SYSTEM OF PARTICLES AND ROTATIONAL MOTION

EXERCISE-I (MHT CET LEVEL)

Q.1 (2)
The coordinates of C.M of three particle are

$$x = \frac{m_1x_1 + m_2x_2 + m_3 + x_3}{m_1 + m_2 + m_3}$$

$$y = \frac{m_1y_1 + m_2y_2 + m_3 + y_3}{m_1 + m_2 + m_3}$$

here $m_1 = m_2 = m_3 = m$

$$\text{so } x = \frac{(x_1 + x_2 + x_3)m}{m + m + m} = 2,$$

$$y = \frac{(y_1 + y_2 + y_3)m}{m + m + m} = 2$$

so coordinates of C.M. of three particle are
(2, 2)
V=300m/s

Q.2 (2)
Centre of mass shifts towands heavier side

Q.3 (2)

$$x_{cm} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$$

$$= \frac{m(0 + PQ + PR)}{3m} = \frac{PQ + PR}{3}$$

Q.4 (2)
$F_{ext} = 0$
$\therefore v_{cm} = u_{cm} = 0$

Q.5 (4)

$$E = \frac{P^2}{2m} \qquad \therefore E \propto P^2$$

i.e. if P is increased n times then E will increase n^2 times.

Q.6 (4)

$$a_{cm} = \frac{m_1g + m_2g}{m_1 + m_2} = g$$

Q.7 (3)

$$V_{cm} = \frac{M_1V_1 + M_2V_2}{M_1 + M_2}$$

$$= \frac{200 \times 10\hat{i} + 500(3\hat{i} + 5\hat{j})}{700} = 5\hat{i} + \frac{25}{7}\hat{j}$$

Q.8 (4)
$V_{CM} = 0$, because internal force cannot change the velocity of centre of mass

Q.9 (1)

$$K.E = \frac{P^2}{2m}$$

Q.10 (1)
$P_4 = P_8 = 20$N.S

$$\therefore K.E_8 = \frac{(20)^2}{2 \times 8}$$

= 25 J

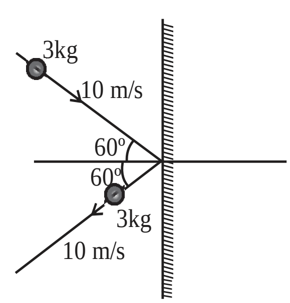
Q.11 (1)
Area of F-t curve = A = Impulse.
Impulse = dP = A = mv – 0

$$\therefore v = \frac{A}{M}.$$

Q.12 (3)
$P = \sqrt{2mE}$
$\therefore P \propto \sqrt{m}$ (if E = const.)

$$\therefore \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$$

Q.13 (2)



$\Delta p = 2mv \cos\theta = 2 \times 3 \times 10 \times \text{Cos } 60°$
$= 30 \text{ kg m/s}$

Q.14 (3)

Q.15 (b)

Q.16 **(c)**

Q.17 (4)

$F = v\frac{dm}{dt}$

$210 = 300 \times \frac{dm}{dt} \quad \Rightarrow \frac{dm}{dt} = 0.7 \text{ kg/s.}$

Q.18 (2)

From $v = r\omega$, linear velocities (v) for particles at different distances (r) from the axis of rotation are different

Q.19 (3)

$\alpha = \frac{\omega_2 - \omega_1}{t}$

$\alpha = \frac{1200 \times 2\pi}{60 \times 20}$

$\alpha = 2\pi \text{ Red/s}^2$

Q.20 (2)

$\frac{\omega_s}{\omega_H} = \frac{T_H}{Ts} = \frac{12 \times 60 \times 60}{60}$

$\frac{\omega_s}{\omega_H} = 720$

Q.21 (1)

$\theta = \left(\frac{\omega_0 + \omega}{2}\right) \times t \ \{\because \alpha = \text{uni form}\}$

Q.22 (1)

$$I = \frac{\tau}{a} = \frac{31.4}{4\pi} = \frac{31.4}{4 \times 3.14} = 2.5 kg\, m^2$$

Q.23 (3)

Q.24 (4)

Q.25 (2)

$I_z = I_X + I_y$

Q.26 (1)

$I_x + I_y = I_z = MK^2$

$0.5 = 2 \times K^2$

$K = 50 \text{ cm}$

Q.27 (3)

For toppling about edge xx'

At the moment of toppling the normal force pass through axis xx'.

$$F_{min}\frac{3a}{4} = mg\frac{a}{2} \text{ or } F_{min} = \frac{2mg}{3}$$

Q.28 (3)

Q.29 (1)

As we know, τ is change in angular momentum.

so, $\tau = \frac{20}{3}$ SI units

Q.30 (4)

Q.31 (1)

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

$\vec{\tau} = 8\hat{i} + 10\hat{j} + 12\hat{k}$

Q.32 (1)

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

V = m/s

Q.33 (3)

as, $KE = \frac{L^2}{2I}$

if L = constant,

then $KE \propto \frac{L}{I}$

as $I_A > I_B$

so $(KE)_A < (KE)_B$

Q.34 (3)

$|\vec{L}| = mvr \perp$

Q.35 (1)

For solid sphere rolling without slipping on incined plane, acceleration

$$a_1 = \frac{g\sin\theta}{1+\frac{K^2}{R^2}}$$

For solid sphere slipping on inclined plane without rolling, acceleration

$$a_2 = g\sin\theta$$

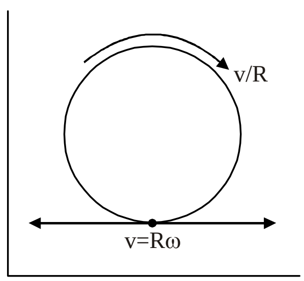
Therefore required ratio $= \frac{a_1}{a_2}$

$$= \frac{1}{1+\frac{K^2}{R^2}} = \frac{1}{1+\frac{2}{5}} = \frac{3}{7}$$

Q.36 (4)
As the disc is in combined rotation and translation, each point has a tangential velocity
and a linear velocity in the forward direction. From figure

v_{net} (for lowest point)

$= v - R\omega = v - v = 0$
and acceleration



$$= \frac{v^2}{R} + 0 = \frac{v^2}{R}$$

(since linear speed is constant)

Q.37 (1)
Q.38 (4)
Q.39 (3)

$$\frac{1}{2}mv^2\left(1+\frac{k^2}{R^2}\right) = mgh$$

$$\Rightarrow \quad v = \sqrt{\frac{2gh}{(1+k^2/R_2)}}$$

$\therefore \quad K_R > K_C > K_S$

$\therefore \; v_R > v_c < v_s$

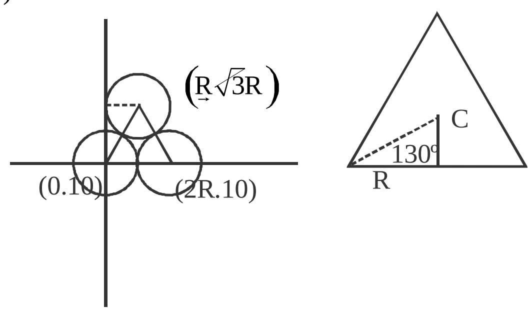
EXERCISE-II (NEET LEVEL)

Q.1 (4)
Centre of mass is a point which can lie within or outside the body.

Q.2 (4)
self explainatory

Q.3 (2)
Centre of mass is nearer to heavier mass

Q.4 (4)



$$x_{com} = \frac{mx_0 + m + 2R + mR}{3M} = \frac{3mR}{3M} = R$$

$$y_{com} = \frac{mxo + mxo + m\sqrt{3}R}{3m} = \frac{R}{\sqrt{3}}$$

Co-ordinats of com is $\left(R - \frac{R}{\sqrt{3}}\right)$. It is at

Q.5 (3)
com is a point while the whale mass of the body is supped to concetrated

Q.6 (3)
Com will more towards heauy body it will be toward of

Q.7 (1)
Body at rest may possess potential energy.

Q.8 (3)
If initial velocity of system is not zero then centre of mass moves with constant velocity.

Q.9 (2)
By conservation of linear momentum
$m_1v_1 = m_2v_2$
$100 \times 30 = (100+200)\,v$
$v = 10$ m/s

100 kg
Q

200 kg

Q.10 (2)

$$V_{com} = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$$

$m_1 = 2kg$ $v_1 = 2\ m/s$

$m_2 = 4kg$ $v_2 = 10\ m/s$

$$V_{com} \frac{2 \times 2 + 4 \times 10}{6}$$

$$= \frac{44}{6} = 7.3\ m/s$$

Q.11 (1)

$$V_{com} = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$$

$$v_{com} = \frac{20 + 2v + 10 \times v}{30}$$

$$= \frac{5pv}{3y} = \frac{5}{3}V$$

Q.12 (1)

$$\bar{r}_{com} = \frac{mi\bar{r} + m_2\bar{r}_2}{m_1 + m_2}$$

$$= \frac{10\left(\hat{i} + \hat{j} + \hat{k}\right) + 30\left(-\hat{i} - \hat{j} - \hat{k}\right)}{40}$$

$$= \frac{-20\hat{i} - 20\hat{j} - 20\hat{k}}{40}$$

$$= -\frac{1}{2}\left(\hat{i} + \hat{j} + \hat{k}\right)$$

Q.13 (2)

$P_i = P_i$

$O = m\vec{v} + M\vec{V}$

$$\vec{V} = -\frac{mv}{M}$$

$$|v| = \frac{mv}{m}$$

Q.14 (2)

$P_i = P_F$

$O = \vec{P}_1 + \vec{P}_2$

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

K.E. of 40 kg mass is 96J rule

So $96 = \frac{P_1^2}{2m_1}$

$P_1^2 = 2 \times 40 + 96$

$P_1^2 = 80 \times 96$

K.E. of other $= \frac{P_2^2}{2m_2} = \frac{P_1^2}{2m_2}$

$$= \frac{80 \times 96}{2 \times 20} = 192\ J$$

Q.15 (2)

Here $\hat{i}mv + \hat{j}mv = 2m\vec{V}$

That is $\vec{v} = \frac{v}{2}(\hat{i} + \hat{j})$

Hence $v = \frac{v}{2} \times \sqrt{2} = \frac{v}{\sqrt{2}}.\left[Here\, v = 5\, ms^{-1}\right]$

So, $V = \frac{5}{\sqrt{2}} ms^{-1}$

Q.16 **(4)**

$P_i = P_f$

$Q = \vec{P}_1 + \vec{P}_2$

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

K.E. of 40 kg mass is 96 Jule

So $96 = \frac{P_1^{\ 2}}{2m_1}$

$P1^2 = 2 \times 40 \times 96$

$P1^2 = 80 \times 96$

K.E. of other $= \frac{P_2^{\ 2}}{2m_2} = \frac{p_1^{\ 2}}{2m_2}$

$$= \frac{80 \times 96}{2 \times 20} = 192\ J$$

Q.17 (2)

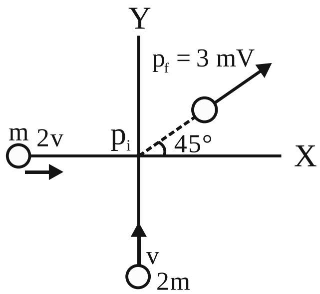
Q.18 (1)

Q.19 (1)

If mass = m

first ball will stop
$\Rightarrow v = 0$
so% K.E. = 0 (min)
In other cases there will be some kinetic energy
(K.E. can't be negative)

Q.20 (1)



Initial mometum of the system

$$p_i = m \times 2v\hat{i} + 2m \times v\hat{j}$$

$$= \sqrt{(m \times 2v)^2 + (2m \times v)^2}$$

(magniatude)

$$= 2\sqrt{2}$$

Final momentum of the system = 3mV
By the law of conservation of momentum

$$2\sqrt{2}mv = 3mV$$

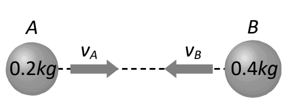
$$\Rightarrow \frac{2\sqrt{2}v}{3} = V_{combined}$$

Loss in energy

$$\Delta E = \frac{1}{2}m_1V_1^2 + \frac{1}{2}m_2V_2^2 - \frac{1}{2}(m_1 + m_2)V_{combined}^2$$

$$\Delta E = 3mv^2 - \frac{4}{3}mv^2 = \frac{5}{3}mv^2 = 55.55\%$$

Q.21 (1)
Q.22 (3)



Initial linear momentum of system = $m_A\vec{v}_A + m_B\vec{v}_B$
$= 0.2 \times 0.3 + 0.4 \times v_B$
Finally both balls come to rest
$\therefore$ final linear momentum = 0
By the law of conservation of linear momenum
$0.2 \times 0.3 + 0.4 \times v_B = 0$

$$\therefore \quad v_B = -\frac{0.2 \times 0.3}{0.4} = -0.15 \text{ m/s}$$

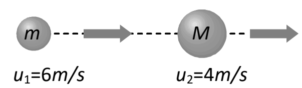
Q.23 (1)

$$v_1 = \frac{(m_1 - em_2)u_1}{m_1 + m_2} + \frac{m_2(1+e)u_2}{m_1 + m_2} =$$

$$\frac{(m - e2m)u_1}{m + 2m} + \frac{2m(1+e) \times 0}{m + 2m} = 0$$

$\Rightarrow \quad 0 = m - e2m$
$\Rightarrow \quad e = 1/2$

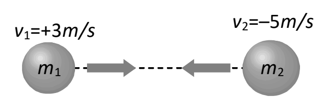
Q.24 (3)
Q.25 (3)
Q.26 (1)



$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$$

Substituting $m_1 = 0$, $v_1 = -u_1 + 2u_2$
$\Rightarrow v_1 = -6 + 2(4) = 2$ m/s
i.e. the lighter particle will move in original direction with the speed of 2 m/s.

Q.27 (4)



As $m_1 = m_2$ therefore after elastic collision velocities of masses get interchanged
i.e. velocity of mass $m_1 = -5$ m/s
and velocity of mass $m_2 = +3$m/s

Q.28 (4)
Q.29 (4)
$0.5 \times v_p + m \times 0 = 5.05\, v$

$$\therefore \frac{v_f}{v_i} = \frac{0.05}{5} = 10^{-2}$$

$$\Rightarrow \frac{\frac{1}{2}m(v_f)^2}{\frac{1}{2}m(v_i)^2} = (10^{-2})^2 = 10^{-4}.$$

Q.30 (1)
After explosion m mass comes at rest and let Rest (M – m) mass moves with velocity v.
By the law of conservation of momentum MV = (M – m)v $\Rightarrow v = \frac{MV}{(M - m)}$

Q.31 (4)

By the conservation of momentum

$40 \times 10 + (40) \times (-7) = 80 \times v \Rightarrow v = 1.5$ m/s

Q.32 (4)

Due to elastic collision of bodies having equal mass, their velocities get interchanged.

Q.33 (2)

Q.34 (3)

Initial momentum of the system = $mv - mv = 0$

As body sticks together

$\therefore$ final momentum = 2mV

By conservation of momentum 2mV = 0

$\therefore$ V = 0

Q.35 (4)

Initial momentum = $\vec{P} = mv\hat{i} + mv\hat{j}$

$|\vec{P}| = \sqrt{2}mv$

Final momentum = 2m × V

By the law of conservation of momentum

$2m \times V = \sqrt{2}mv$

$\Rightarrow V = \frac{v}{\sqrt{2}}$

In the problem v = 10 m/s (given)

$\therefore \quad V = \frac{10}{\sqrt{2}} = 5\sqrt{2}$ m/s

Q.36 (4)

Q.37 (2)

$\theta = \omega t$

$\theta = \frac{27 \times 3000}{60} \times 1$

Q.38 (3)

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

Q.39 (3)

$\omega = \frac{2\pi \times 600}{60} - \alpha \times 80$

$\alpha = \frac{2\pi}{8} = \frac{\pi}{4}$ rad / s

$0 = \left(\frac{2\pi \times 600}{60}\right)^2 - 2 \times \frac{\pi}{4} \times \theta$

$0 = 4\pi^2 \times 100 = \frac{\pi}{2}\theta$

$\theta = 800 \times$ rad

No. of ratution $n = \frac{800\pi}{2\pi} = 400$

Q.40 (4)

$\omega = \frac{d\theta}{dt}$; $\nu = -\omega t$

= 60 rad/ sec. × 5 sec. = 300 rad.

360 – 300 = 60 rad

Q.42 (2)

$I = 2[5(0.2)^2 + 2(0.4)^4]$

Q.42 (1)

The theorem of perpendicular axes is applicable only for 2-D objects.

