Exercise I

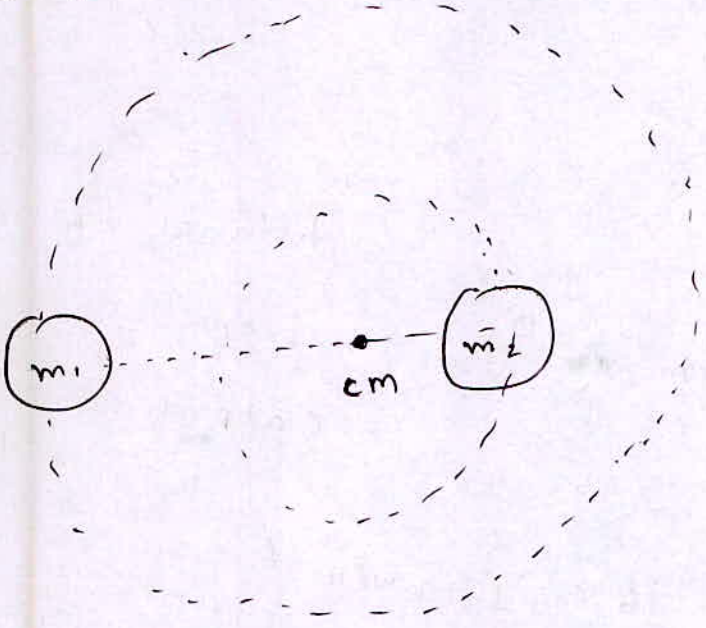
Q 1.

Ans.

$T_2 < T_1$ ⇒ Reading of the balance will be less.

Q 2.

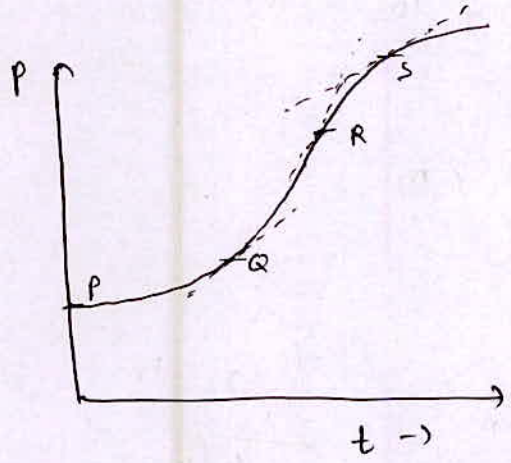
Ans.



revolve around their common center of mass.

Q 3.

Ans.



$$F = \frac{d\vec{P}}{dt}$$

at Fmax, $\frac{d\vec{P}}{dt}$ should be max.

$\left.\frac{d\vec{P}}{dt}\right|_R$ is maximum.

Q 4.

Ans. $$\frac{d\vec{P}}{dt} = \vec{F}$$

$$\int \vec{F}\, dt = \int d\vec{P}$$

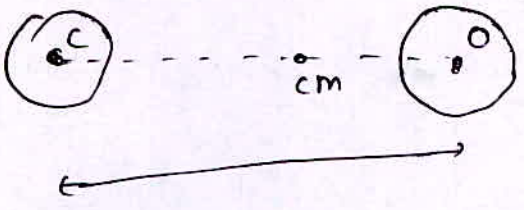
$$= \vec{P}_2 - \vec{P}_1 = \Delta\vec{P}$$

from graph $\Rightarrow$ area of F-t graph = 50 Ns

$$\Delta\vec{P} = 50 \text{ N.s.}$$

Q 5.

Ans.



distance of CM from C atom $= \dfrac{M_O\, d}{M_C + M_O}$

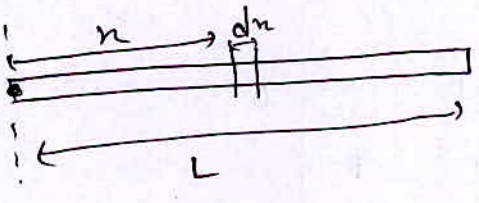
$$= \frac{16 \times 1.12 \times 10^{-8}}{14 + 16}$$

$$= \frac{16}{30} \times 1.12 \times 10^{-8}$$

$$= 0.6 \times 10^{-8} \text{ cm.}$$

Q 6.

Ans.



$$x_{cm} = \frac{\int x\, dm}{\int dm}$$

$$x_{cm} = \frac{\int_0^L x\,dm}{\int_0^L dm} \qquad dm = (A + Bx)\,dx$$

$$= \frac{\int_0^L x(A + Bx)\,dx}{\int_0^L (A + Bx)\,dx}$$

$$= \frac{\left[\frac{Ax^2}{2} + \frac{Bx^3}{3}\right]_0^L}{\left[Ax + \frac{Bx^2}{2}\right]_0^L}$$

$$= \frac{\frac{AL^2}{2} + \frac{BL^3}{3}}{AL + \frac{BL^2}{2}}$$

$$= \frac{L(3A + 2BL)}{3(2A + BL)}$$

Q 7.

Ans.

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots}{m_1 + m_2 + m_3 \cdots}$$

does not depend upon Forces on the particle.

Q 8.

Ans.

$$R_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2}$$

Q 9.

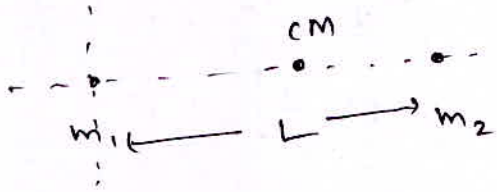
Ans. Center of gravity may lie slightly below the center of mass

~~Q 10.~~

~~Ans.~~

Q 10.

Ans.

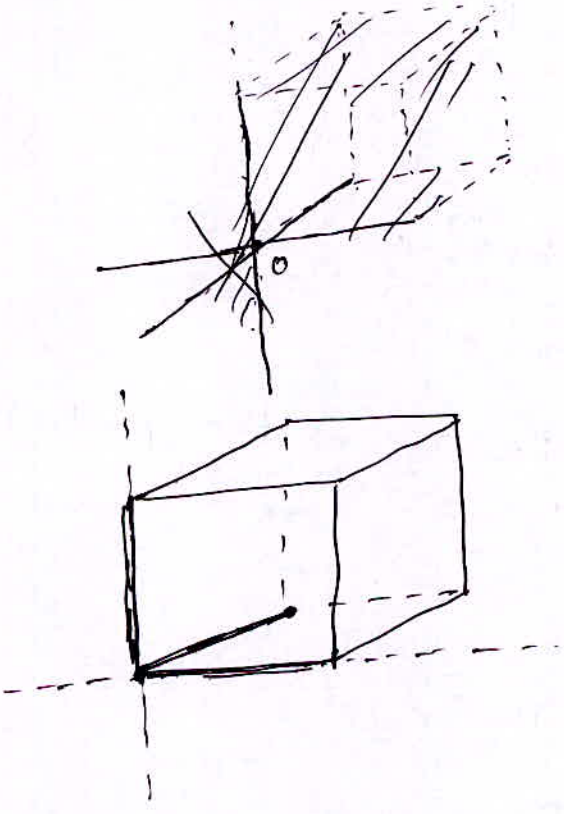


$$d = \frac{m_1 \cdot 0 + m_2 L}{m_1 + m_2}$$

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

Q 11.

Ans.



$$I_{total} = I_1 + I_2 + I_3$$

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

$$= \frac{2}{3} ML^2$$

Q 12.

Ans. $I_1 \omega_1 = I_2 \omega_2$

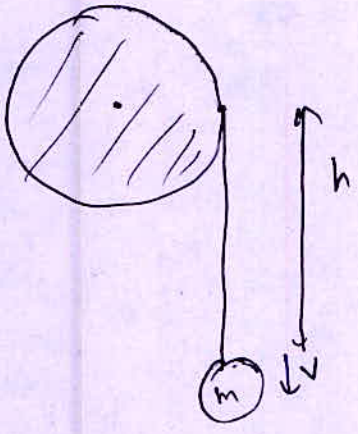
$M K_1^2 = I_1$

$M K_2^2 = I_2$

$\frac{K_1}{K_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{\omega_2}{\omega_2}}$

Q 13.

Ans.



$mgh = \frac{1}{2} I \omega^2 + \frac{1}{2} m v^2$

$2mgh = \frac{1}{2} \times \frac{M \cdot D^2}{8} \times \frac{4V^2}{D^2} + \frac{1}{2} m v^2$

$v^2 = \frac{2mgh}{\left(\frac{M}{2} + m\right)}$

v is independent of D

Q 14.

Ans. rolling $\Rightarrow$ $V = R\omega$

K. E. of cylinder $= \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2$

$= \frac{1}{2} \times \frac{2I}{R^2} V^2 + \frac{1}{2} I \omega^2$

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

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

Q 15.

Ans.

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

$$= \frac{1}{2} \times \frac{MR^2}{2} \times \frac{V^2}{R^2}$$

$$= \frac{1}{4} MV^2$$

Q 16.

Ans.

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

$$= \frac{1}{2} MV^2 + \frac{1}{2} MR^2 \frac{V^2}{R^2}$$

$$= MV^2$$

Q 17.

Ans.

$$\frac{1}{2} mv^2 = \frac{1}{2} mv'^2 + \frac{1}{2} I \omega^2$$

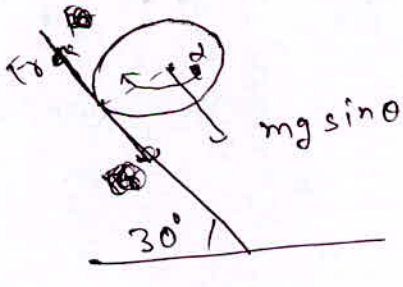
$$= \frac{1}{2} mv'^2 + \frac{1}{2} MR^2 \times \frac{V'^2}{R^2}$$

$$\frac{1}{2} mv^2 = MV'^2$$

$$v' = V/\sqrt{2}$$

Q 18.

Ans.



$$a = \frac{g \sin\theta - Fr}{m}$$

$$Fr\, R = I \alpha$$

$$Fr\, R = \frac{2}{3} mR^2 \alpha$$

$$Fr = \frac{2}{3} mR\alpha$$

$F_r = \frac{2}{3} m R \alpha$ $\qquad R\alpha = a$

$= \frac{2}{3} ma$

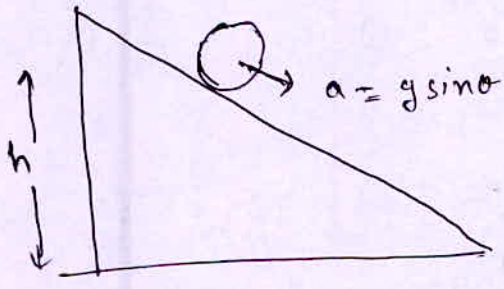
$a = g\sin\theta - \frac{2}{3} a$

$\frac{5}{3} a = g\sin\theta$

$a = \frac{3g}{5} \sin\theta$

Q 19.

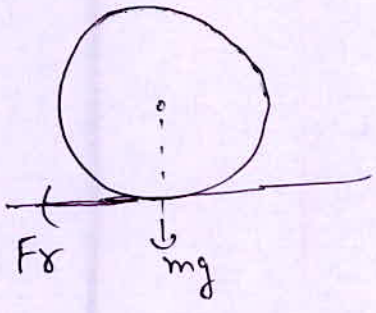
Ans.



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

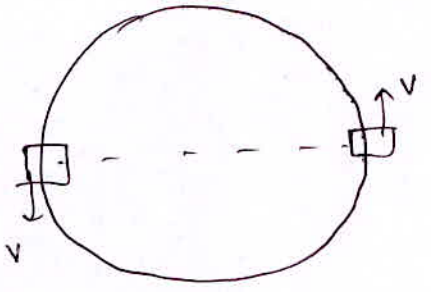
Q 20.

Ans. all the forces pass through the point of contact.



Q 21.

Ans.



$$|\Delta \vec{p}| = |2 m \vec{v}|$$

Q 22.

Ans.

$$\frac{1}{2} m v^2 = \frac{1}{2} I \omega^2$$

$$\frac{1}{2} m v^2 = \frac{1}{2} I \frac{v^2}{R^2}$$

$$I = mR^2 \implies \text{Ring.}$$

Q 23.

Ans.

$$\frac{1}{2} m v^2 + \frac{1}{2} I \omega^2 = \frac{1}{2} m \left(\frac{5v}{4}\right)^2$$

$$\frac{1}{2} m v^2 + \frac{1}{2} m K^2 \frac{v^2}{R^2} = \frac{1}{2} m \frac{25}{16} v^2$$

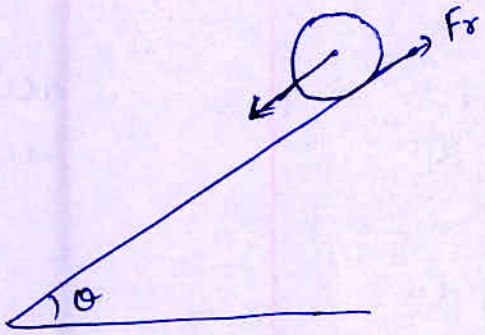
$$1 + \frac{K^2}{R^2} = \frac{25}{16}$$

$$\frac{K^2}{R^2} = \frac{9}{16}$$

$$K = \frac{3R}{4}$$

Q 24.

