Date: 23-11-25 Physics Day: Sunday

Topic:- Chapter # 07

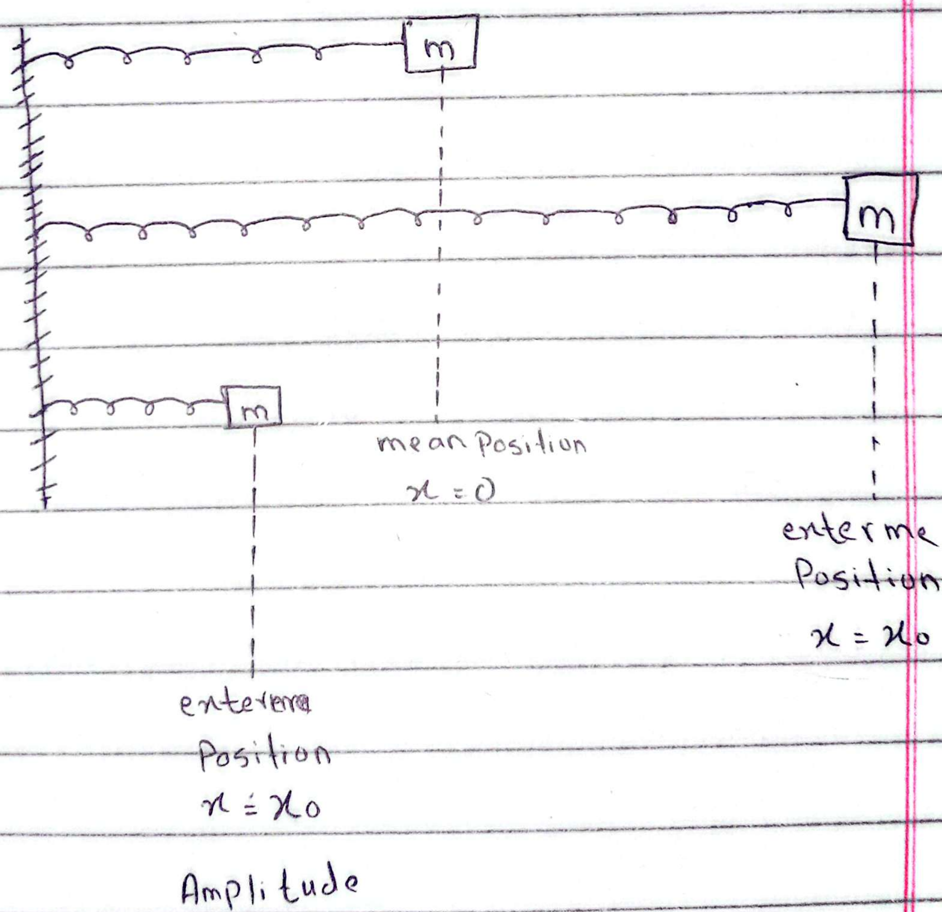
Oscillations

* Simple Harmonic motion:- There are two conditions for a motion to be a simple harmonic motion.

1) Accleration is directly proportional to displacement. $a \propto x$.
2) It is directed towards the mean position.

$a \propto -x$

Mass attached to a spring.



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According to Hook's Law

$F = -kx$ — (I)

According to Newton's 2nd Law.

$F = ma$ — (II)

comparing equ (I) & (II)

$ma = -kx$

$a = -\left(\frac{k}{m}\right)x$

$a = -\omega^2 x$ where

$\omega^2 = k/m$ or $\omega = \sqrt{\frac{k}{m}}$

$\boxed{a \propto -x}$

So we can say that the motion of mass attached to spring is SHM.

Time Period:- Time required to complete one vibration.