Q.43 (3)

For solid shpere

$I = \frac{2}{5}MR^2 = \frac{2}{5}\left(\frac{4}{3}\pi R^3 \rho\right)R^2$

$\rho = \frac{176}{105}R^5\rho$

Q.44 (3)

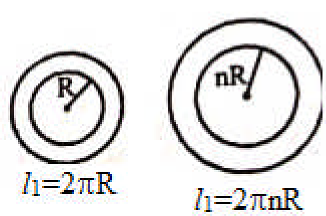
As disc is lying in the x-z plane, so applying perpendicular axis theorem :-

$I_x + I_z = I_y$

$30 + I_z = 40$

$\Rightarrow I_z = 40 - 30 = 10$ kg m^2

Q.45 (1)



Ratio of moment of inertia of the rings

$$\frac{I_1}{I_2} = \left(\frac{M_1}{M_2}\right)\left(\frac{R_1}{R_2}\right)^2$$

$$= \left(\frac{\lambda l_1}{\lambda l_2}\right)\left(\frac{R_1}{R_2}\right)^2 = \left(\frac{2\pi R}{2\pi nR}\right)\left(\frac{R}{nR}\right)^2$$

($\lambda =$ linear density of wire $=$ constant)

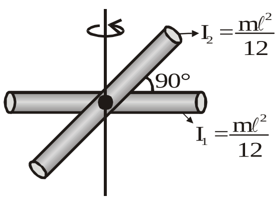
$$\Rightarrow \frac{I_1}{I_2} = \frac{1}{n^3} = \frac{1}{8} \quad \text{(given)}$$

$$\therefore \; n^3 = 8 \Rightarrow n = 2$$

Q.46 (2)

mr^2

Q.47 (2)



So $I = I_1 + I_2 = \; I = I_1 + I_2 = \frac{m\ell^2}{12} + \frac{m\ell^2}{12} = \frac{m\ell^2}{6}$

Q.48 (4)

I is depand and all feacture (1) (2) (3)

Q.49 (3)

According to problem disc is melted and recasted into a solid sphere so their volume will be same.

$$V_{Disc} = V_{Sphere} \Rightarrow \pi R^2{}_{Disc} t = \frac{4}{3}\pi R^3{}_{Shere}$$

$$\Rightarrow \pi R^2{}_{Disc}\left(\frac{R_{Disc}}{6}\right) = \frac{4}{3}\pi R^3{}_{Sphere}\left[t\,\frac{R_{Disc}}{6}, given\right]$$

$$\Rightarrow R^3{}_{Disc} = 8R^3{}_{Sphere} \Rightarrow R_{Sphere} = \frac{R_{Disc}}{2}$$

Moment of inertia of disc

$$I_{Disc} = \frac{1}{2}MR^2_{Disc} = I(\text{given})$$

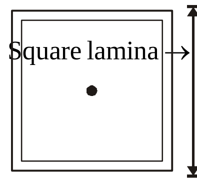
$$\therefore M(R_{Disc})^2 = 2I$$

$$= \frac{2}{5}M\left(\frac{R_{Disc}}{2}\right)^2 = \frac{M}{10}(R_{Disc})^2 = \frac{2I}{10} = \frac{I}{5}$$

Q.50 (4)

Disk $\rightarrow \frac{ma^2}{2}$

Ring $\rightarrow ma^2$



Square lamina $\rightarrow \frac{ma^2}{6}$

a

Four forming a square of side 2a $\rightarrow \left[\frac{ma^2}{12} + m\frac{a^2}{4}\right]4$

$$\rightarrow 4\left[\frac{\frac{m}{4}a^2}{12} + \frac{m}{4}\left(\frac{a}{2}\right)^2\right]$$

$$\rightarrow \frac{ma^2}{12} + \frac{ma^2}{4} = \frac{ma^2}{3}$$

So that moment of inertia least about square lamina.

Q.51 (2)

$I_z = I_x + I_y$ $\qquad\qquad$ $I_z = 2I$

Q.52 (1)

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

Q.53 (1)

Q.54 (2)

M.I. $= mr^2 = 4 \times 1^2 = 4$ kg m^2.

Q.55 (2)

Solid updinader about its axis like a disc

$$I = \frac{mR^2}{2} = \frac{20 \times 0.04}{2}$$

$= 0.4$ kq $\times m^2$

Q.56 (4)

For particle $\qquad I = I_x + I_y$

$= mr_x{}^2 + mr_y{}^2$

$= m(r_x{}^2 + r_y{}^2)$

$= 2(3^2 + 2^2) = 26$ unit

For particle 2, m $[1^2 + (-1)^2] = 2 \times (2) = 4$ unit

For particle 3, $m[1^2 + 1^2] = 2 \times (2) = 4$ unit
For particle 4, $m(0) = 0$
Total inertia = 26 + 4 + 4 = 34 unit.

Q.57 (3)

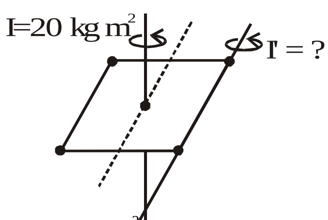
Given, $I_{\text{solid sphere}} = I_{\text{hallow sphere}}$

$\Rightarrow \frac{2}{5}Mr_1^2 = \frac{2}{3}Mr_2^2$

$\Rightarrow \frac{r_1^2}{r_2^2} = \frac{5}{3}$

$\Rightarrow \frac{r_1}{r_2} = \sqrt{5} : \sqrt{3}$

Q.58 (3)



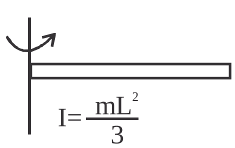
as, $I = \frac{ML^2}{6} = 20$

$\Rightarrow ML^2 = 120$

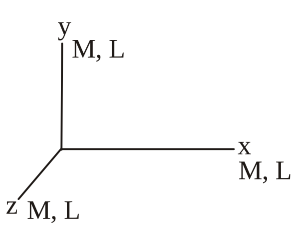
$I' = I_C + M\left(\frac{L}{2}\right)^2 = \frac{ML^2}{12} + \frac{ML^2}{4}$

$\Rightarrow I' = \frac{ML^2}{3} = \frac{120}{3} = 40 \text{ kg m}^2$

Q.59 (3)



Q.60 (2)

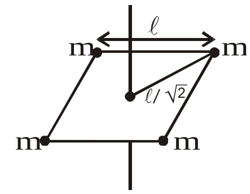


$I = I_1 + I_2 + I_3$

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

Q.61 (1)

so, $I = m \times \left(\frac{\ell}{\sqrt{2}}\right)^2 \times 4$

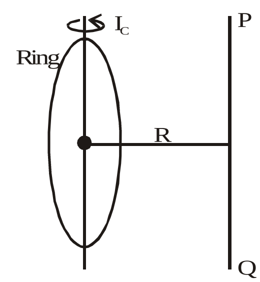


also, $I = MK^2$
{Where M = 4m}

so, $m \times \frac{\ell^2}{2} \times 4 = 4m \times K^2$

$\therefore \quad K = \frac{\ell}{\sqrt{2}}$

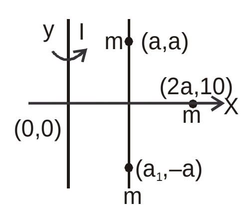
Q.62 (3)



Applying parallel axis theorem
$I_{PQ} = I_C + MD^2$

$\Rightarrow I_{PQ} = \frac{MR^2}{2} + M(R)^2 = \frac{3}{2}MR^2$

Q.63 (4)



$I = ma^2 + ma^2 + m(29)^2$

Q.64 (4)
Torque can be taken about any point in sapce.

Q.65 (1)

Frequency, $n = 20$ Hz

$\omega_i = 2\pi n = 40\pi$ rad/sec

$\omega_f = 0,$ $t = 10$ sec

so, $\omega_f = \omega_i + \alpha t$

$0 = 40\pi + \alpha \times 10$

so, $\alpha = -4\pi$ rad/sec^2

Now, $\tau = I \times \alpha = 5 \times 10^{-3} \times 4\pi = 2\pi \times 10^{-2}$ N-m

Q.66 (4)

$$\tau = \frac{dL}{dt}$$

Q.67 (1)

$$P = \vec{\tau}.\vec{\omega} = (2\hat{i} + 3\hat{j} + 4\hat{k}).(\hat{i} + 2\hat{j} + 3\hat{k})$$

$= 2 + 6 + 12 = 20$ watt.

Q.68 (1)

given, $\omega_0 = 20$ rad/sec

$\omega = 0$

$I = 50$ kg-m^2

$t = 10$ sec

$$\propto = \frac{\omega - \omega_0}{t} = \frac{0 - 20}{10} = -2\text{rad/sec}^2$$

and $\tau = I \propto = 50 \times 2 = 100$ kg-m^2/s^2

$= 100$ N-m

Q.69 (1)

$\tau = I\alpha;$

$$\left[I' = (2m)\left(\frac{r}{2}\right)^2 = \frac{mr^2}{2} = \frac{I}{2} \right]$$

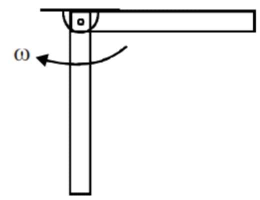
$\tau' = I'\alpha.$

$$\frac{\tau'}{\tau} = \frac{I'\alpha}{I\alpha} = \frac{I'}{I} = \frac{1}{2};\ \tau' = \frac{\tau}{2}$$

Q.70 (4)

$$\frac{1}{2} I\omega^2 \rightarrow \frac{1}{2} \times mr^2\omega^2$$

Q.71 (2)



By work energy theorem

$$mg\frac{L}{2} = \frac{1}{2}\frac{mL^2}{3}\omega^2$$

$$\omega = \sqrt{\frac{3g}{L}}$$

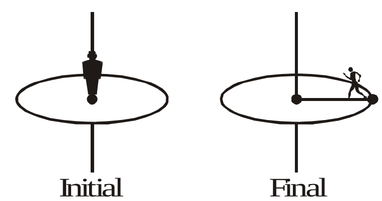
Q.72 (3)

$I\omega$ = constant

$Mr^2\omega = (Mr^2 + 2mr^2)\omega'$

$$\omega' = \frac{\omega M}{M + 2m}$$

Q.73 (1)



Applying conservation of angular momentum :-

$I_1\omega_1 = I_2\omega_2$

$$\Rightarrow\ I_1 \times \frac{2\pi}{T_1} = I_2\omega_2$$

$$\Rightarrow\ 100 \times \frac{2\pi}{10} = [100 + 50 \times (2)^2] \times \omega_2$$

on solving, $\omega_2 = \dfrac{2\pi}{30}$ rad/sec

Q.74 **(1)**

$\tau_{ext} = 0;$

from conservation of angular momentum

$L = I\omega$ = constant

$I_1\omega_1 = (I_1 + I_2)\,\omega_2$

$$(\omega_1 = \frac{600 \times 2\pi}{60} = 20\pi,\ \omega_2 = 400\ \frac{400 \times 2\pi}{60} = \frac{40}{3\pi}\ )$$

$$I_P \times 20\pi = (I_P + I_Q)\,\frac{40}{3\pi}$$

$$6 \times 20\pi = (I_P + I_Q)\,\frac{40}{3\pi} \qquad (\text{Given } I_P = 6)$$

After solving that we get $I_2 = 3$ kg m^2

Q.75 (2)

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

where $v = \omega r$ and $I = I = \frac{2}{5}mR^2$

Q.76 (1)

Q.77 (4)

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

where $w = v/r$, $I = 2/5\ mR^2$

Q.78 (2)

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

$$E_T = \frac{1}{2}mv^2\left[1 + \frac{k^2}{R^2}\right]$$

for Ring $\frac{k^2}{R^2} = 1$

$$E_T = \frac{1}{2}mv^2[1+1] = 2E$$

Q.79 (1)

Kinetic energy of ring,

$$K = \frac{1}{2}mv^2\left(1 + \frac{K^2}{R^2}\right)$$

$$= \frac{1}{2}0.4 \times \left(\frac{10}{100}\right)^2 \times (1+1)$$

$$\left[\therefore \frac{K^2}{R^2} = 1\right]$$

$\Rightarrow$ $K = 4 \times 10^{-3}$ Joule

Q.80 (2)

Final speed only depend's on initial height but time will depend on length and inclination of plane.

Q.81 (1)

$$\text{Fraction} = \frac{K_{\text{Rotation}}}{K_{\text{Total}}} = \frac{\frac{K^2}{R^2}}{1 + \frac{K^2}{R^2}}$$

For disc, $\frac{K^2}{R^2} = \frac{1}{2}$,

$$\text{so, fraction} = \frac{\frac{1}{2}}{1 + \frac{1}{2}} = 1:3$$

Q.82 (3)

As person is coming towards axis, it's distance from axis decreases. So M.O.I. also decreases.

From conservation of angular momentum :

as I decreases so, ω increases

EXERCISE-III (JEE MAIN LEVEL)

Q.1 (3)

Q.2 (3)

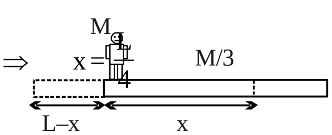
Centre of mass of two particle system lies on the line joining the two particles

Q.3 (2)

Let x be the displacement of man. Then displacement of plank is $L - x$.

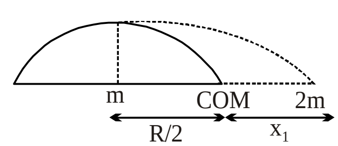
For centre of mass to remain stationary

$$\frac{M}{3}(L - x) = M\,.\,x$$

$\Rightarrow$ 

Q.4 (3)

Centre of mass hits the ground at the position where original projectile would have landed.



$\frac{m.R}{2} = 2mx_1 \Rightarrow x_1 = \frac{R}{4}$

$\therefore$ Distance = $R + \frac{R}{4} = \frac{5R}{4}$

Q.5 (1)

$$v_{cm} = \frac{1\times 2 + \frac{1}{2}\times 6}{1 + 1/2} = \frac{10}{3}\,m/sec.$$

Q.6 (4)

$$v_{cm} = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$$

$$\therefore v_{cm} = \frac{m(2\hat{i}) + m(2\hat{j})}{2m}$$

$$a_{cm} = \frac{m(i + j) + m(0)}{2m}.$$

v_{cm} has same direction as of a_{cm}

$\therefore$ straight line.

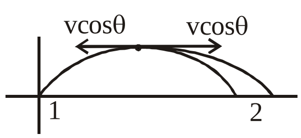
Q.7 (2)

Q.8 (2)

$V_{com} = V\cos\theta$

$$V\cos\theta = \frac{-m\,0 + mv_2}{2m}$$

$\therefore v_2 = 2V\cos\theta$



Q.9 (4)

Speed is constant so K.E. $\rightarrow$ Constant

Gravitational potential energy change.

$\because$ Momentum = $m\vec{v}$

$\because$ Direction of $\vec{v}$ changes

$\therefore$ Momentum changes

Q.10 (2)

Here net force = 0

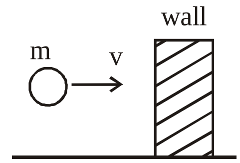
means momentum is conserved.

$p_i = p_f$

$0 = \vec{p}_1 + \vec{p}_2 \Rightarrow \vec{p}_1 = -\vec{p}_2$

$$K.E. = \frac{p^2}{2m} \Rightarrow \therefore \frac{K_1}{K_2} = \frac{m_2}{m_1}$$

Q.11 (1)



Initial momentum of body = mv

& final momentum of body = – mv

Change in momentum = 2mv

Q.12 (3)

$\vec{F}_{net} = 0$

then $\vec{p}$ = conserved

$\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = 0$

$\vec{p}_3 = -(\vec{p}_1 + \vec{p}_2)$

$m\vec{v}_3 = -m(\vec{v}_1 + \vec{v}_2)$

$\therefore \vec{v}_3 = -\left[(3\hat{i} + 2\hat{j}) + (-\hat{i} - 4\hat{j})\right]$

$\vec{v}_3 = -2\hat{i} + 2\hat{j}$

Q.13 (1)

$\vec{F}_{net} = 0$

then $\vec{p}$ = conserved

$p_i = p_f$

$m_1v = m_2(0) + (m_1 - m_2)v_1$

$$v_1 = \frac{m_1v}{(m_1 - m_2)}$$

Q.14 (2)

$v_1 = \sqrt{2gh} = \sqrt{2\times 10\times 10} = 10\sqrt{2}$

$k_2 = \frac{1}{4}k_1 \Rightarrow v_2^2 = \frac{1}{4}v_1^2$

$\therefore v_2 = \frac{v_1}{2} = 5\sqrt{2}$

$|\Delta P| = |-mv_2 - (mv_1)| = m|-v_2 - v_1|$

$|\Delta P| = 50\times 10^{-3}\times \frac{3}{2}\times 10\sqrt{2} = \frac{15\times 10^{-1}}{\sqrt{2}}$

$J = \Delta P = 1.05$ N-s.