Ans.



$$mg\sin\theta - Fr = ma$$

$$Fr \cdot R = \frac{2}{5} mR^2 \frac{a}{R}$$

$$Fr = \frac{2}{5} ma$$

$$\sin\alpha(mg) - \frac{2}{5} ma = ma$$

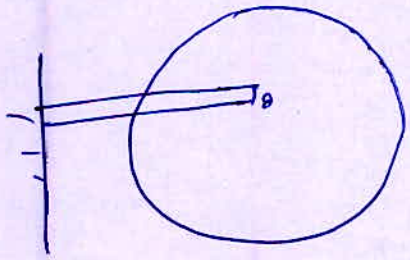
$$a = \frac{5}{7} g\sin\theta$$

$$Fr = \frac{2}{5} \times m \times \frac{5}{7} g\sin\theta = \mu mg\cos\theta$$

$$\mu = \frac{2}{7} \tan\theta$$

Q 25.

Ans.



$$\tau = F \times R = I\alpha$$

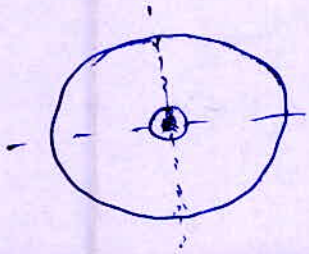
$$\alpha = \frac{F.R}{MR^2/2}$$

$$\alpha = \frac{2F}{MR}$$

$$a_t = R\alpha$$

$$= \frac{2F}{M}$$

Q 26.



$$I_2 = mR^2 = I$$

$$I_z = I_x + I_y = 2I_x$$

$$I_x = I_z/2 = I/2$$

Q 28.

Ans.

$$\omega = a - bt$$

$$\frac{d\omega}{dt} = -b = \omega \frac{d\omega}{d\theta}$$

$$\int_0^{\theta} -b \, d\theta = \int_a^0 \omega \, d\omega$$

$$-b\theta = \left(0 - \frac{a^2}{2}\right)$$

$$\theta = \frac{a^2}{2b}$$

Q 29.

Ans. from perpendicular axis theorem

$$I = I_1 + I_2$$

Q 30.

Ans.

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

$$I_1 \omega_1 = I_2 \omega_2$$

$$\frac{\omega_2}{\omega_1} = \frac{I_1}{I_2}$$

$$\frac{K.E_1}{K.E_2} = \frac{\frac{1}{2} I_1 \omega_1^2}{\frac{1}{2} I_2 \omega_2^2} = \frac{I_1 I_2^2}{I_2 I_1^2} = \frac{I_2}{I_1}$$

$$\frac{K.E_1}{K.E_2} = \frac{I_2}{I_1} < 1 \Rightarrow K.E_2 > K.E_1$$

Q 31.

Ans. $\vec{L}$ is constant

$L = I\omega$

I will decrease so ω will increase.

Q 32.

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

$= \vec{r} \times m\vec{v}$

$= m(\vec{r} \times \vec{v})$

$\vec{L} \perp \vec{p}$

Q 33.

Ans. $\tau = \dfrac{d\vec{L}}{dt}$

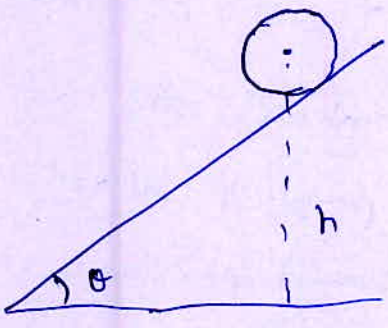
$\int \tau \, dt = \int_{A_0}^{4A_0} d\vec{L}$

$\tau \times 4 = 3A_0$

$\tau = \dfrac{3A_0}{4}$

Q 34.

Ans.



$mgh = \frac{1}{2}mv^2 + \frac{1}{2} \times \frac{mR^2}{2} \frac{v^2}{R^2}$

$mgh = \frac{3}{4} mv^2$

$v = \sqrt{\frac{4}{3} gh}$

Q 35.

Ans.

$$\frac{\frac{1}{2} I \omega_2^2 - \frac{1}{2} I \omega_1^2}{\frac{1}{2} I \omega_1^2} = 3$$

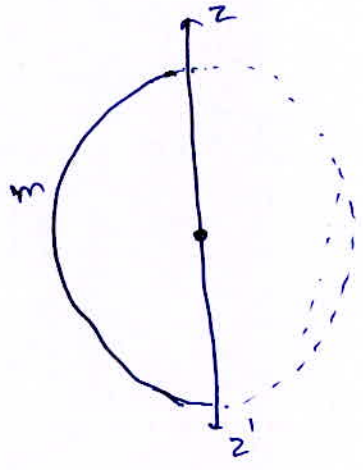
$$\omega_2 = 2\omega_1$$

$$L_2 = I\omega_2 = 2L_1$$

$$\frac{L_2 - L_1}{L_1} \times 100 = 100\ \%$$

Q 36.

Ans.



$I_{zz'}$ of Full Ring $= \frac{2mR^2}{2}$

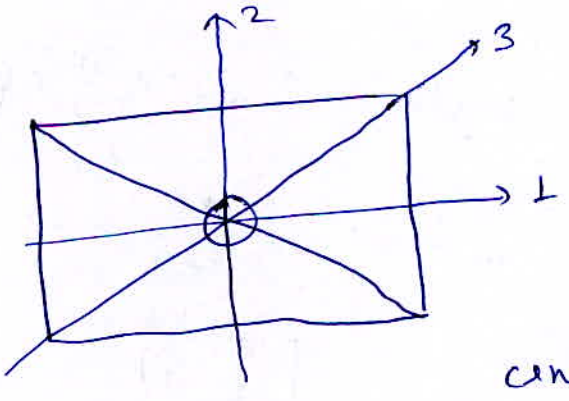
$R = \frac{l}{\pi}$

$I_{zz'}$ of Half Ring $= \frac{2mR^2}{2} \times \frac{1}{2}$

$$= \frac{ml^2}{2\pi^2}$$

Q 37.

Ans.



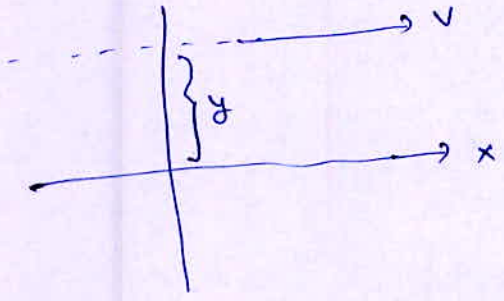
I will be maximum about the axis passing through the center and perpendicular to the plane

Q 38.

Ans. refer Q. 11.

Q 39.

Ans.

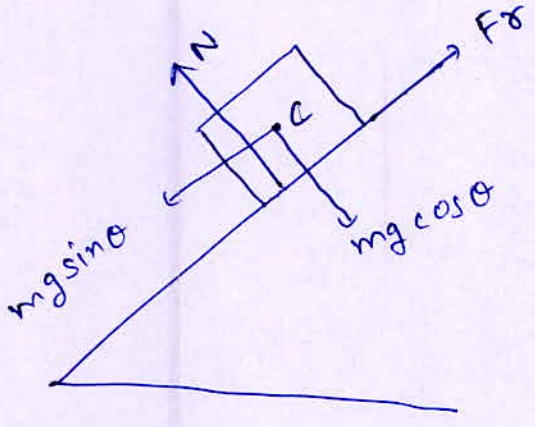


$$|\vec{L}| = |mvy|$$

$\vec{L}$ remains constant

Q 40.

Ans.



$$\Sigma \vec{\tau}_c = 0$$

$$\vec{\tau}_N + \tau_{Fr} = 0$$

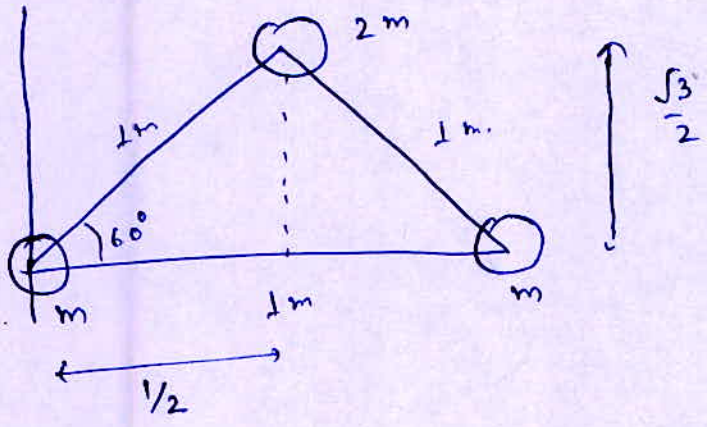
$$F_r = mg\sin\theta$$

$$\tau_{Fr} = mg\sin\theta \frac{a}{2}$$

$$\vec{\tau}_N = -\frac{a}{2} mg\sin\theta$$

Level II

Q 1.



$$x_{cm} = \frac{m.0 + 2m. \times \frac{1}{2} + m \times 1}{4m}$$

$$= 0.5$$

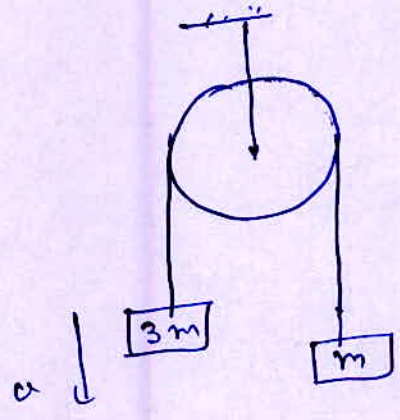
$$Y_{cm.} = \frac{m.0 + 2m. \sqrt{3}/2 + m.0}{4m}$$

$$= \frac{\sqrt{3}}{4}$$

$$\equiv (0.5, \sqrt{3}/4)$$

Q2.

Ans.



$$a = \frac{2mg}{4m} = g/2$$

$$a_{cm} = \frac{3m \cdot g/2 - m\, g/2}{4m}$$

$$= g/4 = 2.5\ m/s^2$$

Q 3.

Ans. Momentum Conservation.

Q 4.

Ans.

there is no external force on the system

$\Rightarrow$ velocity of cm will remain constant

Q5.

Ans.

$$x_{cm} = \frac{60 \times 1 + 40 \times x}{100} = 1$$

$$x = 1$$

$$y_{cm} = \frac{60 \times (-1) + 40 \times y}{100} = 1$$

$$y = \frac{160}{40} = 4$$

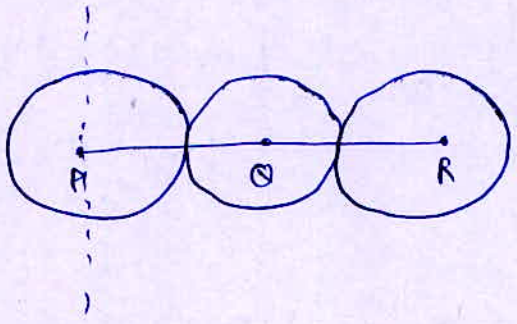
$$z_{cm} = \frac{60 \times 3 + 40 \times z}{100} = 1$$

$$z = -2$$

$\Rightarrow$ $(1, 4, -2)$ Ans.

Q 6.

Ans.

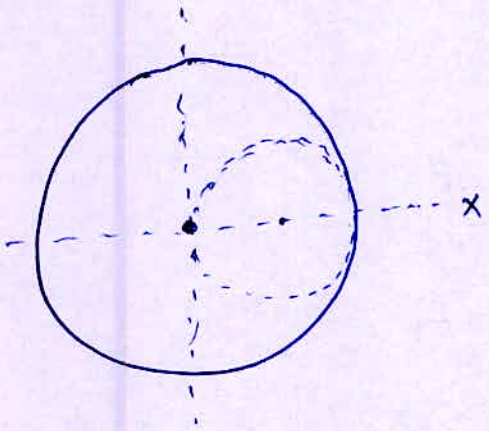


$$d = \frac{1 \times PQ + 1 \times (PQ + QR)}{3}$$

$$= \frac{PQ + PR}{3}$$

Q 7.

Ans.



