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Using first law of thermodynamics

$$dQ = dU + dW \quad -(1)$$

$$dU = \frac{3}{2} R \cdot dT$$

Let C_p and C_v be the specific heat at constant pressure and Vol^m respect.

$$dQ = m \cdot s \cdot dT$$

where, m = mass of gas

S = specific heat

at constant Vol^m :-

$$dW = V \cdot dV$$

Here, $dV = 0$

$$\boxed{dW = 0}$$

So,

$$dQ = 1 \cdot C_v \cdot C_p$$

$$dQ = C_v \cdot dT$$

Put these value in eq^n (1)

$$C_v \cdot dT = \frac{3}{2} R \cdot dT + 0$$

$$C_v \cdot \cancel{dT} = \frac{3}{2} R \cdot \cancel{dT}$$

$$C_v = \frac{3}{2} R$$

or, $C_p - C_v = R$

$$C_p - \frac{3}{2} R = R$$

$$C_p = R + \frac{3}{2} R$$

$$\boxed{C_p = \frac{5}{2} R}$$

Good

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Unit - 10

—: Oscillation and Waves :—

* **Oscillatory motion** – A motion in which body moves To and fro about a fix position/point is called oscillatory motion. Ex- Motion of simple pendulam, vibration in spring

* **Conditions for oscillatory motion:** There are 2-conditions for oscillatory motion

i) It must be periodic means during oscillatory motion the body will repeat it's path after a fixed time.

2) It must be bounded means b/w two points or limited

* **Types of oscillatory motion/Harmonic motion:** There are two types

1) **Simple harmonic motion** (S.H.M.) – If only one harmonic (frequency) is used to represent oscillatory motion then the oscillatory motion is called Simple Harmonic motion.

for ex: $y = a \sin\omega t$

$y = a \sin\omega t \cdot a\cos\omega t$

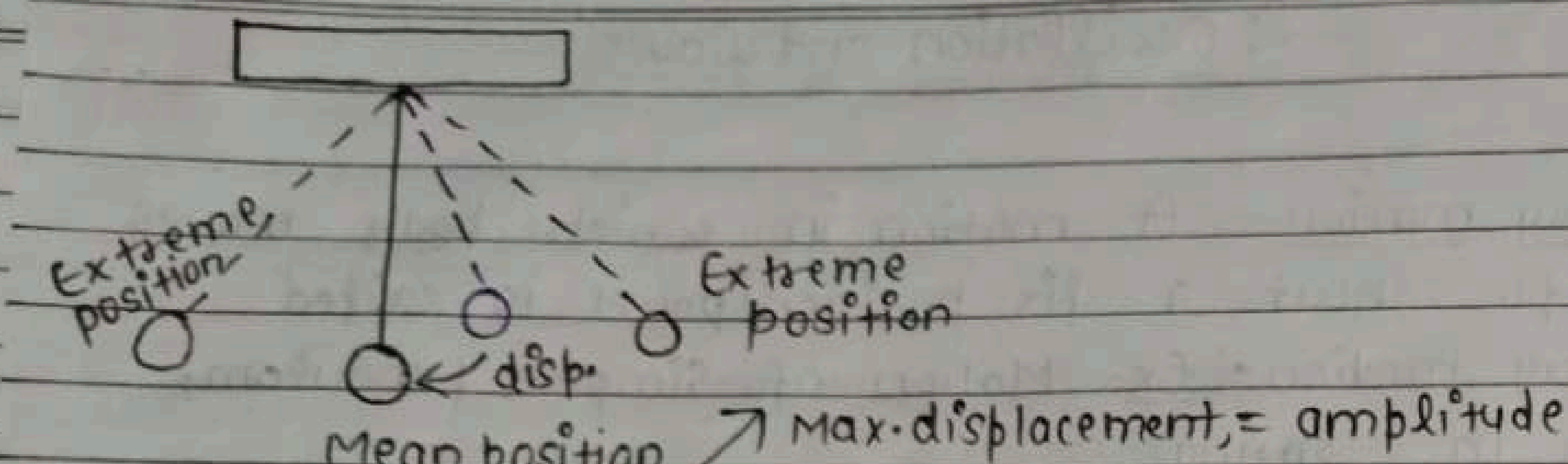
$y = a \cos\omega t$

* **Non-Harmonic motion:** If two or more harmonic (fq) are used to represent oscillatory motion then the oscillatory motion is called non-harmonic motion

Ex: $y = a \sin\omega t \sin 3\omega t$, freq. $= \omega, 3\omega$

$y = a \sin 2\omega t \cdot \sin 5\omega t$, freq. $2\omega \cdot 5\omega$

* **Some important terms related with S.H.M:**



1) **Mean position**: The equilibrium position is called mean position or the position where the body was initally at rest is called Mean position.

2) **Extreme position**: The position at which body have max. oscillation is called extreme position.

3) **Displacement**: Distance of a body from mean position is called displacement. It is represented by 'y' or 'x'

Eqⁿ: $y = a \sin\omega t$

or, $x = a \sin\cos\omega t$

Where, a = amplitude

ω = angular frequency

t = time

$\omega = \frac{2\pi}{T} = 2\pi\nu$

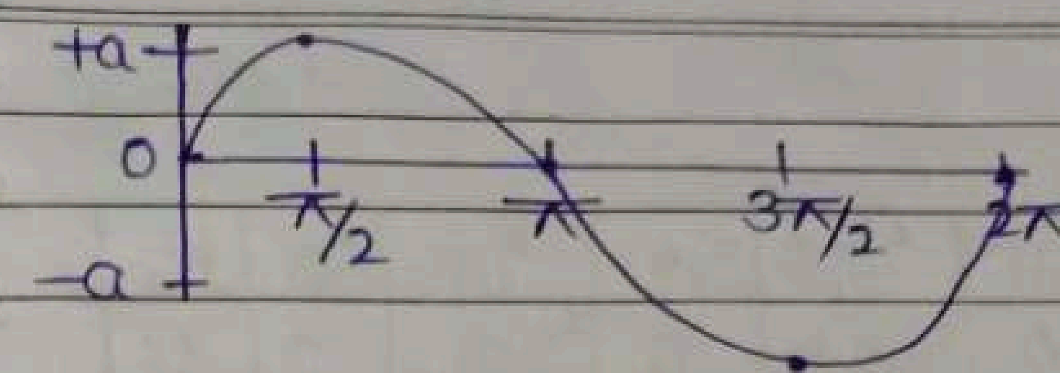
where, T = time period

ν = linear frequency

The direction of disp. will be away from mean position.

*Graph:- $y = a \sin\omega t$

ωt	0	$\pi/2$	π	$3\pi/2$	2π
y	0	a	0	$-a$	0



* **Amplitude**: The max. displacement is called of Amplitude OR Displacement from mean position to extreme position is called amplitude. It is denoted by 'a'.

* **Velocity**: The rate of change of disp. is called velocity.

As disp. is given by

$$y = a \sin\omega t$$

let 'v' be the velocity of S.H.M

$$v = \frac{dy}{dt} = \frac{d(a\sin\omega t)}{dt}$$

$$v = a\cdot\cos\omega t\cdot\omega$$

$$= a\omega\cos\omega t$$

$$v = a\omega\sqrt{1-\sin^2\omega t}$$

$$v = \omega = \sqrt{a^2(1-\sin^2\omega t)}$$

$$v = \omega\sqrt{a^2 - a^2\sin^2\omega t}$$

$$\therefore \boxed{v = \omega\sqrt{a^2-y^2}} \quad [\because y = a\sin\omega t]$$

* At mean position

put $y = 0$ (min.)

$$v = \omega\sqrt{a^2-(0)^2} = a\omega \text{ (max.)}$$

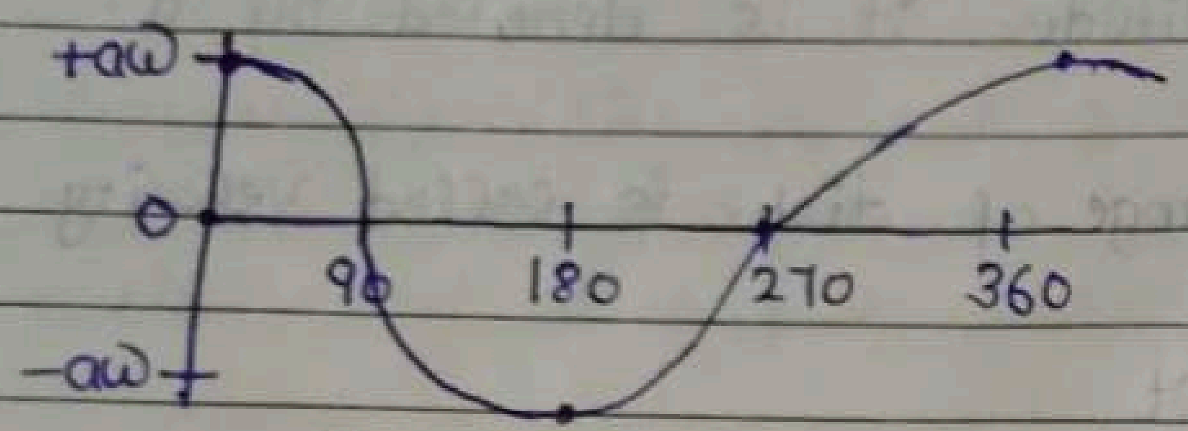
* At extreme point

put $y = a$ (max.)

$$v = \omega\sqrt{a^2-a^2} = 0 \text{ (min.)}$$

Graph :-

ωt	0	90°	180°	270°	360
v	$a\omega$	0°	$-a\omega$	0	$+a\omega$



***Acceleration:** The rate of change of velocity is called acceleration. It is denoted by 'a'.

$$A = \frac{dv}{dt}$$

as, $v = a\omega\cos\omega t$

$$A = \frac{d(a\omega\cos\omega t)}{dt}$$
$$= a\omega(-\sin\omega t)\omega$$
$$= -a\omega^2\sin\omega t$$
$$A = -\omega^2 y \quad [\because y = a\sin\omega t]$$

* At mean position:

$y = 0$

$$A = -\omega^2(0) = 0 \text{ (max.)}$$

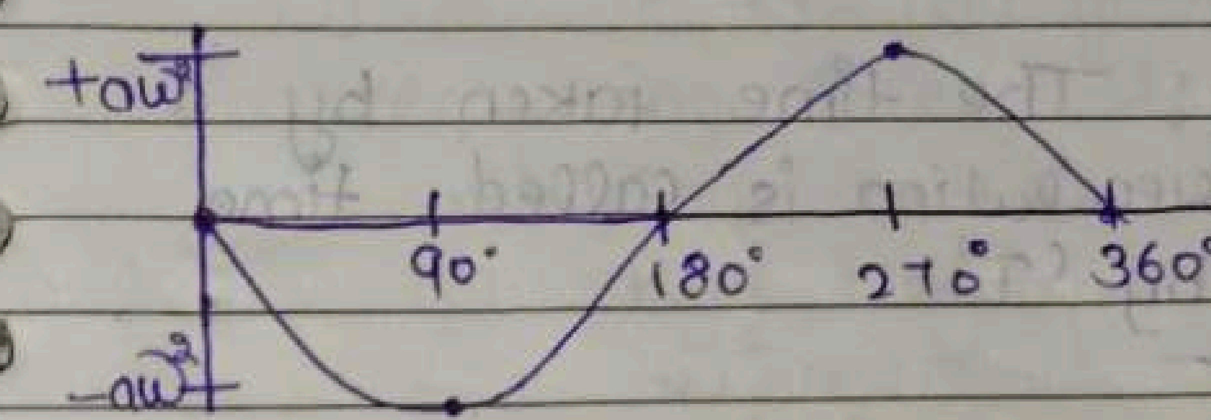
* At extreme position:

$y = a$

$$A = -\omega^2(a)$$
$$A = -a\omega^2 \text{ (min.)}$$

Graph:

ωt	0°	90°	180°	270°	360°
v	0	$-a\omega^2$	0	$+a\omega^2$	0



* **Restoring force:** Restoring force is a force which will take pendullam back to mean position after displacement.

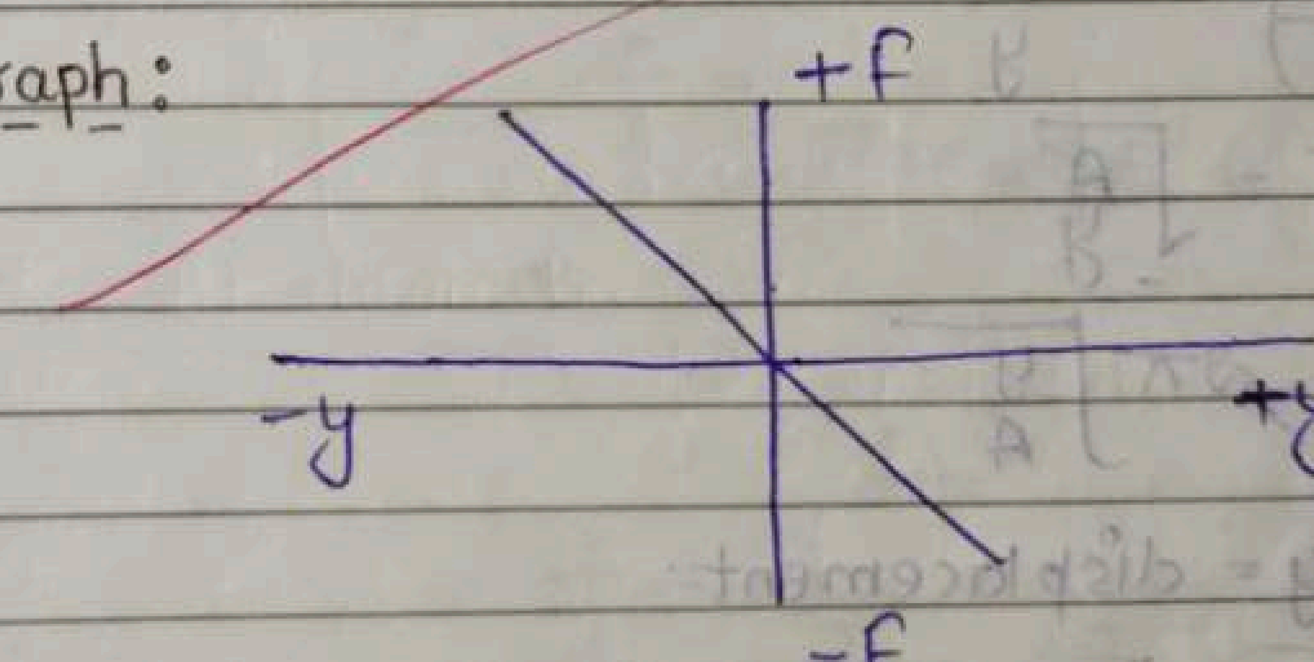
Restoring force $\propto$ Displacement

$$F \propto y$$
$$\boxed{F = -ky}$$

where 'k' is force constant/ spring constant

Negative sign indicate that F and y are in opp. direct.

