SAME DIMENSIONS

■ 1. Any kind of energy work done, heat, torque, couple, moment of force.

- mgh
- $\frac{1}{2}mv^2$
- $\frac{1}{2}LI^2$ [L = Self Inductance]
- $\frac{1}{2}Kx^2$ [K = Spring Constant]
- $\frac{1}{2}mw^2x^2$ [P.E. in SHM]
- $\frac{1}{2}mw^2\left(a^2 - x^2\right)$ [K.E. in SHM]
- $P\triangle V$
- $\frac{3}{2}$ RT(Kinetic theoty of gas) [for 1 mol gas]
  R = universal gas constant
- $\frac{3}{2}$ KT [for 1 molecule gas] K = Boltzman's constant
- $\frac{I^2RT}{J}$ [joule's heating effect]
- $\frac{1}{2}\frac{Q^2}{C}$, $\frac{1}{2}CV^2$, $\frac{1}{2}QV$
- $\frac{1}{2}IW^2$(rotation) I = moment of inertia
- $+\underset{[K.E]}{\frac{GMm}{2r}}$, $-\underset{[P.E]}{\frac{GMm}{r}}$, $-\underset{[T.E]}{\frac{GMm}{2r}}$] gravitation
- $+13.6\frac{z^2}{n^2}$ eV (atomic structure kinetic energy)
- $-27.2\frac{z^2}{n^2}$ eV (atomic structure potential energy)
- $-13.6\frac{z^2}{n^2}$ eV (atomic structure total energy)
- IE = (-TE) [IE = Ionisation energy
  TE = total energy]
- Rhc [R = Rydberg's constant
  h = Planck's constant
  c = speed of EM wave]

— $[ML^2T^{-2}]$

■ 2. Linear momentum
Linear impulse] – $[MLT^{-1}]$

■ 3. Angular Momentum
Angular Impulse
Planck's constant $[h = 6.626 \times 10^{-34} J - S]$] – $[ML^2T^{-1}]$

■ 4. $\frac{L}{R}$
CR
$\sqrt{LC}$] – [T] (see Growth current, Decay current, Charging and discharging of RC circuit)

- 5.

$\frac{R}{L}$

$\frac{1}{RC}$

$\frac{1}{\sqrt{LC}}$

Frequency, ω, velocity gradient,
Decay constant,
Activity of a radioactive substance – $[T^{-1}]$

- 6.

Stress (Tensor)
Pressure (Scalar)
Young's Modulus (Y)
Bulk Modulus (B)
Rigidity Modulus (η)
Energy Density

→ $\frac{1}{2}$ x stress x strain (elasticity)

→ $\frac{1}{2}\frac{B^2_{r.m.s}}{\mu_o}$ (energy density of solenoid or magnetic field energy density of EM wave)

→ $\frac{1}{2}\epsilon_o E^2_{r.m.s.}$ (energy density of capacitor or electric field energy density of EM wave)

ϵ_o = Permittivity of free space Permeability
μ_o = Permeability of free space

– $[ML^{-1}T^{-2}]$

- 7. Velocity of electromagnetic wave – $[LT^{-1}]$

$C = \frac{E_o}{B_o} = \frac{1}{\sqrt{\mu_o \epsilon_o}}$

At first orbit of H,

Velocity of e^- = $\frac{c}{137}$

C = speed of EMW in zero medium.

- 8. Angle, strain, sin θ, π, e^x – $[M^0L^0T^0]$
Refractive index

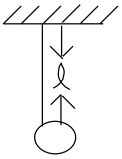
TIME PERIOD ZONE

■ 1.

SHM — $\boxed{T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}}}$ [for second pendulum; $T = 2S$, $l = 99.3$ cm]

■ 2.

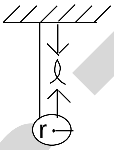
Simple pendulum — $\boxed{T = 2\pi\sqrt{\frac{l}{g}}}$



[Radius of the bob is negligable]

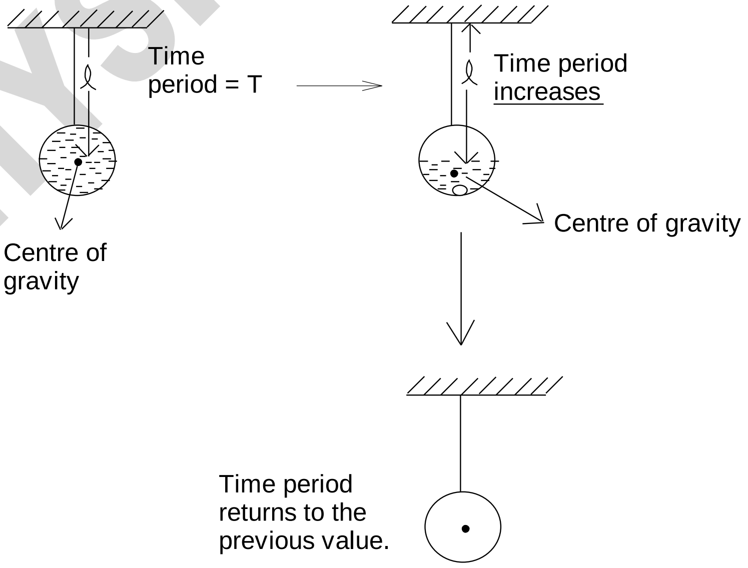
■ 3.

Simple pendulum — $\boxed{T = 2\pi\sqrt{\frac{l+r}{g}}}$



MCQ

Simple pendulum, bob is filled with water , a hole is made at bottom, water is allowed to flow. what will be the change in it's time period?



■ 4.

Simple pendulum (When the length of the pendulum is comparable to the radius of earth) —

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

$[R_e = 6400 \text{ km}]$

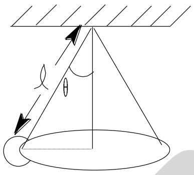
If $l \gg R$, then $T = 2\pi\sqrt{\frac{R}{g}} \approx 84.6$ min

If $l \approx R_e$, then $T = 2\pi\sqrt{\frac{R}{2g}} \approx 1$ hour

■ 5.

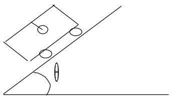
Conical pendulum —

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



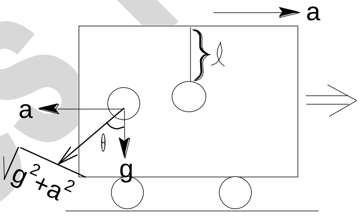
■ 6. Pendulum moving along a inclined plane of inclination (θ)

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



■ 7. Pendulum in a moving car, with acceleration 'a'

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

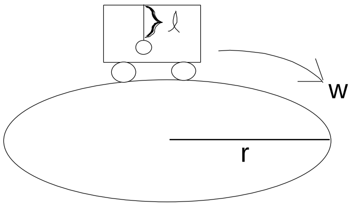


$$\tan\theta = \frac{a}{g}$$

$$\theta = \tan^{-1}\left(\frac{a}{g}\right)$$

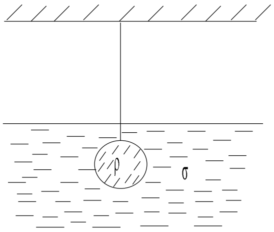
■ 8. Pendulum involving in a circular track (radius 'r') with 'w' angular velocity

$$T = 2\pi\sqrt{\frac{l}{\sqrt{g^2+(w^2r)^2}}}$$



■ 9. When bob of pendulum is immersed in liquid

$$T = 2\pi\sqrt{\frac{l}{g\left(1-\frac{\sigma}{\rho}\right)}}$$

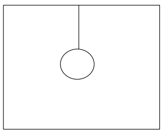


σ = density of liquid

ρ = density of body

Pendulum in lift

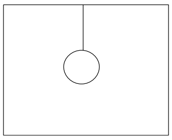
■ 10.



