Chapter (10)

Simple Harmonic Motion and Waves

Simple Harmonic Motion (SHM)

Definition

SHM is to and fro (vibratory) motion in which acceleration of the body is directly proportional to the displacement of the body from the mean position and is always directed towards the mean position. $a \propto -x$

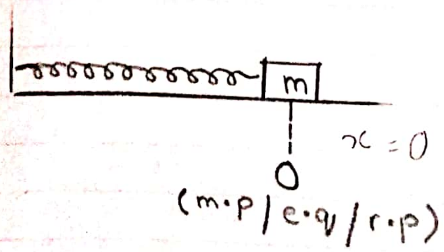
Examples

* mass- spring system
* simple pendulum
* ball and bowl system

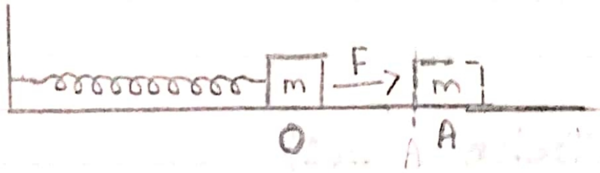
Explanation:-

Motion of mass attached to spring

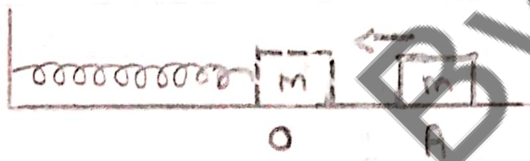
Consider a mass 'm' is attached to one end of spring and the other end of spring is attached with support horizontally. Mass is at its initial position 'O' which is known as mean position (m.p), equilibrium position (e.p) or rest position (r.p).



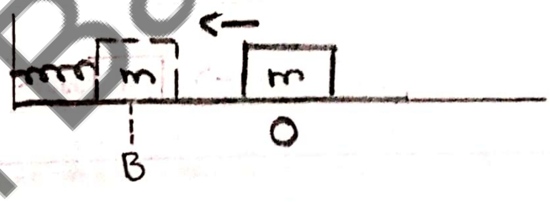
(1) When we apply the force in the right direction, mass will displace to position A which is known as "extreme position."



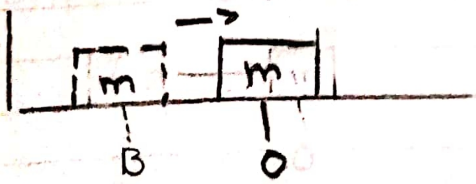
(2) mass is at its new position. mass will some to mean position due to restoring force.



(3) mass will move to the new 2nd E.P 'B' due to inertia. The spring will be compressed.



(4) mass will move back from new E.P to its mean position due to its restoring force.



Acceleration of a body performing SHM

According to Hook's Law, Force is applied to displace mass 'm' to position A.

The restoring force is directly proportional to displacement and always directed toward its mean position.

$$F_r \propto -x$$
$$F_r = -Kx$$

K is spring constant.

According to Newton's 2nd Law:-

$$F = ma$$
$$ma = -Kx$$
$$a = -\frac{K}{m} x$$

$$a \propto -x$$

Restoring Force: The force which acts to bring a body to its equilibrium.

→ Velocity is Zero at E.P

→ Velocity is maximum at M.P

Time Period of mass spring System

→ Time period is specific duration which is required to complete one vibration.

→ It is represented by "T".

→ complete rotation in a circle = 1 vibration.

* We can calculate the time period 'T' of SHM of a mass attached to spring by:

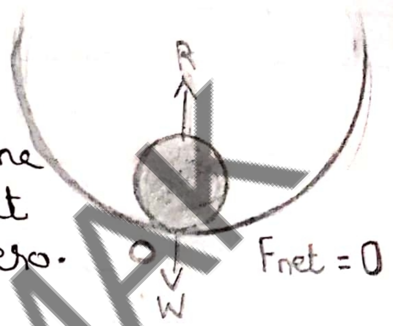
$$T = 2\pi \sqrt{\frac{m}{K}}$$

m = mass attached to the spring
K = Spring Constant.