Q.15 (2)

$mv_i + mvj + 2mv_3 = 0$

$$\vec{v}_3 = -\frac{(vi + v\hat{j})}{2} = -\frac{v}{2}(i + \hat{j}) = -\frac{v}{\sqrt{2}}.$$

$$k_f = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}2m\frac{v^2}{2}.$$

$k_f = \frac{3mv^2}{2}$.

Q.16 (3)
From momentum conservation
$mu = 2mv$

$\Rightarrow v = \frac{u}{2}$

from energy conservation

$\frac{1}{2} \times 2m \times \left(\frac{u}{2}\right)^2 = 2\,mgh$

$\Rightarrow h = \frac{u^2}{8g}$

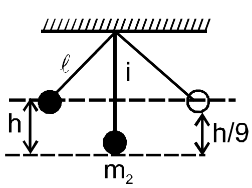
Q.17 (1)
In inelastic collision, due to collision some fraction of mechanical energy is retained in form of deformation potential energy.
$\therefore$ thus K.E. of particle is not conserved.
In absence of external forces momentum is conserved.

Q.18 (4)
$0.5 \times v_p + m \times 0 = 5.05\,v$

$\therefore \frac{v_f}{v_i} = \frac{0.05}{5} = 10^{-2}$

$\Rightarrow \frac{\frac{1}{2}m(v_f)^2}{\frac{1}{2}m(v_i)^2} = (10^{-2})^2 = 10^{-4}$.

Q.19 (1)
$m_1\sqrt{2gh} + 0 = (m_1 + m_2)\,v$



$v = \frac{m_1\sqrt{2gh}}{(m_1 + m_2)}$

$\therefore v^2 - u^2 + 2g \times \frac{h}{9} = 6 + 2g \times \frac{h}{4} = \frac{gh}{2}$

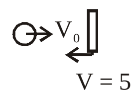
$\therefore v = \sqrt{\frac{gh}{2}}$

Also, $\sqrt{\frac{gh}{2}} = \frac{m\sqrt{2gh}}{m_1 + m_2} \Rightarrow 2m_1 + m_1 + m_2$;

$\therefore \frac{m_1}{m_2} = 1$.

Q.20 (3)
If e = 1 and $m_1 = m_2$ then after collision velocity interchange

Q.21 (1)



$V_2 = Z_0$
Vel. of Sep = Vel of approach ($\therefore$ elastic)
$\therefore 20 + 5 = V - 5$
$\Rightarrow V = 30$ m/s **Ans.**
$v_b = -(v_0 + 2v)$ $\quad\quad \therefore m_1 >> m_2$
$v_b = -(20 + 10) = -30$ m/sec.

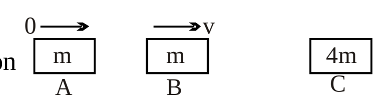
Q.22 (2)
Q.23 (1)
$mu = mv_1 + mv_2$
.......(i)
$u = v_1 + v_2$
.......(i)

$\frac{v_2 - v_1}{u} = e$
......(ii)

as solving have $\frac{v_1}{v_2} = \left(\frac{1-e}{1+e}\right)$.

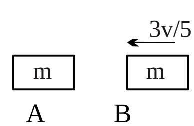
Q.24 (1)

1st Collision



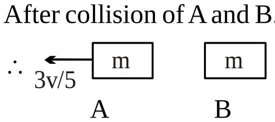
2nd Collision

Velocity of B $v = \frac{mv + 4m(0 - v)}{5m} = \frac{3m}{5}$



After collision of A and B.

$\therefore$



Q.25 (3)

$5 \times 10 = \frac{5}{2}(0) + \frac{5}{2}(v_1) \Rightarrow v_1 = 20$ m/sec

$$KE = \frac{1}{2}\times\frac{5}{2}(20)^2 - \frac{1}{2}\times 5(10)^2$$
$= 500 - 250 = 250$ J.

Q.26 (2)

$$E_i = \frac{1}{2}mu_1^2 + \frac{1}{2}mu_2^2$$

$$m(u_1 - u_2) = 2\,mu \Rightarrow u = \frac{u_1 - u_2}{2}$$

$$\text{Energy loss} = \frac{1}{2}\times\frac{2m}{4}(u_1-u_2)^2 - \frac{1}{2}m(u_1^2+u_2^2)$$

Q.27 (4)
$\Delta p = 0.1\,(6+4)$
$= 0.1 \times 10 = 1$ NS

Q.28 (2)
$\omega_0 = 3000$ rad/min

$\omega_0 = \frac{3000}{60}$ rad/sec = (50 rad/sec)

t = 10 sec
$\omega_f = 0$
$\omega_f = \omega_0 + \alpha t$
$\theta = 50 - \alpha\,(10)$
$\alpha = 5$ rad/sec^2

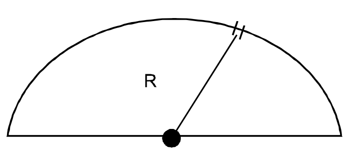
$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$

$$\theta = (50)(10) + \frac{1}{2}(-10)(10)^2$$

$\theta = 500 - 250 = 250$ rad

Q.29 (3)
$V = \omega R$
$V = 10 \times 0.2 = 2$m /sec.

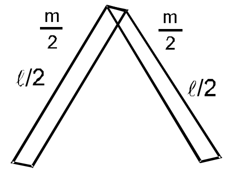
Q.30 (1)



$$I = \int dmr^2$$

$$I = r^2\int dm = r^2 m = mr^2$$

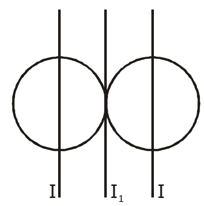
Q.31 (3)



$I_0 = I_1 + I_2$

$$I_0 = \frac{(m/2)\left(\frac{\ell}{2}\right)^2}{3} + \frac{(m/2)\left(\frac{\ell}{2}\right)^2}{3} = \frac{m\ell^2}{12}$$

Q.32 (2)



Moment of inertia about

diameter of sphere $I = \frac{2}{5}mr^2$

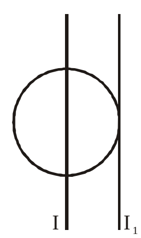
Moment of inertia about tangent at their common point

$$I_1 = \left(\frac{2}{5}mr^2 + mr^2\right)\times 2 = \frac{14}{5}mr^2 \quad I_1 = 7I$$

Q.33 (4)
Moment of inertia of disc

about diameter $I = \frac{mr^2}{4} = 2,$

$mr^2 = 8$



Moment of inertia about the
axis through a point on rim.

$$I_1 = \frac{mr^2}{4} + mr^2 = 10$$

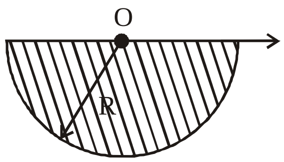
Q.34 (1)

Moment of inertia of solid sphere $I_1 = \frac{2}{5}mr_1^2$

Moment of inertia of hollowsphere $I_2 = \frac{2}{3}mr_2^2$

$$\frac{2}{m}mr_1^2 = \frac{2}{3}mr_2^2 \Rightarrow \frac{r_1}{r_2} = \sqrt{\frac{5}{3}}$$

Q.35 (2)



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

(pasing through 0)

Q.36 (4)

M.O.I. about C.O.M. is Minimum

$I = I_{C.M.} + Mx_0^2$

$I = 2x^2 - 12x + 27$

$\therefore \frac{dI}{dx} = 4x - 12 = 0$

$\Rightarrow x = 3$

Q.37 (2)

$\tau = I\alpha = \frac{mr^2}{2} \times \alpha$

$\alpha = 0.25 rad/sec^2$

Q.38 (2)

$\tau = I\alpha$

τ = constant $\Rightarrow \omega$ = increases

Q.39 (4)

$\omega = \omega_0 + \alpha t$

$100 = 10 + \alpha(15) \Rightarrow \alpha = 6\ rad/sec^2$

$\tau = I\alpha \Rightarrow 60\ Nm$

Q.40 (4)

$\tau = I\alpha$

$2 = I \times 2 \quad \Rightarrow I = 1\ kgm^2$

$I = MR^2$

$1 = M(2)^2$

$M = \frac{1}{4} kg$

Q.41 (1)

$\tau = I\alpha = (mr^2)\alpha$

Now, $\tau_1 = (2m)\ \frac{r^2}{4} \times \alpha = \frac{mr^2}{2} \times \alpha \Rightarrow \tau_1 = \frac{\tau}{2}$

Q.42 (3)

$F = 4\hat{i} - 10\hat{j}$

$\vec{r} = (-5\hat{i} - 3\hat{j})$

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

$= (-5\hat{i} - 3\hat{j}) \times (4\hat{i} - 10\hat{j})$

$= 50\hat{k} + 12\hat{k} = 62\hat{k}$

Q.43 (3)

torque of a couple is always remains constant about any point

Q.44 (2)

Torque about O

$F \times 40 + F \times 80 - (F \times 20 + F \times 60)$

In clockwise direction

$= \quad F \times 40$

Q.45 (1)

Initial velocity of each point onthe rod is zero so angular velocity of rod is zero.

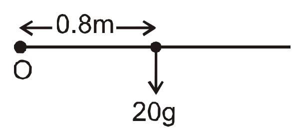
Torque about O

$\tau = I\alpha$

$20g\,(0.8) = \frac{m\ell^2}{3}\alpha \Rightarrow 20g\,(0.8) = \frac{20(1.6)^2}{3}\alpha$

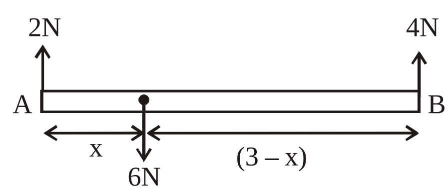
$\Rightarrow \frac{3g}{3.2} = \alpha$ = angular acceleration

$\Rightarrow \alpha = \frac{15\ g}{16}$



Q.46 (4)

Torque about B



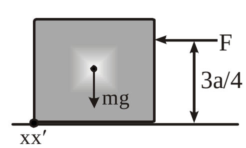
$2 \times 3 = 6\,(3 - x)$

$6 = 18 - 6x$

$6x = 12$

$x = 2m$

Q.47 (1)



For topling about edge xx′ __________

$F_{min.} \frac{3a}{4} = mg\ \frac{a}{2}$

$F_{min.} = \frac{2mg}{3}$.

Q.48 (4)

$\frac{1}{2}I\omega^2 = 1000$

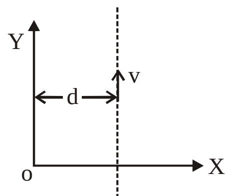
$\omega = 10\,\text{rad/sec}$

$2\pi f = 10 \Rightarrow f = \frac{5}{\pi}\text{rad/sec} = \frac{300}{\pi}\text{rad/min}$

Q.49 (3)

$\vec{\tau} = \frac{d\vec{L}}{dt} = \frac{4A_0 - A_0}{4} = \left(\frac{3A_0}{4}\right)$

Q.50 (2)



$\Rightarrow$ L = (mvd) = constant becouse v = const. and d = const.

Q.51 (4)

$L = I\omega$

$\omega' = 2\omega$

$\frac{1}{2}\left(\frac{1}{2}I\omega^2\right) = \frac{1}{2}I'\omega'^2$

$\frac{I\omega^2}{2} = I'4\omega^2$

$I' = \left(\frac{I}{8}\right)$

$L' = I'\omega' = \frac{I}{8}2\omega = \frac{I\omega}{4} = \left(L/4\right)$

Q.52 (3)

external torque $\vec{\tau}_{ext} = 0$

$I_1\omega_1 = I_2\omega_2$

when he stretches his arms I

so $I_1 < I_2$

then $(\omega_1 > \omega_2)$

so, (L = constant)

Q.53 (2)

$KE = \frac{1}{2}I\omega^2 = \frac{1}{2}\times\left(\frac{\mu R}{2}\right)^2\frac{v^2}{R^2}$

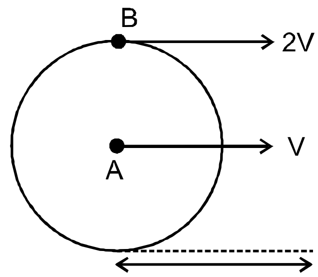
$\frac{1}{4}Mv^2$

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

$\frac{1}{4}Mv^2 + \frac{1}{2}m\mu^2 \Rightarrow \frac{3}{4}mv^2$

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

Q.54 (2)



When A point travels ℓ distance then B point 2ℓ so, 2ℓ length of string passes through the hand of the boy .

Q.55 (2)

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

For solid sphere $\Rightarrow \frac{k^2}{R^2} = \frac{2}{5}$

For hollow sphere = $\frac{2}{3}mR^2 = mk^2$

$\frac{k^2}{R^2} = \frac{2}{3}$

so $k_s < k_H$

then $a_s > a_H$

(so speed of solid sphere is greater then hollow sphere)

Q.56 (1)

$\vec{F} = Ma$

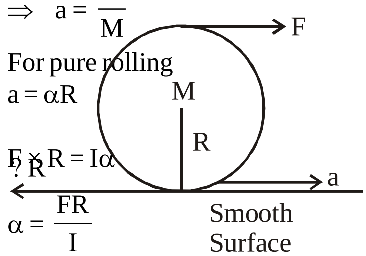
$\Rightarrow \quad a = \frac{F}{M}$

For pure rolling

$a = \alpha R$

$F \times R = I\alpha$

$\alpha = \frac{FR}{I}$



$$\frac{F}{m} = \frac{FR.R}{I}$$

$I = MR^2$

MR^2 is the moment of inertia of chin pipe.

Q.57 (4)

As the inclined plane is smooth, the sphere can never roll rather it will just slip down.

Hence, the angular momentum remains conserved about any point on a line parallel to the inclined plane and passing through the centre of the ball.

EXERCISE-IV

Q.1 [0036]

$$F_{avg}\,\Delta t = \Delta P = m(v_f - v_i) = m\left[\sqrt{2gh_2} + \sqrt{2gh_1}\right]$$

$$\therefore F_{avg} = \frac{m\left[\sqrt{2gh_2} + \sqrt{2gh_1}\right]}{\Delta t} = 36$$

Q.2 [0019]

Area = $mv - mv_0$

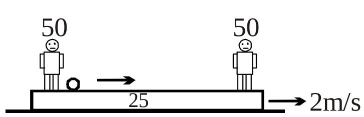
$-42 = 2(v - 2)$

$-21 = v - 2$

$\therefore v = -19$ m/s

Q.3 [0190]

$(50 + 50 + 95 + 5) \times 2 = 195\,v + 5(v + 4)$



v = 1.9

$$t = \frac{4m}{4m/s} = \frac{s_{rel}}{u_{rel}} = 1 \text{ sec.}$$

$1.9 \times 100 \times 1 = 190$

Q.4 [0125]

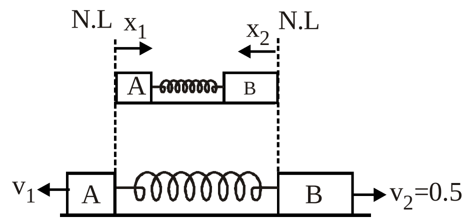
NB $\quad 3mv = FT$

$4m(vx) = FT = 3mv$

$$v_x = \frac{3v}{4} \text{ and } v_y = v$$

$$v' = \sqrt{100^2 + 75^2} = 25\sqrt{4^2 + 3^2} = 125 \text{ m/s}$$

Q.5 [0003 J]



by conservation of momentum

$m_1v_1 = m_2v_2$

$2(v_1) = 6(0.5)$

$v_1 = 1.5$ m/s

by Energy conservation spring potential energy =

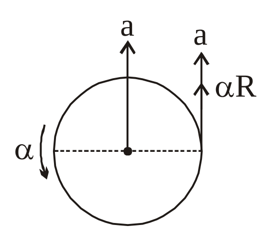
$$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

$$= \frac{1}{2}2(1.5)^2 + \frac{1}{2}6(0.5)^2 = 2.25 + 0.75$$

or U = 3.0 J **Ans.**

Q.6 [0020]

$$FR = \frac{MR^2\alpha}{2}$$



$\alpha = 50$ rad/s^2

$\alpha R = 10$ m/s^2

$$s = \frac{1}{2} \times \alpha R \times t^2 = \frac{1}{2} \times 10 \times 2^2 = 20 \text{ m} \quad]$$

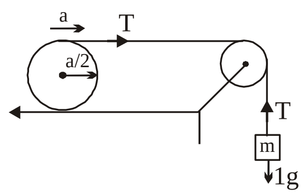
Q.7 [0100]

$$\frac{2}{5}MR^2\omega = \frac{2}{5}M\left(\frac{R}{10}\right)^2 \times \omega'$$

$\omega' = 100$

Q.8 0004

$g - T = 1 \times a$



$T - f = 0.5\,\frac{a}{2}$

$T_r + f_r = Mr^2\alpha = 0.5\frac{a}{2} = \frac{a}{4}$

$2T = \frac{a}{2} \Rightarrow T = \frac{a}{4}$

$g = a + \frac{a}{4} = \frac{5a}{4} \Rightarrow a = 8\ m/s^2$

acceleration of hoop = a/2

Q.9 0001

$K.E_{loss} = P.E._{gain}$

$$\frac{1}{2}mv^2 + \frac{1}{2}I\left(\frac{v}{R}\right)^2 = mgh$$

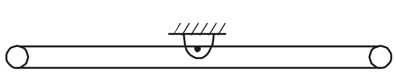
$$\frac{1}{2}I\frac{v^2}{R^2} = mg\left(\frac{3v^2}{4g}\right) - \frac{1}{2}mv^2$$

$$\Rightarrow I = \frac{1}{2}mR^2 = \frac{1}{2}8(0.5)^2 = 1\ kg\ m^2$$

Q.10 0158

$$160 = 80 \times 1^2 + 60 \times 1^2 + \frac{M}{12} \times 2^2$$

$$\Rightarrow 200 = \frac{M}{3} \Rightarrow M = 600\ kg$$



$$x_c = \frac{0 \times 60 \times 60 \times -1 + 80 \times 1}{60 + 80 + 600} = \frac{20}{200} = 0.1m$$

$I = I_c + Mx^2 \Rightarrow I_c = 160 - 200 \times (0.1)^2 = 158\ kg\ m^2$

Q.11 (4)
Q.12 (2)
Q.13 (4)
Q.14 **(2)**
Q.15 (1)
Q.16 (4)

PREVIOUS YEAR'S

MHT CET

Q.1 (3)
Q.2 (1)
Q.3 (4)
Q.4 (2)
Q.5 (3)
Q.6 (4)
Q.7 (3)
Q.8 (1)

Let 2 kg mass be placed at x = 0, therefore 4 kg mass will be situated at x = 9.