↓ or ↑ lift is moving upwards or downwards in uniform velocity/lift is at rest

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

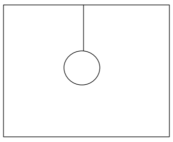
■ 11.



↑ lift is moving upward with 'a' acceleration

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

■ 12.



↓ lift is moving downward with 'a' acceleration

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

↙ ↘

<u>MCQ</u>

If string breaks, (a=g)

$T = \infty$

frequency = 0

(weightlessness)

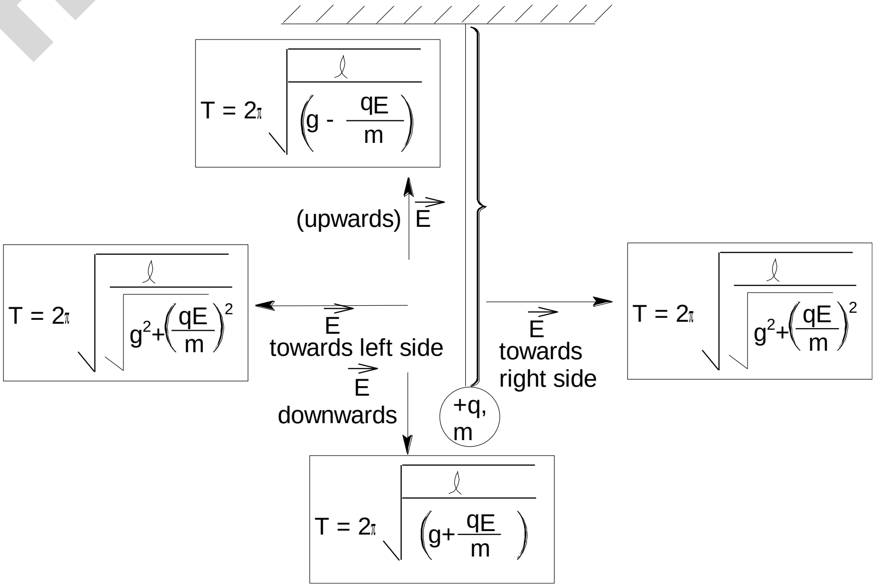
<u>MCQ</u>

a>g

↓

superweightlessness

■ 13. (a) A bob of mass 'm' and charge '+q' is placed in a uniform electric field 'E'



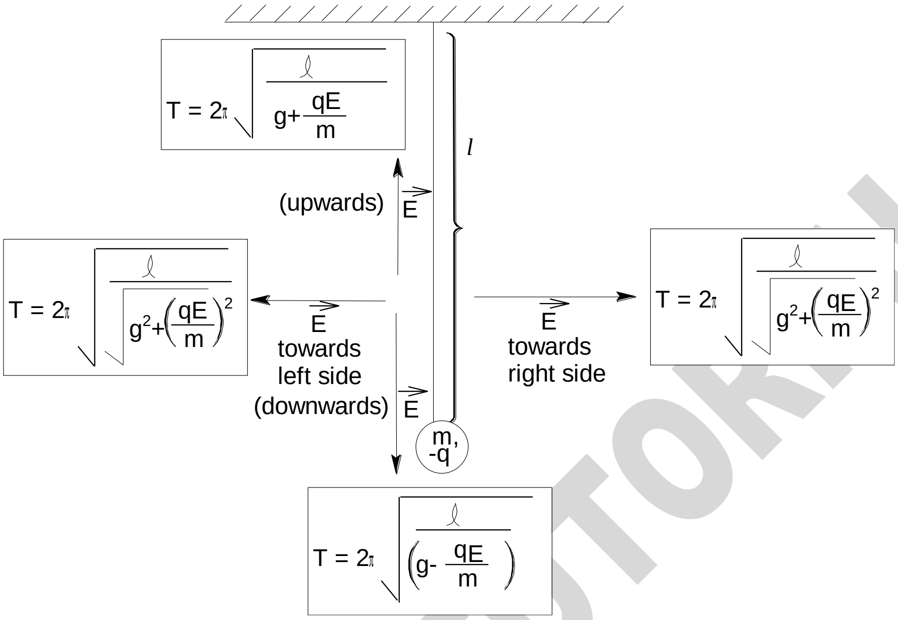
$$T = 2\pi\sqrt{\frac{\ell}{\left(g - \frac{qE}{m}\right)}}$$

$$T = 2\pi\sqrt{\frac{\ell}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$$

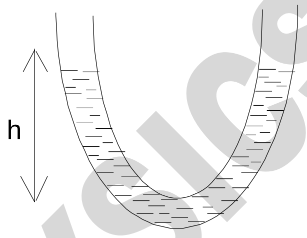
$$T = 2\pi\sqrt{\frac{\ell}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$$

$$T = 2\pi\sqrt{\frac{\ell}{\left(g+\frac{qE}{m}\right)}}$$

(b) A bob of mass ‘m’ and charge ‘–q’ is placed in a uniform electric field ‘E’

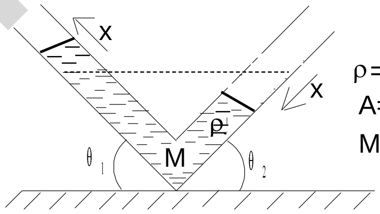


■ 14. (a) Oscillating liquid column in ‘U’ tube



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

(b)

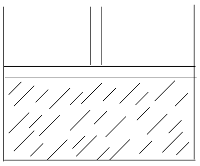


ρ=density of liquid
A= area
M= mass of liquid

$$\boxed{T = 2\pi\sqrt{\frac{M}{\rho gA\left(\sin\theta_1+\sin\theta_2\right)}}}$$

■ 15.Oscillating piston in a gas chamber of volume ‘V’

$$T = 2\pi\sqrt{\frac{VM}{PA^2}}$$



V = Volume
P = Pressure
A = Area of piston
M = Mass of piston
B = Bulk Modulus

$$T = 2\pi\sqrt{\frac{VM}{BA^2}}$$

MCQ — ① Temperature change

time period of pendulum will change.

$= \frac{1}{2}\alpha\Delta t \times 100\%$

α = Linear expansion co-efficient.

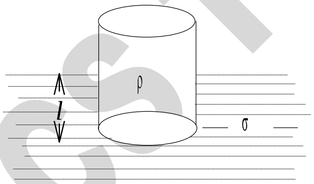
② How much slow / fast the pendulum will go due to temperature change in a day

$= \frac{1}{2}\alpha\Delta tT$ (T= 86400 sec in a day)

(Δt = temperature change)

■ 16.

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

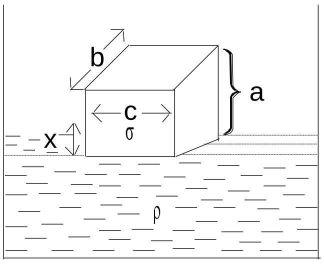


ρ = density of cylinder

σ = density of liquid

■ 17.

$$T = 2\pi\sqrt{\frac{a\rho}{g\sigma}}$$

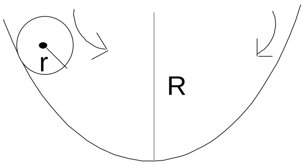


ρ = density of liquid(water)

σ = density of cube.