Graph:



Case I: If 'y' is positive then

$f = -k(+ve\ y)$

$f = -ky$ then 'f' will be negative

(ie in 4^{th} quad.

Case II – If 'y' is –ve then

$$F = -k(-ve\ y)$$
$$F = +ky$$
$$F = +ve$$

'F' will lie in 2nd quadrant.

* <u>Time period of oscillation</u>: The time taken by a body to complete one revolution is called time period. It is denoted by 'T'.

As, acc. is given by –

$$A = -\omega^2 y$$

In magnitude :

$$A = \omega^2 y$$
$$\omega^2 = \frac{A}{y}$$

as, $\omega = \frac{2\pi}{T}$

where 'T' is called time period of oscillation

$$\left(\frac{2\pi}{T}\right)^2 = \frac{A}{y}$$
$$\frac{2\pi}{T} = \sqrt{\frac{A}{y}}$$
$$T = 2\pi\sqrt{\frac{y}{A}}$$

Where y = displacement.

$$\boxed{T = 2\pi\sqrt{\frac{\text{Displacement}}{\text{Acceleration}}}}$$

* <u>Alternate method</u> :

Restoring force is given by

$$F = -ky \quad -(1)$$

as, $F = mA$

$$= m\cdot(-\omega^2 y)$$
$$F = -m\omega^2 y \quad -(2)$$

Equating (1) and (2)

$$\cancel{-}ky\!\!\!/ = \cancel{-}m\omega^2 y\!\!\!/$$
$$k = m\omega^2$$
$$\omega^2 = \frac{k}{m}$$
$$\omega = \sqrt{\frac{k}{m}}$$

as, $\frac{2\pi}{T} = \omega$

$$T = 2\pi\sqrt{\frac{K}{m}} = 2\pi\sqrt{\frac{\text{Inertial factor}}{\text{Spring constant}}}$$

* <u>Frequency</u>:

No. of revolution per second is called frequency.

$$f = \frac{1}{\text{Time period}} = \frac{1}{T}$$

as,

$$T = 2\pi\sqrt{\frac{y}{A}}$$
$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{A}{y}}$$

or, $f = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$

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* **Energy:** Mechanical energy of pendulam has two types Kinetic and potential energy.

Mechanical energy = K.E + P.E

* **Kinetic energy:** The energy which comes due to motion of pendullam is called K.E.

$K.E = \frac{1}{2}mv^2$

where, v is velocity of (S.H.M)

$v = a\omega\cos\omega t$

$K.E = \frac{1}{2}m(a\omega\cos\omega t)^2$

$K.E = \frac{1}{2}m a^2\omega^2\cos^2\omega t$

as, $K.E = \frac{1}{2}m\left(\omega\sqrt{a^2-y^2}\right)^2$

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

* At mean position -

$K.E = \frac{1}{2}m\omega^2(a^2-0^2)$

$\boxed{K.E = \frac{1}{2}m\omega^2a^2}$ max.

* At extreme position

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

$\boxed{K.E = 0}$ min.

* **Potential energy:** The energy which comes due to disp. away from mean position is called P.E.

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let 'dy' be the small disp., then dw be the small workdone

$dw = \vec{F}\cdot\vec{dy}$

$= F\cdot dy\cos 180^\circ$

$F\cdot dy(-1)$

$dw = -Fdy$

as, $F = -ky$

$dw = -(-ky)\cdot dy$

$dw = kydy$

For total workdone, integrate both side

$W = \int dw = \int_0^y ky\cdot dy$

$W = k\left[\frac{y^2}{2}\right]^y$

$\boxed{W = \frac{ky^2}{2}}$

as, workdone = P.E

$W = U$

$U = \frac{1}{2}ky^2$

$\omega^2 = \frac{k}{m}$

$k = m\omega^2$

$U = \frac{1}{2}M\omega^2y^2$

$y = a\sin\omega t$

$\boxed{U = \frac{1}{2}m\omega^2a^2\sin^2\omega t}$

Total mechanical energy = K.E + P.E

$\frac{1}{2}M\omega^2(a^2-y^2) + \frac{1}{2}m\omega^2y^2$

$= \frac{1}{2}M\omega^2a^2 - \cancel{\frac{1}{2}m\omega^2y^2} + \cancel{\frac{1}{2}m\omega^2y^2}$

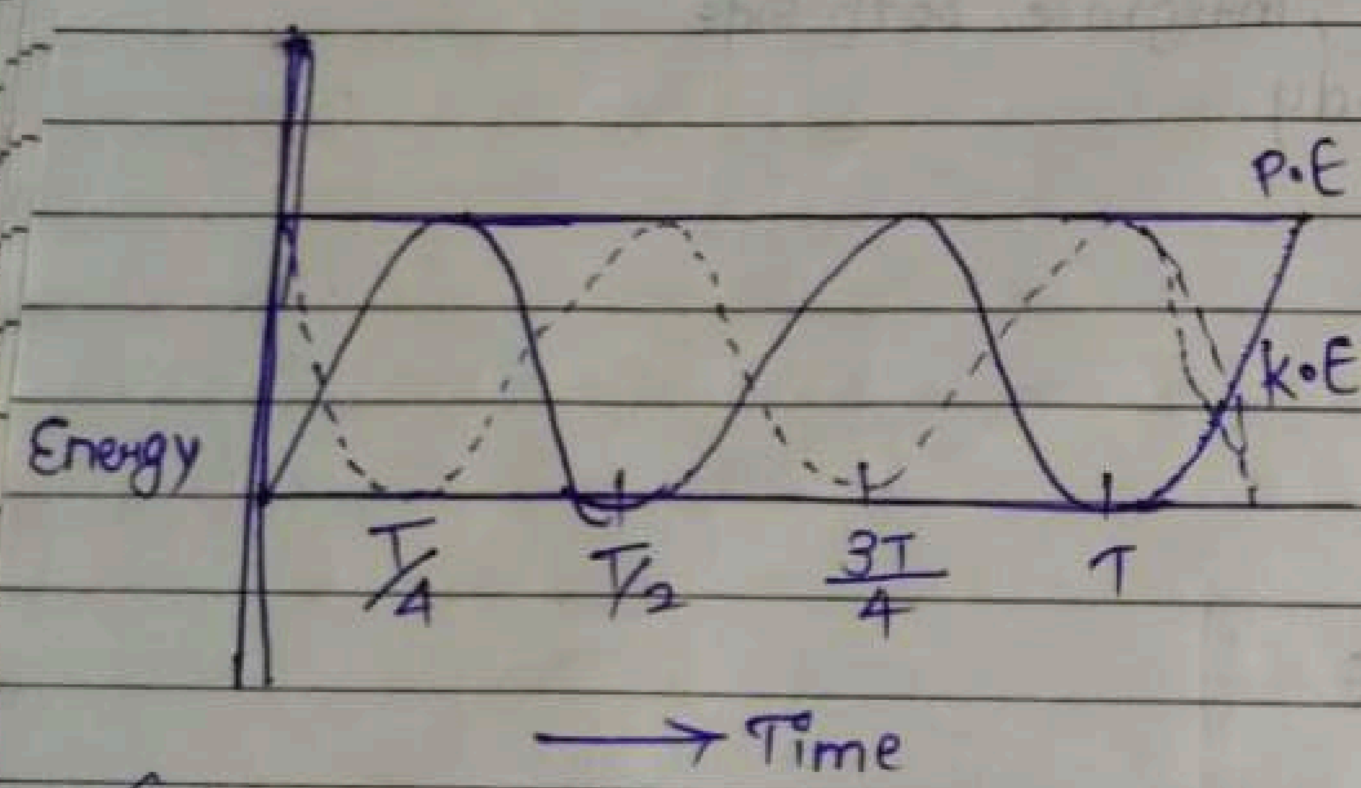
$\boxed{E = \frac{1}{2}M\omega^2a^2}$

as, $E = \frac{1}{2}M\omega^2a^2\cos^2\omega t + \frac{1}{2}M\omega^2a^2\sin^2\omega t$

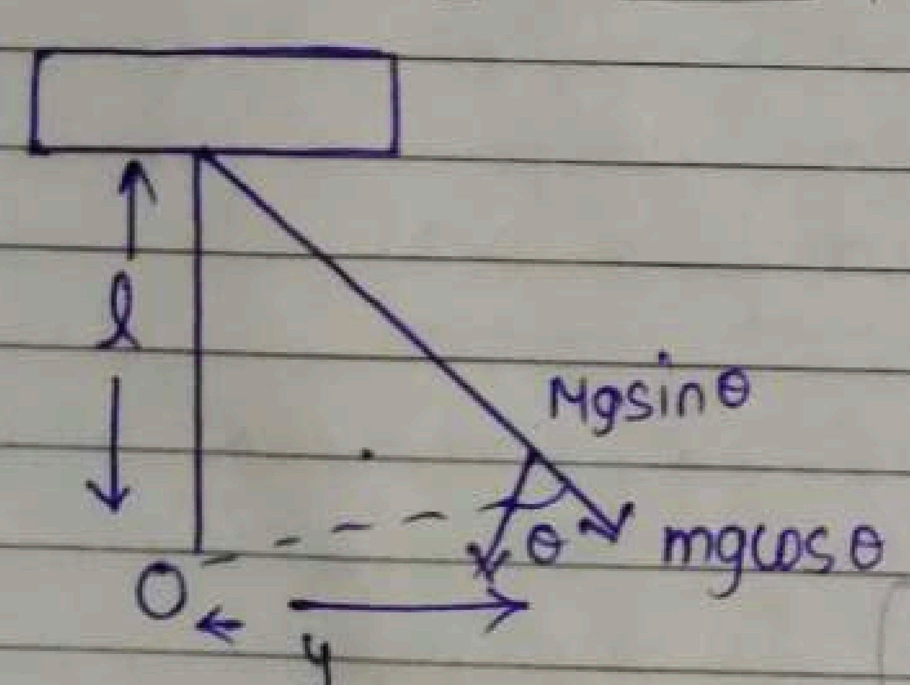
$\frac{1}{2}M\omega^2a^2(1-\sin^2\omega t) + \frac{1}{2}M\omega^2a^2\sin^2\omega t$

$\frac{1}{2}M\omega^2a^2 - \cancel{\frac{1}{2}M\omega^2a^2\sin^2\omega t} + \cancel{\frac{1}{2}M\omega^2a^2\sin^2\omega t}$

$\boxed{E = \frac{1}{2}M\omega^2a^2}$



* Time period of Simple pendulam:



Consider a simple pendullam of length 'l' and Mass 'M'. Let 'θ' be the inclination with mean position. Then weight 'mg' spilt into two components.

Mgsinθ or Mgcosθ

'y' be the disp. and 'f' be the restoring force.

Then,

$F = Mg\sin\theta$

as, θ is small so, $\sin\theta \propto \theta$

$F = mg \cdot \theta$

where $\theta = \frac{\text{length of arc}}{\text{Radius}}$

$\theta = \frac{y}{l}$

$F = mg \cdot \frac{y}{l}$ — ①

Restoring force $(F) = -ky$

In magnitude $F = ky$ — ②

Equate ① and ②

$Mg \cdot \frac{y}{l} = k \cdot y$

$k = \frac{Mg}{l}$

or, $\frac{k}{M} = \frac{g}{l}$ — ③

as, $\omega^2 = \frac{k}{m}$ — (IV)

From eq^n ③ and ④

$\omega^2 = \frac{g}{l}$

$\omega = \sqrt{\frac{g}{l}}$

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

where, T is called time period of simple pendullam,

* If lift is moving upward with acceleration 'a' then,

$g' = g + a$

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

* If lift is moving downward with acc. 'a' then,

$g' = g - a$

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

* Two identical pendullam are oscillating with ampelitude 2cm and 6cm. Calculate the ratio of energies of oscillation.

Soln $E = \frac{1}{2}M\omega^2 a^2$

$E \propto a^2$

$a_1 = 2cm, \quad a_2 = 6cm$

$\frac{E_1}{E_2} = \left(\frac{2}{6}\right)^2 = \frac{E_1}{E_2} = \frac{1}{9}$ $\boxed{E_1 : E_2 = 1:9}$

* A 4Kg body pendullam simple harmonic motion angular fq of 5 radian per second and ampelitude 20cm. find i) Spring constant ii) T.E iii) P.E and K.E when disp is 10cm.

Soln $M = 4Kg$

$\omega = 5 rad/s$

$a = 20cm = \frac{20}{100} m$

i) Spring constant (K) = ?

$\omega^2 = \frac{K}{M}$

$K = M\omega^2$

$= 4 \times (5)^2$

$= 100 N/m$

ii) $T.E = \frac{1}{2} m\omega^2 a^2$

$E = \frac{1}{2} \times 4 \times 5 \times 5 \times \frac{20}{100} \times \frac{20}{100}$

$E = 2J$

iii) $y = 10cm$

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

$\frac{1}{2} \times 4 \times 5 \times 5 \left((0.2)^2 - (0.1)^2\right)$

$= 50 [0.04 - 0.01]$

50×0.03

$50 \times \frac{3}{100} = 1.5J$

3) Find the value of force constant in S.H.M if value restoring from is 0.3N at a position of 5cm from mean position?

$F = 0.3N$

$y = 5cm = 0.05M$

$F = -Ky$

$K = -\frac{F}{y} = \frac{0.3}{5} \times 100 = -6 N/m$

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4) A body is executing S.H.M with amplitude 0.7M and angular fq 1 rads^{-1}. find its acc. at mean position and extreme position

i) At mean position, $y=0$

$a = -\omega^2 0$

$a = 0$

2) At extreme position, $y=a$

$a = -\omega^2 a$

$a = -1^2 \times 0.7$

$a = 0.7 \text{ rads}^{-2}$

5) A body is executing S.H.M with amplit. of 5M of fq. of $2/\pi$. find its velocity when disp. is 1m.

Soln

$\omega = 2\pi\nu$

$\omega = \cancel{2\pi} \times \frac{2}{\cancel{\pi}}$

$\omega = 4 \text{ rads}^{-1}$

$V = \omega\sqrt{a^2-y^2}$

$= 4\sqrt{5^2-1^2}$

$= 4\sqrt{25-1}$

$4\sqrt{24}$

$4 \cdot 2\sqrt{6}$

$= 8\sqrt{6}$

$= 8 \times 2.4$

$= 19.2 \text{ ms}^{-1}$

Formula's

Spring constant = $\boxed{\omega^2 = \frac{k}{m}}$

$T.E = \frac{1}{2} m\omega^2 a^2$

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

$P.E = \frac{1}{2} m\omega^2 y^2$

$F = -ky$ (restoring force)

$v = \omega\sqrt{a^2-y^2}$ (velocity)

$a = -\omega^2 y$ (acceleration)

Time period S.H.M = $T = 2\pi\sqrt{\frac{l}{g}}$

Time period of oscillati. = $T = 2\pi\sqrt{\frac{y}{A}}$

$[T \propto \sqrt{l}]$

6) A particle is executing S.H.M has a velocity 4ms^{-1} when it is at a dist of 3m from mean position Also, it has a velocity of 3ms^{-1} when it is dist of 4m from it. find it amp. and angular velocity.