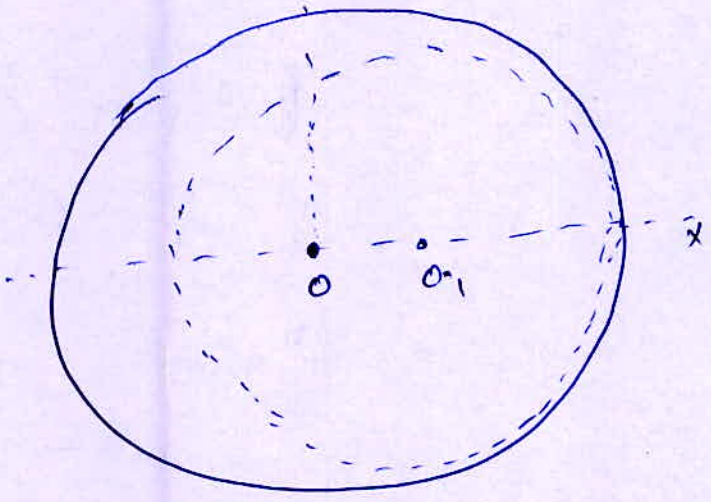
$$x_{cm} = \frac{\sigma \pi R^2 \cdot 0 - \sigma \pi \left(\frac{R}{2}\right)^2 \cdot \frac{R}{2}}{\sigma \pi R^2 - \sigma \pi \left(\frac{R}{2}\right)^2}$$

$$= \frac{-\frac{R}{8}}{1 - \frac{1}{4}}$$

$$= -\frac{R}{6}$$

Q 8.

Ans



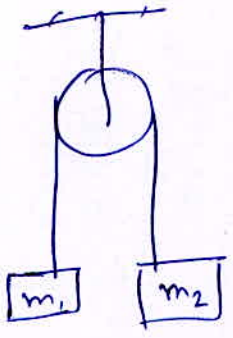
$$x_{cm} = \frac{\sigma \pi R^2 \cdot 0 - \sigma \pi \left(\frac{3R}{4}\right)^2 \cdot \frac{R}{4}}{\sigma \pi R^2 - \sigma \pi \left(\frac{3R}{4}\right)^2}$$

$$= \frac{-\frac{9}{64} R}{1 - \frac{9}{16}}$$

$$= \frac{-9}{4 \times 7} \times 28 = -9 \text{ cm.}$$

Q 9.

Ans.



$$a = \frac{(m_1 - m_2)g}{(m_1 + m_2)}$$

$$a_{cm} = \frac{m_1\left(\frac{m_1 - m_2}{m_1 + m_2}\right)g - m_2\left(\frac{m_1 - m_2}{m_1 + m_2}\right)g}{m_1 + m_2}$$

$$= \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 g$$

Q 10.

Ans. $\vec{F}_{ext} = 0$ (on the system)

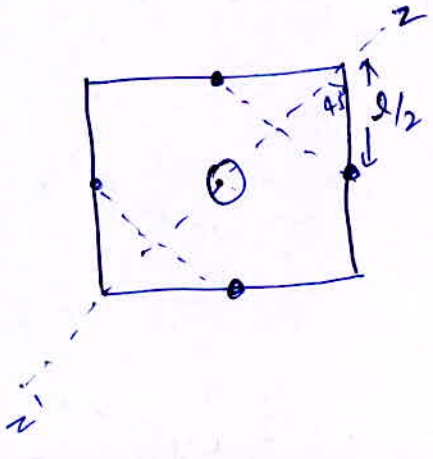
Initial momentum of system is zero.

$$\frac{d\vec{p}}{dt} = 0 \Rightarrow \vec{P}_f = \vec{P}_i = 0$$

$$\Rightarrow \vec{V}_{cm} = 0$$

Q 11.

Ans.



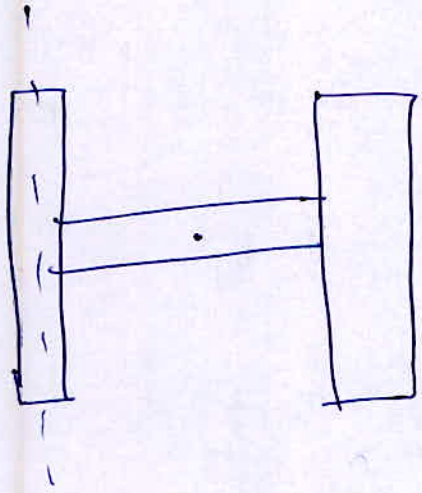
$$I_{zz} = 4\left(\frac{ml^2}{12} + m\left(\frac{l}{2\sqrt{2}}\right)^2\right)$$

$$= \left(\frac{1}{2} + \frac{1}{3}\right) ml^2$$

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

Q 12.

Ans.

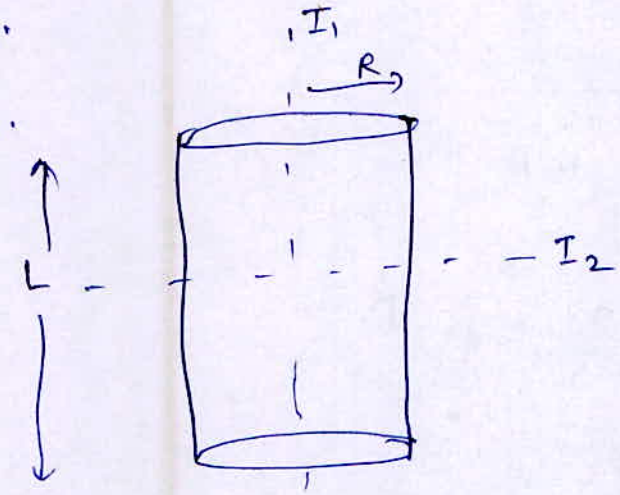


$$I = \frac{ml^2}{3} + \left(\frac{ml^2}{12} + ml^2\right)$$

$$= \frac{4}{3} ml^2$$

Q 13.

Ans.



$$I_1 = \frac{mR^2}{2}$$

$$I_2 = \left[\frac{mL^2}{12} + \frac{mR^2}{4}\right]$$

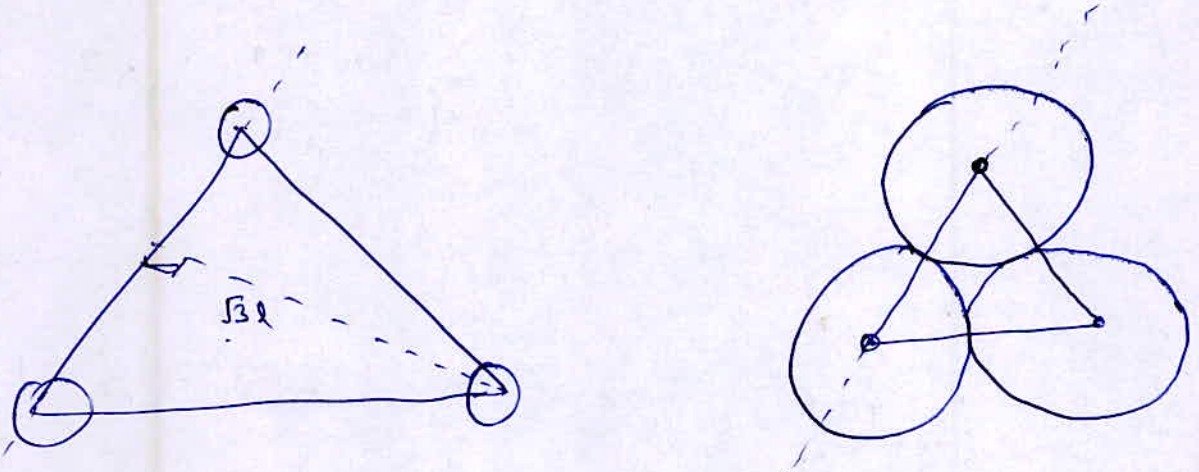
$$I_1 = I_2$$

$$\frac{R^2}{2} = \frac{L^2}{12} + \frac{R^2}{4}$$

$$L = \sqrt{3}R$$

Q 14.

Ans.

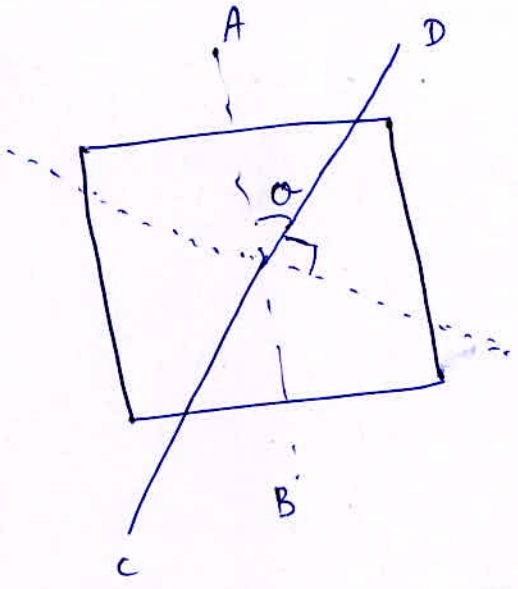


$$I = \frac{2}{5} ml^2 + \frac{2}{5} ml^2 + \left(\frac{2}{5} ml^2 + m(\sqrt{3}l)^2\right)$$

$$= \frac{21}{5} ml^2$$

Q 15.

Ans.



$$I_{CD} = \left(\frac{ma^2}{6}\right) \times \frac{1}{2}$$

$$I_{AB} = \frac{ma^2}{12}$$

$$I_{CD} = I$$

Q 16.

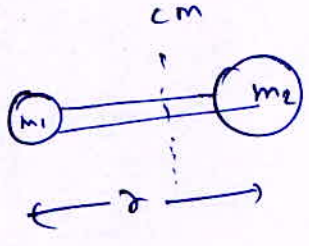
Ans.

$$MK^2 = \frac{2}{5} MR^2 + M(2R)^2$$

$$K = \sqrt{\frac{22}{5}}\, R$$

Q 17.

Ans.



$$I = m_1 \left(\frac{m_2 r}{m_1 + m_2}\right)^2 + m_2 \left(\frac{m_1 r}{m_1 + m_2}\right)^2$$

$$= \frac{m m_2 r^2 (m_1 + m_2)}{(m_1 + m_2)^2}$$

$$= \left(\frac{m_1 m_2}{m_1 + m_2}\right) r^2$$

~~Q 18.~~

~~Ans.~~

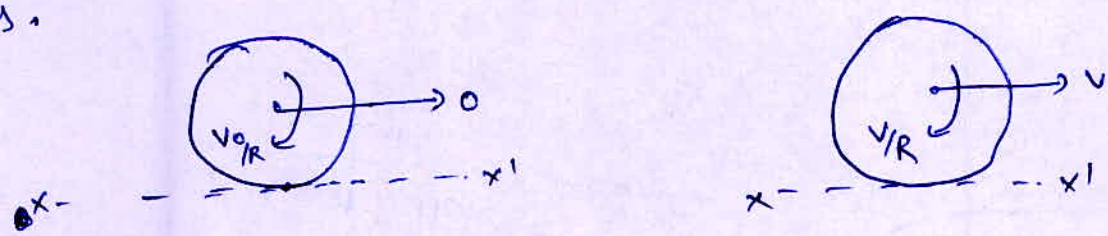
~~$\frac{1}{2} MR^2 \times \left(\frac{V_0}{R}\right)^2 = \frac{1}{2} mV^2 + \frac{1}{2} mR^2 \times \frac{V^2}{R^2}$~~

~~$V_0^2 = 2V^2 + V^2$~~

~~V~~

Q 18.

Ans.



$$(I_1)_{xx'} = (I_2)_{xx'}$$

$$\frac{MR^2}{2}\frac{V_0}{R} = MVR + \frac{MR^2}{2}\frac{V}{R}$$

$$\frac{V_0}{2} = \frac{3}{2}V$$

$$V = V_0/3$$

Q 19.

Ans.

$$\omega = \alpha - \beta t$$

at $t = \alpha/\beta \Rightarrow \omega = 0$

$$\beta \quad \omega \frac{d\omega}{d\theta} = -\beta$$

$$\left[\frac{\omega^2}{2}\right]_{\alpha}^{0} = -\beta\theta$$

$$\theta = \frac{\alpha^2}{2\beta}$$

Q 20.

Ans.

$$I = \frac{MR^2}{4}$$

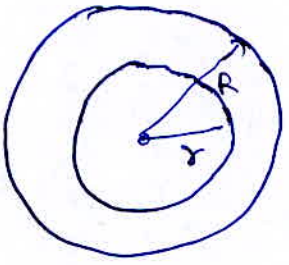
$$I' = \frac{MR^2}{2} + MR^2$$

$$= 3/2\ MR^2$$

$$I' = 6I$$

Q 21.

Ans.



$$\sigma = \frac{m}{\pi (R^2 - r^2)}$$

$$I = \sigma \pi R^2 \frac{R^2}{2} - \sigma \pi r^2 \frac{r^2}{2}$$

$$= \frac{\sigma \pi}{2} (R^4 - r^4)$$

$$= \frac{\sigma \pi}{2} (R^2 - r^2)(R^2 + r^2)$$

$$= \frac{\pi}{2} \times \frac{M}{\pi (R^2 - r^2)} (R^2 - r^2)(R^2 + r^2)$$

$$= \frac{1}{2} m (R^2 + r^2)$$

Q 22.

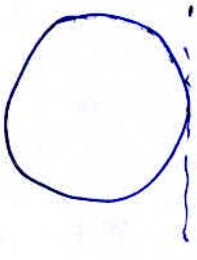
Ans.

$$\frac{1}{2} I \omega^2 = 360$$

$$I = \frac{360 \times 2}{900} = \frac{72}{90} = 0.8 \text{ kg/m}^2$$

Q 23.