Therefore, $x_{com} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$

$= \frac{0 + 4 \times 9}{2 + 4} = \frac{36}{6} = 6m$

Thus, centre of mass will be situated at 6 m from 2 kg mass.

Q.9 (2)
Q.10 (2)
Q.11 (2)
Q.12 (3)
Q.13 (1)
Q.14 (2)
Q.15 (1)
Q.16 (3)
Q.17 (4)
Q.18 (3)
Q.19 (4)
Q.20 (2)
Q.21 (1)
Q.22 (2)
Q.23 (4)
Q.24 (2)
Q.25 (1)
Q.26 (4)
Q.27 (1)
Q.28 (1)
Q.29 (1)
Q.30 (1)
Q.31 (3)
Q.32 (4)
Q.33 (3)

Q.34 (1)
Q.35 (3)
Q.36 (2)
Q.37 (3)
Q.38 (4)
Q.39 (4)
Q.40 (2)
Q.41 (1)

Given, r = 60 cm = 0.6 m
m = 1kg
$\omega_1 = 3$ rev/s $= 2\pi\times3$ rad/s
$\omega_2 = 1$ rev/s $= 2\pi\times1$ rad/s
t = 30s

Torque, $\tau = I\alpha = I\frac{d\omega}{dt} = mr^2\frac{d\omega}{dt}$

$= 1\times(0.6)^2\times\frac{2\pi(3)-2\pi(1)}{30}$

= 0.15 N-m

Q.42 (2)

Given, F = $\left(3\hat{i}+2\hat{j}-\hat{k}\right)$N

r = $\left(\hat{i}+\hat{j}-\hat{k}\right)$m

$\therefore$ **Torque,** $\tau = r\times F = \left(\hat{i}+\hat{j}-\hat{k}\right)\times\left(3\hat{i}+2\hat{j}-\hat{k}\right)$

$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1 & -1 \\ 3 & 2 & -1 \end{vmatrix}$

$= \hat{i}(-1+2)-\hat{j}(-1+3)+\hat{k}(2-3)$

$\tau = \hat{i}-2\hat{j}-\hat{k}$

$|\tau| = \sqrt{1^2+(-2)^2+(-1)^2}$

$= \sqrt{1+4+1} = \sqrt{6}\,N-m$

Q.43 (1)
Q.44 (2)

We know that

$\therefore$ Rotational kinetic energy, $E = \frac{1}{2}I\omega^2$

$1500 = \frac{1}{2}\times1.2\times\omega^2$

$\Rightarrow \quad \omega = \sqrt{\frac{3000}{1.2}} = 50$ rad/s

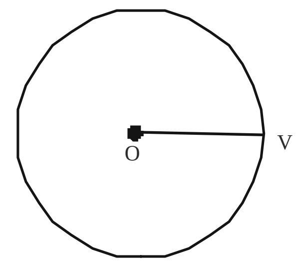
Also, $\omega = \alpha t$

$\Rightarrow t = \frac{\omega}{\alpha} = \frac{50}{25} = 2s$

Q.45 (4)

Initially, the moment of inertia of the system at A,

$$I_i = mR^2 + \frac{MR^2}{2} = \left(\frac{2m+M}{2}\right)R^2$$



Finally the moment of inertia of the system will become

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

By conservation of angular moment about 0

$L_i = L_f$

$\Rightarrow \quad I_i\omega_i = I_f\omega_f$

$\Rightarrow \quad \omega_f = \frac{I_i}{I_f}\omega = \left(\frac{2m+M}{2}\right)R^2\times\frac{2}{MR^2}\times\omega$

$= \left(1+\frac{2m}{M}\right)\omega$

Q.46 (3)

Because kinetic energy K_R and retarding torque τ are same, therefore in accordance with the relation,

Loss in kinetic energy = Work done by torque
$= \tau.\theta$
$= \tau.2\pi n$

So, both ring and disc stop after completing equal number of revolutions n.

Q.47 (3)

As we know, torque, $\tau = I\alpha$.
Also $\tau = FR$

For a disc, $I = \frac{mR^2}{2}$

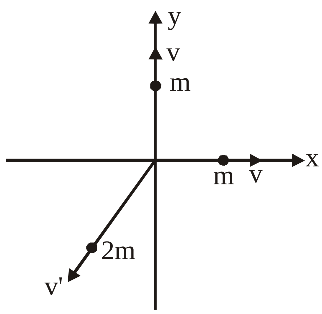
Now, from Eqs. (i) and (ii), we get

$\therefore \quad FR = I\alpha$

$\Rightarrow \quad FR = \frac{mR^2}{2}\times\frac{\omega}{t} \Rightarrow F = \frac{mR\omega}{2t}\left(\because \alpha = \frac{\omega}{t}\right)$

NEET/AIPMT

Q.1 (2)



Let $\vec{v}$ be velocity of third piece of mass 2m.

Initial momentum, $\vec{p}_i = 0$ (As the body is at rest)

Final momentum, $\vec{p}_f = mv\hat{i} + mv\hat{j} + 2m\vec{v}$

According to law of conservation of momentum

$$\vec{p}_i = \vec{p}_f$$

$$\therefore \quad 0 = mv\hat{i} + mv\hat{j} + 2m\vec{v}$$

or $\vec{v} = -\frac{v}{2}\hat{i} - \frac{v}{2}\hat{j}$

The magnitude of $\vec{v}$ is

$$v' = \sqrt{\left(-\frac{v}{2}\right)^2 + \left(-\frac{v}{2}\right)^2} = \frac{v}{\sqrt{2}}$$

Total kinetic energy generated due to explosion

$$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2m)v'^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2m)\left(\frac{v}{\sqrt{2}}\right)^2$$

$$= mv^2 + \frac{mv^2}{2} = \frac{3}{2}mv^2$$

Q.2 (3)

Let the particles A and B collide at time t. For their collision, the position vectors of both particles should be same at time t, i.e.

$$\vec{r}_1 + \vec{v}_1 t = \vec{r}_2 + \vec{v}_2 t$$

or $\vec{r}_1 - \vec{r}_2 = \vec{v}_2 t - \vec{v}_1 t = (\vec{v}_2 - \vec{v}_1)t$

.... (i)

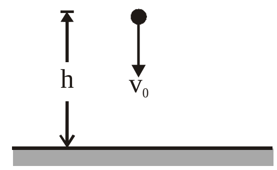
Also, $|\vec{r}_1 - \vec{r}_2| = |\vec{v}_2 - \vec{v}_1|\,t$ or $t = \frac{|\vec{r}_1 - \vec{r}_2|}{|\vec{v}_2 - \vec{v}_1|}$

Substituting this value of t in eqn. (i), we get

$$\vec{r}_1 - r_2 = (\vec{v}_2 - \vec{v}_1)\frac{|\vec{r}_1 - \vec{r}_2|}{|\vec{v}_2 - \vec{v}_1|}$$

or $\frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|} = \frac{(\vec{v}_2 - \vec{v}_1)}{|\vec{v}_2 - \vec{v}_1|}$

Q.3 (4)



The situation is shown in the figure.

Let v be the velocity of the ball with which it collides with ground. Then according to the law of conservation of energy.

Gain in kinetic energy = loss in potential energy

i.e. $\frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 = mgh$ (where m is the mass of the ball)

or $v^2 - v_0^2 = 2gh$ .....(i)

Now, when the ball collides with the ground, 50% of its energy is lost and it rebounds to the same height h.

$$\therefore \quad \frac{50}{100}\left(\frac{1}{2}mv^2\right) = mgh$$

or $\frac{1}{4}v^2 = gh$ or $v^2 = 4gh$

Substituting this value of v^2 in eqn. (i), we get

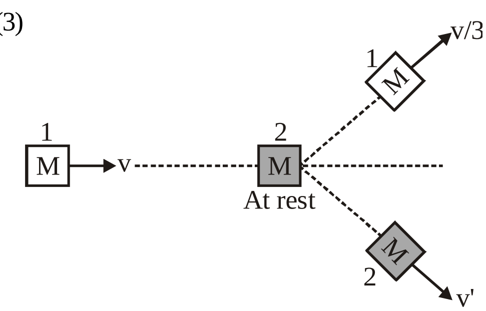
$$4gh - v_0^2 = 2gh$$

or $v_0^2 = 4gh - 2gh = 2gh$ or $v_0 = \sqrt{2gh}$

Here, $g = 10\ ms^{-2}$ and $h = 20\ m$

$$\therefore \quad v_0 = \sqrt{2(10\,ms^{-2})\,(20m)} = 20ms^{-1}$$

Q.4 (3)



Let v' be the speed of second block afte the collision.

As the collision is elastic, so kinetic energy is conserved.
According to conservation of kinetic energy,

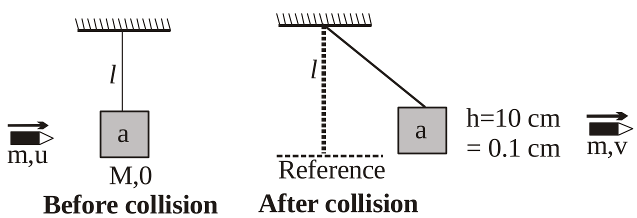
$$\frac{1}{2}Mv^2 + 0 = \frac{1}{2}M\left(\frac{v}{3}\right)^2 + \frac{1}{2}Mv'^2$$

or $v^2 = \frac{v^2}{9} + v'^2$

or $v'^2 = v^2 - \frac{v^2}{9} = \frac{9v^2 - v^2}{9} = \frac{8}{9}v^2$

or $v' = \sqrt{\frac{8}{9}v^2} = \frac{\sqrt{8}}{3}v = \frac{2\sqrt{2}}{3}v$

Q.5 (3)
Mass of bullet, m = 10 g = 0.01 kg
Initial speed of bullet, u = 400 ms^{-1}
Mass of block, M = 2kg
Length of string, l = 5m
Speed of the bullet on emerging from block, v = ?



Using energy conservation principle for the block, $(KE + PE)_{reference} = (KE + PE)_h$

$\Rightarrow \frac{1}{2}Mv_1^2 = mgh$ or, $v_1 = \sqrt{2gh}$

$v_1 = \sqrt{2 \times 10 \times 0.1} = \sqrt{2}$ m s^{-1}

Using momentum conservation principle for block and bullet system.

$(M \times 0 + mu)_{before\ collision} = (M \times v_1 + mv)_{after\ collision}$

$\Rightarrow 0.01 \times 400 = 2\sqrt{2} + 0.01 \times v$

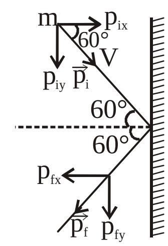
$\Rightarrow v = \frac{4 - 2\sqrt{2}}{0.01} = 117.15\ ms^{-1} \simeq 120\ ms^{-1}$

Q.6 (2)
Masses of the ball are same and collision is elastic so their velocity will be interchanged after collision.

Q.7 (1)
Given $p_i = p_f = mV$
Change in momentum of the ball

$= \vec{p}_f - \vec{p}_i$

$= \left(p_{fx}\hat{i} - p_{fy}\hat{j}\right) - \left(p_{ix}\hat{i} - p_{iy}\hat{j}\right)$



$= \hat{i}\left(p_{fx} - p_{fx}\right) - \hat{j}\left(p_{fy} - p_{iy}\right)$

$= -2p_{fx}\hat{i} = -mV\hat{i}$ [$\because p_{fx} - p_{iy} = 0$]

Here, $p_{ix} = p_{fx} = p_i \cos 60° = \frac{mV}{2}$

$\because$ Impulse imparted by the wall = change in the momentum of the ball = mV.

Q.8 **(Bonus)**
Centre of gravity of a body is the point at which the total gravitational torque on body is zero. Centre of mass and centre of gravity coincides only for symmetrical bodies.
Hence statement (i) and (ii) are incorrect.
A couple of a body produces rotational motion only.
Hence statement(iii) is incorrect.
Mechanical advantage greater than one means that the system will require a force that is less than the load in order to move it.
Hence statement (4) is correct.

Q.9 (2)
Energy transfered to B initial energy of B= zero
Final velocity of

$$V_B = \left(\frac{M_2 - M_1}{M_1 + M_2}\right)u_2 + \frac{2M_1u_1}{M_1 + M_2}$$

$M_1 = 4M \quad u_1 = u$

$M_2 = 2M \quad u_2 = 0$

$$V_B = \frac{2(4M)u}{6M} = \frac{4}{3}u$$

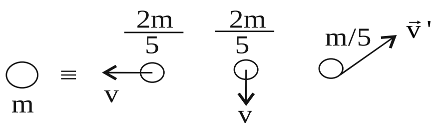
$$\frac{\frac{1}{2}M_2V_B^2}{\frac{1}{2}M_1u_1^2} = \frac{\frac{1}{2}2M\left(\frac{4}{3}\right)^2 u^2}{\frac{1}{2}4Mu^2}$$

Fraction of energy lost $= \frac{8}{9}$

Q.10 (2)

Q.11 (1)

Q.12 (2)



By conservation of momentum :

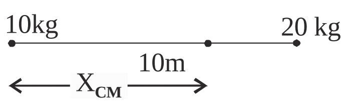
$$m(0) = \frac{2m}{5}\left(-v\hat{i}\right) + \frac{2m}{5}\left(-v\hat{j}\right) + \frac{m}{5}\vec{v}'$$

$$\Rightarrow \vec{v}' = 2v\hat{i} + 2v\hat{j}$$

$$\Rightarrow v' = \sqrt{(2v)^2 + (2v)^2}$$

$$= 2\sqrt{2}\, v$$

Q.13 (1)



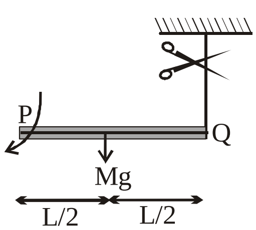
$$X_{CM} = \frac{20 \times 10}{20 + 10} = \frac{20}{3}\text{m}$$

Q.14 (3)

When the string is cut, the rod will rotate about P. Let α be initial angular acceleraiton of the rod. Then

Torque , $\tau = I\alpha = \frac{ML^2}{3}\alpha$ ....(i)

(Moment of inertia of the rod about one end $= \frac{ML^2}{3}$)

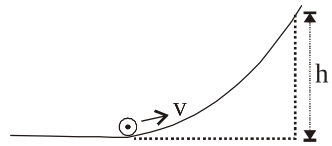


Also, $t = Mg\frac{L}{2}$ ....(ii)

Equating (i) and (ii), we get

$$Mg\frac{L}{2} = \frac{ML^2}{2}\alpha \text{ or } \alpha = \frac{3g}{2L}$$

Q.15 (2)



The kinetic energy of the rolling object is converted in to potential energy at height

$$h = \left(\frac{3v^2}{4g}\right)$$

So, by the law of conservation of mechanical energy, we have

$$\frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 = Mgh$$

$$\frac{1}{2}Mv^2 + \frac{1}{2}I\left(\frac{v}{R}\right)^2 = Mg\left(\frac{3v^2}{4g}\right)$$

$$\left(\therefore\ \omega = \frac{v}{R}\right)$$

$$\frac{1}{2}I\frac{v^2}{R^2} = \frac{3}{4}Mv^2 - \frac{1}{2}Mv^2$$

$$\frac{1}{2}I\frac{v^2}{R^2} = \frac{1}{4}Mv^2 \qquad \text{or}$$

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

Hence, the object is disc

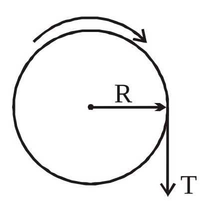
Q.16 (4)

Here,

mass of the cylinder, M = 50 kg

Radius of the cylinder R = 0.5 m

Angular acceleration produced in the cylinder,



$\alpha = 2\text{rev s}^{-2} = 2 \times 2\pi \text{ rad s}^{-2} = 4\pi \text{ rad s}^{-2}$

Moment of inertia of the cylinder about its axis

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

If T is the tension in the string, then torque acting on th cylider is

$\tau = TR$

As $\tau = I\alpha$

\ $a = \frac{\tau}{I} = \frac{TR}{\frac{1}{2}MR^2}$ or $T = \frac{MR\alpha}{2} = \frac{50 \times 0.5 \times 4\pi}{2} = 157N$

Q.17 (1)

Acceleration of the solid sphere slipping down the incline without rolling is

$a_{slipping} = g \sin\theta$

..... (i)

Acceleration of the solid sphere rolling down the incline without slipping is

$$a_{rolling} = \frac{g\sin\theta}{1+\frac{k^2}{R^2}} = \frac{g\sin\theta}{1+\frac{2}{5}} = \frac{5}{7}g\sin\theta$$

..... (ii)

$\left(\therefore \text{ For solid sphere, } \frac{k^2}{R^2} = \frac{2}{5}\right)$

Divide equation (ii) by equation (i), we get

$$\frac{a_{rolling}}{a_{slipping}} = \frac{5}{7}$$

Q.18 (3)

For the conservation of angular momentum about origin, the torque $\vec{\tau}$ acting on the particle will be zero.