$T = \frac{2\pi}{\omega} \Rightarrow T = \frac{2\pi}{\sqrt{\frac{k}{m}}}$

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

Frequency:- Numbers of vibrations completed in one second. $F = \frac{1}{T}$

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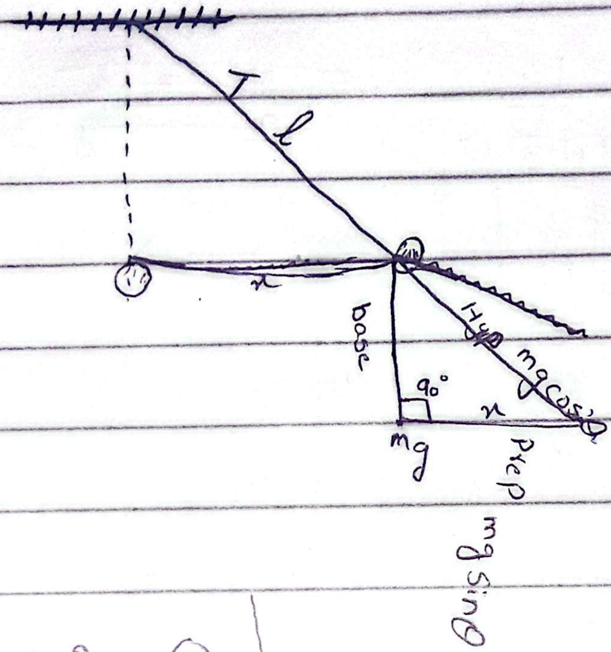
$$f = \frac{1}{2\pi\sqrt{\frac{m}{K}}}$$

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}}$$

* Simple Pendulum:-



$F = -mg\sin\theta$ —(1)

from the fig.

$\sin\theta = \frac{Perp}{Hyp}$

$\sin\theta = \frac{x}{l}$

Put in equ (1)

$F = -mg\left(\frac{x}{l}\right)$ —(11)

From newton second law of motion.

$F = ma$ —(111)

comparing equ (11) & (111)

$\cancel{m}a = -\cancel{m}g\left(\frac{x}{l}\right)$

$$\boxed{a = -\left(\frac{g}{l}\right)x}$$

Where $\omega^2 = \frac{g}{l}$ or $\omega = \sqrt{\frac{g}{l}}$

$\boxed{a \alpha -x}$

Time Period:- $T = \frac{2\pi}{\omega}$

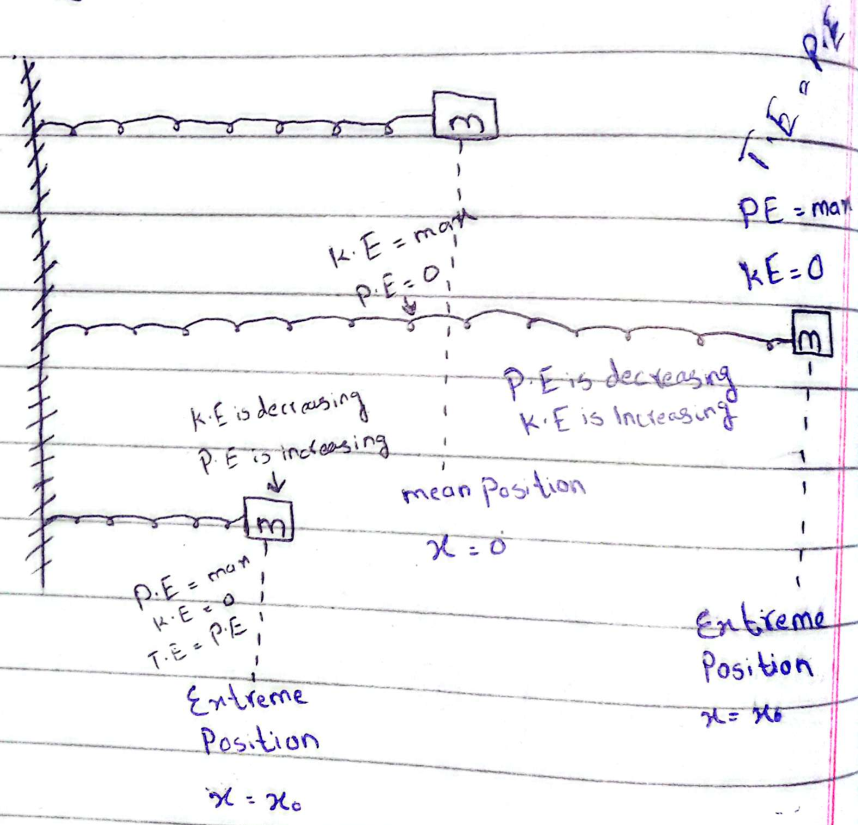
$$T = \frac{2\pi}{\sqrt{\frac{g}{L}}} \Rightarrow \boxed{T = 2\pi\sqrt{\frac{L}{g}}}$$

Frequency $\Rightarrow F = \frac{1}{T}$

$$F = \frac{1}{2\pi\sqrt{\frac{L}{g}}} \qquad \cancel{F = \frac{1}{2}\,2\pi\sqrt{\frac{L}{g}}}$$

$$\boxed{F = \frac{1}{2\pi}\sqrt{\frac{g}{L}}} \qquad \cancel{\frac{\sqrt{g}}{2\pi\sqrt{L}}}$$

* Energy conservation in SHM.