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Soln $V = \omega\sqrt{a^2-y^2}$

$V_1 = \omega\sqrt{a^2-3^2}$ $\quad$ $V_2 = \omega\sqrt{a^2-4^2}$

$V_1 = \omega\sqrt{a^2-9}$ —(1) $\quad$ $V_2 = \omega\sqrt{a^2-16}$ —(2)

Divide eqn (1) And (2)

$\frac{4}{3} = \frac{\omega\sqrt{a^2-9}}{\omega\sqrt{a^2-16}}$

$\frac{16}{9} = \sqrt{\frac{a^2-9}{a^2-16}}$

$\frac{16}{9} \times \frac{a^2-9}{a^2-16}$

$16a^2 - 256 = 9a^2 - 81$

$7a^2 = 175$

$a^2 = 25$

$a = 5M$

$4 = \omega\sqrt{5^2-9}$

$4 = \omega\sqrt{25-9}$

$4 = \omega\sqrt{16}$

$\cancel{4} = \omega \cdot \cancel{4}$

$\omega = 1 \text{ rads}^{-1}$

7) What will be the time-period of a pendullam whose length of string is 10m take $g = 10\text{ms}^{-2}$

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

$T = 2\pi\sqrt{\frac{\cancel{10}}{\cancel{10}}}$

$T = 2\pi \times 1$

$= 2 \times 3.14$

$= 6.28$ sec.

8) If length of string of simple pendullam is doubled what will be the effect on time period

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

$T \propto \sqrt{l}$

$T' \propto \sqrt{2l}$

$T' \propto \sqrt{2}\,T$

Time period will increase $\sqrt{2}$ times.

9) Two strings of length 4cm and 16cm are made to find the ratio of their time period.

Soln $T_1 = 2\pi\sqrt{\frac{l}{g}}$

$T_2 = 2\pi\sqrt{\frac{l_2}{g}}$

$\frac{T_1}{T_2} = \frac{2\pi}{2\pi}\sqrt{\frac{l_1 \times g}{g \times l_2}} = \frac{T_1}{T_2} = \sqrt{\frac{l_1}{l_2}}$

$2\pi\sqrt{\frac{l_2}{g}}$ $\quad \frac{\sqrt{4}}{16\ 4} = \sqrt{\frac{1}{4}} = \frac{1}{2}$

10) What will be the time period of a pendullam in a freely falling lift

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

Here, $g = 0$

$T = \infty$

11) What do you mean by second pendullam what will be the length of a second pendullam?

Soln It is a pendullam which has a time-period of 2 second

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

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$T^2 = 4\pi^2 \frac{l}{g}$

$l = \frac{gT^2}{4\pi^2}$

Here $g = 9.8\,ms^{-2}$, $l = \frac{9.8 \times (2)^2}{4 \times (3.14)^2} = 0.993$

(12) Find the time period of a simple pendullam whose length is equal to radius of earth.

$T = 2\pi\sqrt{\frac{l}{g}}$ Here $l = R = 6400km = 6.4 \times 10^6 m$

$g' = \left(1 + \frac{R}{l}\right) g$

$T = 2\pi\sqrt{\left(\frac{R}{1+\frac{R}{R}}\right) g} = 2\pi\sqrt{\frac{R}{2g}}$

$= 2 \times 3.14\sqrt{\frac{6.4 \times 10^6}{2 \times 9.8}}$

$= 3588.67\,sec.$

(13) A body weigthing 5 kg has a velocity of 6m/s after 1/3 sec from mean position. If the time period is 2sec. Find 1) Angular fq. 2) Amplitude 3) K.E 4) P.E 5) T.E

1) $\omega = \frac{2\pi}{T} = \frac{2 \times 3.14}{2} = 3.14\,rad\,s^{-1}$

(i) $v = a\omega \cos\omega t$

$6 = a \times 3.14 \cos\left(\pi \times \frac{1}{3}\right)$

$6 = a \times 3.14 \times \frac{1}{2}$

$a = \frac{6 \times 2}{3.14} = \frac{6 \times 2 \times 7}{22\ 11} = \frac{42}{11} = 3.8\,cm$

iv) $P.E = \frac{1}{2} m\omega^2 a^2$

$= \frac{1}{2} \times 5 \times (3.14)^2 \times (3.8)^2$

$= 359.68\,J$

iii) $K.E = \frac{1}{2} m\omega^2 a^2 \cos^2\omega t$

$\frac{1}{2} \times 5 \times (3.14)^2 \times (3.8)^2 \times \frac{1}{4}$

$K.E = \frac{1}{2} mv^2 = \frac{1}{2} \times 5 \times 6 \times 6 = 90\,J$

* **Free oscillation:-** When a body oscillates freely without help of any external force then the oscillation is called free oscillation. In free oscillation, the body oscillate with natural frequency.

* **Forced oscillation:**
When a body oscillate with help of any external force then the oscillation is called forced oscillation. In force oscillation the body oscillate with a fq. with other than natural fq.

* **Resonant oscillation:**
When a body oscillate with its natural fq. with the help of any external force then the oscillations are called Resonant oscillations.

* If the mass of load is increased what will be the effect on time period and fq. of oscillation?

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

$T \propto \sqrt{m}$ Teime-period increases

$\nu \propto \frac{1}{T}$ fq. decreases.

* A spring is compressed by 0.1m. A restoring force of 10n comes in the spring.
i) Force constant 2) Now, spring is suspended vertically find extension in spring due to a load of mass 4kg.
3) Find time-period of oscillation
4) Find fq. of oscillation.

Soln i) $y = 0.1\,m$
$F = 10N$
$F = -Ky$
$K = -\frac{F}{y} = \frac{-10}{0.1} = -100\,N/m$

2) $m = 4kg$
$F = -Ky'$
$F = mg$
$Ky' = mg$
$y' = \frac{mg}{K} = \frac{4 \times 10}{100} = \frac{2}{5}m$

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

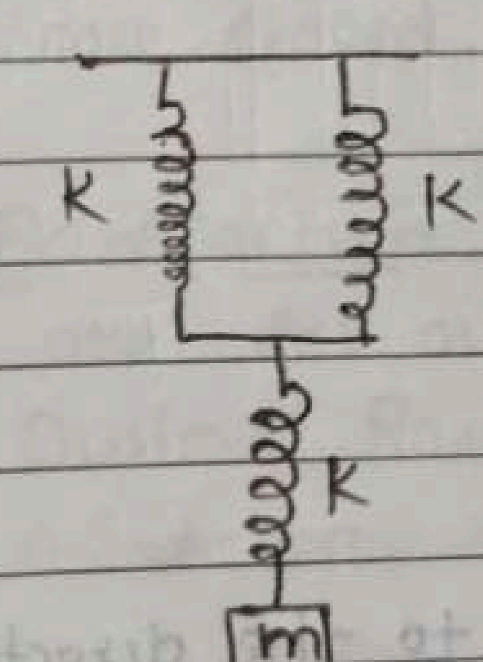
$2 \times \frac{22}{7}\sqrt{\frac{4}{100}}$

$2 \times \frac{22}{7} \times \frac{2}{10} = \frac{44}{35} = 1.256$ sec.

4) $\nu = \frac{1}{T} \Rightarrow \frac{1000}{1256}$ ~~500~~ ~~256~~ 125

$\frac{628}{314} = \frac{125}{157} = 0.7\,sec^{-1}$

* Find the time-period and fq. of group of 3 identica spring shown in diagram



$T = 2\pi\sqrt{\frac{m}{K_{total}}}$

* spring series: $\frac{1}{K_{total}} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \ldots$

* Spring parallel: $K_{total} = K_1 + K_2 + K_3 + \ldots$

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* **Forced oscillation:**
When a body oscillate with help of any external force then the oscillation is called forced oscillation. In force oscillation the body oscillate with a fq. with other than natural fq.

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When a body oscillate with its natural fq. with the help of any external force then the oscillations are called Resonant oscillations.

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i) Force constant 2) Now, spring is suspended vertically find extension in spring due to a load of mass 4kg.
3) Find time-period of oscillation
4) find fq. of oscillation.

Soln i) $y = 0.1m$
$f = 10N$
$f = -Ky$
$K = \frac{-f}{y} = \frac{-10}{0.1} = -100 N/m$

2) $m = 4kg$
$f = -Ky'$
$f = mg$
$Ky' = mg$
$y' = \frac{mg}{K} = \frac{4 \times 10}{100} = \frac{2}{5}m$

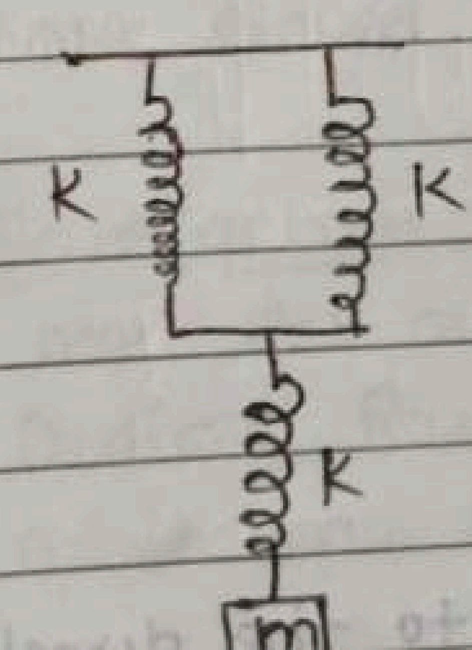
3) $T = 2\pi\sqrt{\frac{m}{K}}$

$2 \times \frac{22}{7}\sqrt{\frac{4}{100}}$

$2 \times \frac{22}{7} \times \frac{2}{10} = \frac{44}{35} = 1.256 sec.$

4) $\nu = \frac{1}{T} \Rightarrow \frac{1000}{1256} = \frac{125}{157} = 0.7 sec^{-1}$

* Find the time-period and fq. of group of 3 identica spring shown in diagram



$T = 2\pi\sqrt{\frac{m}{K_{total}}}$

* spring series: $\frac{1}{K_{total}} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \dots$

* Spring parallel: $K_{total} = K_1 + K_2 + K_3 + \dots$

'T' be the time period of oscillation of cylinder

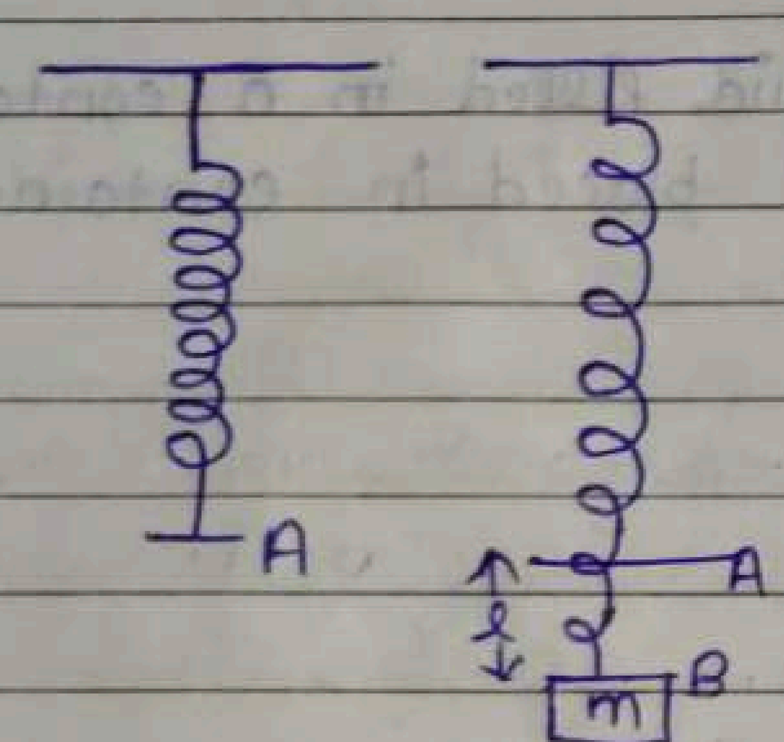
$$T = 2\pi\sqrt{\frac{M}{K}}$$

using eq^n iii) and iv)

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

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

* Vibration in a spring :-



Consider a spring attached with a small mass 'm'. 'l' be the extension in spring. 'F' be the restoring force.

Then,

$F = mg$ - i)

or, $F = kl$ - ii)

From ① and ②

$mg = kl$

$K = \frac{mg}{l}$ - ③

let 'T' be the time period of vibration of spring.

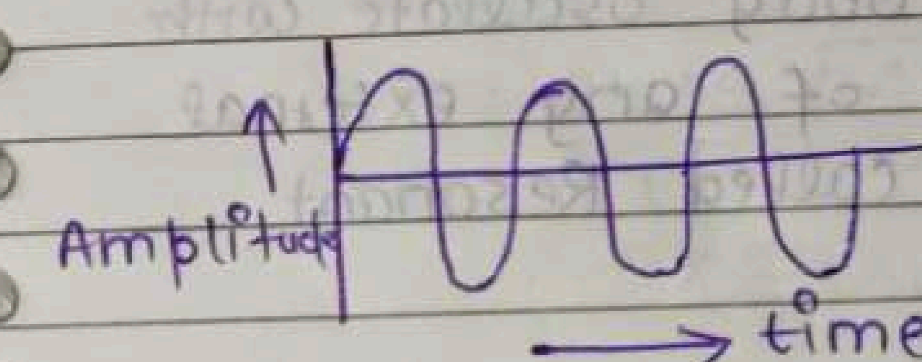
$$T = 2\pi\sqrt{\frac{m}{K}}$$

using eq^n iii)

$$T = 2\pi\sqrt{\frac{m}{\frac{mg}{l}}}$$

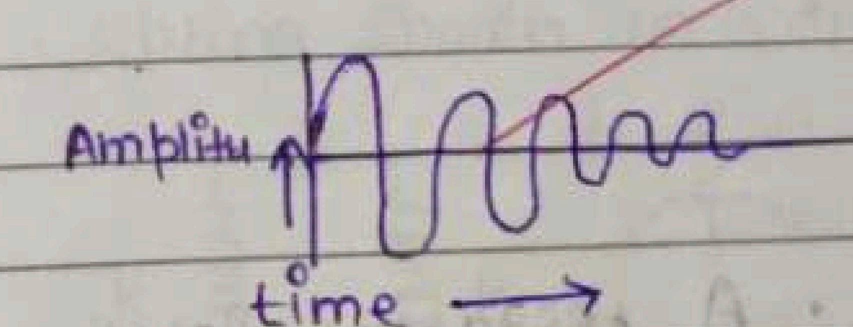
$$\boxed{T = 2\pi\sqrt{\frac{l}{g}}}$$

* Undamped oscillation :-



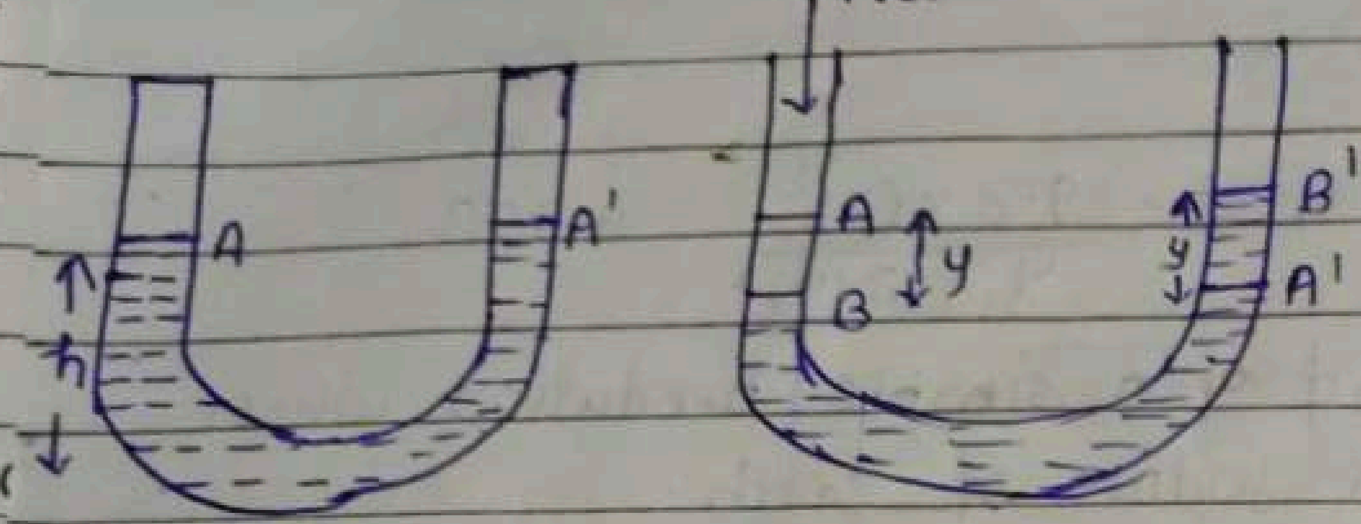
The oscillation in which amplitude of oscillation remains constant and does not change with time are called undamped oscillations.