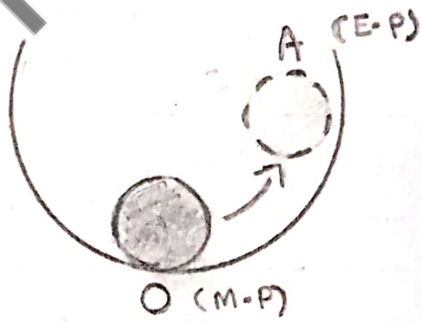
F_r = spring

Ball and Bowl System

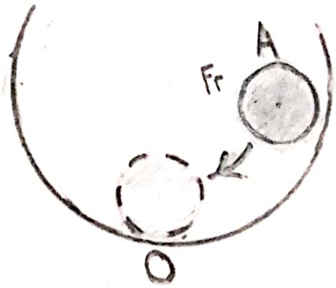
↳ Consider a system of ball and bowl. The ball is at the centre of bowl. The weight of the ball is acting downward and the reaction in upward direction. The ball is at rest position so the net force will be zero.



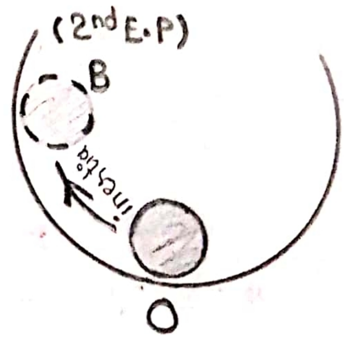
↳ When we apply the force, ball will move to position 'A' which is known as extreme position.



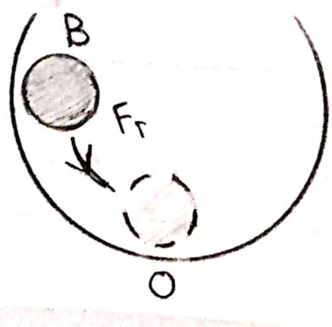
↳ Ball is at its new position. Ball will come to the M.P due to the restoring force.



↳ Ball will move from M.P to 2nd E.P 'B' due to inertia.



↳ Mass will move back from new E.P to its M.P due to Restoring force (Fr).