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According to Hook's law:

$F = kx$ — (i)

When $x = 0$

$F = 0$

When $x = x_0$

$F = kx_0$

Average force $= F = \frac{0 + kx_0}{2}$

$$\boxed{F = \frac{1}{2} k x_0}$$

Work $= F \cdot d$

$W = \frac{1}{2} k x_0 \cdot x_0 \Rightarrow \boxed{P.E = \frac{1}{2} k x_0^2}$ — (ii)

At extreme

* P.E at any point:- $\boxed{\frac{1}{2} k x^2}$ — (iii)

The K.E is given as :- $K.E = \frac{1}{2} m v^2$

$K.E = \frac{1}{2} m \left[\sqrt{\frac{k}{m}(x_0^2 - x^2)}\right]^2$

$\because V = \omega \sqrt{x_0^2 - x^2}$

$V = \sqrt{\frac{k}{m}} \times \sqrt{x_0^2 - x^2}$

$= \sqrt{\frac{k}{m}(x_0^2 - x^2)}$

$K.E = \frac{1}{2} \cancel{m} \left[\frac{k}{\cancel{m}} (x_0^2 - x^2)\right]$

$K.E = \frac{1}{2} k (x_0^2 - x^2)$

$$\boxed{K.E = \frac{1}{2} k x_0^2 \left[1 - \frac{x^2}{x_0^2}\right]}$$ (iv)

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Now at mean position

$x = 0$

$$K.E = \frac{1}{2} k x_0^2 \left[1 - \frac{0}{x_0^2}\right]$$

$$\boxed{(K.E)_{max} = \frac{1}{2} k x_0^2} \quad (v)$$

$$T.E = K.E + P.E$$

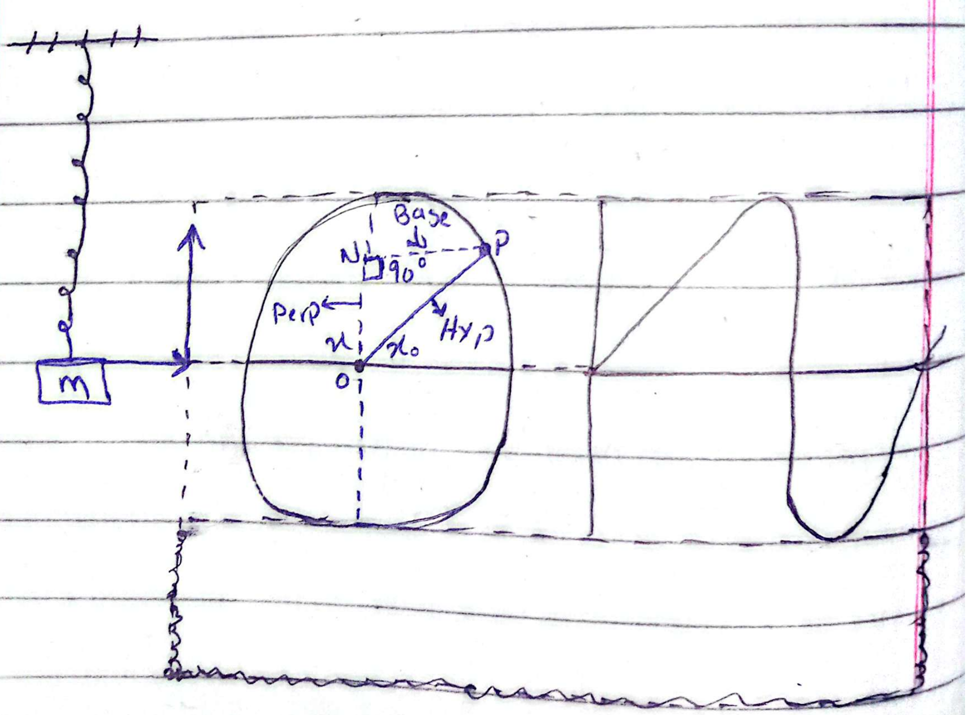
$$= \frac{1}{2} k x_0^2 \left\{1 - \frac{x^2}{x_0^2}\right] + \frac{1}{2} k x^2$$