* Damped oscillation :



The oscillation in which amplitude of oscillation decreases with time is called damped oscillation.

* Motion of liquid in U-tube :-



consider a U-tube having liq. filled upto height 'h'
let 'ρ' be the density of liquid and 'm' be the mass of liquid displaced.
'A' be the area of U-tube arm.

$$\text{Density } (\rho) = \frac{\text{Mass}}{\text{volm}} = \frac{m}{A \cdot 2y} \quad [\text{disp} = 2y]$$

$$\rho = \frac{m}{A \cdot 2y}$$

$$m = \rho \cdot A \cdot 2y \quad \text{— (i)}$$

'F' be the restoring force

$$F = Ky \quad (\text{In magnitude}) \text{ — iii)}$$

or $F = mg$

$$F = \rho \cdot A \cdot 2y \cdot g \quad \text{— (iv)}$$

From eqn iii) and iv)

$$K\cancel{y} = \rho \cdot A \cdot 2\cancel{y} \cdot g$$

$$K = \rho \cdot A \cdot 2g \quad \text{— v)}$$

'M' be the mass of liq. filled in U-tube

$$\text{Density } (\rho) = \frac{M}{2h \cdot A}$$

$$M = \rho \cdot A \cdot 2h \text{ — vi)}$$

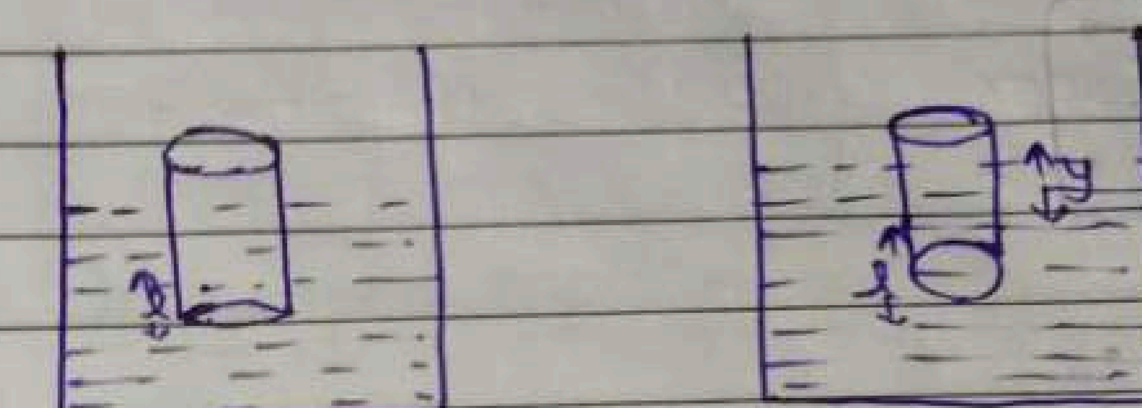
let 'T' be the time period of osscilation of liq.

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

$$T = 2\pi \sqrt{\frac{\rho \cdot A \cdot 2h}{\rho \cdot A \cdot 2g}} \quad [\text{from eqn v) and vi)}]$$

$$\boxed{T = 2\pi \sqrt{\frac{h}{g}}}$$

* Motion of a cylinder in liquid :-



let 'ρ' be the density of liquid filled in a container
A cylinder of mass 'M' is placed in container.
'y' be the disp. of liq.

$$\text{Density } (\rho) = \frac{m}{A \cdot y}$$

$$m = \rho \cdot A \cdot y \text{ — i)}$$

'F' be the restoring force.

$$F = Ky \quad (\text{In magnitude}) \text{ — ii)}$$

~~or~~ $F = mg$

$$F = \rho \cdot A y \cdot g$$

From eqn ii) and iii)

$$K\cancel{y} = \rho \cdot A \cdot \cancel{y} \cdot g$$

$$K = \rho \cdot A \cdot g \text{ — iii)}$$

$$\text{Density} = \frac{\text{Mass of cylinder}}{\text{volm}}$$

$$\rho = \frac{M}{A \cdot l}$$

$$M = \rho \cdot A \cdot l \text{ — iv)}$$

spring constant $\Rightarrow k' = k + k = 2k$

$$\frac{1}{k_{total}} = \frac{1}{2k} + \frac{1}{k} = \frac{1+2}{2k} = \frac{3}{2k}$$

$$k_{total} = \frac{2k}{3}$$

$$T = 2\pi\sqrt{\frac{m}{k_{total}}}$$

$$2\pi\sqrt{\frac{m}{\frac{2k}{3}}}$$

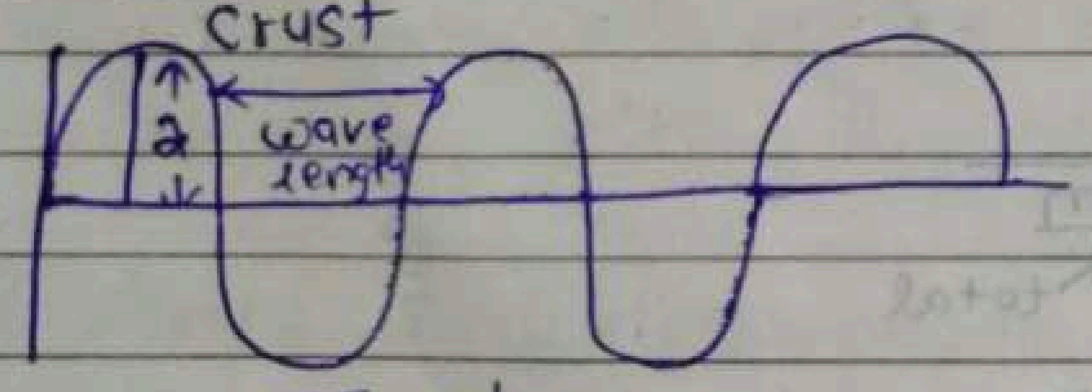
$$\boxed{T = 2\pi\sqrt{\frac{3m}{2k}}}$$

let 'ν' be the fq.

$$\boxed{\nu = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{2k}{3m}}}$$

* **Wave:** A wave is a kind of disturbance which is produced due to oscillation of particles.
There are two types of mechanical wave:

1) **Transverse Wave:**

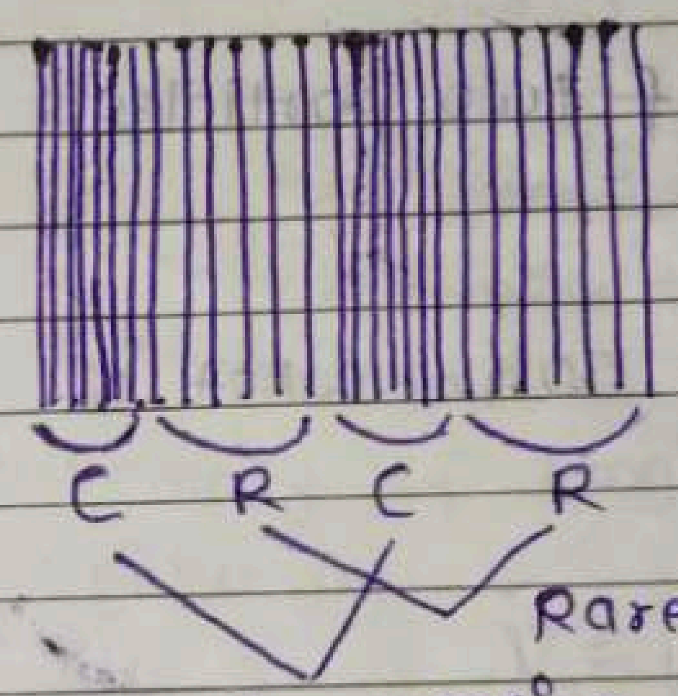


If oscillation of particles take place ⊥ to the direction of propagation of wave then wave is called transverse wave.

***Crest:** The part of medium which is raised above mean position is called crest.

* **Trough:** The part of medium which is depressed below mean position is called trough.
Example: Waves in string, waves on water surface, light waves

2) **Longitudinal wave:**



If oscillation of particles takes place along the direction of propagation of wave then wave is called longitudinal wave. Example: Sound wave

Compression: The part of medium in which particles are closed to each other is called compression.

Rarefaction: The part of medium in which particles are far away from each other is called Rarefaction. During Rarefaction density of medium will be minimum

Amplitude: The max. displacement b/w mean position and extreme position is called amplitude. It is denoted by 'a'.

* Wavelength: Distance b/w two successive crest or trough is called wavelength. It is denoted by 'λ'

* Time period: Time taken by a particle to complete one vibration is called time period.

* Phase and phase diff. Phase is something that gives us information about location of a particle in a wave at a particular time.

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

where ϕ is called phase.

Phase diff. is the diff. b/w phase of two particles or waves.

* The fq. of A.C waves in india is 50Hz. What is its time period?

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

$$T = \frac{1}{\nu} = \frac{1}{50} = 0.02 \text{ sec.}$$

* A tuning fork vibrate with a fq. of 250Hz. If the speed of sound is 332 m/s. find wavelength?

→ $v = \nu\lambda$

$$\lambda = \frac{\cancel{332}^{166}}{\cancel{250}_{125}} = 1.25\,m.$$

* Velocity of transverse wave:

i) Velocity of transverse wave in string is given by

$V = \sqrt{\frac{T}{\mu}}$ where, T = tension in string
μ = mass per unit length
(linear mass density)

ii) Velocity of transverse wave in solid is given by

$v = \sqrt{\frac{\eta}{\rho}}$ where η = modulus of rigidity
ρ = density of solid

* Velocity of longitudinal wave:

i) Velocity of longitudinal wave is given by

$$V = \sqrt{\frac{Y}{\rho}}$$

Y = Yong's modulous of elasticity
ρ = density of solid.

2) Velocity of longitudinal wave in liquid and gases is given by

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

Where, K = bulk modulus of elasticity
ρ = density of liquid/gases.
$\underbrace{\text{liquid/gases}}_{\text{fluid}}$

* Newton's formula for velocity of sound:

Newton assumed that velocity of sound in air is an isothermal process.

As, velocity of sound in fluid is given by

$$v = \sqrt{\frac{K}{\rho}} \quad \text{--i)}$$

In Isothermal process,

PV = constant

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Differentiating both side

$$P\cdot dv + v\cdot dP = 0$$

$$P\cdot dv = -v\cdot dP$$

$$\frac{dP}{dv} = \frac{-P}{v}$$

$$\frac{dP\cdot v}{dv} = -P$$

$$\frac{dP}{\frac{dv}{v}} = -P$$

as, $K = \frac{-dP}{\frac{dv}{v}}$ is called bulk modulus of elasticity

$$\Rightarrow \boxed{K = P}$$

Put this value in eqn i)

$$\left[v = \sqrt{\frac{P}{\rho}} \right]$$

* Laplace's correction for velocity of sound :

Laplace assumed that velocity of sound is adiabatic process.

Velocity of sound in air is given by:

$$v = \sqrt{\frac{K}{\rho}} \quad \text{-i)}$$

In adiabatic process

$$PV^{\gamma} = \text{Constant}$$

Diff. both side

$$P\cdot\gamma\cdot V^{\gamma-1}\cdot dv + V^{\gamma}\cdot dP = 0$$

$$P\cdot\gamma\cdot V^{\gamma-1}\cdot dV = -V^{\gamma}\cdot dP$$

$$-\frac{P\cdot\gamma\cdot V^{\gamma-1}}{V^{\gamma}} = \frac{dP}{dV}$$

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$$-P\cdot\gamma\cdot V^{\gamma-1}\cdot V^{-\gamma} = \frac{dP}{dV}$$

$$-P\cdot\gamma\cdot V^{\cancel{\gamma}-1-\cancel{\gamma}} = \frac{dP}{dV}$$

$$-P\cdot\gamma\cdot V^{-1} = \frac{dP}{dV}$$

$$\frac{-P\cdot\gamma}{V} = \frac{dP}{dV}$$

$$-P\cdot\gamma = \frac{dP}{dV}\cdot V$$

$$-P\gamma = \frac{+dP}{\frac{dV}{V}}$$

$$\gamma\cdot P = \frac{-dP}{\frac{dV}{V}}$$

as, $K = \frac{-dP}{dV/V}$

So, $K = \gamma\cdot P$

Put value in eqn i)

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

Where 'γ' is called specific heat constant.

* Factor affecting velocity of sound in a gas:

i) Effect of Density:

As velocity of sound in gas is given

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

Where, $v \propto \frac{1}{\sqrt{\rho}}$

If density of gas increases then speed of sound will decreases velocity of sound is inversely prop. to square root of density of given gas

2) Effect of pressure:

As, $v = \sqrt{\frac{\gamma P}{\rho}}$ — (i)

$v \propto \sqrt{P}$

So, velocity of sound is directly prop. to press. of gas. But,

as $PV = RT$

$P = \frac{RT}{V}$

$\Rightarrow \rho = \frac{M}{V}$

In eqⁿ i)

$v = \sqrt{\frac{\gamma RT}{M}}$

If temp. of given gas is constant then, velocity of sound is independent to the pressure of given gas.