■ 18. Ball of radius ‘r’ oscillates in a bowl of radius ‘R’

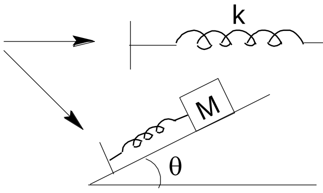
$$T = 2\pi\sqrt{\frac{(R - r)}{g}}$$



TIME PERIOD OF SPRING

■ 19.

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

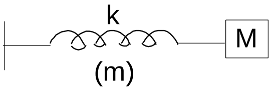


k = spring constant

$$\left(\text{amplitude} = \frac{mg\sin\theta}{k}\right)$$

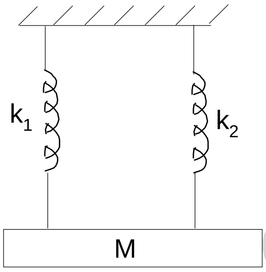
■ 20. When mass of spring is ‘m’

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

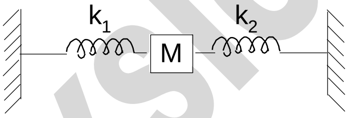


■ 21. Two springs are in parallel

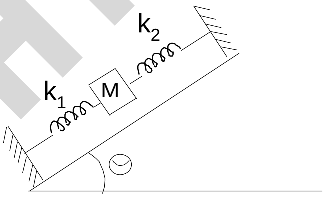
(a)



(b)



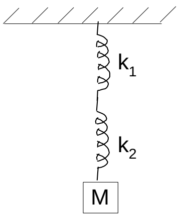
(c)



In (a), (b), (c)

$$\boxed{\begin{gathered} T = 2\pi\sqrt{\frac{M}{keq}} \\ keq = k_1 + k_2 \end{gathered}}$$

(d) Two springs are in series



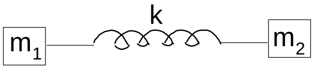
$$\boxed{\begin{gathered} T = 2\pi\sqrt{\frac{M}{keq}} \\ keq = \frac{k_1k_2}{k_1 + k_2} \end{gathered}}$$

■ 22.

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

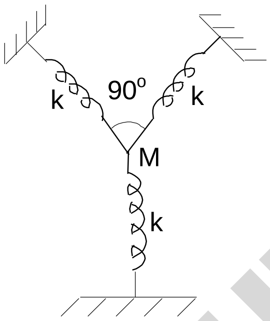
μ = reduced mass

$$= \frac{m_1 m_2}{m_1 + m_2}$$



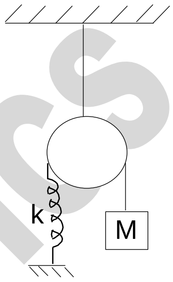
■ 23.

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



■ 24.

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



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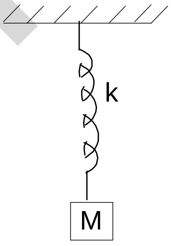
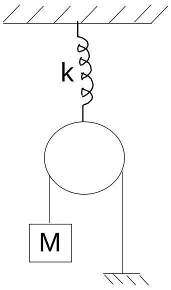
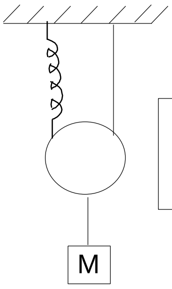


$$T = 2\pi\sqrt{\frac{4M}{k}}$$

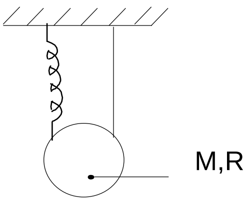




$$T = 2\pi\sqrt{\frac{M}{4k}}$$

■ 25.

$$T = 2\pi\sqrt{\frac{\left(\frac{I}{R^2}\right) + M}{4k}}$$

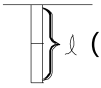


I = moment of inertia
M = mass

■ 26. **Physical Pendulum** –

(a)

$$\boxed{T = 2\pi\sqrt{\frac{2\ell}{3g}}}$$



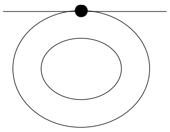
(Rod)

Mother formula =

$$\boxed{T = 2\pi\sqrt{\frac{I}{mgd}}}$$

(b)

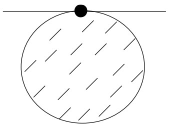
$$\boxed{T = 2\pi\sqrt{\frac{2r}{g}}}$$



(Ring)

(c)

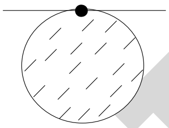
$$\boxed{T = 2\pi\sqrt{\frac{3r}{2g}}}$$



(Disc)

(d)

$$\boxed{T = 2\pi\sqrt{\frac{7r}{5g}}}$$



(Solid sphere)

■ 27. Time period of a magnetometer

$$\boxed{T = 2\pi\sqrt{\frac{I}{MB_H}}}$$

M = magnetic moment

I = moment of inertia

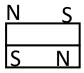
B_H = horizontal component of earth magnetic field

MCQ

(i) Two magnets of magnetic moments M_1 and M_2 ($M_1 > M_2$) are placed one over the other parallely. If T_1 is the time period when like poles touch each other and T_2 is the time period when unlike poles touch each other, then

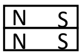
$$\frac{M_1}{M_2} = \frac{T_2^2 + T_1^2}{T_2^2 - T_1^2}$$

(ii)



T = ∝, Net $\vec{M} = 0$

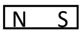
(iii)



$T = 2\pi\sqrt{\frac{I}{(2M)B_H}}$

Net $\vec{M} = 2M$

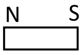
(iv)



T

cut into 'n' equal parts by cutting **normal** to its length : $T' = \frac{T}{n}$

(v)



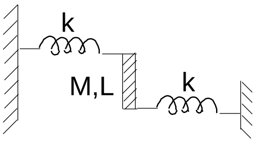
T

cut into 'n' equal parts by cutting **along** its length : T′ = T

■ 28.

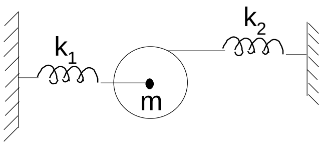
(a)

$$\boxed{T = 2\pi\sqrt{\frac{M}{6k}}}$$



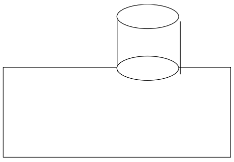
(b)

$$\boxed{T = 2\pi\sqrt{\frac{3m}{2(k_1+4k_2)}}}$$



- 29.

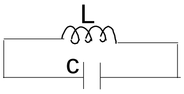
$$T = 2\pi\sqrt{\frac{mv}{EA^2}}$$



A = Area
V = Volume
M = Mass
E = bulk modulus of elasticity.

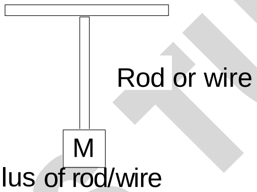
- 30. LC oscillator

$$T = 2\pi\sqrt{LC}$$



- 31. Wire/rod of length ‘l’, cross section ‘A’ ; ‘M’ mass suspended from the wire

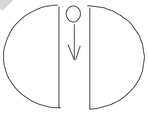
$$T = 2\pi\sqrt{\frac{M\ell}{YA}}$$



Y = Young's modulus of rod/wire
M = Mass of block
A = Cross sectional area

- 32. Tunnel is made through earth, mass is dropped

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



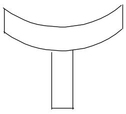
R = Radius of earth
g = acceleration due to gravity

<u>MCQ</u> when the ball goes at centre, $V = \sqrt{gR}$
<u>escape velocity</u>
$= \sqrt{2gR}$

- 33.