Ans.



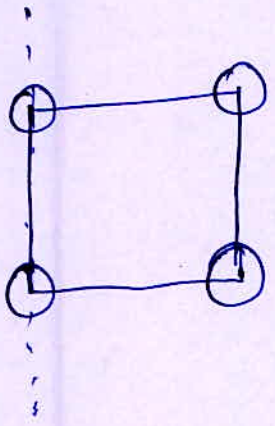
$$I = \frac{2}{3} mR^2 + mR^2$$

$$mk^2 = 5/3\ mR^2$$

$$k = \sqrt{5/3}\ R$$

Q24.

Ans.



$$I = \frac{2}{5}mR^2 \times 2 + 2\left(\frac{2}{5}mR^2 + ma^2\right)$$

$$= \frac{8}{5}mR^2 + 2ma^2$$

Q25.

Ans.

$$I_1 \omega_1 = I_2 \omega_2$$

$$\frac{ML^2}{12}\omega_0 = \left(\frac{ML^2}{12} + \frac{2m}{M}\frac{L^2}{4}\right)\omega_2$$

$$\frac{\omega_0}{12} = \left(\frac{1}{12} + \frac{1}{2}\frac{m}{M}\right)\omega_2$$

$$\omega_2 = \frac{M\omega_0}{M+6m}$$

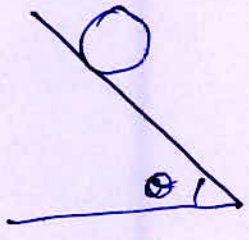
Q 26.

Ans.

$$\vec{\tau}_{ext} = 0 \Rightarrow \vec{L} \text{ constant}$$

Q 27.

Ans.



$f_r = 0$

$a = g\sin\theta$ for all

all will take same time

Q 28.

Ans. $E = \frac{1}{2} I \omega^2$

$L = I\omega$

$L^2 = 2EI$

$L = \sqrt{2EI}$

Q 29.

Ans. $KE_T = \frac{1}{2} m v^2$

$KE_R = \frac{1}{2} I \omega^2 = \frac{1}{2} \frac{2}{5} m R^2 \times \frac{v^2}{R^2}$

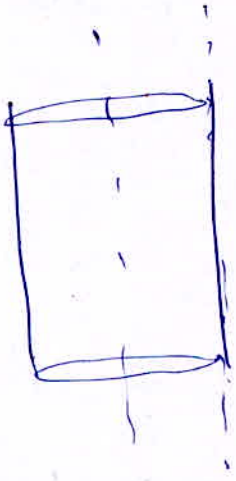
$KE_T / KE_R = 5/2$

Q 30.

Ans. decrease moment of Inertia

Q 31.

Ans.



$I = I_{cm} + MR^2$

$= \frac{MR^2}{2} + MR^2$

$= 3/2\ MR^2$

Q. 32.

Ans.

$$\omega = \omega_0 - \alpha t$$

$$0 = \frac{900}{60} \times 2\pi - \alpha\, 60$$

$$\alpha = \frac{2\pi \times 900}{3600\ 2} = \pi/_2 \text{ rad/s}^2$$

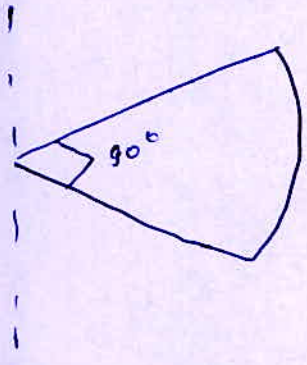
Q 33.

Ans.

$$\omega = \frac{2\pi}{60} = \frac{\pi}{30} \text{ rad/s.}$$

Q 34.

Ans.

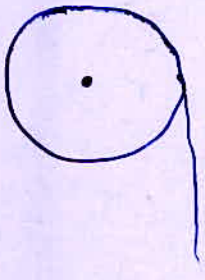


$$I = \frac{M}{4}\frac{R^2}{2}$$

$$= \frac{1}{8} MR^2$$

Q 35.

Ans.



$$K.E \text{ total} = \frac{1}{2} mv^2 + \frac{1}{2} MR^2 \frac{v^2}{R^2}$$

$$= K\mathcal{E}_{trans.} + \text{d}K.E.Rot.$$

$$\text{d } K.\mathcal{E} \text{ Rot.} = \frac{K.\mathcal{E} \text{ total}}{2}$$

Q 36.

Ans. refer Q. 22.

Q 37.

Ans.

$$I_P = \frac{1}{2} \rho (2\pi r) r^2$$

$$I_Q = \frac{1}{2} \rho (2\pi nr)(nr)^2$$

$$\frac{I_Q}{I_P} = 4 = n^3$$

$$n = (4)^{1/3}$$

Q 38.

Ans. refer. Q. 23.

Q 39.

Ans.

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

$$\frac{\Delta g}{g} = -2 \frac{\Delta R}{R}$$

$$T = \frac{1}{2} I \omega^2$$

$$= \frac{1}{2} \frac{L^2}{I}$$

$$\frac{\Delta T}{T} = -\frac{\Delta I}{I}$$

$$\frac{\Delta I}{I} = -2 \frac{\Delta R}{R}$$

g ~~will~~ & T both will increase by 4%

Q 40.

Ans. K.E. total $= \frac{1}{2} m v^2 + \frac{1}{2} m K^2 \frac{v^2}{R^2}$

$$\frac{\frac{1}{2} m K^2 \frac{v^2}{R^2}}{\frac{1}{2} m v^2 + \frac{1}{2} m K^2 \frac{v^2}{R^2}} = \frac{K^2}{K^2 + R^2}$$

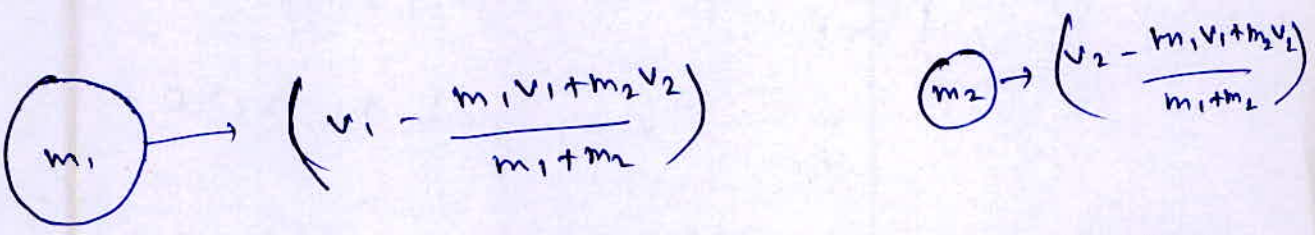
Assertion & Reason Questions

Q 1.

Ans.

$$v_{cm} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

~~in the~~ from the center of mass frame



$$m_1\left(v_1 - \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}\right) + m_2\left(v_2 - \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}\right) = 0$$

Q 2.

Ans.

$$\vec{F}_{ext} = 0 \Rightarrow \vec{a}_{cm} = 0$$

$$\vec{v}_{cm} = \text{constant}$$

Q 4.

Ans.

$$m_1\vec{v}_1 + m_2\vec{v}_2 + \cdots = 0$$

$$K.E. = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 + \cdots \neq 0$$

Q5.
Ans. $\vec{F}_{ext} = \frac{d\vec{P}}{dt}$

Q6.
Ans. $\vec{\tau}_{ext} = 0$ $\vec{\omega}$ will be constant.

$\vec{v}$ can change.

Q7.
Ans. $\vec{F}_{ext} = 0$ $\vec{a}_{cm} = 0$

$\vec{v}_{cm}$ may not be zero.

Q8.
Ans. Just before and after collision momentum is conserved.

Q9.
Ans. $\vec{v}_{cm}$ may not be zero.

Q10.
Ans. position of cm depends upon shape & size.

Q 12.

Ans. point about $\vec{\tau}_{ext} = 0$

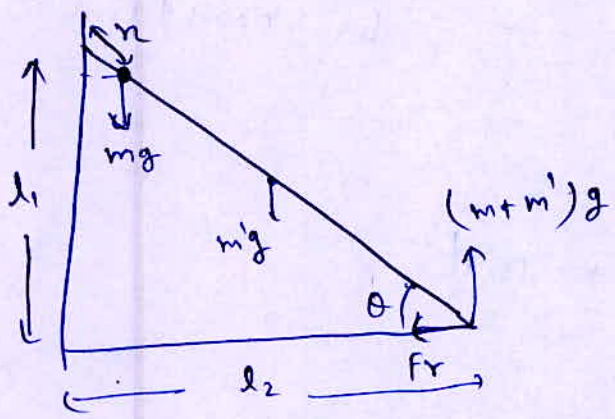
Q 14.

Ans. I increases, ω decreases

$L = I\omega \Rightarrow$ constant

Q 15.

Ans.



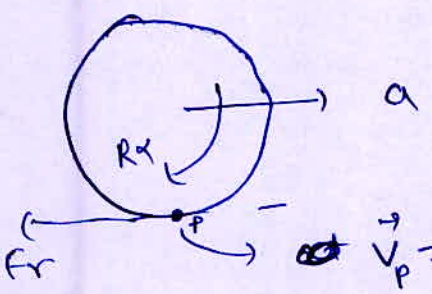
$Fr\, l_1 = (m+m')g\, l_2 - m'g\frac{l_2}{2} - mg\, r\cos\theta$

Fr increases as r decreases

Fr increases as person climbs up.

Q 16?

Ans.



$\vec{V}_p = 0$, $\vec{a}_p \neq 0$

Q 19. LP.

Ans. $\vec{\tau} = \vec{A} \times \vec{L}$

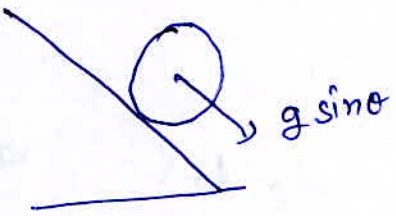
Power = $\vec{\tau} \cdot \frac{d\vec{\omega}}{dt} = 0$

Q 20.

Ans. I depends on the axis

Q 21.

Ans.



$\vec{\tau}$ about CM is zero.

Rotational KE will be constant.

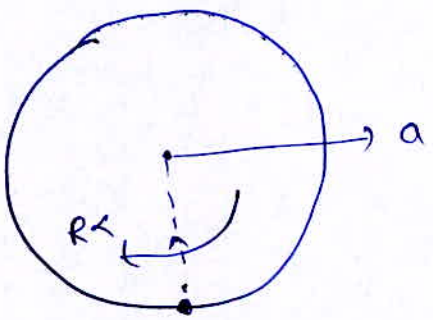
Q 22.

Ans. $I = I_{cm} + md^2$

$I_{min} = I_{cm}$

Q 23.

Ans.

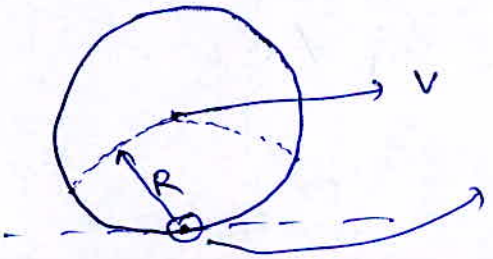


$a_c = \omega^2 R$

$a_t = a - R\alpha = 0$

Q 24.

Ans.



Instantanious axis of Rotation

Q25.
Ans. $\frac{d\vec{\omega}}{dt} = 0 \Rightarrow \alpha = 0 \Rightarrow Fr = 0$

Q26.
Ans. $I_2 = I_x = I_y$ (for uniform sphere)

Q 27
Ans. $\vec{\tau} = \frac{d\vec{L}}{dt}$

$\vec{L} = I\vec{\omega}$

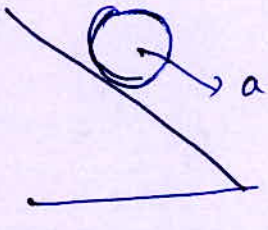
Q 28.
Ans. $\vec{L}$ = Constant $\quad I_1\omega_1 = I_2\omega_2$

$\frac{2}{5}MR^2\omega_1 = \frac{2}{5}M\left(\frac{R}{2}\right)^2\omega_2$

$\omega_2 = 4\omega_1$

$T_2 = \frac{T_1}{4} =$ 6 hours.

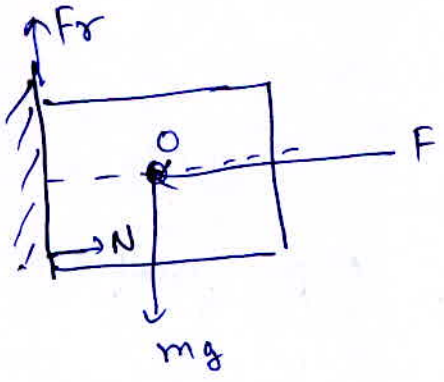
Q31.
Ans.



In pure rolling
Instantaneous speed
of the point of contact
is zero. $\Rightarrow$ Power = 0

Q 32.