3) Effect of temp.

As, $v = \sqrt{\frac{\gamma RT}{M}}$

$v \propto \sqrt{T}$

So, velocity of sound is directly prop. to square root of temp. of given gas.

4) Effect of Humidity:

$v = \sqrt{\frac{\gamma P}{\rho}}$

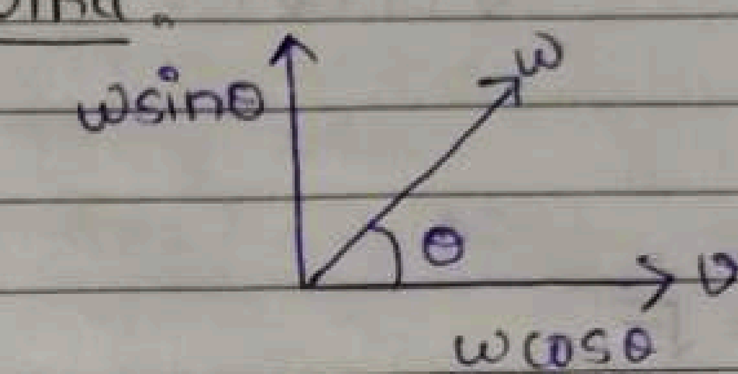
$v \propto \frac{1}{\sqrt{\rho}}$

as, density of air increases then velocity decreases. Due to humidity, density of gas decrease

So, velocity of sound increase.

Effect of

5) Effect of Wind:



1) $v_{net} = v + \omega\cos\theta$

If wind is blowing in direction of sound then

$\theta = 0°$

$v_{net} = v + \omega\cos\theta$

$v_{net} = v + \omega$

So, velocity of sound will increase.

ii) If $\theta = 180°$, wind blowing in opp. direction of sound then,

$v_{net} = v + \omega\cos 180°$

$v_{net} = v + (-1)\cdot\omega$

$\boxed{v_{net} = v - \omega}$

So, velocity of sound decreases.

iii) If $\theta = 90°$ means wind is blowing ⊥ to the direction of velocity of sound.

$v_{net} = v + \omega\cos 90°$

$v_{net} = v + \omega(0)$

$\boxed{v_{net} = v}$

So, velocity of sound remains same.

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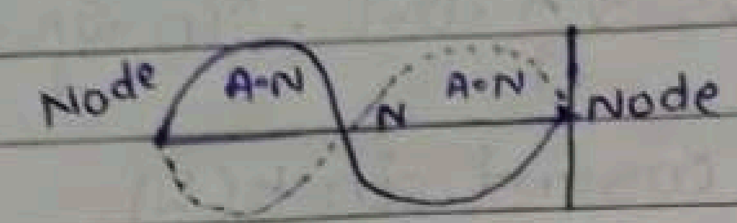
or $L = \frac{2\lambda}{2}$

$\boxed{L = \lambda}$



$x = L$ $\qquad x = 0$

Then freq. $\nu_2 = \frac{v}{\lambda_2} = \frac{1}{L}\sqrt{\frac{T}{\mu}}$

$$\boxed{\nu_2 = \frac{1}{L}\sqrt{\frac{T}{\mu}}}$$

for 'n' mode of vibration :

$$\lambda_2 = \frac{2L}{n}$$

or, $$\boxed{\nu_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}}$$

* **Standing Waves in a closed organ pipe :**

consider an organ pipe having length 'L'. let one end of pipe is closed. A wave is moving from left hand side of pipe.

Eqn of incident wave -

$$y_1 = a\sin(\omega t - kx)$$

Eqn of reflected wave

$$y_2 = a\sin[\omega t - k(-x) + \pi]$$

$$y_2 = a\sin[\omega t + kx + \pi]$$

$$y_2 = -a\sin(\omega t + kx)$$

Now eqn for resultant wave is

$$y = y_1 + y_2$$

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

$$= a[\sin(\omega t - kx) - \sin(\omega t + kx)$$

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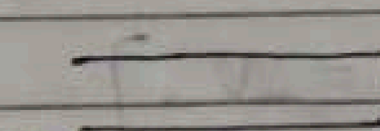
$$y = a\left[2\cos\left(\frac{\omega t - kx + \omega t + kx}{2}\right) \cdot \sin\frac{(\omega t - kx) - (\omega t + kx)}{2}\right.$$

$$y = 2a[\cos\omega t \sin kx]$$

By ignoring -ve sign we have

$$y = 2a\cos\omega t \cdot \sin kx$$

Case I, at $x = 0$, node will be formed



$x = L \qquad x = 0$

Case IInd, at $x = L$, Anti-node will be formed $[y = \max.]$

then,

$$2a\cos\omega t \cdot \sin k(L) = \max.$$

$$\sin k(L) = \sin(2n-1)\cdot\frac{\pi}{2}$$

$$kL = (2n-1)\cdot\frac{\pi}{2}$$

$$\frac{2\pi}{\lambda}\cdot L = (2n-1)\cdot\frac{\pi}{2}$$

$$L = \frac{(2n-1)\lambda}{4}$$

$$\boxed{\lambda = \frac{4L}{(2n-1)}}$$

for Ist mode of vibration, put $n = 1$

λ_1 and ν_1 be the wavelength and fq. of wave respectively.

$$\lambda_1 = \frac{4L}{2\times1-1} = \frac{4L}{2-1} = \frac{4L}{1}$$

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$y = y_1 + y_2$

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

$= a[\sin(\omega t - kx) - \sin(\omega t + kx)]$

$y = a\left[2\cos\frac{(\omega t - kx) + (\omega t + kx)}{2}\ \sin\frac{(\omega t - kx - (\omega t + kx))}{2}\right]$

$y = 2a\left[\cos\frac{\omega t - \cancel{kx} + \omega t + \cancel{kx}}{2}\right]\sin\left[\frac{\cancel{\omega t} - kx - \cancel{\omega t} - kx}{2}\right]$

$2a[\cos\omega t \cdot \sin(-kx)]$

$= -2a\cos\omega t\sin kx \quad (\because \sin(-\theta) = -\sin\theta$

By ignoring -ve sign we get

$y = 2a\cos\omega t\sin kx$

as, $\omega = \frac{2\pi}{T}$, $k = \frac{2\pi}{\lambda}$

$y = 2a\cos\frac{2\pi}{T}.t\ \sin\frac{2\pi}{\lambda}.x$

$= 2a\cos\frac{2\pi . v . t}{T . v}\ \sin\frac{2\pi}{\lambda}.x$

$= 2a\cos\frac{2\pi v . t}{\lambda} . \sin\frac{2\pi}{\lambda}.x$

<u>Case I</u>

Case I^{st} — at, $x = 0$

$y = 2a\cos\frac{2\pi}{\lambda}.v.t . \sin\frac{2\pi}{\lambda}.0$

$\boxed{y = 0}$

So, node will be formed.

Case II^{nd} : at, $x = L$

another node will be formed so,
amp. will be zero.

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Put $y = 0$

$y = 2a\cos\frac{2\pi}{\lambda}.v.t . \sin\frac{2\pi}{\lambda}.L$

$0 = 2a\cos\omega t\sin k(L)$

$\sin k(L) = \sin n\pi$

$\frac{2\cancel{\pi}}{\lambda}.L = n\cancel{\pi}$

$\boxed{L = \frac{n.\lambda}{2}}$

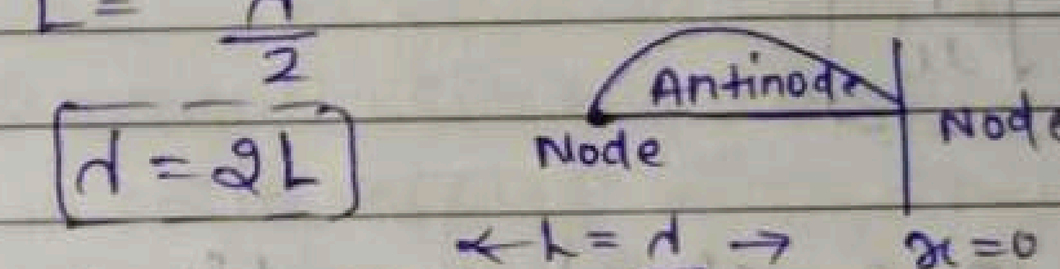
or $\boxed{\lambda = \frac{2L}{n}}$

Where 'n' is called mode of vibration.

* For I^{st} mode of vib. put $n = 1$

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

$\boxed{\lambda = 2L}$



Let ν_1 be the fq of first mode of vibration.
'v' be the velocity of wave.

$v = \nu_1 . \lambda_1$

$\nu_1 = \frac{v}{\lambda_1}$

as, $v = \sqrt{\frac{T}{\mu}}$

Where μ = mass/length

$\nu_1 = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

For 2^{nd} mode of vib. put $n = 2$

Then, λ be the wavelength and ν_2 be the fq. of 2^{nd} mode of vibration.

$\lambda_2 = \frac{2L}{2} = \boxed{\lambda_2 = L}$

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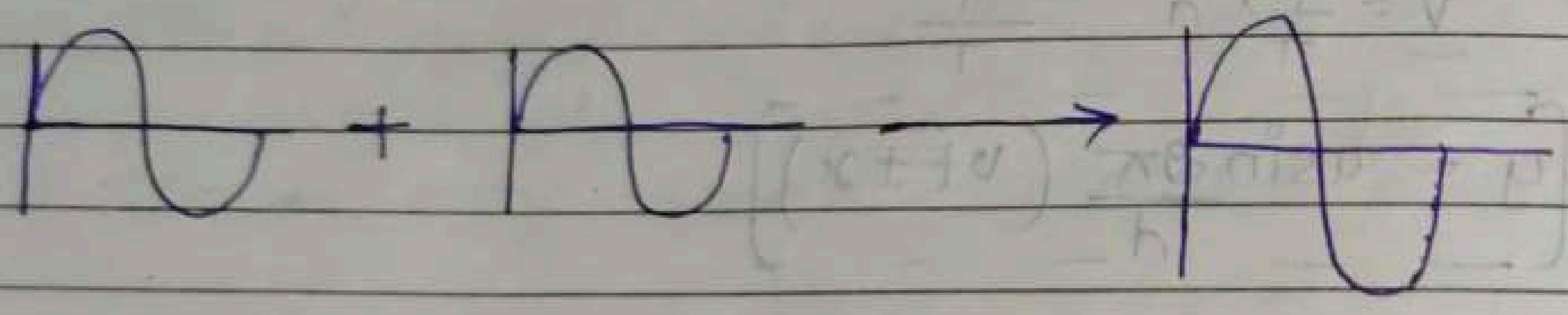
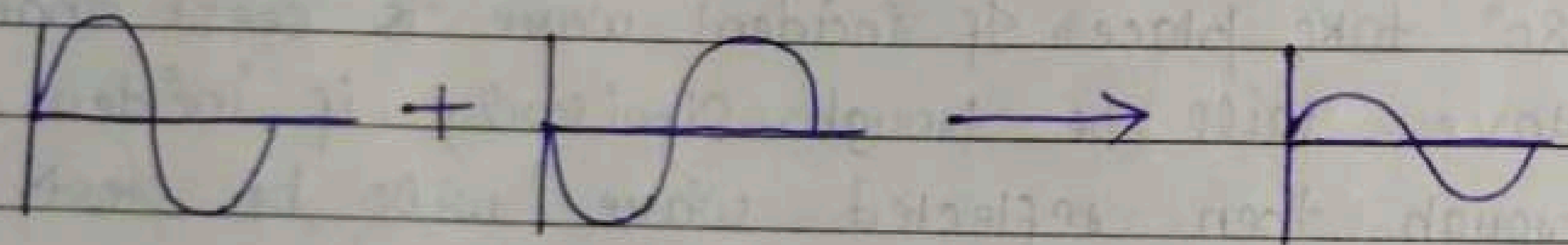
* * **Superposition principle:** The mixing of two or more waves is called superposition of wave.

Sl. It has two types.

i) **Constructive Superposition:** When crest of one wave falls on crest of other wave and trough of one wave falls on the trough of other wave. Then superposition is called constructive superposition. The amplitude of resultant wave increases.



2) **Destructive Superposition:** When crest of one wave falls on the trough of other wave and trough of one wave falls on the crest of other wave. This superposition is called Destructive Superposition. The amp. of resultant wave decreases.



* **Application of Superposition principle:**

1) Standing Waves: When two progressive wave of same amp., same wavelength, same type travelling along same line but in opp. direction. Superimpose (mix) with each other then standing waves are formed.

2) Beats 3) Interferance.

* **Characterstics of standing waves:**

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1) There are some points/particles which are permanent at rest. Their amp. of oscillation is zero are called nodes.

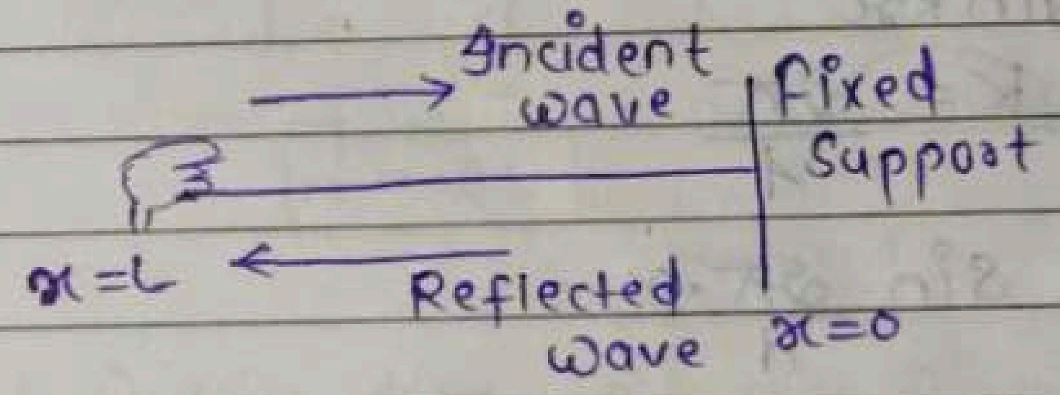
2) There are some points which oscillates with max. amplitude are called anti-nodes.

3) Path diff. b/w two successive nodes or anti-nodes is $\lambda/2$.

4) Particles of a particular segment are oscillating in same direction. So, phase diff. b/w them will be zero.

5) Particles of two successive segments are oscillating in opp. direction. So, phase diff b/w them will be 180°.

Standing waves in a string:



Consider a string of length 'L' is hold by a fixed support.