<u>Tuning fork</u>

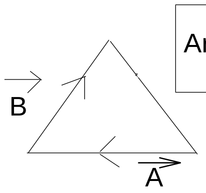
$$T = \frac{\ell^2}{kt}\sqrt{\frac{\ell}{Y}}$$



ℓ = length of prong
ρ = density of prong
Y = Young's modulus.
k = constant
t = thickness of prong

AREA CALCULATION FORMULAS

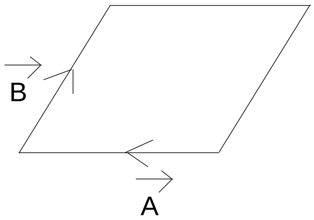
■ 1.



$$\text{Area} = \frac{1}{2}\left|\vec{A} \times \vec{B}\right|$$

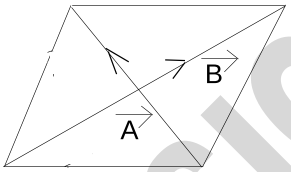
$$\text{direction } (\hat{n}) = \frac{\left(\vec{A} \times \vec{B}\right)}{\left|\vec{A} \times \vec{B}\right|}$$

■ 2.



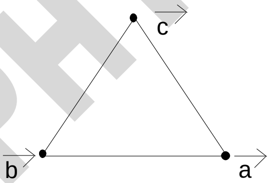
$$\text{Area} = \left|\vec{A} \times \vec{B}\right|$$

■ 3.



$$\text{Area} = \frac{1}{2}\left|\vec{A} \times \vec{B}\right|$$

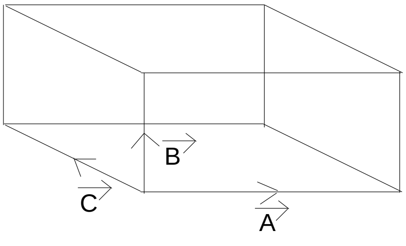
■ 4.



$\vec{a}, \vec{b}, \vec{c}$ position vectors of three vertices

$$\text{Area} = \frac{1}{2}\left|\left(\vec{a} \times \vec{b}\right) + \left(\vec{b} \times \vec{c}\right) + \left(\vec{c} \times \vec{a}\right)\right|$$

■ 5.

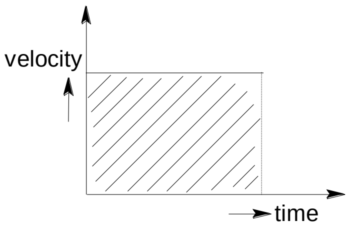


$$\text{volume of Parallelepiped} = \left(\vec{A} \times \vec{B}\right)\,\vec{C}$$

If $(\vec{A} \times \vec{B}).\,\vec{C} = 0$, then three vectors are co-planar ; condition of co-planarity

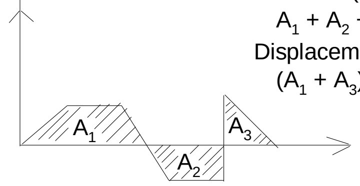
AREA WITHIN THE GRAPH

■ 1.



Area = Displacement

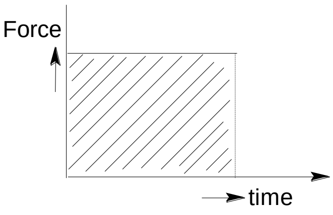
MCQ



Distance (scalar) = $A_1 + A_2 + A_3$

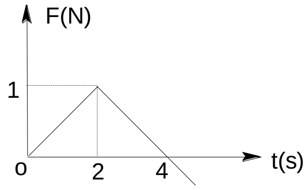
Displacement (vector) = $(A_1 + A_3) - A_2$

■ 2.



Area = Impulse = change in momentum. (△P)

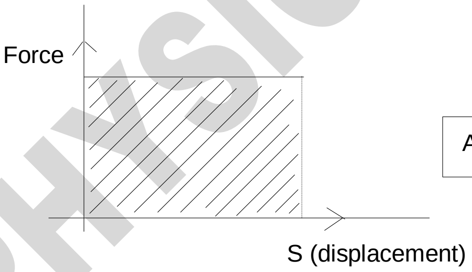
MCQ



Time taken by body to retain it's initial momentum?

$\Rightarrow 4 + 2\sqrt{2}$ s (Answer)

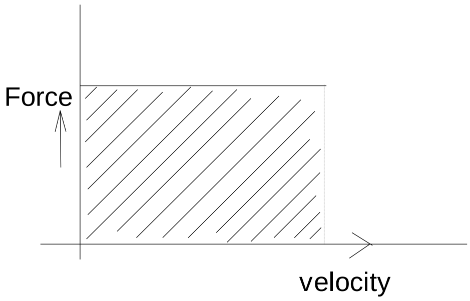
■ 3.



Area = work done

w = $\vec{F} \cdot \vec{S}$

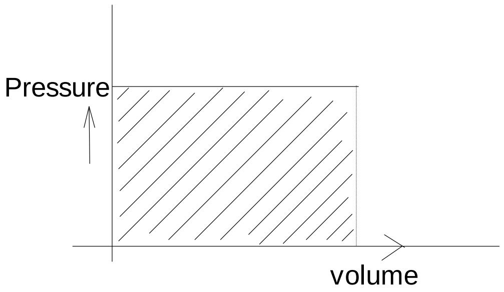
■ 4.



Area = Power

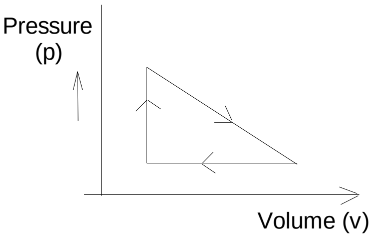
P = $\vec{F} - \vec{V}$

■ 5.



Area = Work done

■ 6.



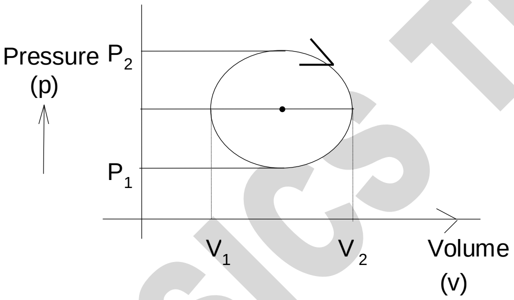
Area = $\frac{1}{2}$ x base x height = work done (Thenmodynamics)

↻ clockwise = +ve work done

↺ anticlockwise = -ve work done

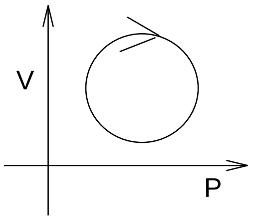
v v/s Pressure → <u>sign convension opposite.</u>

■ 7.