Ans.



$$\Sigma \vec{\tau}_O = 0$$

$$\vec{\tau}_{Fr} + \vec{\tau}_N = 0$$

Q 33.

Ans.

$$mgh = \frac{1}{2} mv^2 \rightarrow \text{sliding}$$

$$mgh = \frac{1}{2} m v_2^2 + \frac{1}{2} mK^2 \frac{v_2^2}{R_2} \rightarrow \text{rolling}$$

$$v > v_2$$

Q 34.

Ans.

$$m_1 \vec{v_1} + m_2 \vec{v_2} + \dots = 0$$

$$\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 + \dots \neq 0$$

but if

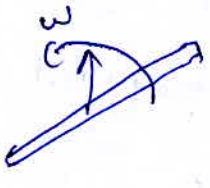
$$\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 + \dots = 0$$

$$v_1 = v_2 = \dots = 0$$

$$m_1 \vec{v_1} + m_2 \vec{v_2} + \dots = 0$$

Q 35.

Ans.

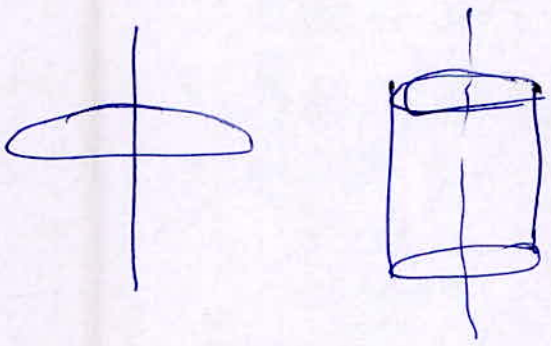


$$\vec{\tau}_{cm} = 0 \Rightarrow \vec{\omega} = \text{constant}$$

v will decrease ($\vec{a} = -\vec{g}$)

Q36.

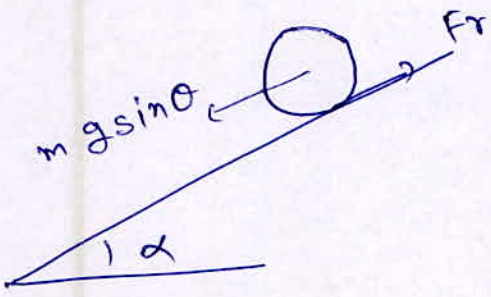
Ans.



$$I_1 = I_2 = \frac{MR^2}{2}$$

Q38.

Ans.



$$mg\sin\theta - Fr = ma$$

$$Fr\ R = \frac{MR^2}{2}\ \frac{a}{R}$$

$$Fr = \frac{ma}{2}$$

$$mg\sin\theta - \frac{ma}{2} = ma$$

$$a = \frac{2}{3} g\sin\theta$$

$$Fr = \frac{1}{3} mg\sin\theta$$

Previous Year's Questions

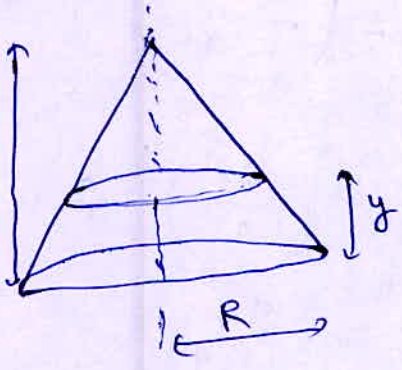
Q 1.

Ans.

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

Q 2.

Ans.



$$y_{cm} = \frac{\int y \, dm}{\int dm}$$

$$= \frac{\int y \rho \pi r^2 \, dy}{\int \rho \pi r^2 \, dy}$$

$$\frac{R}{h} = \frac{r}{h-y} \qquad r = \frac{R}{h}(h-y)$$

$$y_{cm} = \frac{\int_0^h y \frac{R^2}{h^2}(h-y)^2 \, dy}{\int_0^h \frac{R}{h}(h-y)^2 \, dy}$$

$$= \frac{\left[\frac{h^2 y^2}{2} - \frac{2hy^3}{3} + \frac{y^4}{4}\right]_0^h}{\left[h^2 y - \frac{2hy^2}{2} + \frac{y^3}{3}\right]_0^h}$$

$$= \left[\frac{\frac{h^4}{2} - \frac{2h^4}{3} + \frac{h^4}{4}}{h^3 - \frac{2h \cdot h^2}{2} + \frac{h^3}{3}}\right] = \frac{h}{4}$$

Q 3.

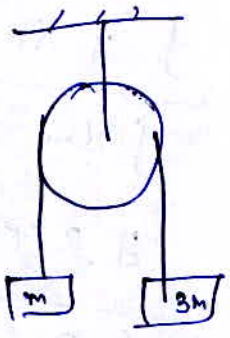
Ans.

$$(\hat{i} + 2\hat{j} + 3\hat{k}) = \frac{4\alpha(\hat{i} + 2\hat{j} + 3\hat{k})}{10}$$

$$\alpha = 5/2$$

Q 4.

Ans.



$$a_{cm} = -\left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 g$$

$$= -\left(\frac{2}{4}\right)^2 g$$

$$= -g/4$$

Q 5.

Ans.

$$6 \times 3 + 4x = 10$$

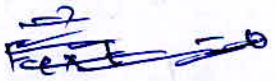
$$6 \times 3 + 4y = 10$$

$$6 \times 3 + 4z = 10$$

$$x = y = z = -2$$

Q 07

Ans.



$$v_{cm} = \frac{m_1\vec{v_1} + m_2\vec{v_2}}{m_1 + m_2}$$

$$= \frac{-4 + 40}{6}$$

$$= 6 \text{ m/s}$$

Q 8.

Ans. $x_{cm} = \dfrac{0.4 \times 2 + 0.6 \times 7}{1}$

$= 5\,m.$

Q 10.

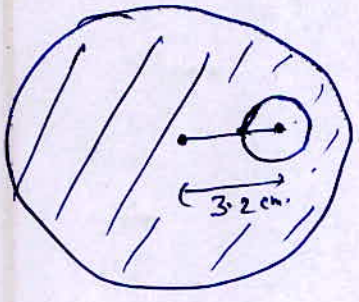
Ans. P & Q

Q 11.

Ans. $\vec{F}_{ext} = m\vec{a}_{cm}$

Q 12.

Ans.



$$x_{cm} = \frac{\sigma\pi R^2 \cdot 0 - \sigma\pi\left(\frac{R}{3}\right)^2 \times 3.2}{\sigma\pi R^2 - \sigma\pi\left(\frac{R}{3}\right)^2}$$

$$= \frac{-\frac{1}{9} \times 3.2}{1 - \frac{1}{9}}$$

$$= -0.4\ cm$$

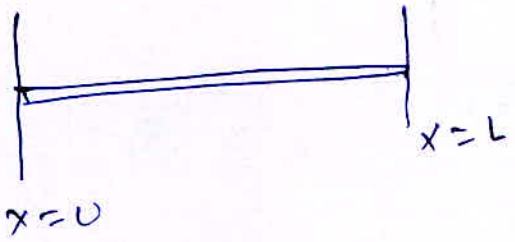
Q 13.

Ans. $\vec{v}_{cm} = \dfrac{1 \times 2\hat{i} + 2 \times \frac{\sqrt{3}}{2} \times 2\hat{i} - 2 \times 2 \times \frac{1}{2}\hat{j}}{3}$

$$= \left(\frac{2 + 2\sqrt{3}}{3}\right)\hat{i} - \frac{2}{3}\hat{j}$$

Q 14.

Ans.



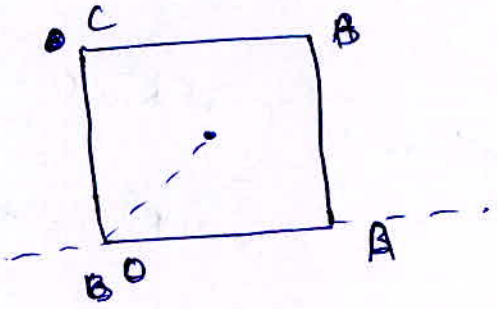
$$\rho = Ax$$

$$x_{cm} = \frac{\int_0^L Ax^2\,dx}{\int_0^L Ax\,dx}$$

$$x_{cm} = \frac{\left[\frac{x^3}{3}\right]_0^L}{\left[\frac{x^2}{2}\right]_0^L} = \frac{2L}{3}$$

Q 15.

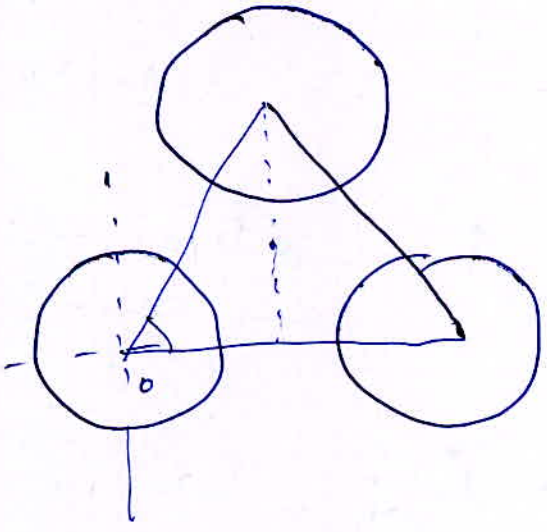
Ans.



$$\vec{r}_{cm} = \frac{1}{2}(\hat{i} + \hat{j})$$

Q 16.

Ans.



$$x_{cm} = \frac{m\,2 + m \cdot 1}{3m}$$

$$= 1$$

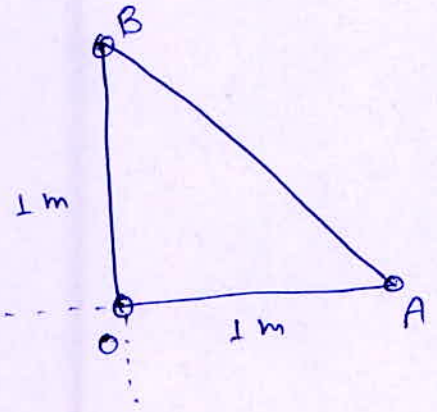
$$y_{cm} = \frac{m \cdot 0 + m\,\sqrt{3}/2 \times 2}{3m}$$

$$= \frac{1}{\sqrt{3}}$$

$$\left(\hat{i} + \hat{j}/\sqrt{3}\right)$$

Q 19

Ans.



$$x_{cm} = \frac{1\hat{i}}{3}$$

$$y_{cm} = \frac{1\hat{j}}{3}$$

$$\equiv \left(\frac{\hat{i}+\hat{j}}{3}\right)$$

Q 20.

Ans.

$$x_{cm} = \frac{\int_0^3 x(2+x)\,dx}{\int_0^3 (2+x)\,dx}$$

$$x_{cm} = \frac{\left[x^2 + \frac{x^3}{3}\right]_0^3}{\left[2x + \frac{x^2}{2}\right]_0^3}$$

$$= \frac{18}{6+9/2}$$

$$= \frac{36}{27} = \frac{12}{7}\ m$$

Q 21.

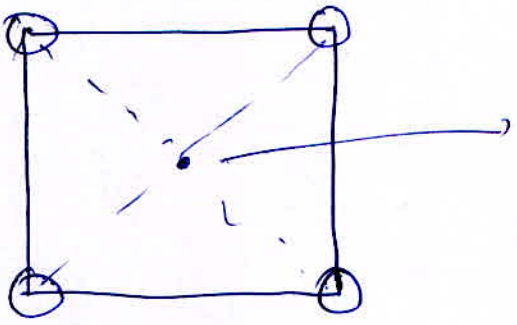
Ans.

$$\Delta x_{cm} = \frac{m_1 d + m_2 x}{m_1 + m_2} = 0$$

$$x = -\frac{m_1}{m_2} d$$

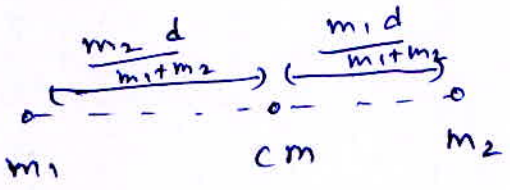
Q 22.

Ans.



Q 23.

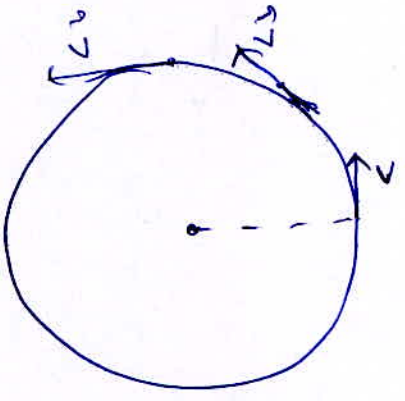
Ans.



Rotational Variables

Q 24.

Ans.



ω constant

$|\vec{V}|$ = constant

Q 25.

Ans.

$$\theta = 2 \times 2 + \frac{1}{2} \times 3 \times 2^2$$

$$= 4 + 6 = 10 \text{ rad}$$

Q 26.