$$= \frac{1}{2} k x_0^2 - \frac{1}{2} k \cancel{x_0^2} \left(\frac{x^2}{\cancel{x_0^2}}\right) + \frac{1}{2} k x^2$$

$$= \frac{1}{2} k x_0^2 - \cancel{\frac{1}{2} k x^2} + \cancel{\frac{1}{2} k x^2}$$

$$\Rightarrow \boxed{T.E = \frac{1}{2} k x_0^2}$$

* Simple Harmonic motion and circular motion.



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* Displacement

$\sin\theta = \frac{Perp}{HYP}$

$\sin\theta = \frac{x}{x_0}$ $\because \theta = \omega t$

$x = x_0 \sin\theta$

$\boxed{x = x_0 \sin\omega t}$

$\cos\omega t = \frac{base}{HYP}$

$(HYP)^2 = (Perp)^2 + (base)^2$

$x_0^2 = x^2 + (NP)^2$

$\sqrt{x_0^2 - x^2} = \sqrt{(NP)^{\cancel{2}}}$

$\sqrt{x_0^2 - x^2} = NP$

$\cos\omega t = \frac{\sqrt{x_0^2 - x^2}}{x_0}$

Put in equ ①

$V = x_0 \omega \cos\omega t$

$V = \cancel{x_0}\omega \times \frac{\sqrt{x_0^2 - x^2}}{\cancel{x_0}}$

$\boxed{V = \omega\sqrt{x_0^2 - x^2}}$

* Instantaneous velocity

$x = x_0 \sin\omega t$

Diff. w.r.t 't'

$\frac{dx}{dt} = x_0 \cos\omega t\,(\omega)$

$V = x_0 \omega \cos\omega t$ — ①

* Acceleration:-

$V = x_0 \omega \cos\omega t$

Diff w.r.t 't'

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$-x_0 \omega \sin \omega t \; (\omega)$

$$\frac{dv}{dt} = -x_0 \omega \sin \omega t \; (\omega)$$

$$a = -\omega^2 x_0 \sin \omega t$$

$$\boxed{a = -\omega^2 x}$$

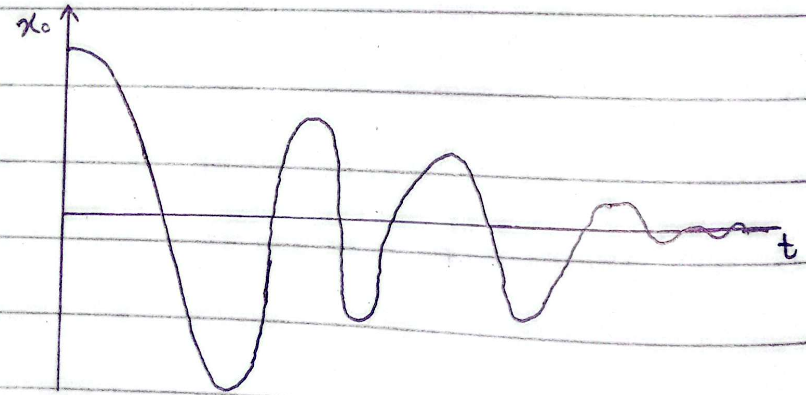
* **Free and forced ~~osc~~ Oscillations.**

A body is said to be having free oscillations if it oscillate without the interfarance of an external force. e.g:- Motion of Pendulum.