Let a wave pulse incident from left side along +ve x-axis

Eqn of incident wave:

$$y_1 = a\sin(\omega t - kx) \quad \text{— i)}$$

After reflection from fixed support wave moves in opp. direction then eqn of reflected wave will be:

$$y_2 = a\sin(\omega t - k(-x) + \pi)$$

$$y_2 = a\sin(\omega t + kx + \pi)$$

$$= -a\sin(\omega t + kx)$$

Then eqn for resultant wave will be

* Find at what temp. the velocity of sound will become double to that at 27°C.

Sol^n $v \propto \sqrt{T}$ $\quad 273+27 = \underline{300K}$

$\frac{v_1}{T_1}, \frac{v_2}{T_2}$

$v_1 = v$
$T_2 = ?$
$v_2 = 2v$

$\frac{v_1}{v_2} = \frac{\sqrt{T_1}}{\sqrt{T_2}}$

$\frac{v}{2v} = \sqrt{\frac{300}{T_2}}$

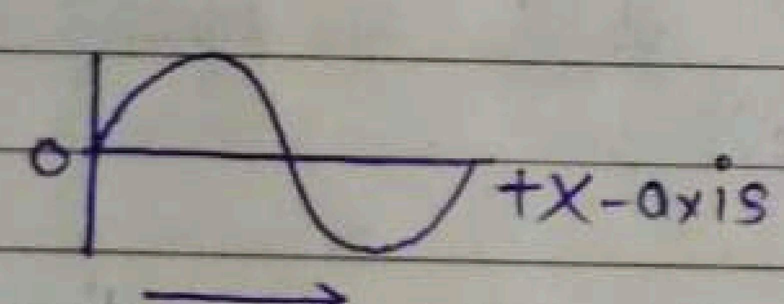
$\frac{1}{2} = \sqrt{\frac{300}{T_2}}$

square both side

$\frac{1}{4} = \frac{300}{T_2}$

$T_2 = 1200K = 1200 - 273 = \underline{927^\circ C}$

* Eq^n of a plane progressive simple harmonic wave:



Consider a plane progressive S.H.W moving with a velocity 'v' along + X-axis
'y' be the disp. of wave:
$y = a\sin\omega t$
'ϕ' be the phase diff.. then,
$y = a\sin(\omega t \pm \phi)$

As, Phase diff. $\phi = \frac{2\pi}{\lambda} \cdot x$

$v = \nu\lambda$, $\nu = \frac{1}{T}$

where 'x' be position of wave at particular time 't'.

$y = a\sin(\omega t \pm \frac{2\pi}{\lambda} \cdot x)$ $\quad \omega = 2\pi\nu = 2\pi \times \frac{1}{T} = \frac{2\pi}{T}$

$y = a\sin(\frac{2\pi \cdot t}{T} \pm \frac{2\pi \cdot x}{\lambda})$

$= a\sin\frac{2\pi}{\lambda}(\frac{\lambda \cdot t}{T} \pm x)$

as, $v = \nu\lambda$

$v = \frac{1}{T} \times \lambda = \frac{\lambda}{T}$

$$\boxed{y = a\sin\frac{2\pi}{\lambda}(vt \pm x)}$$

* Reflection of wave: Ref of wave follow same rules as that of reflection of light.

i) Reflection of wave from closed end/ fixed end :- When a wave strikes on a closed wave is crest then a phase diff. of 180° take place. If incident wave is crest than reflected wave will be trough. Similarly, if incident wave is trough then reflected wave will be crest.

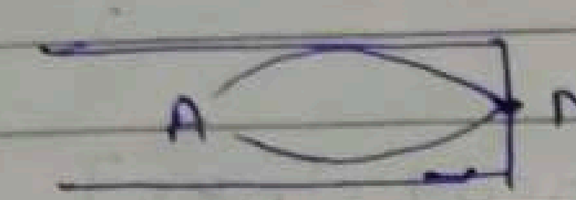
→ crest	trough →
Trough ←	Crest ←

ii) Reflection of wave from open end/ free end: When a wave strikes an open end, no phase diff. change takes place. If crest is incident, then reflected wave will be also crest. If incident wave is trough then reflected will also be trough.

→ crest	→ trough
← crest	← trough

$\boxed{\lambda_1 = 4L}$

or $\boxed{L = \frac{\lambda_1}{4}}$



'v' be the velocity of wave

$v = \nu_1 \lambda_1$

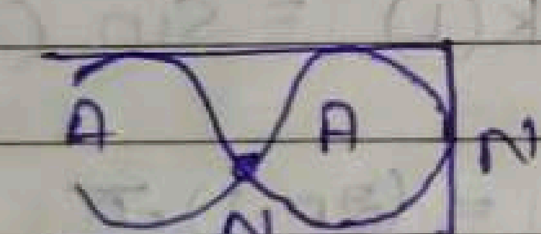
$\nu_1 = \frac{v}{\lambda_1} = \frac{v}{4L}$

$\boxed{\nu_1 = \frac{v}{4L}}$

For IInd mode of vib. but $n=2$

$\lambda_2 = \frac{4L}{2\times2-1} = \frac{4L}{4-1} = \frac{4L}{3}$

$\boxed{\lambda_2 = \frac{4L}{3}}$



or $L = \frac{3\lambda_2}{4}$

$\nu_2 = \frac{v}{\lambda_2} = \frac{v}{\frac{4L}{3}} = \frac{3v}{4L}$

$\boxed{\nu_2 = \frac{3v}{4L}}$

In general:

$\lambda_n = \frac{4L}{2n-1}$

or $\nu_n = \frac{(2n-1)v}{4L}$

* **Standing wave in a pipe:**

Consider an open organ pipe having length 'L'. Let a wave is moving from left hand side then eq^n of incident wave is given by:

$y_1 = a\sin(\omega t - kx)$ —(i)

Eq^n of reflected wave will be

$y_2 = a\sin(\omega t - k(-x))$

$y_2 = a\sin(\omega t + kx)$

Now, eq^n of resultant wave will be

$y = y_1 + y_2$

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

$= a[\sin(\omega t - kx) + \sin(\omega t + kx)]$

$\sin C + \sin D = 2\sin\frac{C+D}{2}\cdot\cos\frac{C-D}{2}$

$y = a\left[2\sin\left(\frac{\omega t - kx + \omega t + kx}{2}\right)\cos\left(\frac{\omega t - kx - \omega t + kx}{2}\right)\right.$

$y = 2a[\sin\omega t\cos kx]$

$y = 2a\sin\omega t\cos kx$

Case Ist: at $x=0$, and end is open so antinode will be formed.

Case II: at $x=L$ ~~end~~ is also open so antinode will to be formed.

Max. $= 2a\sin\omega t\cdot\cos k(L)$

$\cos(k)(L) = $ max.

$\cos k(L) = \pm 1$

as, $k(L) = \cos n\pi$

$k(L) = n\pi$

$\frac{2\cancel{\pi}}{\lambda}(L) = n\cancel{\pi}$

$\boxed{L = \frac{n\lambda}{2}}$

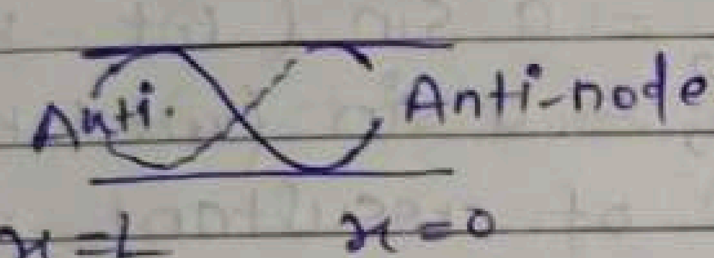
or $\boxed{\lambda = \frac{2L}{n}}$

For I^{st} mode of vibration put 'n = 1'

λ_1, ν_1 be the wavelength and freq. respect

$L = \frac{1 \times \lambda_1}{2}$

$L = \frac{\lambda_1}{2}$



or, $\boxed{\lambda_1 = 2L}$

let 'v' be the velocity of wave

$v = \nu_1 \lambda_1$

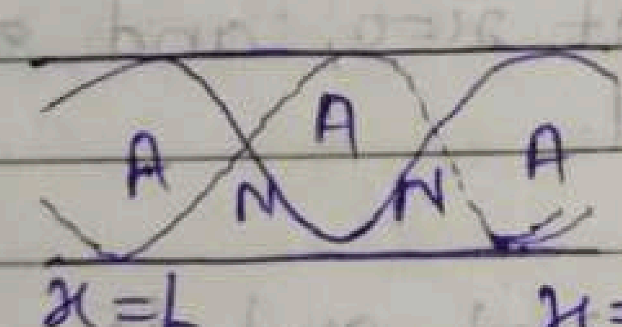
$\nu_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$

for II^{nd} mode of vibration : put n = 2

λ_2, ν_2 be the wavelength and fq.

$L = \frac{2 \times \lambda_2}{2}$

$\boxed{L = \lambda_2}$



$[\lambda_2 = L]$

'v' be the velocity of wave

$v = \nu_2 \cdot \lambda_2$

$\nu_2 = \frac{v}{\lambda_2} = \frac{v}{L}$

$\boxed{\nu_2 = \frac{v}{L}}$

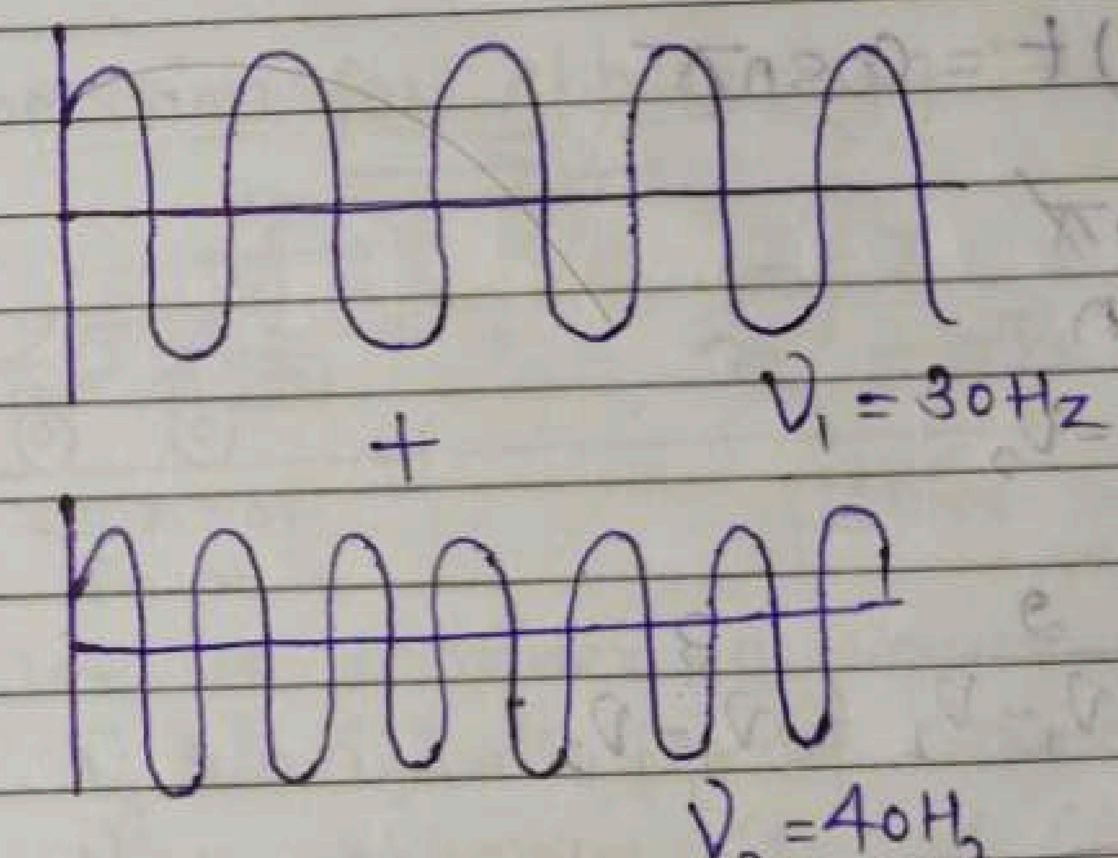
In general

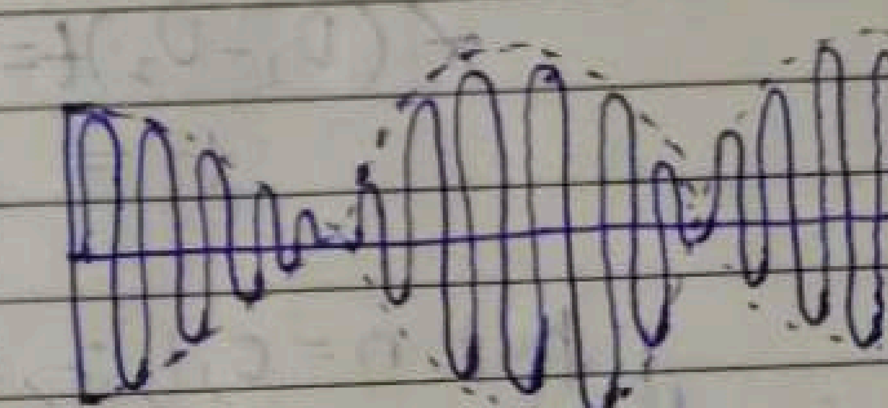
$\lambda_n = \frac{2L}{n}$

or, $\boxed{\nu_n = \frac{nv}{2L}}$

* **Beats** :- When two sound waves of same amp. but nearly same fq. moving in same direction superimpose with each other then beats are produced. Due to this the intensity of resultant sound at a particular position rises and falls alternately.

* Formation of Beats :





Beat fq. (b) = $\nu_2 - \nu_1$

Consider two sound waves having amp. (a) are moving in same direction with slightly different fq. ν_1 and ν_2 respect.