By definition, $\vec{\tau} = \vec{r} \times \vec{F}$

Here, $\vec{r} = 2\hat{i} - 6\hat{j} - 12\hat{k}$ and $\vec{F} = \alpha\hat{i} + 3\hat{j} + 6\hat{k}$

$$\therefore \quad \vec{\tau} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & -6 & -12 \\ \alpha & 3 & 6 \end{vmatrix}$$

$$= \hat{i}(-36+36) - \hat{j}(12+12\alpha) + \hat{k}(6+6\alpha)$$

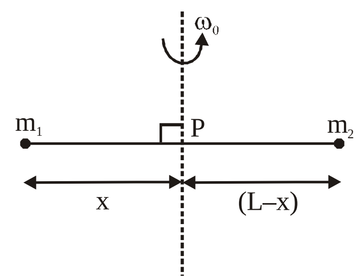
$$= -\hat{j}(12+12\alpha) + \hat{k}(6+6\alpha)$$

But $\vec{\tau} = 0$

$\therefore \quad 12 + 12\alpha = 0 \quad$ or $\quad \alpha = -1$

and $6 + 6\alpha = 0 \quad$ or $\quad \alpha = -1$

Q.19 (2)



Moment of inertia of the system about the axis of rotation (through point P) is

$I = m_1x^2 + m_2(L-x)^2$

By work energy theorem,

Work done to set the rod rotating with angular velocity ω_0 = Increase in rotational kinetic energy

$$\therefore \quad W = \frac{1}{2}I\omega_0^2 = \frac{1}{2}\left[m_1x^2 + m_2(L-x)^2\right]\omega_0^2$$

For W to be minimum, $\frac{dW}{dx} = 0$

i.e., $\frac{1}{2}\left[2m_1x + m_2(L-x)(-1)\right]\omega_0^2 = 0$

or $m_1x - m_2(L-x) = 0$

$(\therefore \omega_0 \neq 0)$

or $(m_1 - m_2)x = m_2L$

or $x = \frac{m_2L}{m_1+m_2}$

Q.20 (3)

Here,

Speed of the automobile

$v = 54 \text{ km h}^{-1} = 54 \times \frac{5}{18} \text{ ms}^{-1} = 15 \text{ ms}^{-1}$

Radius of the wheel of the automobile, R = 0.45 m

Moment of inertia of the wheel about its axis of rotation.

$I = 3 \text{ kg m}^3$

Time in which the vehicle brought torest, t = 15 s

The initial angular speed of the wheel is :

$$\omega_i = \frac{v}{R} = \frac{15\text{ms}^{-1}}{0.45\text{m}} = \frac{1500}{45} \text{ rad s}^{-1} = \frac{1500}{45} \text{ rad s}^{-1}$$

and its final angular speed is

$\omega_f = 0$ (as the vehicle comes to rest)

$\therefore$ The angular retardation of the wheel is

$$\alpha = \frac{\omega_f - \omega_i}{t} = \frac{0+\frac{100}{3}}{15s} = \frac{100}{45} \text{ rad s}^{-2}$$

The magnitude of required torque is

$$\tau = I|\alpha| = (3\,\text{kgm}^2)\left(\frac{100}{45}\text{rads}^{-2}\right)$$

$$= \frac{20}{3}\ \text{kg m}^2\text{s}^{-2} = 6.66\ \text{kgm}^2\text{s}^{-2}$$

Q.21 (3)

Given, $r = 50\text{ cm} = 0.5\text{ m}$, $\alpha = 2.0\text{ rad s}^{-2}$, $\omega_0 = 0$

At the end of 2s,

Tangential acceleration, $a_t = r\alpha = 0.5 \times 2 = 1\text{ ms}^{-2}$

Radial acceleration, $a_r = \omega^2 r = (\omega_0 + \alpha t)^2 r$

$\therefore$ Net acceleration,

$$a = \sqrt{a_t^2 + a_r^2} = \sqrt{1^2 + 8^2} = \sqrt{65} = 8\,\text{ms}^{-2}$$

Q.22 (4)

Time taken by the body to reach the bottom when it rolls down on an inclined plane without slipping is given by

$$t = \sqrt{\frac{2.1.\left(1 + \frac{k^2}{R^2}\right)}{g\sin\theta}}$$

Since g is constant and l, R and sinθ are same for both

$$\therefore\ \frac{t_d}{t_s} = \frac{\sqrt{1 + \frac{k_d^2}{R^2}}}{\sqrt{1 + \frac{k_s^2}{R^2}}} = \sqrt{\frac{1 + \frac{R^2}{2R^2}}{1 + \frac{2R^2}{5R^2}}}$$

$$\left(\therefore\ k_d = \frac{R}{\sqrt{2}},\ k_s = \sqrt{\frac{2}{5}}R\right)$$

$$= \sqrt{\frac{3}{2} \times \frac{5}{7}} = \sqrt{\frac{15}{14}}$$ Þ $t_d > t_s$

Hence, the sphere gets to the bottom first.

Q.23 (3)

Here, $m_A = m$, $m_B = 2m$

Both bodies A and B have equal kinetic energy of rotation $k_A = k_B$

$$\Rightarrow\ \frac{1}{2}I_A\omega_A^2 = \frac{1}{2}I_B\omega_B^2$$

$$\Rightarrow\ \frac{\omega_A^2}{\omega_B^2} = \frac{I_B}{I_A}$$

.... (i)

Ratio of angular momenta,

$$\frac{L_A}{L_B} = \frac{I_A\omega_A}{I_B\omega_B} = \frac{I_A}{I_B} \times \sqrt{\frac{I_B}{I_A}}$$

[Using eqn. (i)]

$$= \sqrt{\frac{I_A}{I_B}} < 1$$

$(\because I_B > I_A)$

$\therefore\ L_B > L_A$

Q.24 (2)

$$\frac{E_{Sphere}}{E_{Cylinder}} = \frac{\frac{1}{2}I_s\omega_s^2}{\frac{1}{2}I_c\omega_c^2} = \frac{I_s\omega_s^2}{I_c\omega_c^2}$$

Here, $I_s = \frac{2}{5}mR^2$, $I_c = \frac{1}{2}mR^2$

$$\frac{E_{Sphere}}{E_{Cylinder}} = \frac{\frac{2}{5}mR^2 \times \omega_s^2}{\frac{2}{5}mR^2 \times (2\omega_s)^2} = \frac{4}{5} \times \frac{1}{4} = \frac{1}{5}$$

Q.25 (1)

Here, $\ell_1 + \ell_2 = \ell$

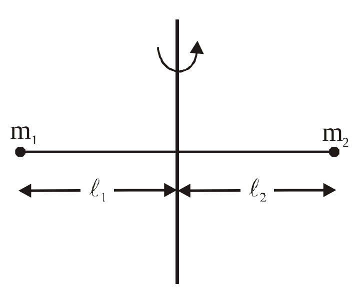
Centre of mass of the system,

$$\ell_1 = \frac{m_1 \times 0 + m_2 \times}{m_1 + m_2} = \frac{m_2\ell}{m_1 + m_2}$$

$$\ell_2 = \ell = \ell_1 = \frac{m_1\ell}{m_1 + m_2}$$

Required moment of inertia of the system,

$$I = m_1\ell_1^2 + m_2\ell_2^2$$



$$= (m_1m_2^2 + m_2m_1^2)\frac{\ell^2}{(m_1 + m_2)^2}$$

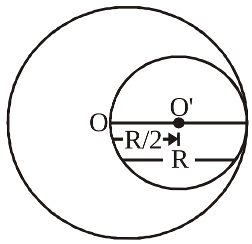
$$=\frac{m_1m_2(m_1+m_2)\ell^2}{(m_1+m_2)^2}=\frac{m_1m_2}{m_1+m_2}\ell^2$$

Q.26 (4)

Mass per unit area of disc = $\frac{M}{\pi R^2}$

Mass of removed portion of disc,

$$M'=\frac{M}{\pi R^2}\times\pi\left(\frac{R}{2}\right)^2=\frac{M}{4}$$



Moment of inertia of remove portion about an axis passing through centre of the disc O and perpendicular to the plane of disc,

$I'_O = I_{O'} + M'd^2$

$$=\frac{1}{2}\times\frac{M}{4}\times\left(\frac{R}{2}\right)^2+\frac{M}{4}\times\left(\frac{R}{2}\right)^2=\frac{MR^2}{32}+\frac{MR^2}{16}=\frac{3MR^2}{32}$$

When portion of disc would not have been removed, the moment of inertia of complete disc about centre O is

$$I_0=\frac{1}{2}MR^2$$

So, moment of inertia of the disc with removed portion is

$$I=I_0-I'_O=\frac{1}{2}MR^2-\frac{3MR^2}{32}=\frac{13MR^2}{32}$$

Q.27 (2)

$m = 3$ kg, $r = 40$ cm $= 40\times10^{-2}$ m, $F = 30$ N

Moment of inertia of hollow cylinder about its axis = $mr^2 = 3\text{kg}\times(0.4)^2\,\text{m}^2 = 0.48\,\text{kgm}^2$

The torque is given by

$\tau = I\alpha$

where I = moment of inertia

In the given case, $\tau = rF$, as the force is acting perpendicularly to the radial vector.

$$\therefore\ \alpha=\frac{\tau}{I}=\frac{Fr}{mr^2}=\frac{F}{mr}=\frac{30}{3\times40\times10^{-2}}=\frac{30\times100}{3\times40}$$

$\alpha = 25$ rad s^{-2}

Q.28 (1)

Initial angular momentum = $I\omega_1 + I\omega_2$

Let ω be angular speed of the combined system.

Final angular momentum = $2I\omega$

∴ According to conservation of angular momentum

$I\omega_1 + I\omega_2$ or $\omega=\frac{\omega_1+\omega_2}{2}$

Initial rotational kinetic energy.

$$E=\frac{1}{2}I(\omega_1^2+\omega_2^2)$$

Final rotational kinetic energy.

$$E_f=\frac{1}{2}(2I)\omega^2=\frac{1}{2}(2I)\left(\frac{\omega_1+\omega_2}{2}\right)^2=\frac{1}{2}I(\omega_1+\omega_2)^2$$

Loss of energy $\Delta E = E_i - E_f$

$$=\frac{I}{2}I(\omega_1^2+\omega_2^2)-\frac{I}{4}(\omega_1^2+\omega_2^2+2\omega_1\omega_2)$$

$$=\frac{I}{4}\left[\omega_1^2+\omega_2^2-2\omega_1\omega_2\right]-\frac{I}{4}(\omega_1-\omega_2)^2$$

Q.29 (3)

Work done required to bring them rest

$\Delta W = \Delta KE$

$$\Delta W=\frac{1}{2}I\omega^2$$

$\Delta W\ \alpha$ I for same (t)

$$W_A:W_B:W_C=\frac{2}{5}MR^2:\frac{1}{2}MR^2:MR^2$$

$$=\frac{2}{5}:\frac{1}{2}:1\qquad=4:5:10$$

$\Rightarrow W_C > W_B > W_A$

Q.30 (2)

According to law of conservation of linear momentum,

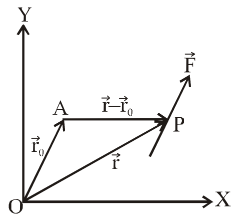
$mv + 4m\times0 = 4mv^2 + 0$

$$v'=\frac{v}{4}$$

$$e=\frac{\text{realtive velocity of separation}}{\text{Relative velocity of approach}}=\frac{v/4}{v}$$

$$e=\frac{1}{4}=0.25$$

Q.31 (4)



$$\vec{\tau} = (\vec{r} - \vec{r}_0) \times \vec{F}$$

$$\vec{r} - \vec{r}_0 = (2\hat{i} + 0\hat{j} - 3\hat{k}) - (2\hat{i} - 2\hat{j} - 2\hat{k})$$

$$= 0\hat{i} + 2\hat{j} - \hat{k}$$

$$\vec{\tau} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 2 & -1 \\ 4 & 5 & -6 \end{vmatrix} = -7\hat{i} - 4\hat{k} - 8\hat{k}$$

Q.32 (4)

$\tau_{ex} = 0$

ex = 0

So, $\frac{dL}{dt} = 0$

i.e. L = constant

So angular momentum remains constant.

Q.33 (2)

$$K_1 = \frac{1}{2}mv^2 \qquad \Rightarrow$$

$$K_t + K_r = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\right)\left(\frac{v}{r}\right)^2$$

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

So, $\frac{K_t}{K_t + K_r} = \frac{5}{7}$

Q.34 (1)

$$\omega_0 = 3\,\text{rpm} = 3 \times \frac{2\pi}{60}\,\text{rad/sec} = \frac{\pi}{10}$$

$$\omega^2 = \omega_0^2 + 2 \propto \theta$$

$$0^2 = \left(\frac{\pi}{10}\right)^2 + 2(\alpha)(2\pi \times 2\pi)$$

$$\alpha = -\frac{1}{800}\,\text{rad/sec}^2$$

$$I = \frac{mR^2}{2} = \frac{(2)\left(\frac{4}{100}\right)^2}{2} = \frac{16}{10^4}$$

$$\tau = I\alpha = \left(\frac{16}{10^4}\right) \times \left(-\frac{1}{800}\right) = -2 \times 10^{-6}\,\text{N.m}$$

Q.35 (1)

work done = ΔKE

$$(KE)_i = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 = \frac{3}{4}mv^2$$

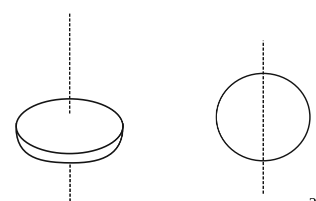
$$= \frac{3}{4} \times 100 \times \left(20 \times 10^{-2}\right)^2 = \frac{3}{4} \times 100 \times 400 \times 10^{-4} = 3J$$

Q.36 (2)

Q.37 (4)

Q.38 (3)

Q.39 (1)



$$I_1 = \frac{mR^2}{2} \qquad I_2 = \frac{mR^2}{4}$$

$$k = \sqrt{\frac{I}{m}}$$

$$\Rightarrow \frac{k_1}{k_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{mR^2/2}{mR^2/4}} = \sqrt{2} : 1$$

Q.40 (1)

$\omega = \omega_0 + \alpha t$

$$\alpha = \frac{\omega - \omega_0}{t}$$

$$= \frac{(3120 - 1200)}{16s}\,\text{rpm}$$

$$= \frac{1920}{16} \times \frac{2\pi}{60}\,\text{rad/s}^2$$

$= 4\pi$ rad/s^2

JEE MAIN

Q.1 (3)

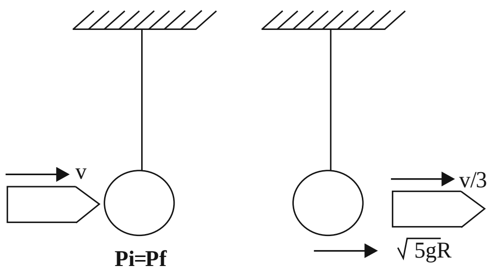
$$\Delta X_G = \frac{m_1\Delta x_1 + m_2\Delta x_2}{m_1 + m_2}$$

$$0 = \frac{10\times 6 + 30(\Delta x_2)}{40}$$

$\Delta x_2 = -2$ cm

Blocks of mass 30 kg will to move towards 10 kg.

