration.

Or

It is the distance between two consecutive crest.

Or

It is the distance between two consecutive trough.

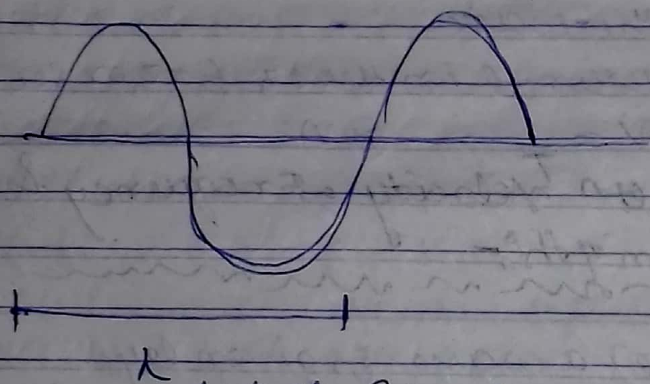


fig:- 6:- Wavelength of a wave

unit of λ is metre or centimetre

(ii) Wave number ($\bar{\nu}$):-

Wave number of a wave is defined as the reciprocal of the wavelength of the wave.

$$\bar{\nu} = \frac{1}{\lambda} \quad \text{— (xiv)}$$

units of wave number are m^{-1} or cm^{-1}.

(iii) Amplitude:-

The height of a wave is known as its amplitude. It is measured in metre or centimetre.

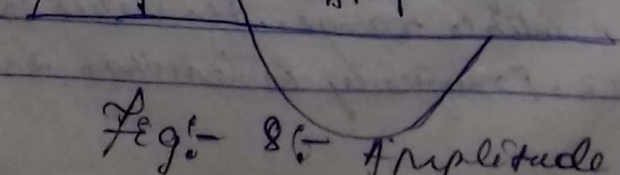


Fig:- 8:- Amplitude of a wave

(iv) Time period (T):-
The time period of a wave is defined as the time taken by a complete wave to pass through a given point. It is measured in second (sec).

(v) Frequency (ν):-

The number of complete waves that pass through a point in 1 sec. is called frequency of the wave.
It is measured in Hertz (Hz or sec^{-1}).

$$\nu = \frac{1}{T} \quad \text{—— (xv)}$$

Relation betn velocity, Frequency & wavelength:-

Velocity of a wave is given by

$$v = \frac{\text{displacement}}{\text{time}} = \frac{\lambda}{T} \quad \text{—— (xvi)}$$

We know that,

$$\frac{1}{T} = \nu$$

$$\Rightarrow v = \lambda\nu \quad \text{—— (xvii)}$$

∴ Velocity of a wave = frequency × wavelength.

Ultrasonics:-
Sound:- It is the form of energy which produces the sensation of hearing on us. Sound waves are longitudinal waves.
Human ear is sensitive to a particular range of frequencies. The range is known as audible range. Its value is 20 Hz to 20,000 Hz, frequency is less than 20 Hz are

called "Infrasonic" while frequency is more than ~~200~~ 20,000 Hz are called "ultrasonics".
Hence sound waves of frequencies higher than ~~2000~~ 20,000 HZ or 20 KHZ are called ultrasonics.

properties of ultrasonics:-

(i) The ultrasonic waves cannot travel through vacuum.
(ii) These waves travel with speed up sound in a given medium.
(iii) Their velocity remains constant in homogenous media.
(iv) These can produce vibrations in low viscosity medium.
(v) The ultrasonic waves are reflected and refracted just like light waves, i.e.
   a) Angle of incidence is equal to angle of reflection.
   b) Incident ray, reflected ray and normal to the incident plane lie on same plane.

Applications of ultrasonic waves:-

(i) Ultrasonics are used in the detection of air-craft, submarines, etc.
(ii) The reflection of ultrasonics is used to estimate the depth of the sea.
(iii) An ultrasonic drill is used for preparing teeth for filling.
(iv) ultrasonic waves of frequency 60 KHz are used for removing grease, dust etc. from metals.
(v) Ultrasonics find a number of applications in the

field of medicine as ultrasound ~~scan~~ scanners. They are used in the diagnosis of tumours and to the treatment of certain cancers.