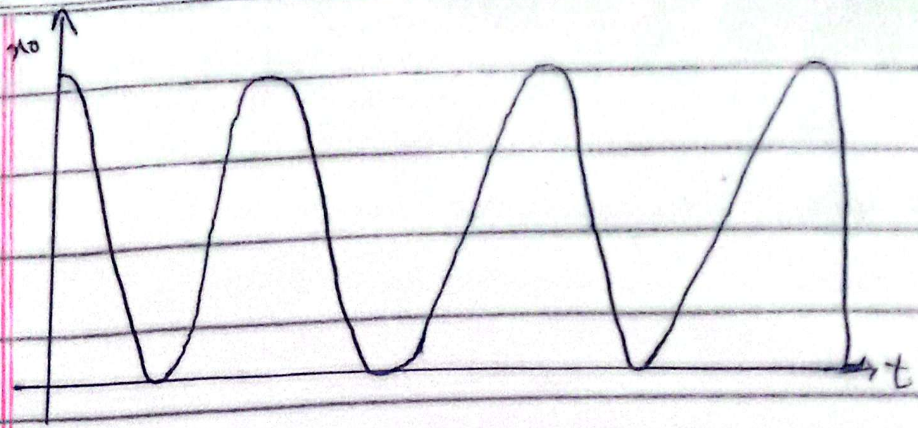
A body is said to be having forced oscillation if it oscillate under the action of an external force. e.g:- Road vibrates due to train movement.

* **Damped Oscillation:-**

The Oscillation in which Amplitude of vibration decreases with time is called damped Oscillation.



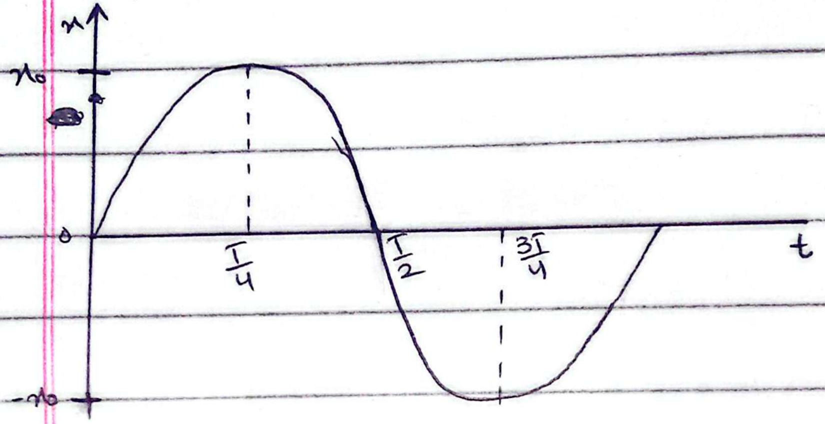
-: Damped oscillation:-



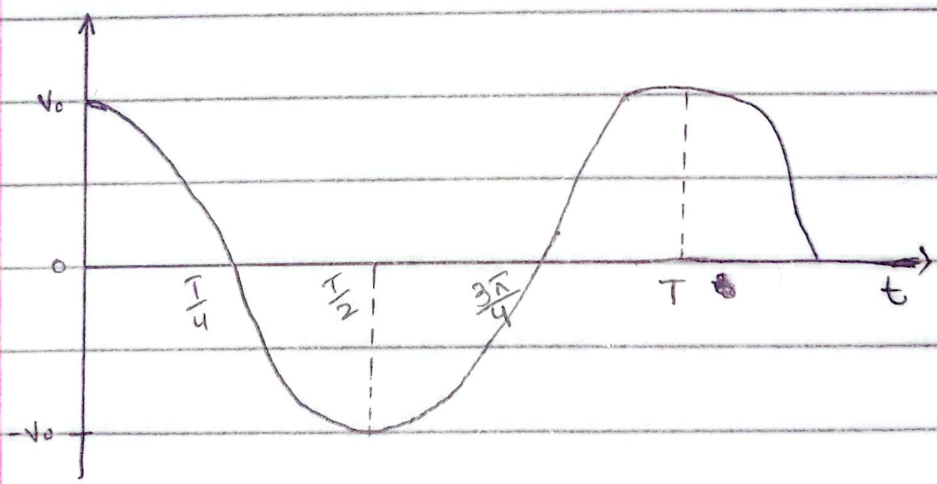
undamped oscillation

:- Graphs :-

i) Displacement - Time graph.



ii) Velocity - Time graph



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* Resonance:- It occour when the frequency of applied force is equal to the one of the natural frequences of a body.

* Application of damped oscillation.

1) Simple pendulum.
2) Swing
3) Shock absorbed
4) ~~RAtC~~ RLC Circuit

* Phase:- The angle $\theta = \omega t$ which specifies the displacement as well as direction of motion having SHM.

* Angular frequency:- It is defined as the angular displacement per unit of time.

$$\omega = \frac{\theta}{t}$$