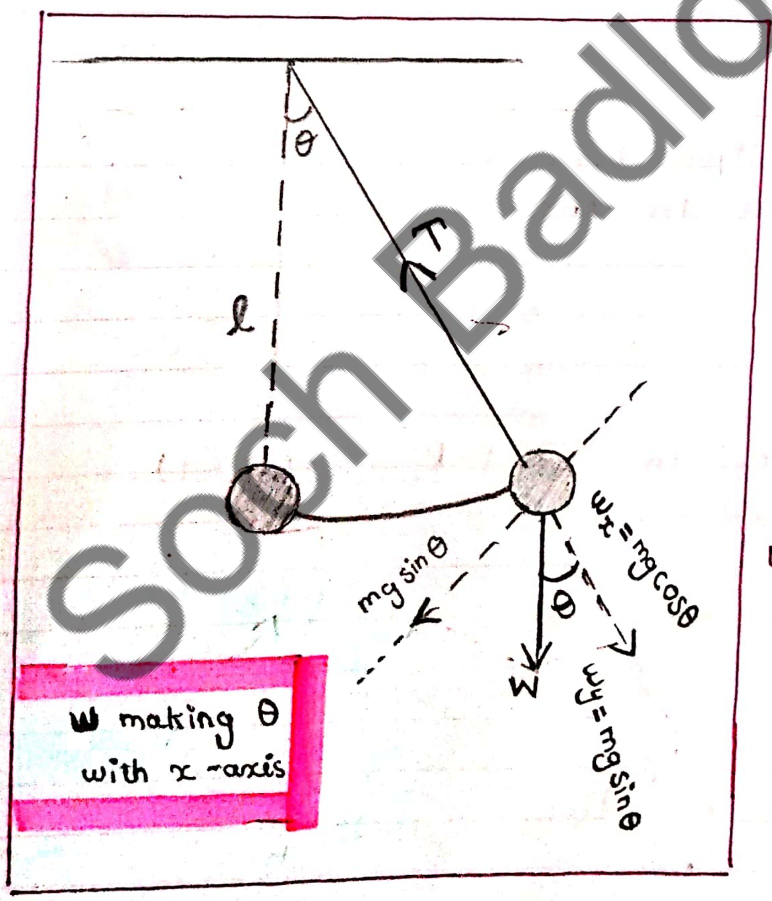
Conclusion

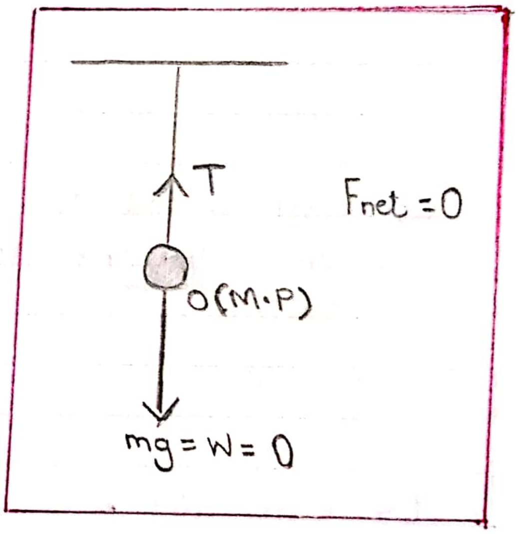
To and fro motion of ball about M.P is an example of SHM.

Simple Pendulum

↳ Simple Pendulum consists of small mass 'm' and connected with spring of length 'l' suspended with the help of certain support.

↳ When bob is at M.P, weight is acting in downward direction.





↳ When bob is displaced from M.P to E.P, **$F_{net} \neq 0$**

$$F_{net} = mg\cos\theta + mg\sin\theta + T$$
$$F_{net} = F_r = mg\sin\theta$$

$$\boxed{F_r = W}$$

PISK-GW

Physics-x **Assessment #1**

1) Simple pendulum consists of small mass......'m'...suspended with string of length....'l'.....
2) O= mean position
   A , B =......extreme. position
3) If F_{net} = 0 on the bob , then bob is ....stationary
   - When the bob is displaced from M.P to E.P
     - * F_{net} ≠.... 0
     - * Weight is divided into its two component(w_x , w_y)

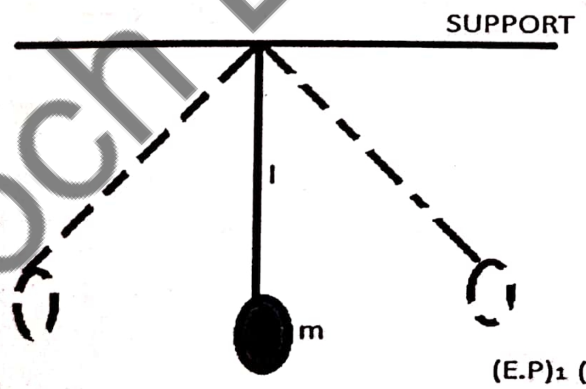
       F_{net} = mgcosθ + mgsinθ + T

       *There is no net force acting along the string

       mgcosθ = T

- <u>Only force which is acting on the bob</u> that is F=mgsinθ
- mgsinθ is always directed to ......M.P.........
- ..mg.sinθ...=restoring force=F_r

4) Complete the diagram according to my class instructions.



(E.P)₂ (B)
X=F/K
a -x
F_r=-kx
v=........0.....
P.E=mgx
K.E=.......0.....

M.P(O)
x=....0.....
a=...0....
F_r=...0.....
v=....max
P.E=...0
K.E=....max

(E.P)₁ (A)
X=Xo=amplitude=max
a=max
F_r=max
v=0
P.E=max
K.E=0

$K.E = \frac{1}{2} K(a^2 - x^2)$

At M.P
The weight is equal and opposite to T
W = T
(Net Force = 0)

Motion from O to A
when bob is displaced from M.P(O) to E.P(A)
$F_{net} \neq 0$
Tension in string cancels the component of weight
F_{net} = T + mg cos + mgsin
T = mg cosθ

F_r
component of weight mg sinθ act as F_r.