Ans.

$$\left(\frac{\omega}{2}\right)^2 = \omega^2 - 2\alpha \times 36 \times 2\pi \Rightarrow \frac{3\omega^2}{4(36 \times 2\pi)} = 2\alpha$$

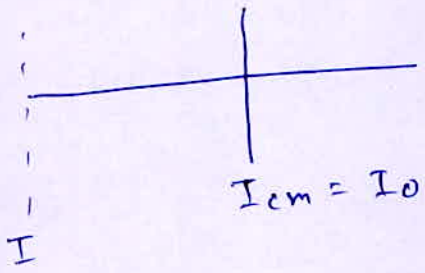
$$0 = \left(\frac{\omega}{2}\right)^2 - 2\alpha\theta$$

$$\theta = \frac{\omega^2}{8\alpha} = \frac{36 \times 2\pi}{3} = 12 \times 2\pi$$

Moment of Inertia

Q 27.

Ans.

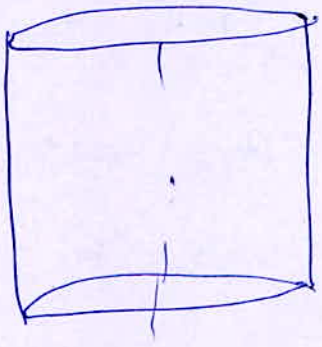


$$I = I_{cm} + m\left(\frac{l}{2}\right)^2 = I_o + \frac{mL^2}{4}$$

Q 28.

Ans.

MR^2



Q 29.

Ans.

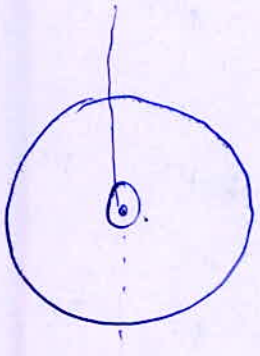
$$\tau = I\alpha$$

$$3.14 = I \; 4\pi$$

$$I = \frac{1}{4} \; kg\text{-}m^2$$

Q 30.

Ans.



$$I_1 = \frac{MR^2}{2} = 2 \; kg\text{-}m^2$$

$$I_2 = \frac{MR^2}{2} + MR^2 = 3 \times 2 = 6 kg\text{-}m^2$$

Q 31.

Ans. $I = \frac{MR^2}{4} + MR^2 = \frac{5}{4} MR^2$

$I' = \frac{MR^2}{2} + MR^2 = \frac{3}{2} MR^2$

$I' = \frac{6}{5} I$

Q 32.

Ans

$I = \frac{2}{5} MR^2 + MR^2$

$= 7/5 \times 10 \times \frac{1}{4}$

$= 3.5 \text{ kg-m}^2$

Q 33.

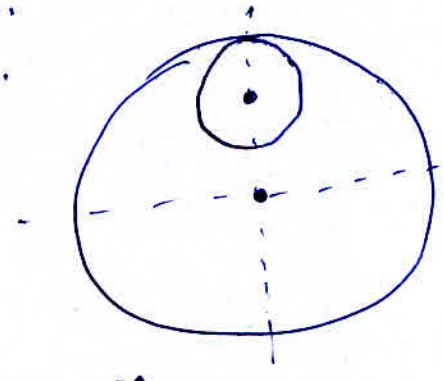
Ans.

$I = \frac{ML^2}{12} + 2 \times m\left(\frac{l}{2}\right)^2$

$= \frac{(M+6m)L^2}{12}$

Q 34.

Ans.



$I = \frac{MR^2}{2} - \left(\frac{M'}{2}\left(\frac{R}{3}\right)^2 + M'\left(\frac{2R}{3}\right)^2 \right)$

$= R^2 \left(\frac{M}{2} - \frac{M'}{18} - \frac{4}{9}M' \right)$

$= R^2 \left(\frac{9m}{2} - \frac{m}{18} - \frac{4m}{9} \right)$

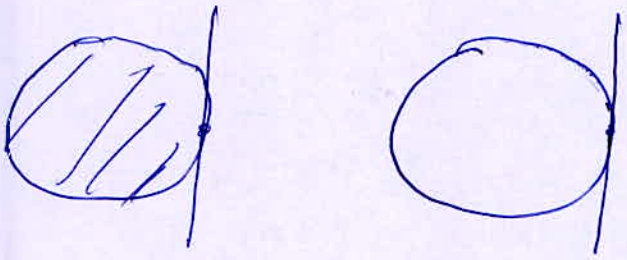
$= 4mR^2$

$M' = \frac{M}{9}$

$M' = m$

Q 35.

Ans.



$I_1 = \frac{MR^2}{2} + MR^2$

$I_2 = MR^2 + MR^2$

$MK_1^2 = \frac{3}{2} MR^2$

$MK_2^2 = 2MR^2$

$\frac{K_1}{K_2} = \frac{\sqrt{3}}{2}$

Q 36.

Ans.

$MK^2 = \frac{MR^2}{2}$

$K^2 = \frac{R^2}{2}$

$K = \frac{R}{\sqrt{2}} = 0.4437 \text{ cm.}$

Q 37.

Ans.

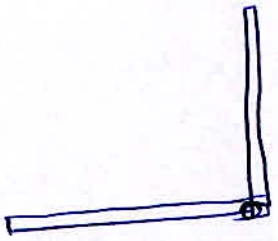
$I_1 = MK_1^2 = M\frac{R^2}{2}$

$I_2 = MK_2^2 = MR^2$

$\frac{K_1}{K_2} = \frac{1}{\sqrt{2}}$

Q 38.

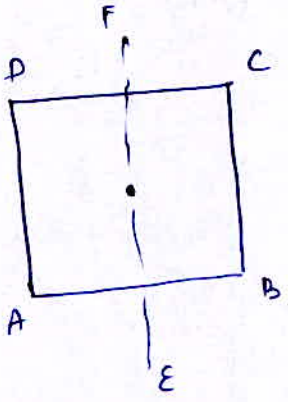
Ans.



$$I = \frac{ML^2}{12}$$

Q 39.

Ans.



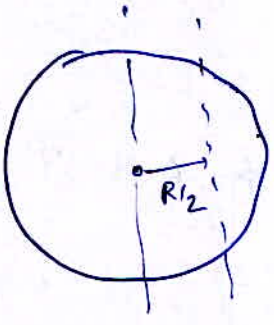
$$I_{EF} = \frac{1}{2} M \frac{a^2}{6}$$

$$I_{AD} = I_{EF} + \frac{ma^2}{4}$$

$$= \frac{ma^2}{3} = 4 I_{EF}$$

Q 40.

Ans.



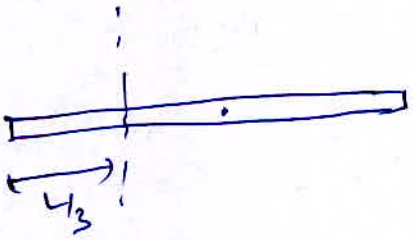
$$I = I_{cm} + M\left(\frac{R}{2}\right)^2$$

$$= \frac{MR^2}{2} + \frac{MR^2}{4}$$

$$= \frac{3}{4} MR^2$$

Q 41.

Ans.



$$I = I_{cm} + m\left(\frac{L}{2} - \frac{L}{3}\right)^2$$

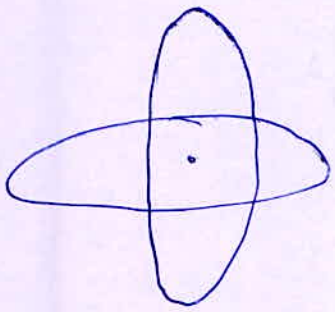
$$MK^2 = \frac{ML^2}{12} + \frac{ML^2}{36}$$

$$= \frac{ML^2}{9}$$

$$K = \frac{L}{3}$$

Q 42.

Ans.



$$I = MR^2 + \frac{MR^2}{2}$$

$$= \frac{3}{2} MR^2$$

Q 43.

Ans.

$$I_1 = \frac{2}{3} MR_1^2 \qquad I_2 = \frac{2}{5} MR_2^2$$

$$\frac{R_1}{R_2} = \sqrt{\frac{3}{5}\frac{I_1}{I_2}} = \sqrt{\frac{3}{5}}$$

Q 44.

Ans. $2I$ (perpendicular axis thc.)

Q 45.

Ans.

$$I = MR^2 = 4 \text{ Kg-m}^2$$

$$R = 2 \text{ m.}$$

Q 46.

Ans.

$$K.E_R = \frac{1}{2} I \omega^2 \Rightarrow \omega = 1$$

$$I = 2 K.E_R$$

Q 47.

Ans.

$$I = I_{cm} + MR^2$$

$$= 2 + 2 \times 2^2$$

$$= 10 \text{ kg-m}^2$$

Q 48.

Ans.

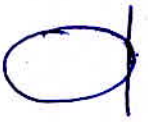
$$360 = \frac{1}{2} I \times (20)^2$$

$$I = \frac{360 \times 2}{400} = \frac{18}{10} = 1.8 \text{ kg-m}^2$$

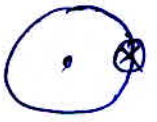
Q 49.

Ans.

$$I_1 = \frac{MR^2}{4} + MR^2 = Mk_1^2$$



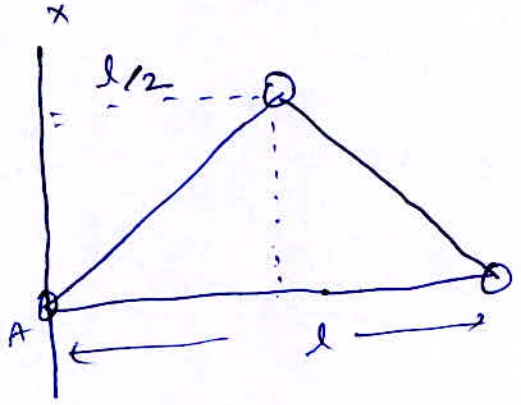
$$I_2 = \frac{MR^2}{2} + MR^2 = Mk^2$$



$$\frac{k_1}{k_2} = \sqrt{\frac{5}{6}}$$

Q 50.

Ans.

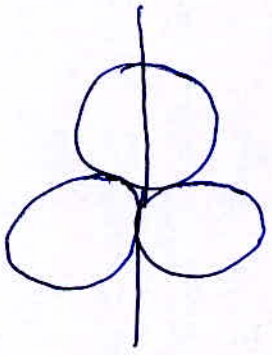


$$I_{AX} = m.0^2 + m\left(\frac{l}{2}\right)^2 + ml^2$$

$$= \frac{5}{4} ml^2$$

Q 51.

Ans.

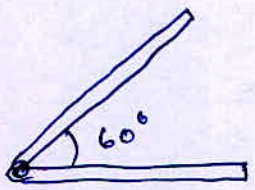


$$I_{xx'} = \frac{MR^2}{2} + 2\left(\frac{MR^2}{2} + MR^2\right)$$

$$= \frac{7}{2} MR^2$$

Q 52.

Ans.

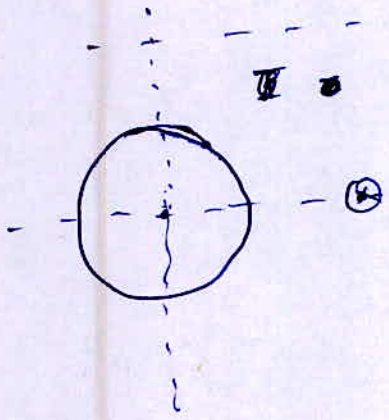


$$I = \frac{M}{2}\left(\frac{\ell}{2}\right)^2 \times \frac{1}{3} + \frac{M}{2}\left(\frac{\ell}{2}\right)^2 \times \frac{1}{3}$$

$$= \frac{M\ell^2}{12}$$

Q 53.

Ans.



$$I_1 = \frac{MR^2}{4} + M(2R)^2$$

$$I_2 = \frac{MR^2}{2} + Md^2$$

$$I_1 = I_2$$

$$\frac{17}{4}MR^2 = \frac{MR^2}{2} + Md^2$$

$$\frac{15}{4}MR^2 = Md^2$$

$$d = \sqrt{\frac{15}{4}}\,.R = \frac{\sqrt{15}}{2}R$$

Q 55.

Ans.

$$I = 5 \times MR^2$$

$$= 5 \times 2 \times (0.1)^2 = 0.1\ kg\text{-}m^2$$

Q 56.

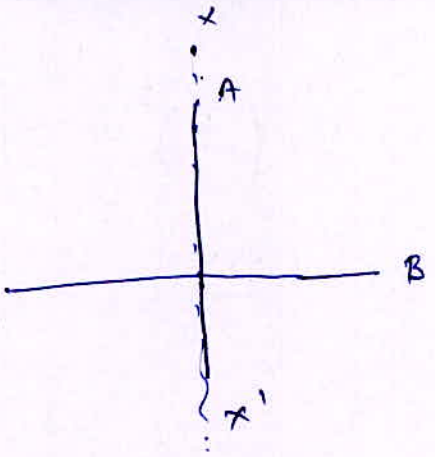
Ans.

$$MK^2 = \frac{2}{5}MR^2 + M(2R)^2$$

$$K = \sqrt{\frac{22}{5}}\,R$$

Q 57.