Then eq^n of wave is given by

$y_1 = a \sin \omega_1 t$

$y_2 = a \sin \omega_2 t$

Then eq^n for resultant wave will be

$y = y_1 + y_2$

$y = a \sin \omega_1 t + a \sin \omega_2 t$

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$y = a\sin 2\pi\nu_1 t + a\sin 2\pi\nu_2 \cdot t$

$= a[\sin 2\pi\nu_1 t + \sin 2\pi\nu_2 \cdot t]$

$y = a\left(\frac{2a\sin \nu b\pi t}{2}\ \cos \frac{2\pi\nu_1 t - 2\pi\nu_2 t}{2}\right.$

$y = 2a[\sin\pi(\nu_1+\nu_2)t \cdot \cos\pi(\nu_1-\nu_2)t$

as, intensity of resultant wave rise and fall alternately

Then for maxi. amplitude

$2a\cos\pi(\nu_1-\nu_2)t = max.$

$\cos\pi(\nu_1-\nu_2)t = \pm 1$

$\cos\pi(\nu_1-\nu_2)t = \cos n\pi$

$\cancel{\pi}(\nu_1-\nu_2)t = n\cancel{\pi}$

$t = \frac{n}{\nu_1-\nu_2}$

put $n = 0, 1, 2, 3$

$t = 0, \frac{1}{\nu_1-\nu_2}, \frac{2}{\nu_1-\nu_2}, \frac{3}{\nu_1-\nu_2}$

For ~~max.~~ minimum amplitude,

$2a\cos\pi(\nu_1-\nu_2)t = min$

$\cos\pi(\nu_1-\nu_2)t = 0$

$\cos\pi(\nu_1-\nu_2) = \cos(2n+1)\frac{\pi}{2}$

$\cancel{\pi}(\nu_1-\nu_2)t = (2n+1)\frac{\cancel{\pi}}{2}$

$t = \frac{(2n+1)}{2(\nu_1-\nu_2)}$

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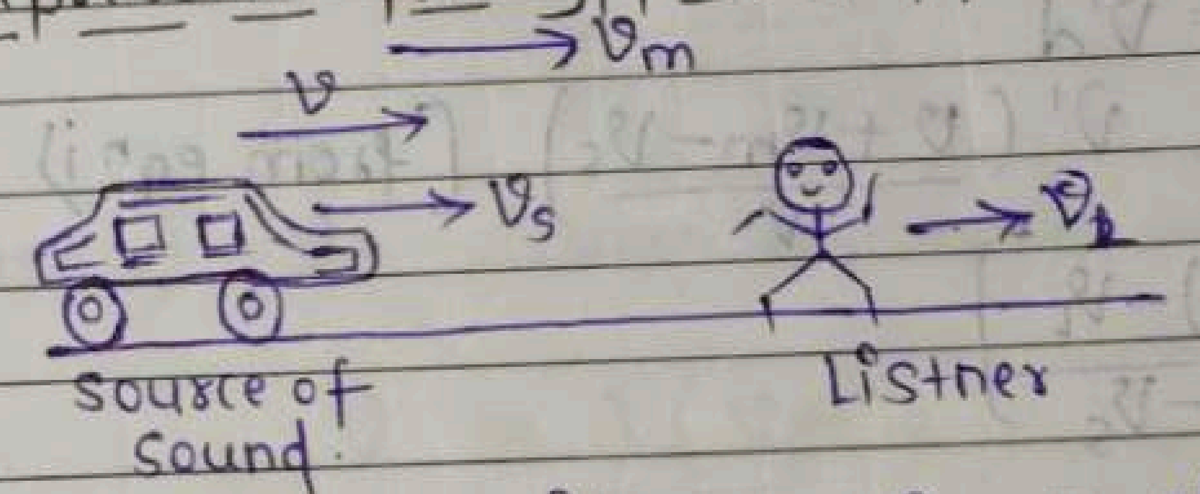
Put $n = 0, 1, 2, 3$

$t = \frac{1}{2(\nu_1-\nu_2)}, \frac{3}{2(\nu_1-\nu_2)}, \frac{5}{2(\nu_1-\nu_2)}$ ---

* **Doppler Effect of Sound:** Whenever their is a relative motion b/w a source of a sound and listner, Apparent fq. of sound heared by the listner is diff. from the actual fq. of sound emitted by source.

When dist. b/w source and listner increases, Apparent fq. heared by listner decreases. If the distance b/w source and listner decreases, the Apparent fq. heared by listner increases.

* Expression for Apparent fq. :-



Let us consider a source of sound 's' and listner 'L'

ν = original fq. of sound

ν' = apparent fq. of sound

v = velocity of sound

v_m = velocity of medium/air

v_s = velocity of sound

v_L = velocity of listner

Case I[st] : When both source and listner are at rest. Then, effective velocity of sound will increase due to medium velocity. So, relative velocity of sound with respect to air $= v + v_m$

Case IInd: When Source of sound moving towards listner

Relative velocity of sound w.r.t source $= (v+v_m) - v_s$

Let, λ = wavelength, ν = fq.

Then, $v = \nu\lambda$

$\lambda \cdot \nu = (v+v_m) - v_s$

$\lambda = \dfrac{(v+v_m) - v_s}{\nu}$ ——1)

Case IIIrd: When listner is moving towards left hand side then, relative velocity of sound w.r.t listner, $= v + v_m - v_L$

Then, ν' be the apparent fq.

λ = wavelength

as, $v = \nu'\lambda$

$(v+v_m) - v_L = \nu'\lambda$

$(v+v_m) - v_L = \nu'\left(\dfrac{v+v_m-v_s}{\nu}\right)$ [from eq^n i)

$$\left[\nu' = \frac{\nu(v+v_m) - v_L}{(v+v_m) - v_s}\right]$$

Case i) If wind/air is not blowing then put $v_m = 0$

$$\nu' = \frac{\nu(v - v_L)}{v - v_s}$$

Case ii) If listner is at rest $v_L = 0$ and source is moving towards listner

$$\nu' = \frac{\nu(v-0)}{v - v_s}$$

$$\left[\nu' = \frac{\nu v}{v - v_s}\right]$$

Case III) If listner is at rest and source is moving away from listner. put $v_s = -v_s$

$$\nu' = \frac{v \cdot \nu}{v - (-v_s)}$$

$$\nu' = \frac{v\nu}{v + v_s}$$

Case iv) If ~~listner~~ source is at rest and listner is moving towards source then, put $v_s = 0$, $v_L = -v_L$

$$\nu' = \frac{\nu(v - (-v_L))}{v - 0}$$

$$\nu' = \frac{\nu(v + v_L)}{v}$$

Case v) If ~~source~~ listner is moving away from listner

$$\nu' = \frac{\nu(v - v_L)}{v}$$

Case vi) When both source and listner are moving towards each other.

$v_s = +v_s$, $v_L = -v_L$

$$\nu' = \frac{\nu(v - (-v_L))}{v - v_s}$$

$$\nu' = \frac{\nu(v + v_L)}{v - v_s}$$

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Q=2

Ans- $\frac{1}{2}mv^2 = mgh$

Dimensional formula of LHS = $[M^1L^2T^{-2}]$
Dimensional formula of RHS = $[M][L][LT^{-2}]$
$= [M^1L^2T^{-2}]$

Q=3 $S = ut + \frac{1}{2}at^2$

Ans- $v = \frac{dx}{dt}$

$dx = v.dt$
$dx = (u+at).dt$
for total integrating both side

$$\int_{x_1}^{x_2} dx = \int_0^t (u+at).dt$$

$$[x_2 - x_1] = u[t-0] + \left[\frac{t^2}{2} - \frac{0}{2}\right]$$

$$S = ut + \frac{1}{2}at^2$$

Q=4 **Friction:** Friction is a force which opposses motion or applied force. It will act opp. to the direction of force or motion.

Laws of motion:
1) It is directly prop. to normal reaction.
2) It is acting in opp. direction.
3) It does not depend to nature of material.

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Q=5]

Ans- **Potential energy:** The energy possessed by body due to change its configuration or position known as potential energy. So, the potential energy of a spring is $\frac{1}{2}kx^2$.

Q=6]

Ans- **Geostationary Satellite:** The satellite which appears to be at rest of a fixed location w.r.t earth.

Condition for it:
i) The height of satellite is 36000 km.
ii) The orbital speed is 3.1 km/s
iii) It's time period is 24 hour.

Q=7] **Impulse:** Impulse may be defined as the product of force and time. It is denoted by I. It's S.I unit in Nm.

$$\boxed{I = F_{av} \cdot t}$$

Q=8] **Dimensional variable quantity:** The quantity which have dimensional formula and magnitude is variable. Ex- Force.

Q=9]

Ans- Coff. of friction:

$F \propto R$

as, $F = \mu R$

where 'μ' is called coff. of friction

It has no unit and no dimensional formula.

5. What is potential energy ? Find the expression for potential energy of a spring. (2)

6. What are geostationary satellite ? Write necessary condition for it. (2)

7. Write a short note on Impulse. (2)

8. What do you mean by dimensional variable quantities ? (2)

9. What do you mean by coefficient of friction ? (2)

10. What is mean by torque ? (2)

11. Find the kinetic energy of a ball of mass 20g moving with a speed of 10cm/sec. (2)

12. Given $x = \frac{A^p B^q}{C^r}$. Write an expression for percentage error in 'x'. (2)

13. Name and define the various absolute and gravitational units of Force. How are these units related to each other ? (3)

14. A simple pendulum having a bob attached to a string, that oscillates under the force of gravity. Suppose that the time period depends on it length (l), mass of bob (m) and acceleration due to gravity (g). Derive the expression of its time period, using method dimensions, (3)

15. Analytically derive the formula for the work done by one mole of an Ideal gas during isothermal expansion from volume V_1 to volume V_2. (3)

16. Find the torque of a force 7i + 4j – 5k about the origin whose position vector is i – j + k. (3)

17. State and prove theorem of perpendicular axis. Using this theorem, Find the moment of inertia of a disc about one of its diameters. (3)

18. Derive an expression for dalton's law of partial pressure. (3)

19. Derive an expression for effect of depth on 'g'. (3)

20. Derive an expression for
(a) Equation of trajectory (b) time of flight
(c) horizontal range of horizontal projection of projectile. (5)

OR

21. (i) State work – energy theorem. (2)
(ii) What is elastic potential energy ? Derive an expression for elastic Potential energy of a spring. (3)

OR

What do you mean by elastic collision ? Derive an expression for velocity of separation for one dimension elastic collision.

22. What is escape speed? Derive an expression for it. (5)

OR

Derive an expression for specific heat of a monoatomic gas. (5)

T^{-2})

opposses
t opp. to

Laws of motion:
i) It is directly prop. to normal reaction.
2) It is acting in opp. direction.
3) It does not depend to nature of material.

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Ans- Coff. of friction:
$F \propto R$
as, $F = \mu R$
where 'μ' is called coff. of friction
It has no unit and no dimensional formula.

Case viii) When both source and listner are moving away from each other

$v_s = -v_s$, $v_l = v_l$

$$v' = \frac{v(v - v_l)}{v - (-v_s)} = \boxed{\frac{v(v - v_l)}{v + v_s}}$$

Good

8/12/23

December Exam:

Q=1

i) Impulse

ii) Both K.E and mom. conserved.

iii) 3.6×10^6 J

iv) $T^2 \propto R^3$

v) Zero

vi) Remains same

vii) 3

viii) Low press. and high temp.

ix) kgm^2

x) 9.5×10^{16} m.

xi) 4

xii) 24 hours.

xiii) $v = \sqrt{gR}$

xiv) Gravitational force.

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Case vii) When both source and listner are moving away from each other

$v_s = -v_s$, $v_L = v_L$

$$v' = \frac{v(v - v_L)}{v - (-v_s)} = \boxed{\frac{v(v - v_L)}{v + v_s}}$$

8/12/23

December Exam:

Q=1

i) Impu

ii) Both

iii) 3.6 x

iv) $T^2 \propto$

v) Zero

vi) Rem

vii) 3

viii) Low

ix) Kg

x) 9.5

xi) 4

xii) 24

xiii) $V = \sqrt{gR}$

xiv) Gravitational force.

Roll no. = 19

SHIVA PUB. SR. SEC.SCHOOL,DAHINA

Sub - Physics   Class – 11th 'As'   M.M=70

Time : 3:00 Hrs.   Dec. Exam .2023

1.(i) Pick the only vector quantity in the following list :
(a)Temperature (b) Impulse
(c) current (d) charge

(ii) In an elastic collision of two bodies , which of the following physical quantities are conserved ?
(a) Kinetic energy only (b) Momentum only
(c)Both kinetic energy and momentum (d) None

(iii) 1 killowatt – hour is equivalent to :
(a) 10^{-7} Joule (b) 1.6×10^{-19}J (C) 4.186J (d) 3.6×10^{6}J

(iv) Kepler third ;law related to the planetary motion is :
(a)$T \propto r$ (b) $T \propto r^2$ (c) $T \propto r^3$ (d) $T \propto r2^{3/2}$

(v) The weight of a body at the centre of the earth is :
(a) Zero (b) infinite (c) Slightly less than at the poles
(d) Slightly less than at the equator

(vi) In a cyclic process , the internal energy of a gas
(a) Increases (b) decreases (c) Remain same (d) Zero

(vii) The number of degree of freedom of molecule of a monatomic gas will be : (a) 1 (b) 2 (c) 3 (d) 4

(viii) At what condition real gas approach ideal gas behavior ?
(a)Low pressure and low temperature .
(b)Low pressure and high temperature .
(c)High pressure and high temperature
(d)High pressure and low temperature

(ix) Unit of moment of inertia in S.I system is :
(a)$Kglm^2$ (b) Kgm^2 (c) kgm (d) kgm/sec

(x) One light year = ________.
(a) 1.5×10^{11} m (b) 9.5×10^{16}m (c)3.1×10^{16}m (d)4.7×10^{20}m

(xi) Number of significant in 4.304 are : (a) 2 (b) 4 (c) 3 (d) 5

(xii) Time period of geostationary satellite is :
(a)100 minutes (b) 24 hours (c) 12 hours (d) Infinite

(xiii) Correct expression for orbital velocity near the surface of earth is :
(a)$v = \sqrt{0.5\,gr}$ (b) $v = \sqrt{gr}$ (c) $v=\sqrt{1.5\,gr}$ (d) $v=\sqrt{2gr}$

(xiv) The force of attraction between earth and object is known as :
(a)Gravitational force (b) equator
(c) gravity (d) centripetal force (1x14=14)

2. Check whether $\frac{1}{2}m\vartheta^2$ = mgh equation is dimensionally correct or not. Here 'm' is mass , ϑ is velocity , g is gravitational acceleration and 'h' is height . (2)

3. Obtain equation of motion S= ut + $\frac{1}{2}$at^2 for constant acceleration using method of calculus. (2)

4. What do you mean by friction ? Write laws of friction. (2)

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Q=21)

i) $d\omega = F \cdot dx$

$d\omega = ma \cdot dx$

$d\omega = m\frac{dv}{dt} \cdot dx$

$d\omega = mv \cdot dv$

for total integrate both side

$$\int d\omega = \int_u^v mv \cdot dv$$

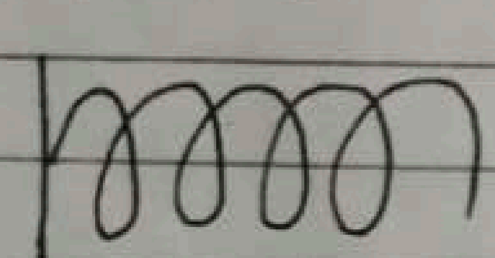
$$\omega = \int d\omega = m\int v \cdot dv$$

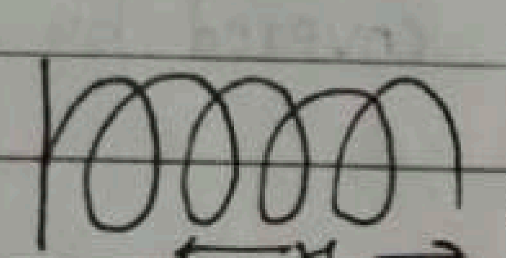
$$\omega = m\left[\frac{v^2}{2} - \frac{u^2}{2}\right]$$

$$\omega = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$$

ii) **Elastic potential energy**: The energy possessed by body due to change its Configuration.
The force which back the spring about its original Config. about removal of applied force.