Work done = $\frac{\Pi\,(V_2-V_1)}{2}\,\frac{(P_2-P_1)}{2}$ (Area)

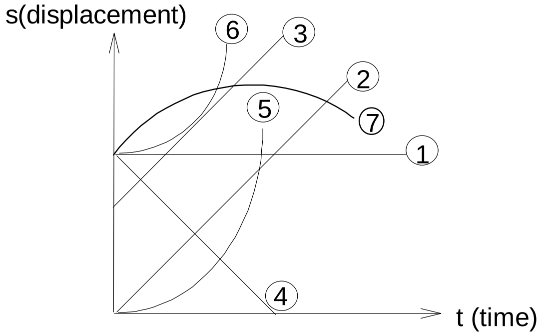
(Note : If the graphs is



; Answer will be = $-\ \frac{\Pi(V_2-V_1)}{2}\,\frac{(P_2-P_1)}{2}$)

KINEMATICS GRAPH

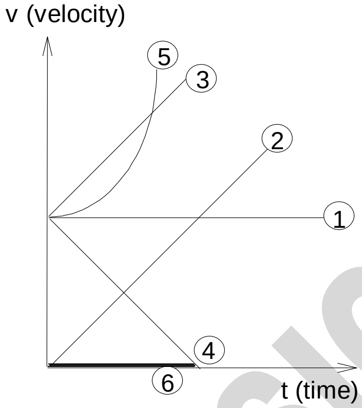
■ 1.



slope of Graph = Velocity
= tanθ.

- ① body at rest.
- ② uniform velocity starting from origin
- ③ uniform velocity with initial displacement.
- ④ uniform velocity with -ve slope. ('-ve' velocity)
- ⑤ uniform acceleration without any initial displacement.
- ⑥ uniform acceleration with initial displacement.
- ⑦ Uniform retardation

■ 2.

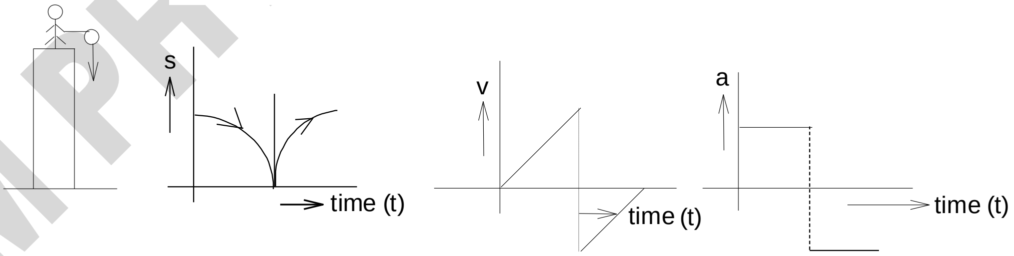


- ① uniform velocity.
- ② uniform acceleration without any initial velocity
- ③ uniform acceleration with initial velocity.
- ④ uniform retardation.
- ⑤ SLAP → unit (m/s^3) = $d\vec{a}/dt$
- ⑥ Rest body.

Slope of graph = tanθ = acceleration

■ 3.

Graphs of ball drop :

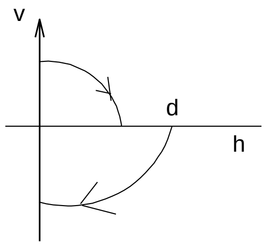


s = distance

v = velocity

a = acceleration

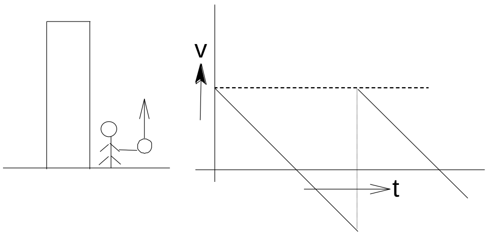
■ 4.



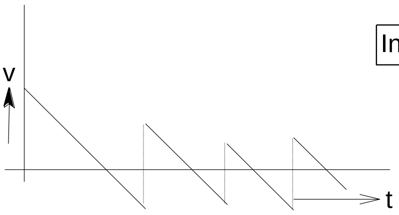
A ball is dropped for a height 'd'. It hits the ground & bounces up to d/2. Graph of velocity vs height

■ 5.

Ball is thrown from Ground —



Perfectly elastic collision

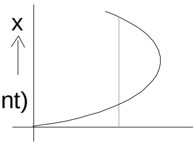


Inelastic collision

■ 6. Graphs which are **NOT** possible in kinematics :

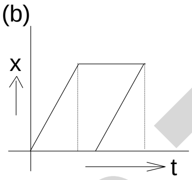
(a)

(x = displacement)



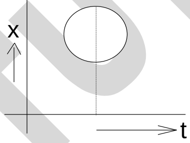
At same instance of time, same position not possible.

(b)



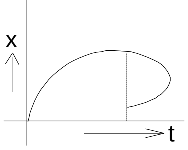
At same instance of time two positions not possible.

(c)



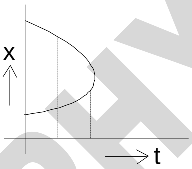
At same instance of time two positions not possible.

(d)



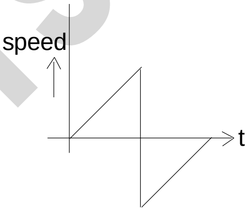
At same instance of time two positions not possible.

(e)



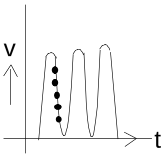
At same instance of time two positions not possible.

(f)



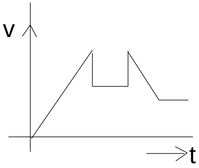
Speed scalar (-ve) not possible

(g)



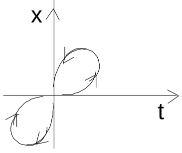
Slope = -ve
acc = -ve
at same instance two value not possible.

(h)



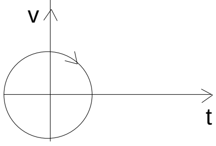
At same instance two value not possible.

(i)



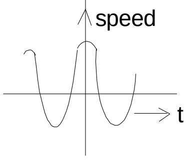
Same instance two value not possible.

(j)



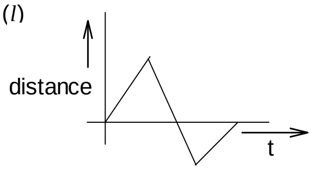
Same instance two value not possible.

(k)



Speed (-ve) not possible.

(*l*)



Distance is scalar quantity so -ve not possible

EXAMPLES OF DOT PRODUCT AND CROSS PRODUCTS

- 1.

Dot Product (scalar)

$\vec{W} = \vec{F}\cdot\vec{S}$

$P = \vec{F}\cdot\vec{V}$

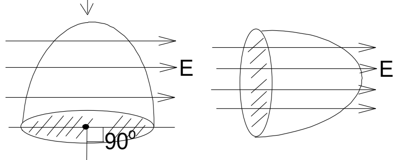
$\boxed{\phi_E = \vec{E}\cdot\vec{A}}$

$\phi_B = \vec{B}\cdot\vec{A}$

$U_E = \vec{p}\cdot\vec{E}$

$U_B = \vec{M}\cdot\vec{B}$

$I = \vec{J}\cdot\vec{A}$



$\boxed{\begin{array}{l}\phi_{In} = -\,{}^{1}/_{2}\,\pi r^2 E,\\ \phi_{Out} = +\,{}^{1}/_{2}\,\pi r^2 E,\\ \phi_{Total} = 0\end{array}}$

ϕ = flux

$\boxed{\begin{array}{l}\phi_{In} = -\,\pi r^2 E,\\ \phi_{Out} = +\,\pi r^2 E,\\ \phi_{Total} = 0\end{array}}$

inward flux = (-ve)
outward flux = (+ve)

Cross (Vector) Product

$\vec{V} = \vec{w} \times \vec{r}$

$\vec{a} = \vec{\alpha} \times \vec{r}$

$\vec{L} = \vec{r} \times \vec{p}$

$\vec{\tau} = \vec{r} \times \vec{F} = I\alpha$ (I = moment of inertia)

$\vec{\tau}_E = \vec{p} \times \vec{E}$

$\vec{\tau}_B = \vec{M} \times \vec{B}$

$\vec{F} = q\left(\vec{V} \times \vec{B}\right)$ [Flemming left hand rule]

If charge is (-ve),
$\Rightarrow \vec{F} = -q\left(\vec{V} \times \vec{B}\right)$

All cross products in magnetism $\vec{B}$ will be at end. Like:
$\vec{l} \times \vec{B}$
$\vec{v} \times \vec{B}$
$\vec{M} \times \vec{B}$ etc.