Q.2 [10]



Considering Only Horizontal direction

$$(75v) + 0 = 50\left(\sqrt{5gR}\right) + 75\frac{v}{3}$$

$$75\left(v - \frac{v}{3}\right) = 50\sqrt{100}$$

v = 10 m/s

Q.3 [6]

$P_i = P_f$

$60 \times v = (60 + 120) \times 2$

$60 \times v = 180 \times 2$

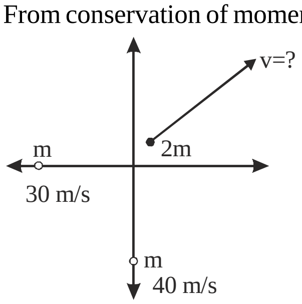
V = 6 m/s

Q.4 (2)

Ratio of masses = 1 : 1 : 2

i.e. m : m : 2m

From conservation of momentum



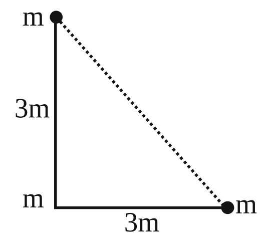
$$\vec{P}_i = \vec{P}_f$$

$0 = (-30i - 40j)m + 2mv$

$$v = \frac{30\hat{i} + 40\hat{j}}{2} = 15\,\hat{i} + 20\,\hat{j} \text{ m/s}$$

$|v| = 25$ m/s

Q.5 [2]



$$\overrightarrow{R_{CM}} = \frac{m(3\hat{i}) + m(3\hat{j})}{3m}$$

$$\overrightarrow{R_{CM}} = \hat{i} + \hat{j}$$

$$|\vec{R}| = \sqrt{2}$$

x = 2

Q.6 (3)

Applying constant retardation equation

$$\left(\frac{v}{3}\right)^2 = v^2 - 2a(4)$$

$$a = \frac{8v^2}{9\times 8} \qquad \text{....(i)}$$

And now $0^2 = V^2 - 2a\,(4 + x)$

$$= v^2 - 2\left(\frac{v^2}{9}\right)(4 + x)$$

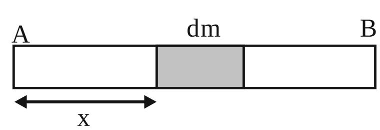
$8 + 2x = 9$

$2x = 1$

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

Q.7 [8]

$$\rho = \rho_0\left(1 - \frac{x^2}{L^2}\right)$$



$$\frac{dm}{dx} = \rho = \rho_0\left(1 - \frac{x^2}{L^2}\right)$$

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

$$= \frac{\int_0^L x\rho_0(1-\frac{x^2}{L^2})dx}{\int_0^L \rho_0(1-\frac{x^2}{L^2})dx}$$

$$= \frac{\int_0^L (x-\frac{x^3}{L^2})dx}{\int_0^L (1-\frac{x^2}{L^2})dx} = \frac{\left(\frac{x^2}{2}-\frac{x^4}{4L^2}\right)_0^L}{\left(x-\frac{x^3}{3L^2}\right)_0^L}$$

$$= \frac{\left(\frac{L^2}{2}-\frac{L^2}{4}\right)}{\left(L-\frac{L}{3}\right)} = \frac{\left(\frac{L^2}{4}\right)}{\frac{2L}{3}} = \frac{3L}{8}$$

So, $\alpha = 8$

Q.8 (1)

$$\overrightarrow{r_{com}} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1+m_2} = \frac{1(\hat{i}+2\hat{j}+\hat{k})+3(-3\hat{i}-2\hat{j}+\hat{k})}{1+3}$$

$$= -2\hat{i} - \hat{j} + \hat{k}$$

$$|2\hat{i}-\hat{j}+\hat{k}| = \sqrt{(2)^2+(1)^2+(1)^2} = \sqrt{6}$$

Q.9 (2)

according to Newton's second law of motion: $F = \frac{dp}{dt}$

And average force if $F = \frac{\Delta p}{\Delta t}$

Here $\Delta p = 2 \times 0.15 \times 12 = 3.6$kgm/s

F= 100N

$$\therefore \Delta t = \frac{\Delta p}{F} = \frac{3.6}{100} = 0.036\,s$$

Q.10 [12]

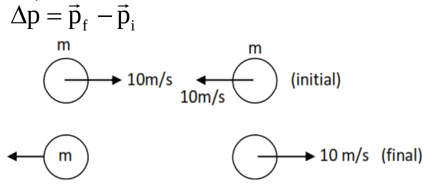
Impulse = change in momentum

$= m[v-(-v)] = 2\,mv$

$= 2 \times 0.4 \times 15 = 12$ Ns

Q.11 (2)

$$\overrightarrow{\Delta p} = \vec{p}_f - \vec{p}_i$$



$= (-)\,10\,m - 10m$

$= -20m$

$= -20 \times 0.05$

$= -1$ kg m/s

$$\text{Force} = \frac{\Delta p}{\Delta t}$$

$$= \frac{1}{0.005} = \frac{1000}{5}$$

$= 200$ N

Q.12 (2)

$$\theta_1 = \frac{1}{2}\alpha(1)^2 = \frac{\alpha}{2} = 5 \text{ rad}, \ \alpha = 10\,\text{rad/sec}^2$$

$$\theta_2 = \frac{1}{2}\alpha(2)^2 = 2\alpha = 2\times 10 = 20\,\text{rad}$$

$$\therefore \theta_2 - \theta_1 = 20 - 5 = 15 \text{ radian}$$

Q.13 (3)

Q.14 (2)

$$K_{total} = K_{rotational} + K_{Translational}$$

$$K_{total} = \frac{1}{2}I_{cm}\omega^2 \ \frac{1}{2}mv_{cm}^2$$

$v_{cm} = R\omega$ for pure rolling

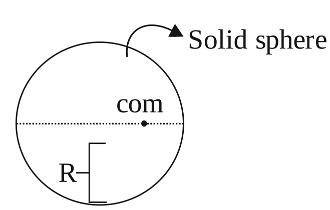
$$I_{cm} = \frac{2}{5}mR^2$$

$$K_{Rot} = \frac{1}{2}I_{cm}\omega^2 = \frac{1}{2}\times\frac{2}{5}mR^2\times\frac{v_{cm}^2}{R^2} = \frac{1}{5}mv_{cm}^2$$

$$K_{total} = \frac{1}{5}mv_{cm}^2 + \frac{1}{2}mv_{cm}^2 = \frac{7}{10}mv_{cm}^2$$

$$\frac{K_{Rot}}{K_{Total}} = \frac{\frac{1}{5}mV_{cm}^2}{\frac{7}{10}mV_{cm}^2} = \frac{2}{7}$$

Q.15 (1)



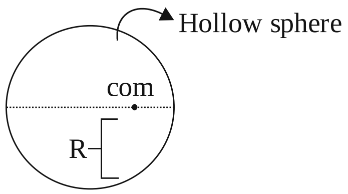
Apply parallel axis theorem

$$I_{com} = \frac{2}{5}MR^2$$

$$I_{Tangent} = I_{com} + Ma^2$$

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

$= \frac{7}{5}MR^2$



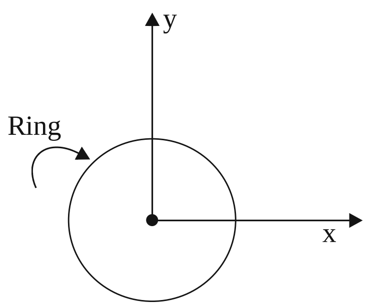
Apply parallel axis theorem

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

$I_{Tangent} = I_{com} + Ma^2$

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

$= \frac{5}{3}MR^2$



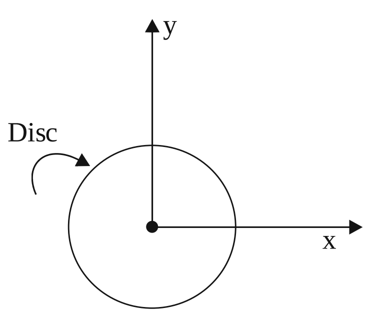
Perpendicular axis theorem

$I_x = I_y = I$

$I_z = I_x + I_y$

$MR^2 = I + I$

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



Perpendicular axis theorem

$I_x = I_y = I$

$I_z = I_x + I_y$

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

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

Q.16 (2)

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

$\int_{10}^{\omega} d\omega = 2t^3 - t^2$

$\omega = 10 + 2t^3 - t^2$

$\frac{d\theta}{dt} = 10 + 2t^3 - t^2$

$\int_{4}^{\theta} d\theta = 10 + 2t^3 - t^2$

$\int_{4}^{\theta} d\theta = 10t + \frac{t^4}{2} - \frac{t^3}{3}$

$\theta = 4 + 10t + \frac{t^4}{2} - \frac{t^3}{3}$

Q.17 (4)

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

For solid cylinder $I = \frac{mR^2}{2}$

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

For solid sphere $I = \frac{2}{5}mR^2$

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

Velocity when they reach at - ground

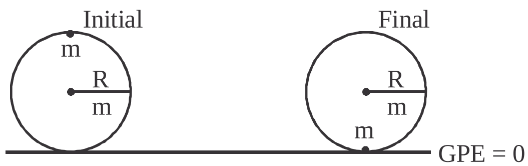
$v^2 = 2as \; \{u = 0\}$

$v = \sqrt{2as}$

$$\frac{v_c}{v_s}=\sqrt{\frac{a_c}{a_s}}\ \{S=\text{Diplacement of COM}, S=\text{Same}\}$$

$$\frac{V_c}{V_S}=\sqrt{\frac{14}{15}}$$

Q.18 [5]



By MEC→

$$mg\,(2R)=\frac{1}{2}I_{disc}\omega^2+\frac{1}{2}I_{particle}\omega^2$$

$$mg(2R)=\frac{1}{2}\omega^2\left[\frac{mR^2}{2}+mR^2\right]$$

$$mg2R=\frac{1}{2}\omega^2\left[\frac{3mR^2}{2}\right]=\frac{3}{4}m\omega^2R^2$$

$$\omega^2=\frac{8g}{3R}=\boxed{\omega=\sqrt{\frac{80}{3R}}}$$

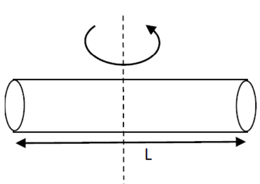
Given

$$\omega=4\sqrt{\frac{x}{3R}}=\sqrt{\frac{80}{3R}}$$

$$\frac{16x}{3R}=\sqrt{\frac{80}{3R}}$$

$$\boxed{x=5}$$

Q.19 [5]



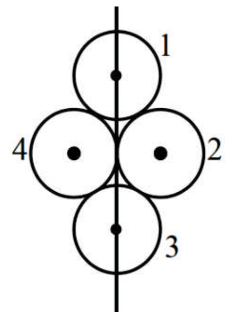
$$I=\frac{ML^2}{12}=MK^2$$

$$K=\frac{L}{\sqrt{12}}=\frac{10\sqrt{3}}{\sqrt{4}\times\sqrt{3}}=5$$

Q.20 (3)

$$I_1=I_3=\frac{MR^2}{4}$$

$$I_2=\frac{MR^2}{4}+MR^2=\frac{5}{4}MR^2=I_4$$



So, $I=I_1+I_2+I_3+I_4$

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

$$=3MR^2,\ \text{Putting } R=\frac{a}{2}$$

$$I=\frac{3Ma^2}{4},\ \text{So } x=3$$

Q.21 (4)

$$F=\int(dm)\omega^2x$$

$$=\int_0^L\left(\frac{m}{l}dx\right)\omega^2x$$

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

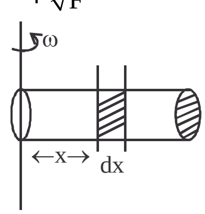
$$=\frac{m\omega^2L}{2}$$

$$\omega=\sqrt{\frac{2}{mL}}\sqrt{F}$$

$$=\sqrt{\frac{2}{0.25\times0.5}}\sqrt{F}$$

$$=\sqrt{16}\sqrt{F}$$

$$=4\sqrt{F}$$



Q.22 (3)

Net loss in PE = Gain in KE

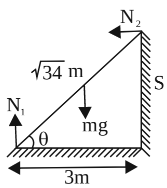
$$12gh-3gh=\frac{1}{2}3v^2+\frac{1}{2}12v^2+\frac{1}{2}\left[12r^2\right]\left(\frac{v}{r}\right)^2$$

$$9gh = \frac{1}{2}[3+2+12]v^2$$

$$v^2 = \frac{2gh}{3} \Rightarrow v = \frac{1}{2}\sqrt{\frac{8}{3}gh}$$

$$x = \frac{8}{3} \simeq 3$$

Q.23 (3)



$f = N_2$
$N_1 = mg$

$$N_2 \times \ell \sin\theta = mg\frac{\ell}{2}\cos\theta$$

$$N_2 = \frac{mg}{2}\cot\theta$$

$$\frac{F_w}{F_f} = \frac{\frac{mg}{2}\cot\theta}{\sqrt{(mg)^2 + \left(\frac{mg}{2}\cot\theta\right)^2}}$$

$$= \frac{1}{\sqrt{1+\frac{4}{\cot^2\theta}}}$$

$$= \frac{3}{\sqrt{109}}$$

Q.24 [18]

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

$$(45)\alpha = (12t - 3t^2)\frac{3}{2}$$

$$\alpha = (12t - 3t^2)\frac{3}{2} \times \frac{2}{9}$$

$$\alpha = 4t - t^2$$

$$\frac{d\omega}{dt} = 4t - t^2$$

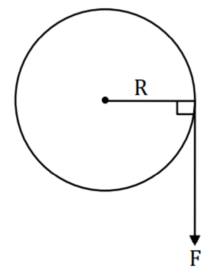
$$\int d\omega = \int (4t - t^2)dt$$

$$\int d\omega = \int\left(\frac{4t^2}{2} - \frac{t^3}{3}\right)_0^t$$

$$(\omega - 0) = 2t^2 - \frac{t^3}{3} \Rightarrow \omega = 2t^2 - \frac{t^3}{3}$$

For direction change $\omega = 0$

$$2t^2 - \frac{t^3}{3} = 0 \Rightarrow \boxed{t = 6\sec}$$



Now

$$\frac{d\theta}{dt} = 2t^2 - \frac{t^3}{3}$$

$$\int_0^\theta d\theta = \int_0^6 (2t^2 - \frac{t^3}{3})dt$$

$$(\theta - 0) = \left(\frac{2t^2}{3} - \frac{t^4}{12}\right)_0^3$$

$$\theta = \frac{2}{3}(6)^3 - \frac{1}{12}.(6)^4$$

$\theta = 144 - 108$
$\theta = 36$

$$\text{No. of rotation } = \frac{\theta}{2\pi} = \frac{36}{2\pi} = \frac{18}{\pi}$$

$$\text{So } \frac{K}{\pi} = \frac{18}{\pi} \Rightarrow \boxed{K = 18}$$

GRAVITATION

EXERCISE-I (MHT CET LEVEL)

Q.1 (2)

Q.2 (1)

Q.3 (4)

Gravitational constant = G

$$G = \frac{Fr^2}{m_1 m_2}\ \frac{N-m^2}{kg^2}$$

Unit of G is $\frac{N-m^2}{kg^2}$

The value of G is constant and it does not depend on the nature of medium in which bodies are kept.