Expression:





→ Applied force

← Restoring force.

Let a variable force is acting on a body. 'x' be the disp. work will be stored in the form of elastic potential energy.

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$d\omega = F \cdot dx$

$d\omega = Fdx \cos 180^\circ$

$d\omega = -Fdx$

as,

$F = -Kx$

Put this value

$d\omega = -(-Kx)dx$

$d\omega = Kxdx$

integrating the eqⁿ

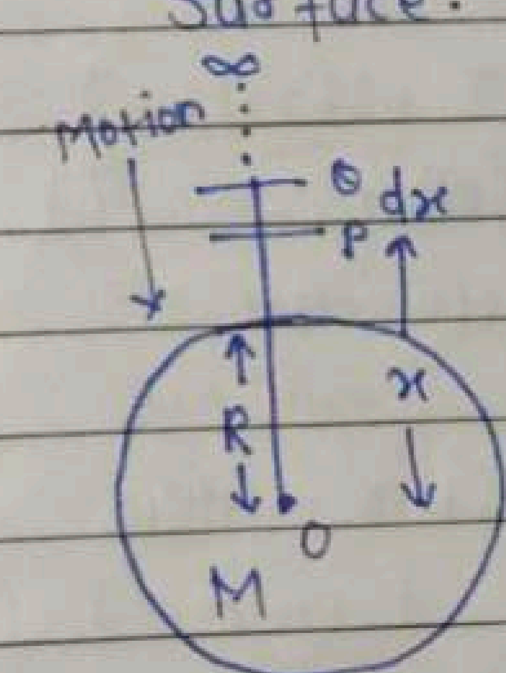
$$\omega = \int d\omega = \int Kxdx$$

$$\omega = \frac{Kx^2}{2}$$

Then, potential energy of a elastic spring $= \frac{1}{2}Kx^2$

Q=22)

Ans - **Escape velocity**: The minimum velocity through which a body is thrown upward from the surface of earth and never returns on the earth surface. It is denoted by v_e.



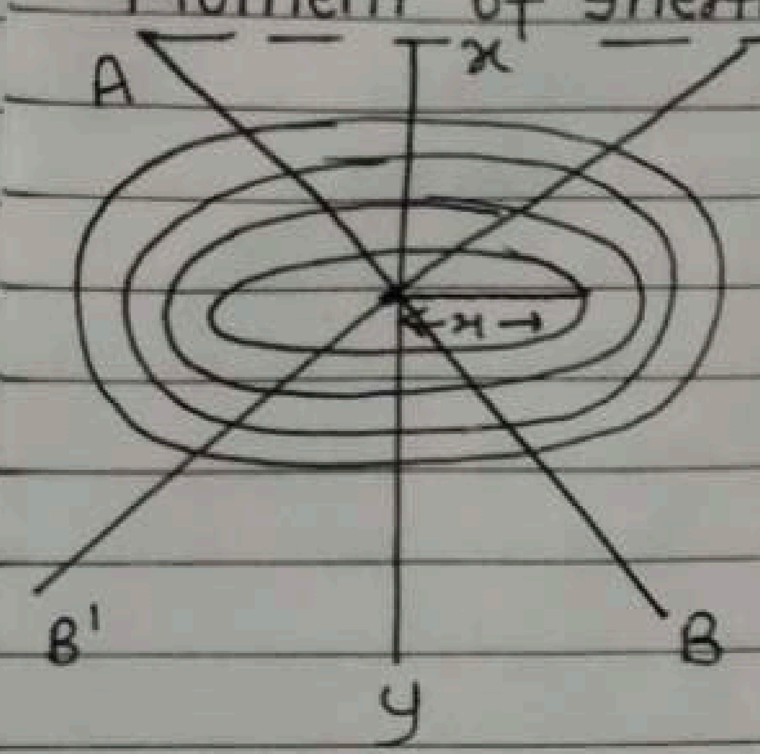
Let a earth be as sphere of mass 'M' with radius 'R'. Let 'dx' be the small displacement. 'dω' be the small workdone.

$d\omega = F \cdot dx$

As, $F = \frac{GMm}{x^2}$

$$d\omega = F \cdot \frac{GMm}{x^2} \cdot dx$$

Moment of Inertia about disc:



Let xy $A'B'$ and AB be the axis passing through the diameter of disc. I be the moment of inertia

$$I_d + I_d = I$$
$$2I_d = I$$
$$I_d = \frac{I}{2} \quad -(*)$$

as, $I = \frac{MR^2}{2}$

Put value in (*)

$$I_d = \frac{MR^2}{2} \times \frac{1}{2} = \frac{MR^2}{4}$$

18) Dalton's law of partial pressure: Acc. to this law the pressure exerted by the mixture of gases will be equal to the sum of partial pressure of the gases if each gas occupy same Volm in a given temp.
Let 'p' be the total pressure and P_1, P_2, P_3 --- be the partial pressure.

As, we know

$$P = \frac{1}{3}\rho v^2$$

$$P = \frac{1}{3}\frac{M}{V} \cdot v^2$$

$$P_1 = \frac{1}{3}\frac{M_1}{V_1} \cdot v_1^2 \quad P_2 = \frac{1}{3}\frac{M_2}{V_2} \cdot v_2^2 \; ----$$

$$P_1 + P_2 + --- = \frac{1}{3}\frac{M_1}{V_1} v_1^2 + \frac{1}{3}\frac{M_2}{V_2} \cdot v_2^2 + ---$$

$v_1 = v_2 = v$
$V_1 = V_2 = V$

$$\Rightarrow \frac{1}{3V}[M_1 + M_2 + --]v^2 = \frac{1}{3}\frac{M}{V} \cdot v^2 = \frac{1}{3}\rho v^2$$

20)

Ans= Eqn of Trajectory: Let 'x' be the displacement 'u' and 'a' be the acc. and initial velocity.

As, $S = ut + \frac{1}{2}at^2$

$S = x, \quad u_x = u, \quad a_x = 0$

$$x = u_x \cdot t + \frac{1}{2}a_x \cdot t^2$$
$$x = u \cdot t + 0$$
$$t = \frac{x}{u}$$

Along y-axis

$$S = ut + \frac{1}{2}at^2$$
$$S = y, \quad u_y = 0, \quad a_y = +g$$
$$y = 0 \times t + \frac{1}{2}gt^2$$
$$y = \frac{1}{2}gt^2$$

* Time of flight: It is the time taken by the flight to complete its Journey.

$$S = ut + \frac{1}{2}at^2$$

Along y-axis

$$H = ut + \frac{1}{2} \times g \times t^2$$
$$H = 0 + \frac{1}{2}gt^2$$

$$T = \sqrt{\frac{2h}{g}}$$

* Horizontal Range: It is the total dist covered by projectile to complete it's Journey.

$S = R, \quad u = u_x, \quad a_x = ~~+g~~ \; 0$

$$R = ut + \frac{1}{2} \times 0 \times T^2$$
$$R = u\sqrt{\frac{2h}{g}}$$

Q=15

Ans- Let 'dx' be the small disp. , then 'dW' be the small workdone.

$dW = F \cdot dx$

Where P is called pressure exerted and A be the area.

$P = \frac{F}{A}$

$F = P \cdot A$

$dW = P \cdot A \cdot dx$

$dW = P \cdot dv$

Integrate both side

$\int dW = \int_{V_1}^{V_2} P \cdot dv$

$W = \int_{V_1}^{V_2} P \cdot dv$

using ideal gas

$PV = RT$

$P = \frac{RT}{V}$

$W = \int_{V_1}^{V_2} \frac{RT}{V} \cdot dv$

$W = RT [V_e^2 - V_{1e}^2]$

$W = RT [V_e^m - V^n = \frac{V_2}{V_1}]$

$W = RT \log_{10} \frac{V_2}{V_1}$

$W = 2.303 RT \log_{10} \frac{V_2}{V_1}$

16)

Ans- $\vec{r} = \hat{i} - \hat{j} + k$.

$\vec{F} = 7\hat{i} + 4\hat{j} - 5\hat{k}$

$\vec{\tau} = ?$

$\vec{\tau} = \vec{r} \times \vec{F}$

$\vec{\tau} = \hat{i} - \hat{j} + \hat{k} \times 7\hat{i} + 4\hat{j} - 5\hat{k}$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -1 & 1 \\ 7 & 4 & -5 \end{vmatrix}$$

$\hat{i}(5-4) + \hat{j}(7+5) + \hat{k}(4+7)$

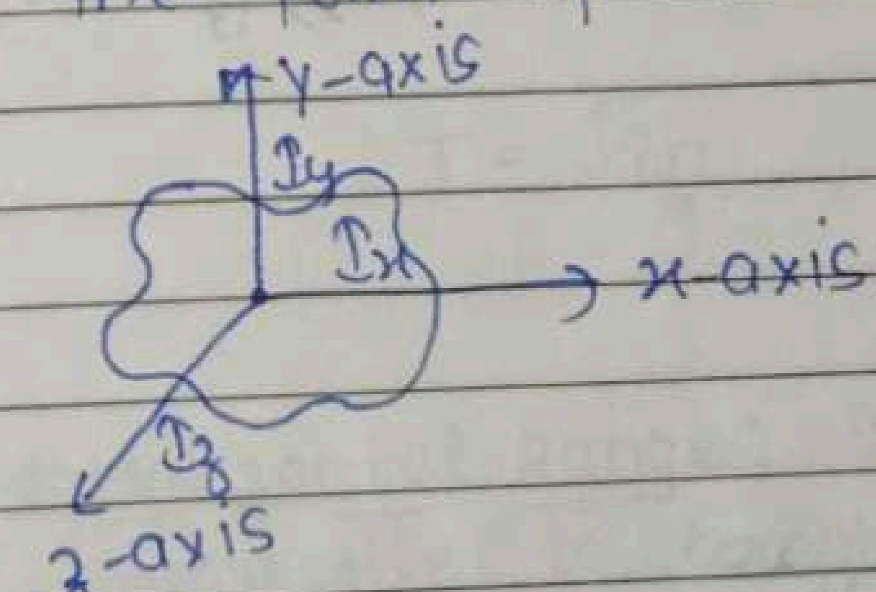
$\hat{i} + 12\hat{j} + 11\hat{k}$

Magnitude $= \sqrt{(1)^2 + (12)^2 + (11)^2}$

$\sqrt{1 + 144 + 121} = \sqrt{266}$

17)

Ans- Th^m of $\perp$ axis : The moment of inertia about an axis will be equal to the sum of moment of inertia of two mutually ⊥ axis passing throug the point of intersection at any be axis



let I_x, I_y, I_z be the moment of inertia along x-axis, y-axis and z-axis

$I_x = I_y + I_z$

$I_y = I_z + I_x$

$I_z = I_x + I_y$

Q= 10

Ans- Torque: Turning effect of the force is called torque. It is denoted by 'τ'. It S.I unit is Nm. It is also known as movement of force.

$\vec{\tau} = \vec{r} \times \vec{F}$

Q=11

Ans- K.E = ?

Mass = 20Kg

Speed = 10 cm/sec.

$= \frac{1}{2} \times m \times v^2$

$= \frac{1}{2} \times \frac{1}{50} \times \left(\frac{1}{10}\right)^2 = \frac{1}{10,000} J$

Q=12 $X = \frac{A^p B^q}{r^c}$

Ans- Relative error in 'x'

$\frac{\Delta x}{x} = \frac{p \Delta a}{a} + \frac{q \Delta b}{b} + \frac{r \Delta c}{c}$

% error =

$\frac{\Delta x}{x} \times 100 = \frac{p \Delta a}{a} \times 100 + q \frac{\Delta b}{b} \times 100 + \frac{r \Delta c}{c} \times 100$

Q=13

Absolute units:

(a) S.I unit: $F = ma$

$1N = 1 kg m s^{-2}$

When 1 kg mass of an obj. produce an acc. of $1 ms^{-2}$ then force will be 1N.

(b) C.G.S unit: $F = ma$

dyne = $gm cm s^{-2}$

Gravitational units:

(a) S.I unit: $F = mg$

$1 kgf = 1 kg \times 9.8 ms^{-2}$

When 1 kg mass of an obj. produce an accelerat. of $9.8 ms^{-2}$ then force will be 1 kgf.

(b) C.G.S unit: $F = mg$

$1 gf = 1 gm \times 980 cm s^{-2}$

$1 gf = 980$ dyne

When 1 gm mass of an obj. produce an acc. of $980 cm s^{-2}$ is called to be 1 gf.

Q=14

Ans- $t \propto M l g$ — ①

$t = K M^a l^b g^c$

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

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

equate M, L, T from both side

$1 = -2c$ | $b = \frac{1}{2}$

$c = -\frac{1}{2}$ | $a = 0$

Put these in eqn ①

$t \propto l^{1/2} g^{-1/2}$

$t = K \sqrt{\frac{l}{g}}$

$K = 2\pi$

$t = 2\pi \sqrt{l/g}$

Integrating both side

$$\int dw = \int_R^{\infty} \frac{GMm \cdot dx}{x^2}$$

$$w = \int dw = GMm \int_R^{\infty} \frac{1}{x^2} \cdot dx$$

$$w = GMm \left[\frac{x^{-2+1}}{-2+1} \right]_R^{\infty}$$

$$w = GMm \left[\frac{-1}{\infty} + \frac{1}{R} \right]$$

$$w = \frac{GMm}{R}$$

As, $K \cdot E = w$

$$\frac{1}{2} \cancel{m} v_e^2 = \frac{GM\cancel{m}}{R}$$

$$v_e^2 = \frac{2GM}{R}$$

$$v_e = \sqrt{\frac{2GM}{R}} \quad \text{as, } GM = gR^2$$

$$v_e = \frac{\sqrt{2gR^{\cancel{2}}}}{\cancel{R}}$$

$$v_e = \sqrt{2gR}$$

$$v_e \cong 11.2 \text{ kms}^{-1}$$

Good

30/12/23

Unit=7

Properties of Bulk matter ~~and~~ Radiations

Chapter- Ist

'Elasticity'

* **Deforming force:** Deforming force is a force which changes shape and size of a body.

* **Restoring force:** The force which helps to regain its original shape and size after removal of deforming force is called restoring force.

* **Elasticity:** The property of material of body to regain its original shape and size after removal of deforming force is called Elasticity.

* **Perfectly Elastic body:** A body which regain 100% its original shape and size after removal of deformin force is called perfectly elastic body. Their is no body which is perfectly elastic but Quartz and Phosphorus Bronze are nearly perfectly elastic body.

* **Perfectly Plastic body:** A body which does not regain its original shape and size at all after removal of deforming force. is called perfectly plastic body. No body is perfectly plastic body but Paraffin wax are examples of nearly plastic body.

* **Elastic limit:** Elastic limit is the largest value of deforming force upto which the body will regain it's shape and size after removal of deforming force. Whereas Elastic limit is the property of body whereas Elasticity is the property of material of body.