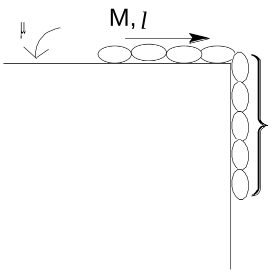
- Biot Savart Law

$\vec{dB}\ \alpha \left(\vec{dl} \times \vec{r}\right)$

W = work done	$\vec{w}$ = angular velocity
$\vec{F}$ = Force	$\vec{a}$ = acceleration
$\vec{S}$ = displacement	$\vec{\alpha}$ = angular acceleration
P = power	$\vec{L}$ = angular momentum
$\vec{V}$ = velocity	$\vec{\tau}$ = torque
ϕ_B = magnetic flux	$\vec{r}$ = radius (vector)
ϕ_E = electric flux	$\vec{\tau_E}$ = torque in electric field
$\vec{E}$ = electric field	$\vec{\tau_B}$ = torque in magnetic field
$\vec{B}$ = magnetic field	$\vec{dl}$ = length (vector) [In Biot Savart's law]
$\vec{A}$ = area (vector)	U_E = electric potential energy
U_B = magnetic potential energy	$\vec{p}$ = dipole moment
$\vec{M}$ = magnetic moment	I = current
$\vec{J}$ = current density	

CHAIN NUMERICAL

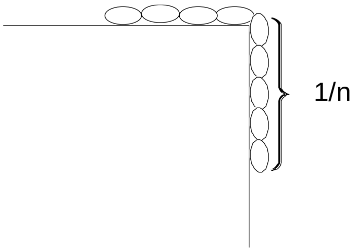
■ 1.



M = mass of the chain
l = length of the chain
μ = co-efficient of friction
'n' = maximum part of the chain which is hanging

$$\boxed{n = \frac{(\mu)\,l}{\mu + 1}}$$

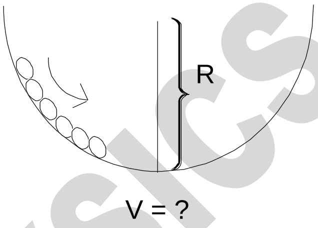
■ 2.



work done to lift the hanging part?

$$\boxed{w = \frac{Mgl}{2n^2}}$$

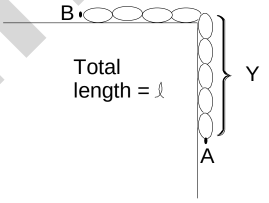
■ 3.



Velocity of chain = ?

$$\boxed{v = \sqrt{2gR\left(1 - \frac{2}{\pi}\right)}}$$

■ 4.



Velocity of chain during falling downward?

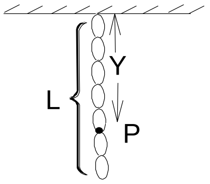
$$\boxed{v = \sqrt{\frac{g}{\ell}}\;Y}$$

velocity of B end

$$v = \sqrt{\frac{(l^2 - h^2)g}{l}}$$

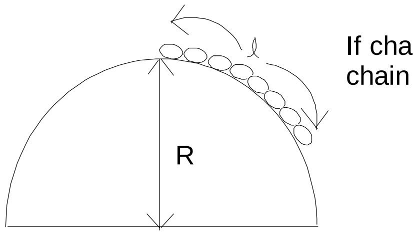
h = fraction of total length '*l*' hangs at the table

■ 5.



$$\boxed{\underset{\text{at 'P' point}}{\text{Tension}} = \frac{m(L-Y)g}{L}}$$

■ 6.

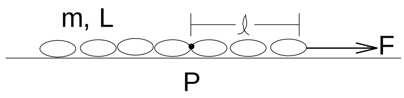


ℓ = length of chain

If chain released, accelaration of chain = $\boxed{\frac{gR}{\ell}\left[1-\cos\left(\frac{\ell}{R}\right)\right]}$

If $\ell = \frac{\pi R}{2}$, $\boxed{a = \frac{gR}{\ell}}$

■ 7.



Tension at 'P' point

$\boxed{T = \frac{(L - \ell)\,F}{L}}$ $\left(T = \text{Tension}\right)$

■ 8. A uniform chain of length l and mass m overhangs a smooth table with its two third part lying on the table. Find the kinetic energy of the chain as it completely slips off the table.

Ans: 4/9 mgl

PROJECTILE MOTION

■ 1. 2D motion.

■ 2.

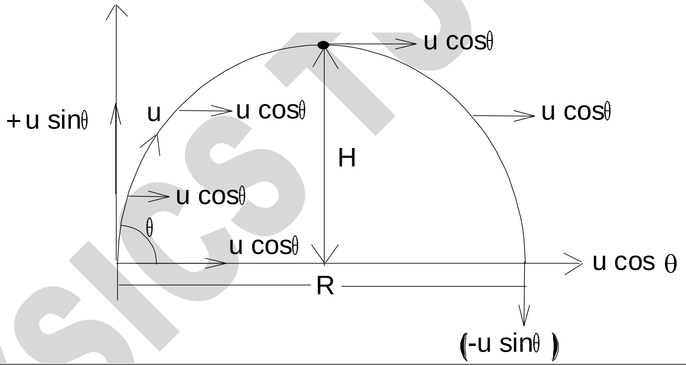
<u>Equation</u> : — $\boxed{Y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}}$ $\boxed{Y = x\,(1 - x/R)\tan\theta}$

■ 3. <u>Pathway</u> = Parabola.

■ 4. Pathway of one projectile motion with respect to another projectile motion = straight Line.

■ 5.

at highest position, the vertical component of the velocity = 0, but the horizontal component = u cosθ



T (Total Time) = $\frac{2u\sin\theta}{g}$; Ascending time = Descending time = t = $\frac{u\sin\theta}{g}$

H = (height) = $\frac{u^2\sin^2\theta}{2g}$

R = (Range) = $\frac{u^2\sin 2\theta}{g}$

(u = velocity at which body is thrown)
(θ = angle at which body is thrown)

■ 6. At angle $\theta = \tan^{-1}(4)$, Range = Height of projectile.

■ 7. At $\theta = 45°$, Range will be maximum.

■ 8.

At any point velocity → horizontal velocity = $u\cos\theta\ \hat{i}$

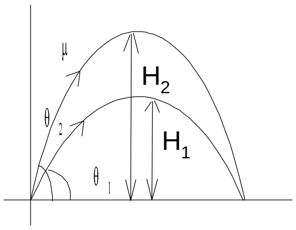
At any point velocity → vertical velocity = $(u\sin\theta - gt')\hat{j}$

So, total velocity at any point of projectile = $u\cos\theta\ \hat{i} + (u\sin\theta - gt')\ \hat{j}$

MCQ : When the velocity of a projectile will be perpendicular to the initial velocity ?