Q.4 (1)

Change in force of gravity

$$= \frac{GMm}{R^2} - \frac{G\frac{M}{3}m}{R^2}$$

(Only due to mass $\frac{M}{3}$ due to shell gravitational field is zero (inside the shell))

$$= \frac{2GMm}{3R^2}$$

Q.5 (2)

Q.6 (2)

Because acceleration due to gravity increases

Q.7 (2)

$$\frac{g'}{g} = \frac{M'}{M}\left(\frac{R}{R'}\right)^2 = \left(\frac{2M}{M}\right)\left(\frac{R}{2R}\right)^2 = \frac{1}{2}$$

$$\Rightarrow g' = \frac{g}{2} = \frac{9.8}{2} = 4.9\ m/s^2$$

Q.8 (1)

Q.9 (4)

Q.10 (3)

Q.11 (2)

Q.12 (1)

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

$$= \sqrt{\frac{2Gd\frac{4}{3}\pi R^3}{R^2}R}$$

as $v_e \propto R$ for same density, $\frac{V_A}{V_B} = 2$

Q.13 (3)

$$\frac{G\times 100}{x^2} = \frac{G\times 10000}{(1-x)^2} \Rightarrow \frac{10}{x} = \frac{100}{1-x} \Rightarrow x = \frac{1}{11}\ m$$

Q.14 (2)

$$\Delta U = \frac{mgh}{1+\frac{h}{R}} = \frac{mg\times 3R}{1+\frac{3R}{R}} = \frac{3}{4}mgR$$

Q.15 (4)

Change in potential energy in displacing a body from r_1 to r_2 is given by

$$\Delta U = GMm\left[\frac{1}{r_1}-\frac{1}{r_2}\right] = GMm\left(\frac{1}{2R}-\frac{1}{3R}\right) = \frac{GMm}{6R}$$

Q.16 (4)

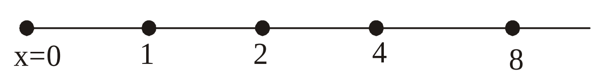
Gravitational field inside the shell is zero, so no work required.

Q.17 (2)

$$v_e = \sqrt{2g_e R_e}\,;\ v_m = \sqrt{2g_m R_m}$$

$$\frac{v_e}{v_m} = \sqrt{\frac{g_e}{g_m}\frac{R_e}{R_m}} = \sqrt{\frac{\frac{g_e}{g_e}\ \frac{R_e}{R_e}}{\ \ 6\quad\ 4}} = \sqrt{24}$$

Q.18 (3)



$$V = -\frac{GM}{r} = -G\left(\frac{1}{1}+\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+....\infty\right)$$

$$= -G\left(\frac{1}{1-\frac{1}{2}}\right) = -2G$$

Q.19 (4)

Conservation of energy

$$0=\frac{1}{2}MV_e^2-\frac{GMm}{(R+R)}$$

$$\Rightarrow V_e=\sqrt{\frac{GM}{R}}$$

We have escape velocity

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

and, $v_e^{'}=\sqrt{\frac{2GM}{(R+h)}}=\sqrt{\frac{2GM}{(R+R)}}=\frac{v_e}{\sqrt{2}}$

$$\therefore f=\frac{1}{\sqrt{2}}$$

Q.20 (3)

Q.21 (3)

Geo-stationary satellites are also called synchronous satellite. They always remain about the same path on equater, i.e., it has a period of exactly one day (86400 sec)

So orbit radius $\left(T=2\pi\sqrt{\frac{r^3}{GM}}\right)$ comes out to be 42400km, which is nearly equal to the circumference of earth. So height of Geostationary satellite from the earth surface is 42,400–6400=36,000km.

Q.22 (1)

Energy required $\Delta E=E_f-E_i$

$$\Rightarrow \Delta E=\frac{1}{2}m\left(\sqrt{\frac{GM}{R+2R}}\right)^2-\frac{GMm}{(R+2R)}-\left(-\frac{GMm}{R}\right)$$

$$=\frac{GMm}{6R}-\frac{GMm}{2R}+\frac{GMm}{R}=\frac{GMm}{2R}$$

Q.23 (2)

Q.24 (4)

For geostationary satellite

$$T=2\pi\sqrt{\frac{r^3}{GM}}=24\text{ hour}$$

$$r^{3/2}=\sqrt{\frac{6.67\times10^{-11}\times5.97\times10^{24}}{2\pi}}\times24\times3600$$

$\Rightarrow r=42400\text{ km}$

$\therefore$ Height above surface of earth is

$42400-6400=36000\text{ km}$

$\simeq 6R_e$

Where, $R_e=6400$ km

Q.25 (2)

Time period of communication satellite T_c = 1 day

Time period of another satellite = T_s

$$\frac{T_s}{T_c}=\left(\frac{r_s}{r_c}\right)^{3/2}=(4)^{3/2}\Rightarrow T_s=T_s\times(4)^{3/2}=8\text{ days}$$

Q.26 (3)

Q.27 (1)

Q.28 (1)

Q.29 (2)

$$\frac{dA}{dt}=\frac{L}{2m}=\text{Constant}$$

Q.30 (3)

Q.31 (3)

Q.32 (2)

EXERCISE-II (NEET LEVEL)

Q.1 (4)

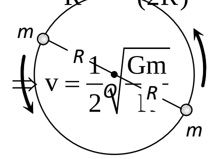
$F\propto\frac{1}{r^2}$. If r becomes double then F reduces to $\frac{F}{4}$

Q.2 (3)

Centripetal force provided by the gravitational force of attraction between two particles

i.e. $\frac{mv^2}{R}=\frac{Gm\times m}{(2R)^2}$

$$\Rightarrow v=\frac{1}{2}\sqrt{\frac{Gm}{R}}$$



Q.3 (1)

k represents gravitational constant which depends only on the system of units.

Q.4 (2)

The value of g at the height h from the surface of earth, $g' = g\left(1-\frac{2h}{R}\right)$

The value of g at depth x below the surface of earth,

$$g' = g\left(1-\frac{x}{R}\right)$$

These two are given equal, hence $\left(1-\frac{2h}{R}\right)=\left(1-\frac{x}{R}\right)$

On solving, we get x = 2h

Q.5 (1)

$g = \frac{4}{3}\pi\rho GR$. If ρ = constant then $\frac{g_1}{g_2}=\frac{R_1}{R_2}$

Q.6 (3)

Q.7 (3)

Q.8 (2)

True weight equator, W = mg observed weight at equator,

$$W' = mg' = \frac{3}{5}mg$$

At equator, latitude $\lambda = 0$ Using the formula,

$mg' = mg - mR\omega^2\cos^2\lambda$

$$\frac{3}{5}mg = mg - mR\omega^2\cos^2 0 = mg - mR\omega^2$$

$$\Rightarrow mR\omega^2 = -\frac{3}{5}mg = \frac{2}{5}mg$$

$$\therefore \omega = \left(\frac{2}{5}\frac{g}{R}\right)^{1/2}$$

$$= \left(\frac{2\times 9.8}{5\times 6.4\times 10^6}\right)^{1/2} = 7.8\times^{-4} rad/s.$$

Q.9 (2)

Q.10 (3)

Value of g decreases when we go from poles to equator.

Q.11 (3)

Acceleration due to gravity at poles is independent of the angular speed of earth

Q.12 (4)

Range of projectile $R = \frac{u^2\sin 2\theta}{g}$

if u and θ are constant then $R \propto \frac{1}{g}$

$$\frac{R_m}{R_e} = \frac{g_e}{g_m} \Rightarrow \frac{R_m}{R_e} = \frac{1}{0.2} \Rightarrow R_m = \frac{R_e}{0.2} \Rightarrow R_m = 5R_e$$

Q.13 (1)

$$g = \frac{4}{3}\pi G\rho R$$

$$\Rightarrow g \propto \rho R \Rightarrow \frac{g_e}{g_m} = \frac{\rho_e}{\rho_m}\times\frac{R_e}{R_m}$$

$$\Rightarrow \frac{6}{1} = \frac{5}{3}\times\frac{R_e}{R_m} \Rightarrow R_m = \frac{5}{18}R_e$$

Q.14 (3)

$$\Delta U = \frac{mgh}{1+h/R}$$

Substituting R = 5h

We get $\Delta U = \frac{mgh}{1+1/5} = \frac{5}{6}mgh$

Q.15 (1)

$$U = -\frac{GMm}{r}$$

$$\Rightarrow 7.79\times 10^{28} = \frac{6.67\times 10^{-11}\times 7.4\times 10^{22}\times 6\times 10^{24}}{r}$$

$\Rightarrow r = 3.8\times 10^8$ m

Q.16 (1)

Gravitational potential at mid point

$$V = \frac{-GM_1}{d/2} + \frac{-GM_2}{d/2}$$

Now, $PE = m\times V = \frac{-2Gm}{d}(M_1+M_2)$

[m = mass of particle]

So, for projecting particle from mid point to infinity

KE = |PE|

$$\Rightarrow \frac{1}{2}mv^2 = \frac{2Gm}{d}(M_1+M_2) \Rightarrow v = 2\sqrt{\frac{G(M_1+M_2)}{d}}$$

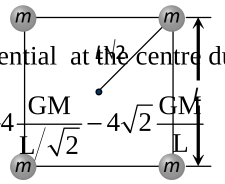
Q.17 (2)

If missile launched with escape velocity then it will escape from the gravitational field and at infinity its

total energy becomes zero.
But if the velocity of projection is less than escape velocity then sum of energies will be negative. This shows that attractive force is working on the satellite.

Q.18 (1)

Potential at the centre due to single mass = $\frac{-GM}{L/\sqrt{2}}$



Potential at the centre due to all four masses

$= -4\frac{GM}{L/\sqrt{2}} - 4\sqrt{2}\frac{GM}{L}$

$= -\sqrt{32}\times\frac{GM}{L}$

Q.19 (2)
The escape vaeloccity from earth is gien by $v_e = \sqrt{2gR_e}$ ....(i) The orbital velocity of a satellite revolving around earth is given by $v_0 = \frac{\sqrt{GM_e}}{(R_e+h)}$

where, M_e = mass of earth, R_e = radius of earth, h = height of stellite form surface of earth. by teh realtion

$GM_e = gR_e^2$

So, $v_0 = \frac{\sqrt{gR_e^2}}{(R_e+h)}$....(ii)

Dividing equation (i) by (ii), we get]

$\frac{v_e}{v_0} = \frac{\sqrt{2(R_e+h)}}{(R_e)}$

Given, $v_0 = \frac{v_e}{2}$.

$\frac{2v_e}{v_e} = \frac{\sqrt{2(R_e+h)}}{R_e}$

Squaring on both side, we get

$4 = \frac{2(R_e+h)}{R_e}$

or $R_e + h = 2R_e$ i.e., $h = R_e$

Q.20 (2)

$v_e = R\sqrt{\frac{8}{3}G\pi\rho}$ $\quad \therefore\ v_e \propto R\sqrt{\rho}$

Q.21 (4)

$\frac{GMm}{r^2} = \frac{mv^2}{r}$

$v^2 = \frac{GM}{r}$

Q.22 (2)

$v = \sqrt{\frac{GM}{r}}$ if $r_1 > r_2$ then $v_1 < v_2$

Orbital speed of satellite does not depends upon the mass of the satellite

Q.23 (1)

$$\mathbf{v_0 = \sqrt{\frac{GM}{(R+h)}}}$$

Q.24 (1)
A we know, orbital speed, v_{orb}

$= \frac{\sqrt{GM}}{r}$ Time period T = $\frac{2\pi r}{v_{ord}} = \frac{2\pi r}{\sqrt{GM}}\sqrt{r}$

$T^2 = \left(\frac{2\pi r\sqrt{r}}{\sqrt{GM}}\right)^2 = \frac{4\pi^2}{GM}r^3$

$\Rightarrow \frac{T^2}{r^3} = \frac{4\pi^2}{GM} = K \Rightarrow GMK = 4\pi^2$

Q.25 (2)
$T \propto r^{3/2}$. If r becomes double then time period will becomes $(2)^{3/2}$ times.

So new time period will be $24\times 2\sqrt{2}$ hr i.e. T = $48\sqrt{2}$ hours

Q.26 (3)
Areal velocity of the planet remains constant. If the areas A and B are equal then $t_1 = t_2$.

Q.27 (2)
As per Kepler's Law of orbits.

Q.28 (4)

$$T^2 \propto r^3 \Rightarrow \frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}$$

Q.29 (1)

Angular momentum = Mass × Orbital velocity × Radius

$$= m \times \left(\sqrt{\frac{GM}{R_0}}\right) \times R_0 = m\sqrt{GMR_0}$$

Q.30 (1)

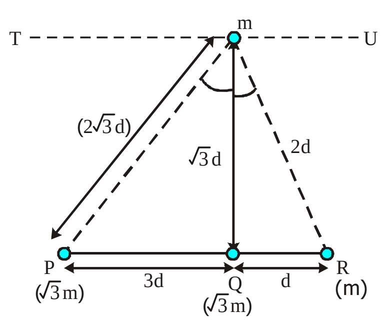
$T \propto r^{3/2}$

EXERCISE-III (JEE MAIN LEVEL)

Q.1 (3)

In horizontal direction

$$\text{Net force} = \frac{G\sqrt{3}\,mm}{12d^2}\cos 30° - \frac{Gm^2}{4d^2}\cos 60°$$



$$= \frac{Gm^2}{8d^2} - \frac{Gm^2}{8d^2} = 0$$

in vertical direction

$$\text{Net force} = \frac{G\sqrt{3}\,m^2}{12d^2}\cos 60° + \frac{G\sqrt{3}\,m^2}{3d^2} + \frac{Gm^2}{4d^2}$$

cos30°

$$= \frac{\sqrt{3}Gm^2}{24d^2} + \frac{\sqrt{3}Gm^2}{3d^2} + \frac{\sqrt{3}Gm^2}{8d^2}$$

$$= \frac{\sqrt{3}Gm^2}{d^2}\left[\frac{1+8+3}{24}\right] = \frac{\sqrt{3}Gm^2}{2d^2} \text{ along SQ}$$

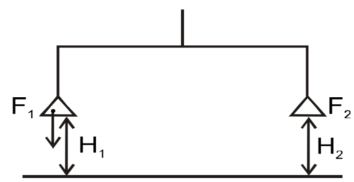
Q.2 (2)

$$F = \frac{Gm_1m_2}{r^2}$$

$$F' = \frac{Gm_1m_2}{(2r)^2} = \frac{F}{4}$$

Q.3 (2)

$$\text{Net torque} = F_2 \cdot \frac{\ell}{2} - F_1 \cdot \frac{\ell}{2}$$



$$= (F_2 - F_1)\frac{\ell}{2}$$

$$F_2 = mg_{H_2} = mg\left\{1 - \frac{2H_2}{R}\right\}$$

$$F_1 = mg_{H_1} = mg\left\{1 - \frac{2H_1}{R}\right\}$$

$$\tau = (F_2 - F_1)\frac{\ell}{2} = \frac{mg\,(H_1 - H_2)\,\ell}{R} \text{ Ans.}$$

Q.4 (2)

$$\frac{g}{4} = \frac{g}{\left(1 + \frac{h}{R_e}\right)^2}$$

$$2 = 1 + \frac{h}{R_e}$$

$h = R_e$

Q.5 (2)

$$\frac{g}{4} = \frac{GM_e}{(R_e + h)^2}$$

$$\frac{GM_e}{4R^2} = \frac{GM_e}{(R_e + h)^2}$$

$R_e + h = 2R_e$

$R_e = h$

Q.6 (3)

$$g_h = g\left(1 - \frac{r}{R}\right)$$

$$g_h = \frac{GM}{R^2}\left(1 - \frac{r}{R}\right)$$

$$\frac{GMr}{R^3} = \text{constant} \Rightarrow d \propto \frac{1}{r}$$

Q.7 (4)

$$g = \frac{GM_e}{R_e^2} = \frac{GM_e'}{(5R_e)^2}$$

$$\frac{\frac{4}{3}\pi R_e^3 \rho}{R_e^2} = \frac{\frac{4}{3}\pi (5R_e)^3 \rho'}{(5R_e)^2}$$

$$\rho = 5\rho'$$

Q.8 (2)

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

Q.9 (2)

$$dv = -Edr$$

$$= \frac{k}{r}\,dr$$

Integrating both sides

$$[v]_{v_i}^{v} = k\; k[\ell n\, r]_{d_1}^{r}$$

$$v - v_i = k\,\ell n \frac{r}{d_i}$$

$$v = v_i + k\,\ell n \frac{r}{d_i}$$ **Ans.**

Q.10 (3)

Initial total energy = Initial kinetic energy + initial potential energy

$$= \frac{1}{2}m(0)^2 + \left(-\frac{GMm}{R_0}\right) = -\frac{GMm}{R_0}$$

Total energy, when it reaches the surface of earth $= \frac{1}{2}$

$$mv^2 + \left(-\frac{GMm}{R}\right)$$

Applying energy conservation,

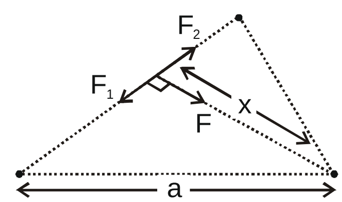
$$\frac{1}{2}mv^2 - \frac{GMm}{R} = -\frac{GMm}{R_0}$$

$$v = \sqrt{2GM\left\{\frac{1}{R} - \frac{1}{R_0}\right\}}$$ **Ans.**

Q.11 (2)

By geometry,

$$x^2 + \frac{a^2}{4} = a^2 \text{ and } F_1 = F_2$$



$$x^2 = \frac{3a^2}{4}$$

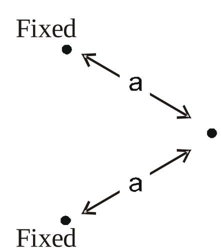
$$x = \frac{\sqrt{3}a}{2}$$

$$F_{net} = F = \frac{Gm^2}{x^2} = \frac{4}{3}\frac{Gm^2}{a^2}$$

Q.12 (2)

Initial kinetic energy = 0

Initial potential energy $= -\frac{Gm^2}{a} - \frac{Gm^2}{a}$



$$= -\frac{2Gm^2}{a}$$

Total initial energy $= -\frac{2Gm^2}{a}$

Now, kinetic energy $= \frac{1}{2}mv^2$

Potential energy = $-\dfrac{2Gm^2}{a/2} - \dfrac{Gm^2}{a/2} = -\dfrac{4Gm^2}{a}$

Total energy = $\dfrac{1}{2}mv^2 - \dfrac{4Gm^2}{a}$

$$\frac{2Gm^2}{a} = \frac{1}{2}mv^2$$

$$\sqrt{\frac{4Gm}{a}} = v$$

$v = 2\sqrt{\dfrac{Gm}{a}}$ **Ans.**

Q.13 (1)

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

$$v' = \sqrt{2}\,v_0$$

$$v' = v_e$$

$\therefore$ so escape.