Ans.



$$I_{xx'} = I_A + I_B$$

$$= 0 + \frac{ML^2}{12}$$

Q 58.

Ans.

$$I_H = \frac{2}{3} MR^2 \qquad I_S = \frac{2}{5} MR^2$$

Q 59.

Ans.

$$I = \frac{MR^2}{4} + MR^2 = 5/4\, MR^2$$

$$I_2 = \frac{MR^2}{2} + MR^2 = \frac{3}{2} MR^2$$

$$I_2 = \frac{6}{5} I$$

Q 60.

Ans.

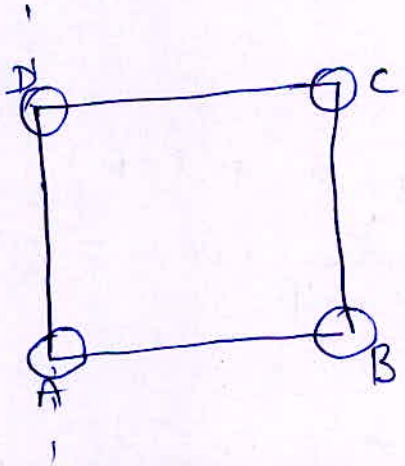
$$I_1 \omega_1 = I_2 \omega_2$$

$$mK_1^2 \omega_1 = mK_2^2 \omega_2$$

$$\frac{K_1}{K_2} = \sqrt{\frac{\omega_2}{\omega_1}}$$

Q 62.

Ans.



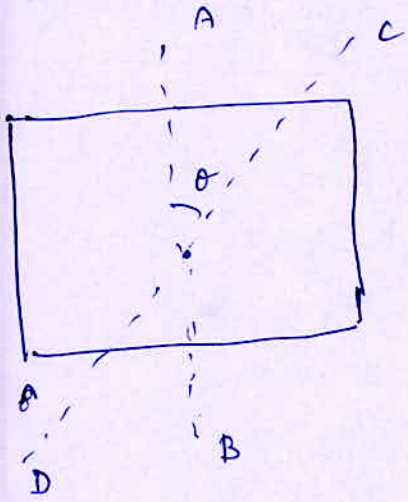
$$I = \frac{2}{3} MR^2 + \left(\frac{2}{3} mR^2 + mb^2\right)$$

$$+ \frac{2}{5} MR^2 + \left(\frac{2}{5} MR^2 + mb^2\right)$$

$$= \frac{32}{15} MR^2 + 2mb^2$$

Q 62.

Ans.



$$I_{CD} = I_{AB} = I$$

Q 63.

Ans.

$$L_1 = L_2$$

$$I_1 \omega = I_2 \omega_2$$

$$I_2 = I_1 + I_2$$

$$\omega_2 = \frac{I_1 \omega}{I_1 + I_2}$$

Q 65.

Ans.

$$I_A = \rho \, 2\pi r_A \, r_A^2$$

$$I_B = \rho \, 2\pi r_B \, r_B^2$$

$$\frac{I_B}{I_A} = \left(\frac{r_B}{r_A}\right)^3 = 8$$

$$\frac{r_B}{r_A} = 2$$

Torque, Couple and Angular Momentum

Q 66.

Ans. $\theta(t) = 2t^3 - 6t^2$

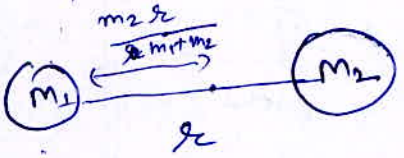
$$\frac{d\theta}{dt} = 6t^2 - 12t$$

$$\tau = \frac{d^2\theta}{dt^2} = 12t - 12 = 0$$

$$t = 1 \text{ sec.}$$

Q 67.

Ans.

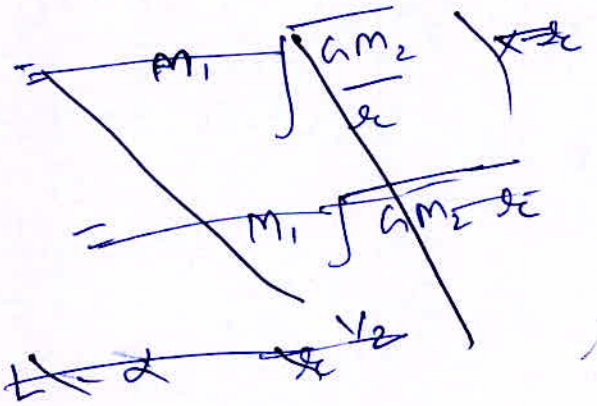


$$\frac{m_1 v^2}{\frac{m_2 r}{(m_1+m_2)}} = \frac{G m_1 m_2}{r^2}$$

$$v \propto r^{-1/2}$$

$$L = m_1 v_1 r$$

$$L \propto r^{1/2}$$



Q 68.

Ans. Angular Momentum

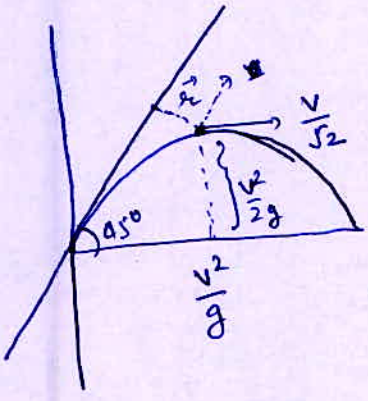
Q 69.

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

$|\vec{L}| = rp\sin\theta$ will be max. when $\theta = 90°$

Q 70.

Ans.



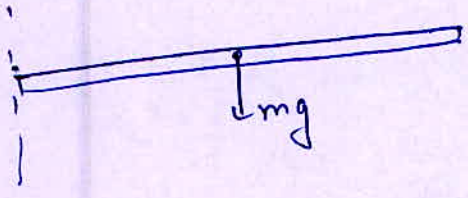
$\vec{L} = m\,\vec{r} \times \vec{p}$

$= \left(\frac{\frac{v^2}{g} - \frac{v^2}{2g}}{\sqrt{2}} \right) \times m \frac{v}{\sqrt{2}} \sin 45°$

$= \frac{mv^2}{4\sqrt{2}\,g}$

Q 71.

Ans.



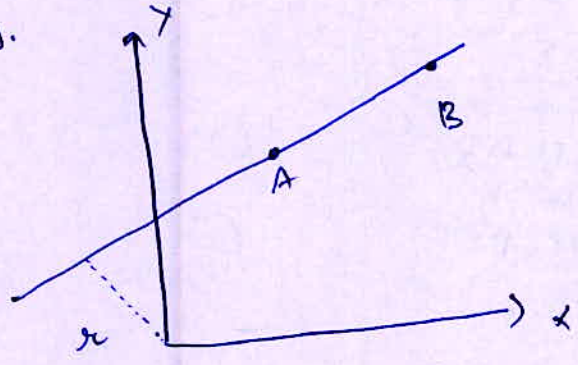
$\vec{\tau} = I\alpha$

$mg\frac{l}{2} = \frac{ml^2}{3}\alpha$

$\alpha = \frac{3g}{2l}$

Q 72.

Ans.



$\vec{L_A} = mvr$

$\vec{L_B} = mvr$

Q 73.

Ans.

$$\vec{\tau} = I\alpha$$

$$= \frac{m\ell(2\ell)^2}{12} \times \frac{\omega}{t}$$

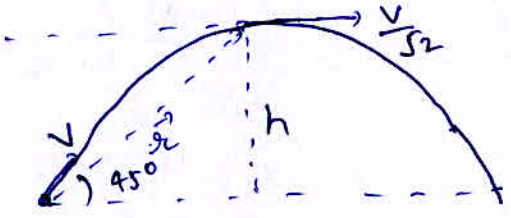
$$= \frac{m\ell^2\omega}{3t}$$

$$\omega = 0 + \alpha t$$

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

Q 74.

Ans.



$$\vec{L} = m(\vec{r} \times \vec{v})$$

$$= m \cdot \frac{V}{\sqrt{2}} \underbrace{r \sin\theta}_{h}$$

$$= \frac{mvh}{\sqrt{2}}$$

Q 75.

Ans.

$$K.E. = \frac{1}{2} I_1 \omega_1^2 = \frac{1}{2} I_2 \omega_2^2$$

$$0 = \omega_1^2 - 2\alpha(2\pi n)$$

$$\omega_1^2 = 2 \cdot \frac{\tau}{I_1} 2n\pi$$

$$\omega_2^2 = 2\frac{\tau}{I_2}(2\pi n_2)$$

$$I_2 \omega_2^2 = 2\tau\, 2\pi n_2 \quad -(1)$$

$$I_1 \omega_1^2 = 2\tau\, 2\pi n \quad -(2)$$

$$(1)/(2) \qquad \frac{n_2}{n} = 1 \qquad n_2 = n$$

Q 76.

Ans.

$$\omega^2 = \omega_0^2 - \alpha t$$

$$0 = \frac{60 \times 2\pi}{60} - \alpha \times 60$$

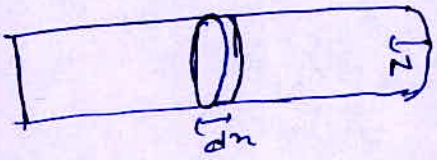
$$\alpha = \frac{2\pi}{60}$$

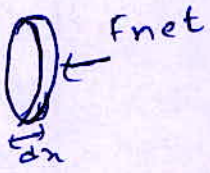
$$\tau = I\alpha$$

$$= 2 \times \frac{2\pi}{60} = \frac{\pi}{15} \text{ N-m}$$

Q 77.

Ans.





$$F_{net} = \frac{M}{L} dx \, x \, \omega^2$$

$$N = \int_0^L \frac{M}{L} dx \, x \, \omega^2$$

$$= \frac{M}{L} \omega^2 \frac{L^2}{2} = \frac{ML\omega^2}{2}$$

Q 78.

Ans.

$$\omega_2 = 2\omega$$

$$K.E._1 = \frac{L^2}{2I}$$

$$K.E._2 = \frac{L_2^2}{2I_2} = \frac{L^2}{4I}$$

$$K.E._2 = \frac{1}{2} I_2 (2\omega)^2 = \frac{1}{2} \times \frac{1}{2} I_1 \omega^2$$

$$I_2 = \frac{I_1}{8}$$

$$\frac{L_2^2}{2 \times \frac{I_1}{8}} = \frac{L^2}{4I_1} \Rightarrow L_2^2 = \frac{L}{4}$$

Q 78.

Ans.

$$I_1 \omega_1 = I_2 \omega_2$$

$$m R_1^2 \omega_1 = m \left(\frac{R_1}{n}\right)^2 \omega_2$$

$$\omega_2 = n^2 \omega_1$$

Q 80.

Ans.

$$I_1 \omega_1 = I_2 \omega_2$$

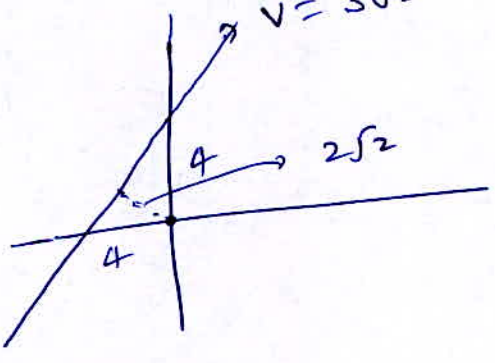
$$\frac{M_1 R^2}{2} \omega_1 = \left(\frac{M_1 R^2}{2} + M_2 R^2\right) \omega$$

$$\omega = \frac{M_1 \omega_1}{M_1 + 2M_2} = \frac{2}{2.5} \times 30$$

$$= 24 \text{ rad./s.}$$

Q 81.

Ans.



$y = x + 4$

$$\vec{L} = m v r \sin 45^\circ$$

$$= 5 \times 3\sqrt{2} \times 4 \times \frac{1}{\sqrt{2}}$$

$$= 60$$

Q 82.

Ans.

$$r = 8i - 4j \qquad v = 8\hat{i} + 4\hat{j}$$

$$\vec{L} = \vec{r} \times \vec{p} = \left(8\hat{i} - 4\hat{j}\right) \times \left(8\hat{i} + 4\hat{j}\right)$$

$$= 32\hat{k} + 32\hat{k}$$

$$= 64\hat{k}$$

Q 83.
Ans. $I_1 \omega_1 = I_2 \omega_2$

I increases $\Rightarrow$ ω decreases

Q 84.
Ans. $\tau = \frac{d\vec{L}}{dt}$

Q 85.
Ans. $\tau = I\alpha$

$\tau R = \frac{MR^2}{2} \alpha$

$\therefore \alpha = \frac{2T}{MR}$

Q 86.
Ans. $\tau = \frac{\Delta L}{\Delta T} = \frac{3A\theta}{4}$

Q 87.
Ans. $\vec{\tau} = \frac{d\vec{L}}{dt} = 0 \Rightarrow \vec{L}$ constant

Q 88.
Ans. $I_1 \omega_1 = I_2 \omega_2 =$ Constant

$\frac{\Delta I}{I} = -\frac{\Delta \omega}{\omega}$

$\frac{\frac{M(R(1+\alpha\Delta T))^2}{2} - \frac{MR^2}{2}}{MR^2/2} = -\frac{\Delta \omega}{\omega}$

$$\frac{\Delta w}{w} = 2 \alpha \Delta T$$

$$\Delta w = 2 w \alpha \Delta T$$

Q 89.