(Hint) : $(u\sin\theta\ \hat{j} + u\cos\theta\ \hat{i}).\{u\cos\theta\ \hat{i} + (u\sin\theta - gt')\hat{j}\} = 0$, $\boxed{\mathbf{t} = \frac{\mathbf{u}}{\mathbf{g\sin\theta}}}$

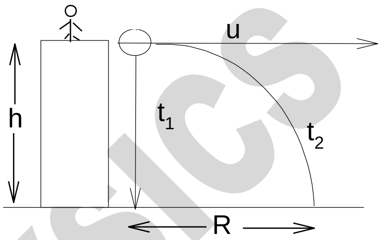
■ 9. Two projectile thrown at complementary angle i.e one in θ and another in angle (90^o - θ) then Range will be same, but maximum height will be different i.e. H_1 and H_2. The time of flight will also be different i.e. t_1 and t_2.



$\boxed{R = 4\sqrt{H_1H_2}}$ $\boxed{t_1t_2 = \frac{2R}{g}}$

$\theta_1 = \theta$, $\theta_2 = (90^o - \theta)$

■ 10.

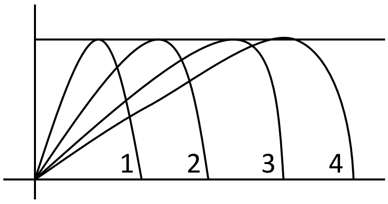


$\boxed{t_1 = t_2 = \sqrt{2h/g}}$ $\boxed{R = u.\sqrt{2h/g}}$

t_1 = time for the ball to reach the ground, when it is **dropped** from height 'h'.
t_2 = time for the ball to reach the ground, when it is **thrown** with a horizontal velocity 'u' from height 'h'

■ 11. Four paths for a kicked football. Rank the paths according to initial horizontal velocity component :

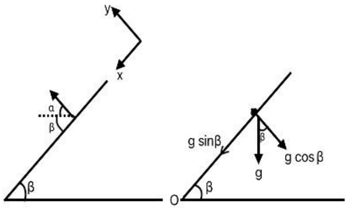
Answer : 4, 3, 2, 1



■ 12. PROJECTILE MOTION AT INCLINED PLANE :

Down the plane:

- $T = 2u \sin(\alpha + \beta) / g \cos\beta$
- $R = (u^2 / g \cos^2\beta) [\sin(2\alpha + \beta) + \sin\beta]$



Up the plane:

- $R = (u^2 / g \cos^2\beta) [\sin(2\alpha - \beta) - \sin\beta]$
- $T = 2u \sin(\alpha - \beta) / g \cos\beta$

■ 13. A projectile is fired from level ground at an angle θ above the horizontal. The elevation angle Φ of the highest point as seen from the launch point is related to θ by the relation:

Ans: $\tan\Phi = 1/2 \tan\theta$

■ 14. A particle is projected horizontally with a speed u from the top of a plane inclined at an angle with the horizontal. How far from the point of projection will the particle strike the plane?

Ans: $(2u^2 / g) \tan\theta \sec\theta$

MOMENT OF INERTIA

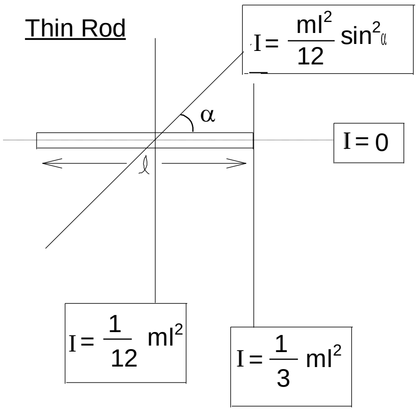
■ 1.

MOMENT OF INERTIA

- Tensor quantity.
- $I = \sum mr^2$ (kg - m^2)
- depends on position and orientation of axis
- depends on distribution of mass.

(I = moment of inertia)

Thin Rod



$$I = \frac{ml^2}{12}\sin^2\alpha$$

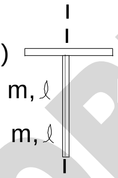
$$I = 0$$

$$I = \frac{1}{12}ml^2$$

$$I = \frac{1}{3}ml^2$$

MCQ

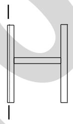
(1)



$$I = \frac{1}{12}ml^2 + 0$$
$$= \frac{1}{12}ml^2$$

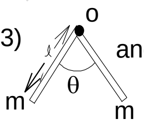
(2)

each rod massm, length = ℓ



$$I = 0 + \frac{1}{3}ml^2 + ml^2$$
$$= \frac{4}{3}ml^2$$

(3)



(I is angle independent)

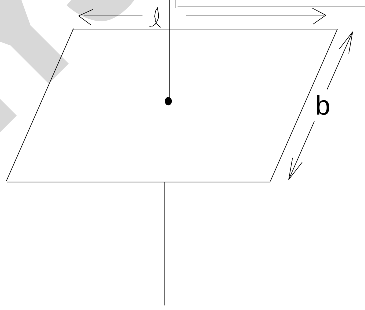
$$I = \frac{2}{3}ml^2$$

axis passing through 'o' & perpendicular to the plane

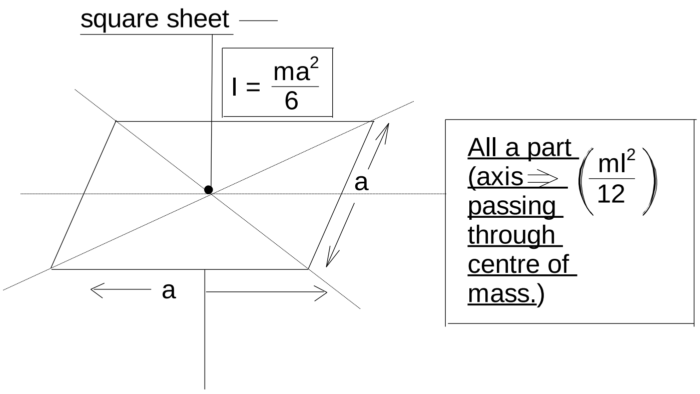
■ 2.

Reclangular sheet / slab / lamina / plate

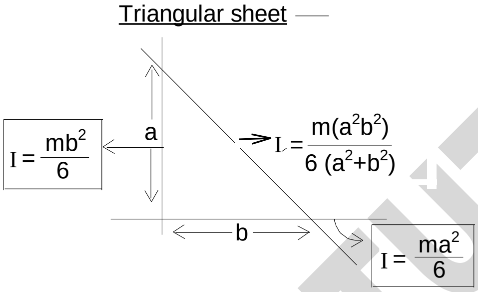
$$I = \frac{1}{12}m(\ell^2 + b^2)$$

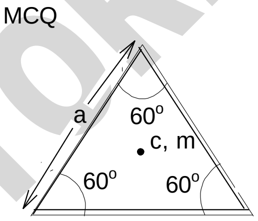


■ 3.



■ 4.