Important Features

→ $a \propto -x$
→ $a = 0$ at M.P
$a = max$ at E.P

→ $V = 0$ at E.P
$V = max$ at M.P

→ P.E = max] at E.P
K.E = min]

Time Period

* Time Period of SHM of Simple Pendulum can be calculated by:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

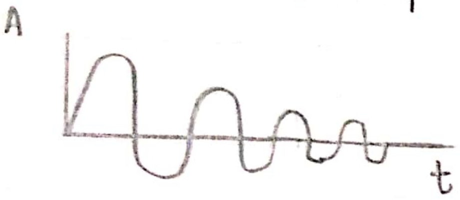
* Time depends on :

l = length of pendulum.
g = gravitational acceleration.

$$F_r = mg\sin\theta$$

Damped Oscillations

- Such oscillation in which amplitude decreases with passage of time is called damped Oscillation.



- Amplitude decreases due to resistive friction (frictional force, air resistance.)
- Energy loss will take place.
- Example : swinging pendulum.

Undamped Oscillations

- Such oscillation in which amplitude does not decrease with passage of time is known as Undamped oscillation.

- Amplitude remain same so resistive force (frictional force) is ignored.
- Energy loss will not occur (ideal case)
- Example : Kid's spring horse or a toy.

Practical Example

Shock absorbers consists of (i) piston (moving through oil and (ii) spring. The upper part consi is attached to the car and lower part is attached to car axle. When the car will pass through bumby road, car will vibrate. Shock absorber will reduce the vibrations and convert their energy into heat energy.

Wave Motion

Definition: A wave is disturbance in the medium in which particles of the medium undergo vibratory motion about their M.P in equal intervals of time

↳ Energy is transferred from one place to another due to the distrurbance in the medium.

Examples:

- Sound Reaches in our ears in the form of waves.
- Sunlight and heat reaches us through waves.
- Radio and television broadcasting through waves.

Practical Examples:

1. Take a tub. Fill it with water. Take a pencil, move it up and down vertically at a certain point. Ripples are produced in water surface moving away from the source. Pencil is the source and water is the medium in which Ripples are generated.

2. Take a string. Connect its one end with a support and keep the other end in your hand. Give a jerk. Waves are produced. Hand is the source and string is the medium in which waves are produced.

Conclusion:

Particles of medium vibrate about their M.P and will transmit energy.

TYPES OF WAVES

Mechanical Waves

- Require medium to travel.
- Formed due to the vibrations of particles of medium.
- The properties of Mechanical waves can be calculated by $v = f\lambda$
- Examples:
  - → Sound waves
  - → water waves
  - → Waves in string

Electromagnetic Waves

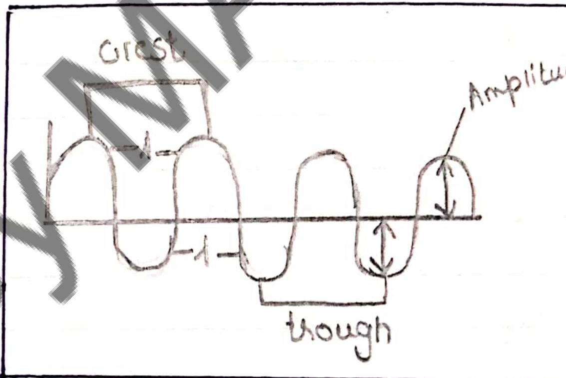
- Don't require medium to travel.
- Formed due to the vibration of electro-magnetic field.
- The properties of electromagnetic waves can be calculated by $c = f\lambda$, $c = 3 \times 10^8$ m/s
- Examples:
  - → light waves
  - → microwaves
  - → Radio waves
  - → X-Ray.

Important Terminologies

Crest: The part of a wave above M.P.

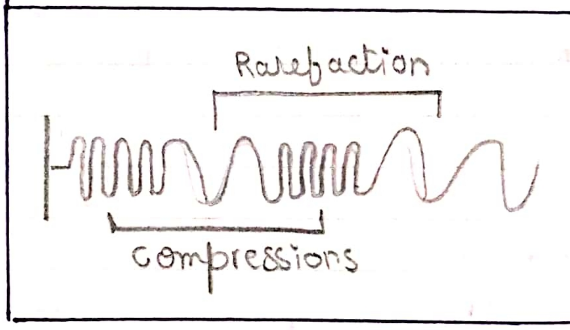
Trough: The part of a wave below M.P

Amplitude: distan from M.P to the extreme top of crest or extreme top of trough



Rarefaction: Such part of longitudinal waves where particles are far apart. (less dense)

Compressions: Such part of longitudinal waves where particles are closed to one another. (more dense).