Ans. $I w = L$

T Double $\Rightarrow$ w half

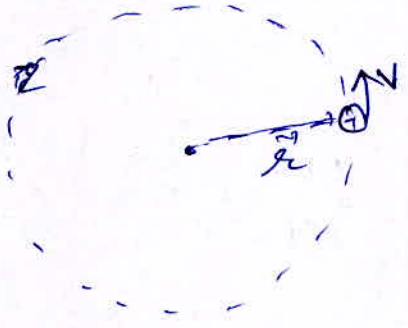
L will be half

Q 90.

Ans. $\vec{\tau} = \frac{d\vec{L}}{dt}$

Q 93.

Ans.



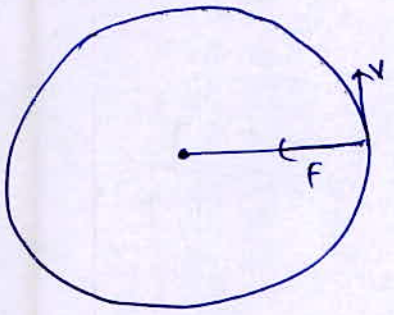
$\vec{L} = m(\vec{r} \times \vec{v})$

constant

Rotational Energy and Power

Q 94.

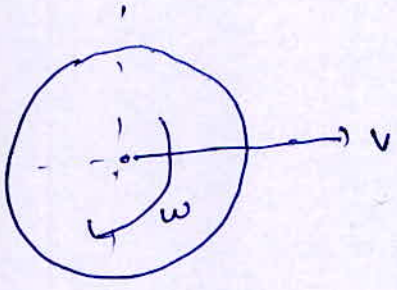
Ans.



$$\text{Power} = \vec{F} \cdot \vec{V} = 0$$

Q 95.

Ans.



$$K.E_R = \frac{1}{2} \times \frac{2}{5} mR^2 \frac{V^2}{R^2}$$

$$K.E_{Total} = \frac{1}{2} mv^2 + \frac{1}{2} \times \frac{2}{5} mR^2 \frac{V^2}{R^2}$$

$$\frac{K.E_R}{K.E_{Total}} = \frac{2/5}{1 + 2/5} = \frac{2}{7}$$

Q 96.

Ans.

$$K.E_{total} = \frac{1}{2} I\omega^2 + \frac{1}{2} mv^2$$

$$= \frac{1}{2} \frac{mR^2}{2} \omega^2 + \frac{1}{2} m R^2 \omega^2$$

$$= \frac{3}{4} mR^2 \omega^2$$

$$= \frac{3}{4} \times 4.8 \times 1 \times (40)^2 \times 4\pi^2$$

$$= 1440\,\pi^2\ J$$

Q 97.

Ans.

$$K.E. = \frac{1}{2} I\omega^2 \qquad \omega = \frac{1}{2} \frac{L^2}{I}$$

L remains constant but I decreases

Q 98.

Ans. $K.E_R = \frac{1}{2} I \omega^2$

$K.E_T = \frac{1}{2} mv^2 = \frac{1}{2} m R^2 \omega^2$

$\frac{K.E_R}{K.E_T} = \frac{4}{10} = \frac{I}{mR^2}$

$I = \frac{2}{5} MR^2 \Rightarrow$ solid ball

Q 99.

Ans. $\frac{1}{2} I \omega^2 = 8$

$\frac{1}{2} \times \frac{2}{5} \times 1^2 \times \omega^2 = 8$

$\omega = 4$

$L = I\omega = 1 \times 4 = 4$

Q 100.

Ans. $\frac{K.E_R}{K.E_{Total}} = \frac{\frac{1}{2} m k^2 \omega^2}{\frac{1}{2} m k^2 \omega^2 + \frac{1}{2} m R^2 \omega^2}$

$= \frac{k^2}{k^2 + R^2}$

Q 101.

Ans.

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

$$\frac{1}{2} \times \frac{}{2} (R\omega)^2 = 4$$

$$(R\omega)^2 = 8$$

$$R\omega = 2\sqrt{2} = V$$

Q 102.

Ans.

$$K.E. = \frac{1}{2} mv^2 + \frac{1}{2} \times \frac{2}{5} mR^2 \frac{v^2}{R^2}$$

$$= \frac{1}{2} mv^2 \left(1 + 2/5\right)$$

$$= \frac{7}{10} \times 2 \times \left(\frac{1}{2}\right)^2$$

$$= 0.35 \text{ J}$$

Q 103.

Ans.

$$\frac{1}{2} I_1 \omega_1^2 = \frac{1}{2} I_2 \omega_2^2$$

$$\frac{1}{2} I_1 \omega_1^2 = \frac{1}{2} 2I \omega_2^2$$

$$\left(\frac{\omega_1}{\omega_2}\right)^2 = 2$$

$$\frac{\omega_1}{\omega_2} = \sqrt{2}$$

Q 104.

Ans.

$$mgh \geq \frac{1}{2}mv^2 + \frac{1}{2}\times\frac{2}{5}mR^2\frac{v^2}{R^2}$$

$$gh \geq \frac{7}{10}v^2$$

$$v \geq \sqrt{\frac{10}{7}gh}$$

Q 105.

Ans.

$$I_A\omega_A = I_B\omega_B$$

$$K_A = \frac{1}{2}I_A\omega_A^2$$

$$K_B = \frac{1}{2}I_B\omega_B^2$$

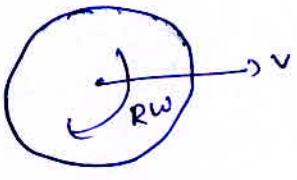
$$\frac{K_A}{K_B} = \left(\frac{\omega_A}{\omega_B}\right)^2 \times \frac{I_A}{I_B} = \frac{I_B^2}{I_A^2}\times\frac{I_A}{I_B}$$

$$\frac{K_A}{K_B} = \frac{I_B}{I_A} < 1$$

$$K_B > K_A$$

Q 107.

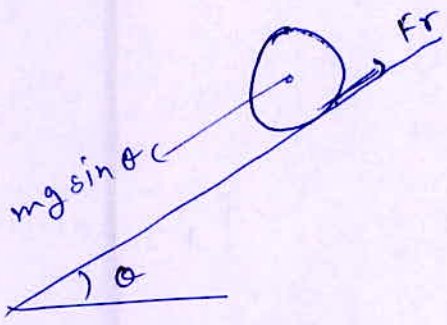
Ans.



it ~~won't stop~~ will never stop.

Q 108.

Ans.



$$mg\sin\theta - F_r = ma$$

$$F_r = I\frac{a}{R^2}$$

$$mg\sin\theta = ma\left(\frac{I}{mR^2} + 1\right)$$

$$a = \frac{mg\sin\theta R^2}{mR^2 + I}$$

$$I_s < I_{hollow}$$

Q 109.

Ans.

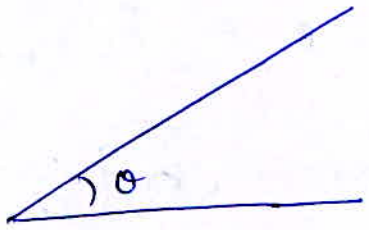
$$K.E. = \frac{1}{2}mv^2 + \frac{1}{2}mR^2\frac{v^2}{R^2}$$

$$= mv^2$$

Rolling Motion

Q 110.

Ans.



v_{max} without friction

$$v_{max} = \sqrt{Rg\tan\theta}$$

Q 111.

Ans.

$$\mu = \frac{m_1 m_2}{m_1 + m_2} = {}^{2m}/_{3}$$

Q 112.

Ans.

$$a = \frac{g\sin\theta}{R^2 + I/m}$$

$$a \text{ solid sphere} = \frac{g\sin\theta}{R^2\left(1 + \frac{2}{5}\right)}$$

$$a \text{ disc} = \frac{g\sin\theta}{R^2\left(1 + \frac{1}{2}\right)}$$

$$s = \frac{1}{2} a t^2$$

$$t \propto a^{-1/2}$$

$$\frac{t \text{ solid}}{t \text{ disc}} = \left(\frac{a \text{ disc}}{a \text{ solid}}\right)^{1/2} = \left(\frac{7/5}{3/2}\right)^{1/2}$$

$$= \sqrt{14/15}$$

Q 113.

Ans.

$mgh = \frac{1}{2}mv^2$ → sliding

$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\cdot\frac{v^2}{R^2}$ → Rolling

$V_{rolling} < V_{sliding}$

Q 114.

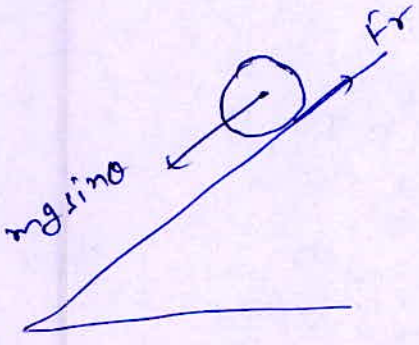
Ans.

$$a = \frac{g\sin\theta\, R^2}{R^2 + \frac{I}{m}}$$

$\frac{I}{m}$ is same for both.

Q 115.

Ans.



$$a = \frac{g\sin\theta}{R^2}$$

$mg\sin\theta - Fr = ma$

$Fr\,R = I\,\frac{a}{R}$

$Fr = \frac{I\,a}{R^2}$

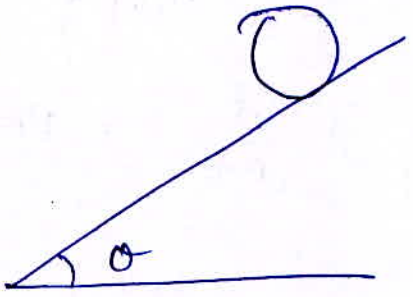
$mg\sin\theta = ma + \frac{I\,a}{R^2}$

$$a = \frac{mg\sin\theta}{m\left(1+\frac{I}{mR^2}\right)} = \frac{g\sin\theta}{\left(1+\frac{1}{2}\right)}$$

$$a = \frac{g \times \sqrt{3}/2}{3/2} = g/\sqrt{3}$$

Q 116.

Ans.



$mg\sin\theta - f_r = ma$

$f_r = \frac{mR^2}{2}\frac{a}{R}$

$f_r = \frac{ma}{2}$

$a = \frac{2}{3}g\sin\theta$

$F_r = \frac{mg\sin\theta}{3} \leq \mu_s mg\cos\theta$

$\tan\theta \leq 3\mu_s$

Q 117.

Ans.

$mgh = \frac{1}{2}mR^2\omega^2 + \frac{1}{2} \times \frac{mR^2}{2} \times \omega^2$

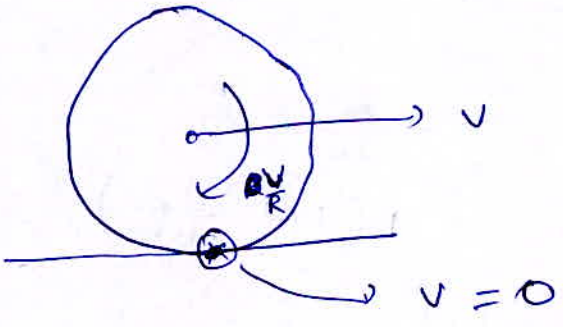
$mgh = \frac{3}{4}mR^2\omega^2$

$R^2 = \frac{4}{3}\frac{gh}{\omega^2} = \frac{4}{3} \times \frac{30}{8}$

$R = \sqrt{5}$ m.

Q 119.

Ans.



Q 120.

Ans. $mgh = \frac{1}{2}mv^2 + \frac{1}{2} \times \frac{2}{5} mR^2 \frac{v^2}{R^2}$

$mgh = \frac{7}{10} mv^2$

$h = \frac{7}{10} \frac{v^2}{g}$

Q 121.

Ans. $I_1 \omega_1 + I_2 \omega_2 = 0$

$\omega_2 = -\frac{I_1}{I_2} \omega_1$

~~$R(\omega_1 + \omega_2) =$~~

$\omega_1 = \frac{1}{2}$

$\omega_2 = -\frac{50 \times R^2}{200} \times \frac{1}{2}$

$= -\frac{50 \times 4 \times \frac{1}{2}}{200}$

$= -\frac{1}{2}$

$\omega_{Relative} = \omega_1 - \omega_2 = \frac{1}{2} + \frac{1}{2} = 1$

$T = \frac{2\pi}{\omega_{relative}} = \frac{2\pi}{1} = 2\pi$ sec.