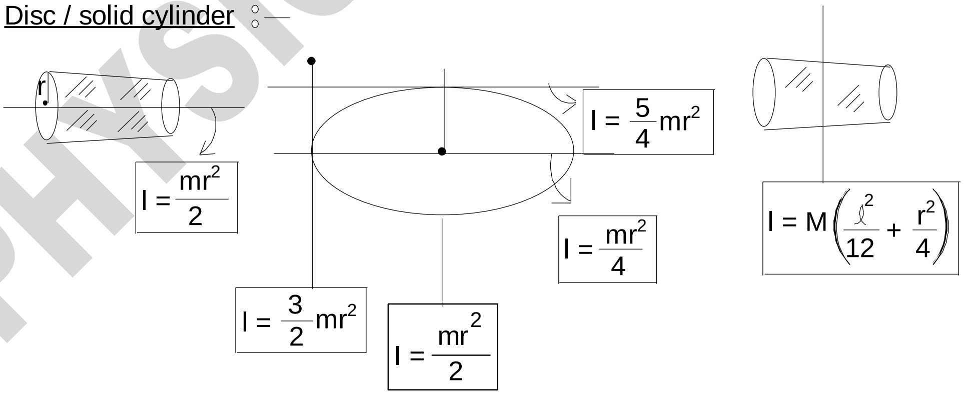




Three rods each mass 'm' and side 'a' form equilateral triangle. Moment of inertia about centre of mass and perpendicular to the plane = **$I = ma^2/6$** and along any of the three rods, **$I = ma^2/2$**

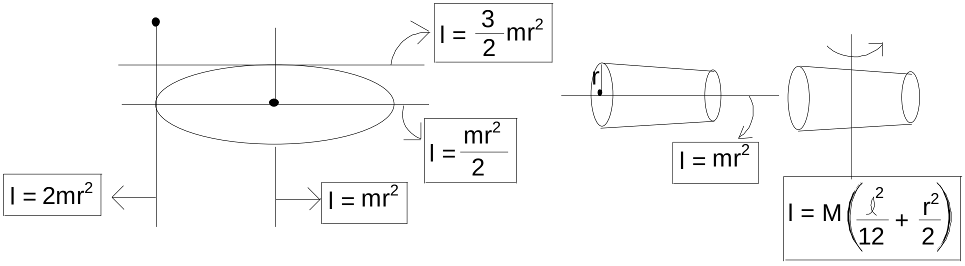
■ 5.

Disc / solid cylinder :—



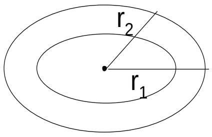
■ 6.

Ring / Hollow cylinder :—



- 7.

Annular Ring :—



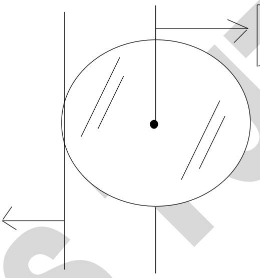
$$\boxed{I = \frac{1}{2} m (r_1^2 + r_2^2)}$$

- 8.

Solid Cone :— $\boxed{I = \frac{3}{10} MR^2}$ Hollow Cone :- $\boxed{I = \frac{1}{2} MR^2}$

- 9.

Solid sphere :—

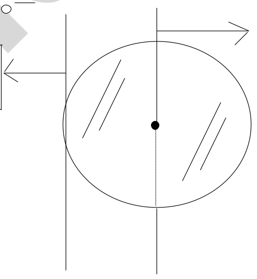


$$\boxed{I = \frac{2}{5} mr^2}$$

$$\boxed{I = \frac{7}{5} mr^2}$$

- 10.

Hollow sphere :—



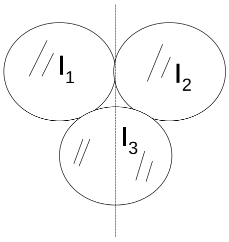
$$\boxed{I = \frac{2}{3} mr^2}$$

$$\boxed{I = \frac{5}{3} mr^2}$$

Typical —

(a)

Disc

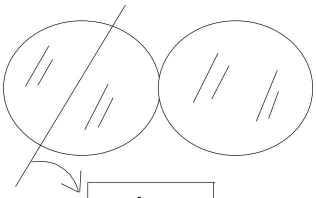


$$I = I_1 + I_2 + I_3$$

$$I = \left(2 \text{ x } \frac{5}{4} mr^2\right) + \frac{1}{4} mr^2$$

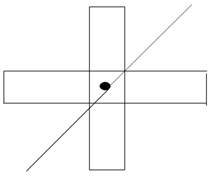
$$\boxed{I = \frac{11}{4} mr^2}$$

(b)



$$\boxed{I = \frac{1}{4}mr^2}$$

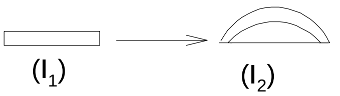
(c)



$$\boxed{I = \frac{m\ell^2}{6}}$$

(d)

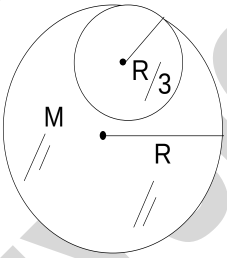
Thin rod bents to form semicirele —



$\frac{I_1}{I_2} = ?$

$$\boxed{\frac{I_1}{I_2} = \frac{\pi^2}{6}}$$

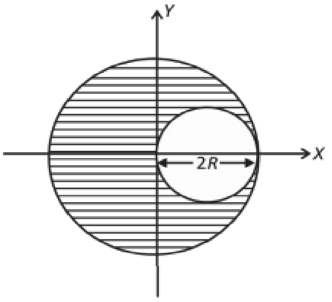
(e)



Disc of uniform thickness R = Radius. R/3 portion is cut. Moment of inertia of remaining portion?

$\boxed{I = 4MR^2}$ [mass of R/3 portion = M
mass of R section = 9M]

(f) A sphere of radius R is cut from a larger solid sphere of radius 2R as shown in the figure. The ratio of the moment of inertia of the smaller sphere to that of the rest part of the sphere about the Y-axis is:



Ans. : $I_S / I_r = 7/57$

EQUILIBRIUM

Stable equilibrium

- Net force = 0
- dU/dr (slope) = 0
- d^2U/dr^2 = **positive (P.E. in equilibrium is minimum)**
- When displaced from equilibrium, net restoring force has a tendency to bring the body to bring the body back to equilibrium.
- When displaced from equilibrium, centre of gravity goes up.

Unstable equilibrium

- Net force = 0
- dU/dr (slope) = 0
- d^2U/dr^2 = **negative (P.E. in equilibrium is maximum)**
- When displaced from equilibrium, net force moves the body in the direction of displacement or away from equilibrium.
- When displaced from equilibrium, centre of gravity goes down.

Neutral equilibrium

- Net force = 0
- dU/dr (slope) = 0
- d^2U/dr^2 = **0 (P.E. in equilibrium is constant)**
- When displaced from equilibrium, the body has neither the tendency to come back or move away from original position
- When displaced from equilibrium, centre of gravity remains at same level.

LAMINAR (STREAMLINE) FLOW / TRANSITIONAL FLOW / TURBULENT FLOW

Laminar flow

- **Re < 2000 (< 1000 as per NCERT)**
- 'low' velocity
- Dye does not mix with water
- Fluid particles move in straight lines
- Simple mathematical analysis possible
- Rare in practice in water systems.

Transitional flow

- **2000 > Re < 4000 (1000 - 2000 as per NCERT)**
- 'medium' velocity
- Dye stream wavers in water - mixes slightly.

Turbulent flow

- **Re > 4000 (> 2000 as per NCERT)**
- 'high' velocity
- Dye mixes rapidly and completely
- Particle paths completely irregular
- Average motion is in the direction of the flow
- Mathematical analysis very difficult - so experimental measures are used
- Most common type of flow.

CAPACITOR IS CONNECTED / DISCONNECTED AND DIELECTRIC IS INSERTED

Battery disconnected from the capacitor and dielectric is inserted	Battery kept connected across the capacitor and dielectric is inserted
$Q = Q_0$ (constant)	$Q = K Q_0$ (increased)
$V = V_0/K$ (decreased)	$V = V_0$ (constant)
$E = E_0/K$ (decreased)	$E = E_0$ (constant)
$C = K C_0$ (increased)	$C = K C_0$ (increased)
P.E., $U = U_0/K$ (decreased)	P.E., $U = K U_0$ (increased)