Wave length 'λ' (m, cm):

→ Distance between two consecutive crest or trough.

→ one complete crest and one complete trough makes one wave length.

→ one crust makes $\frac{\lambda}{2}$ and one trough makes $\frac{\lambda}{2}$

$$\lambda = \frac{\lambda}{2} + \frac{\lambda}{2} = \frac{2\lambda}{2} = \lambda$$

→ Distance b/w 2 consecutive compression.

Mechanical Waves

Transverse Waves

* Such a wave in which particles of medium vibrate perpendicularly to the direction of propagation.

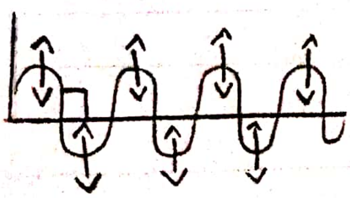
* It is made of crest and trough.

* F_r exerted during up and down motion of particles of medium is less.

* They die out rapidly in solid.

* moves at a speed of less than half of speed of longitudinal waves in solid.

* Examples:
  → waves in string
  → water waves
  → When light enters in atmosphere it becomes transverse in nature



Longitudinal Waves

* Such a wave in which particles of medium vibrates along the direction of propagation.

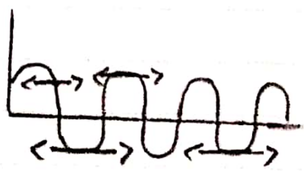
* It is made of compressions rarefaction

* F_r exerted during back and forth motion of particles is more.

* They move faster through solids than gases or liquid.

* moves at a speed of greater than half of speed of transverse waves in solid

* Examples:
  → Sound waves
  → Waves in slinky waves.



Relation b/w velocity, frequency and wavelength

Consider a disturbance produced in medium, waves are generated and moving with a certain speed.

Let the distance covered by wave is $d = \lambda$

$$V = \frac{d}{t} \qquad (d = \lambda)$$

$$V = \frac{\lambda}{t}$$

$$V = \lambda \times \frac{1}{T} \qquad (f \text{ is reciprocal of } t \; ; \; f = \frac{1}{T})$$

$$V = \lambda f$$

V = speed
λ = wave length
T = time period

Conclusion

The relation between 'V', 'f' and 'λ' is known as wave equation

[Waves as carriers of Energy]

- Energy can be transferred from one place to another through waves
- Waves cannot carry matter
- The energy in wave depends on the amplitude of the wave.
- Water waves also transfer energy from one place to another.
- Energy is transferred from one place of medium to another in the form of waves

Example:

Take a tub, Fill it with water. Place a cork. Now we will drop a stone and waves will be produced. The waves will propagate in every direction and when the waves reach the cork, it will move up and down. Waves carry energy due to which cork move up and down. This shows that waves can transfer energy without transferring matter.

Pakistan International School Al-Khobar

PHYSICS: X Student name: ....

WORK SHEET **By, Ms. Asiya Majid**

10.5 RIPPLE TANK

INTRODUCTION:

1. It is a device to produce and study ....water....waves
2. It is also used to study ..their....characteristics...

APPARATUS:

It consists of:

1. *Rectangular tray* having glass bottom, and is placed ½ m above the table surface.
2. *Vibrator* is an oscillating electric motor fixed on wooden plate, its lower surface touches water surface.
3. *Electric bulb (lamp)*, it is hung above table to observe water waves on screen (paper).

WORKING: On setting the vibrator ON, wooden plate will touch the water surface and plain water waves will produce. Crest dark (bright lines due to convergence of light) and trough (dark lines, due to divergence) will appear on screen.

• water particles move up and down.

water waves
↓
Transverse waves

STUDY OF WATER WAVES

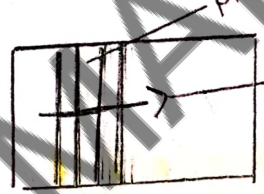
Properties of waves

1. *Reflection* 2. *Refraction* 3. *Diffraction* 4. *Interference*

REFLECTION: Place a barrier in ripple tank, water waves will reflect from the barrier.

If barrier is placed at an angle to the incoming waves (wave front), reflected waves will show 'Law of Reflection'.

wave front: such surface in which all particles are in same phase of vibration



1. <i = <r

AN: ..incident....plain....wave.....

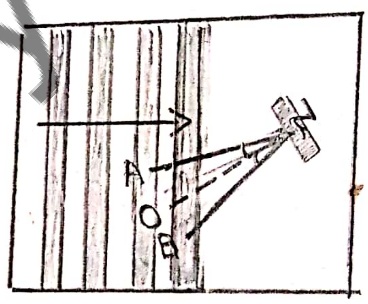
ON: ....normal.....wave.....................

NB: ...Reflected.....plain..wave

<ANO = <i ....angle......of...incident...

<ONB = <r ...angle.....of.....reflection.

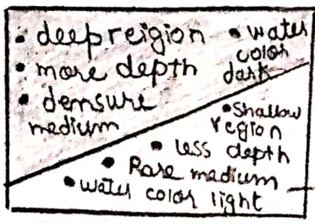
<ANO = <ONB ....<i = <r..................



DEFINITION:

When waves moving in one medium fall on the surface of the other medium they bounce back into the first medium such that <i = <r.

REFRACTION: We divide the water in tray into two regions deep and shallow by submerging a boundary at some angle. In this way deep region shows denser medium and shallower region shows rare medium.

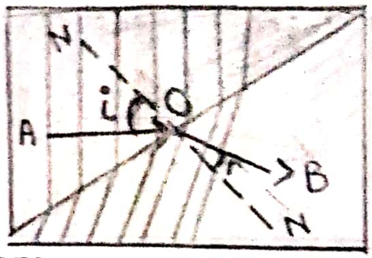


normal = ⊥ = 90°

air — Rare M
particles — denser M

$v = f\lambda$

$v \propto \lambda$



When water waves enter from deep to shallow region:

1. Speed of water waves will slow in shallow region.
2. Their wave lengths will decrease.
3. Their direction of propagation will change.
4. Frequency of waves = Frequency of vibrator (frequency will remain same)

λ_1 = ...wave length of deep region...

λ_2 = ...wave length of shallow region...

V_1 = ...speed of water wave in deep region...

V_2 = ...speed of water wave in shallow region

<ANO = <i = ...angle of incidence

<ONB = <r = ...angle of refraction

<i ≠ <r = ...∠ANO ≠ ∠ONB...

DEFINITION: When a wave from one medium enters into the second medium at some angle, it will deviate from its original path.

DIFFRACTION: Generate plain waves in tray (of ripple tank), place two obstacles (hurdle) in a line in such a way that separation between them is equal to the wave length of the water waves.

After passing through slit (small opening)

1. Waves will spread in every direction.
2. Diffracted waves changes into semicircular pattern.

CONDITION TO OBSERVE DIFFRACTION:

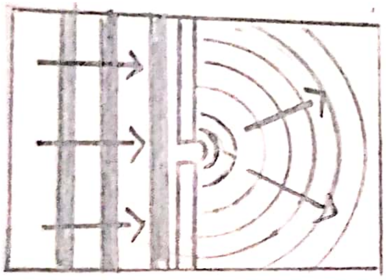
Size of slit should be comparable to the wavelength of wave.

0.1cm ≃ 1cm → 0.2cm water

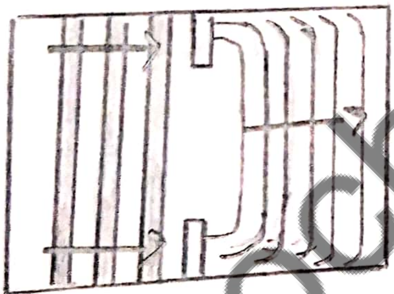
1. When slit size is large diffraction will be ...less......(corner)
2. When slit size is small diffraction will be ...more.........

DEFINITION:

The bending and spreading of waves around the sharp edges or corners of obstacles or slits is called diffraction.



When the slit size is large diffraction will be less and the waves will spread only at the corners.



When the slit size is small diffraction will be more and waves will spread in all the directions.