Q.14 (1)

$$g_A = \frac{G\frac{4}{3}\pi R_A^3\rho}{R_A^2}\ ;\ g_B = \frac{G\frac{4}{3}\pi R_B^3\rho}{R_B^2}$$

$R_A = 2R_B$

$\Rightarrow g_A = 2g_B$

$V_{es} = \sqrt{2gR}$

$(V_{es})_A = \sqrt{2g_AR_A} = 2\sqrt{2g_BR_B}$

$(V_{es})_B = \sqrt{2g_BR_B}$

$$\frac{v_A}{v_B} = 2$$

Q.15 (3)

$$V_e = \sqrt{\frac{2GM}{R}}$$

$$V = KV_e = K\sqrt{\frac{2GM}{R}}$$

Initial total energy = $\dfrac{1}{2}mv^2 - \dfrac{2GMm}{R}$

$= \dfrac{1}{2}m.K^2\dfrac{2GM}{R} - \dfrac{2GMm}{R}$

Final total energy = $\dfrac{1}{2}m0^2 - \dfrac{2GMm}{x}$

Applying energy conservation :

$$\frac{1}{2}mx^2.\frac{2GM}{R} - \frac{2GMm}{R} = 0 - \frac{2GMm}{x}$$

$$\frac{1}{x} = \frac{1}{R} - \frac{x^2}{R}$$

$x = \dfrac{R}{1-k^2}$ **Ans.**

Q.16 (2)

$$W = \frac{GmM}{R} - \frac{GmM}{nR+R}$$

$$= \frac{GMm}{R}\left[1 - \frac{1}{nH}\right] = \frac{GMm}{R}\left[\frac{n}{n+1}\right]$$

$$= mgR\left(\frac{n}{n+1}\right)$$

Q.17 (3)

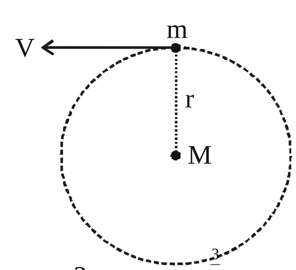
$$\frac{1}{2}mv^2 = \frac{GM_em}{Re+h} = \frac{g\,Re^2\,m}{Re+4Re}$$

$$\frac{1}{2}mv^2 = \frac{Mg\,Re}{5}$$

Q.18 (2)

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

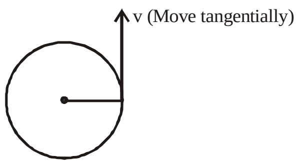
$$v = \sqrt{\frac{GM}{r^2}}$$



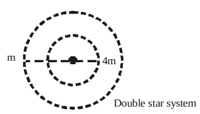
$$T = \frac{2\pi r}{v} = \frac{2\pi r^{\frac{3}{2}}}{\sqrt{GM}} = \frac{2\pi r^{\frac{3}{2}}}{\sqrt{G\rho\times\frac{4}{3}\pi r^3}}$$

$T \propto \frac{1}{\sqrt{\rho}}$ **Ans.**

Q.19 (2)



Q.20 (1)



$$\frac{k_1}{k_2} = \frac{1/2I_1\omega^2}{1/2I_2\omega^2} = \frac{m_2}{m_1}$$

Q.21 (4)

$$P.E. = -\frac{Gm_1m_2}{r}$$

$$T.E. = -\frac{Gm_1m_2}{2r}$$

$$K.E. = +\frac{Gm_1m_2}{2r}$$

Q.22 (1)

$w_e = 50 \times 10 = 500\ N$

$w_p = 50 \times 5 = 250\ N$

Hence option A is correct

Q.23 (1)

$$E = -\frac{Gm_1m_2}{2r} \qquad \frac{E}{E_A} = \frac{v_A}{v_B} = \frac{1.4}{1}$$

Q.24 (2)

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

Q.25 (1)

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

$$\frac{v_A}{v_B} = \sqrt{\frac{r_B + R}{r_A + R}}$$

Q.26 (1)

$$\frac{A}{T} = \frac{L}{2m}$$

$$L = \frac{2mA}{T}$$

Q.27 (3)

$$r \propto T^{2/3}$$

$$\frac{r_1}{r_2} = \left(\frac{3}{24}\right)^{2/3} = \frac{1}{4}$$

$$T = \frac{2\pi r}{v} \Rightarrow v = \frac{2\pi r}{T}$$

$$\frac{v_1}{v_2} = \left(\frac{r_1}{r_2}\right)\left(\frac{T_1}{T_2}\right) = \left(\frac{1}{4}\right)\left(\frac{24}{3}\right) = \frac{2}{1}$$

PREVIOUS YEAR'S

Q.1 [0008]

$$v = \sqrt{\frac{GM}{R}} = \frac{11.2}{\sqrt{2}} \simeq 8\text{km/sec.}$$

Q.2 [0004]

$$W_{ext} + W_g = 4K = 0$$

$$W_{ext} - m_4V = 0$$

$$Wext = 2 \times \frac{4}{2} = 4\ J$$

Q.3 [0023]

$$T = \frac{2\pi(a)^{3/2}}{\sqrt{GM}} \text{ so } M = \frac{4\pi^2(a)^3}{GT^2}$$

Putting values we get

$M = 2 \times 10^{21}$ kg

Q.4 [837.33]

The particle will perform SHM

$$\left(w = \sqrt{\frac{GM}{R^3}} = \sqrt{\frac{g}{R}}\right)$$

$$= w\sqrt{A^2 - \frac{R^2}{4}} = \sqrt{\frac{3gR}{4}}$$

$= \sqrt{\frac{g}{R}}\sqrt{A^2 - \frac{R^2}{4}} = \sqrt{\frac{3gR}{4}}$

$= A^2 - \frac{R^2}{4} = \frac{3}{4}R^2$

$A^2 = R^2$
$A = R$

$t = \frac{\pi}{3w} = \frac{\pi}{3}\sqrt{\frac{R}{g}}$

$= \frac{3.14}{3} \times 800 \Rightarrow 837.33$ sec. **Ans.**

Q.5 [0003]

w.r.t. COM K.E. = $\frac{1}{2}$ (red mass) v_{rel}^2

w.r.t. COM Angular momentum = $\frac{mr}{2} v_{rel}$

$\therefore$ Equating energy

$$\frac{1}{2}\frac{m}{2}v_0^2 - \frac{Gm^2}{r^0} = \frac{1}{2}\frac{m}{2}v_{rel}^2 - \frac{Gm^2}{r}$$

(Here v_{rel} is relative velocity $\perp$ to line as v_{rel} along the line joining is zero when separation is either min. or max.)
Angular momentum conservation

$$\frac{mr_0}{2} v_0 = \frac{mr}{2} v_{rel}$$

$\therefore \quad v_{rel} = \frac{r_0 v_0}{r}$

solving $3r^2 - 4rr_0 + r_0^2 = 0$

$\therefore r_{max} = r_0 \qquad r_{min} = \frac{r_0}{3}$

ratio = 3 (ans)

Q.6 [3000]

$T = \frac{2\pi R}{V} = 2\pi\sqrt{\frac{R^3}{GM}} = \sqrt{\frac{3\pi}{GP}} = 3 \times 10^3$ sec = 3000 sec.

Q.7 [8]

$$\frac{-GM \times 3M}{d} + \frac{1}{2}\mu V_{rel}^2 = 0$$

$$\frac{+3GM^2}{d} = \frac{1}{2} \times \frac{3M^2}{4M} \times V_{rel}^2 \Rightarrow V_{rel}^2 = \frac{8GM}{d}$$

$V_{rel} = \sqrt{\frac{8GM}{d}} \Rightarrow \eta = 8$ Ans.

Q.8 [0023]

$$T = \frac{2\pi(a)^{3/2}}{\sqrt{GM}} \text{ so } M = \frac{4\pi^2(a)^3}{GT^2}$$

Putting values we get
$M = 2 \times 10^{21}$ kg

Q.9 [0004]
$W_{ext} + W_g = 4K = 0$

$W_{ext} - m_4 V = 0$

Wext = $2 \times \frac{4}{2} = 4$ J

Q.10 [0023]

$$T = \frac{2\pi(a)^{3/2}}{\sqrt{GM}} \text{ so } M = \frac{4\pi^2(a)^3}{GT^2}$$

Putting values we get
$M = 2 \times 10^{21}$ kg

Q.11 (4)
According to kepler' law, the angular momentum of planet is constant.
Gravitational force acts along the line joining the earth and sun.

Q.12 (4)

Binding energy = $\frac{GMm}{2r}$

Kinetic energy = $\frac{1}{2}mv^2 = \frac{GMm}{2r}$

Total energy = $-\frac{GMm}{2r}$

Q.13 (3)

Orbital velocity, $V_0 = \sqrt{\frac{GM}{r}} \times \frac{1}{\sqrt{r}}$

$\therefore$ orbital velocity is greater when r is smaller

Q.14 (3)
A person sitting in an artificial satellite revolving around the earth feels weight less since the gravitational pull

of earth is cancelled out by centrifugal force of circular motion.

Q.15 (3)
Factual.

Q.16 (4)
(a) Total energy is always conserved. and negative
(b) Angular momentum is always conserved.
(c) Net Torque about sun is always zero.
(d) Linear momentum is not constant as the direction of velocity changes continously.

PREVIOUS YEAR'S

MHT CET

Q.1 (4)
Q.2 (3)
Q.3 (4)
Q.4 (3)
Q.5 (1)
Q.6 (2)
Q.7 (2)
Q.8 (1)
Q.9 (3)
Q.10 (4)
Q.11 (4)
Q.12 (2)
Q.13 (4)
Q.14 (3)
Q.15 (1)
Q.16 (1)
Q.17 (3)
Q.18 (1)
Q.19 (4)
Q.20 (4)
Q.21 (1)
Q.22 (3)
Q.23 (3)
Q.24 (1)
Q.25 (2)
Q.26 (4)
Q.27 (2)
Q.28 (4)
Q.29 (4)
Q.30 (4)
Q.31 (3)
Q.32 (4)
Q.33 (4)
Q.34 (3)
According to Kepler's third law, time period

$$T^2 = \frac{4\pi^2}{GM}a^3$$

where, a is the semi - major axis

$$\Rightarrow a = \left[\frac{76\times 86400\times 365\times 6.67\times 2\times 10^{300}}{4\times 3.14\times 3.14}\right]^{-1/3}$$

$= 27\times10^{12}$ m
Also in case of ellipse
2a = perihelion + aphelion
$\Rightarrow$ Aphelion = 2a - perihelion
$= 2 \times 2.7 \times 10^{12} - 8.9 \times 10^{10}$
$\approx 5.3\times10^{12}$ m

Q.35 (1)
According to deduction of Kepler's third law and with the help of Newton's law, the law of period is given by

or $T^2 = \frac{4\pi^2}{GM}r^3$

$$\Rightarrow T = 2\pi\sqrt{\frac{r^3}{GM}}$$

Where, r is the radius of orbit and M is mass of the planet or **star.**
As satellite is very close of the planet, thus r = R
Also mass (M) = density (ρ) × volume (V)

$$= \rho\times\frac{4}{3}\pi R^3$$

$$T = 2\pi\sqrt{\frac{R^3}{G\times\frac{4}{3}\pi R^3}} = \sqrt{\frac{3\pi}{\rho G}}$$

Q.36 (3)
According to conservation of energy,
Total energy of asteroid at $10R_e$ = Total energy of asteroid at surface of earth
$\Rightarrow$ **$U_1 + K_1 = U_2 + K_2$**

$$\Rightarrow \frac{-GM_em}{10R_e} + \frac{1}{2}mv_0^2 = \frac{-Gm_em}{R_e} + \frac{1}{2}mv^2$$

$$\Rightarrow \frac{9}{10}\frac{GM_em}{R_e} + \frac{1}{2}mv_0^2 = \frac{1}{2}mv^2$$

$$\Rightarrow \frac{9}{10}\times\frac{2GM}{R_e} + v_0^2 = v^2$$

$$v^2 = \frac{9}{10}(v_e)^2 + v_0^2$$

where, v_e = escape velocity = 11.2 km/s

$$\Rightarrow v^2 = \frac{9}{10}\times(112)^2 + (12)^2$$

$$= \frac{9}{10}\times(11.2)^2 + 144 = 16 \text{ kms}^{-1}$$

Q.37 (3)

For time period of a satellite, we can write

$$T=\frac{2\pi r}{v}=\frac{2\times r}{\sqrt{\frac{GM}{r}}}=\left(\frac{r^3}{GM}\right)^{1/2}2\pi$$

According to question,

$$24=2\pi\left[\frac{(6400+36000)^3}{GM}\right]^{1/2}$$

and for spy satellite, $T'=2\pi\left[\frac{(6400)^3}{GM}\right]^{1/2}$

$$\therefore\ \frac{T'}{24}=\left[\frac{(6400)^3}{(6400+36000)^3}\right]^{\frac{1}{2}}$$

$\Rightarrow T' = (24)\times(0.4)^3$
$\Rightarrow T' = 1.53$ h

Q.38 (3)
The value of acceleration due to gravity due to rotation of earth

$g' = g - \omega^2 R\cos^2\lambda$

At poles, $\lambda = 90°$

$\therefore\ g_p = g - \omega^2 R\cos^2 90° = g$

At equator, $\lambda = 0°$

$\therefore\ g_e = g - \omega^2 R\cos^2 0° = g - \omega^2 R$

$\therefore\ g_p - g_e = g - g + R\omega^2 = R\omega^2$

Q.39 (3)
The acceleration due to gravity in terms of density is given by

$$g=\frac{4}{3}\pi GR\rho \Rightarrow g\propto R\rho$$

$$\therefore\ \frac{g_m}{g_e}=\frac{R_m\rho_m}{R_e\rho_e}$$

Here, $\frac{g_m}{g_e}=\frac{1}{6}$ and $\frac{\rho_e}{\rho_m}=\frac{5}{3}$

$$\Rightarrow\ \frac{1}{6}=\frac{R_m}{R_e}\times\frac{3}{5}\Rightarrow\frac{R_m}{R_e}=\frac{5}{18}$$

or $R_m=\frac{5}{18}R_e$

Q.40 (3)
For a satellite moving in an orbit close to the planet's surface,

$$\frac{mv^2}{R}=mg$$

$\Rightarrow\ v^2 = gR$ .....(i)

The escape speed of satellite, $v_e = \sqrt{2gR}$

$\Rightarrow\ v_e^2 = 2gR$ .....(ii)

Kinetic energy, KE = $\frac{1}{2}mv^2$ [using Eqs. (i) and (ii)]

$$\therefore\ \frac{(KE)_e}{(KE)}=\frac{\frac{1}{2}mv_e^2}{\frac{1}{2}mv^2}=\frac{2gR}{gR}=2$$

Q.41 (1)
The value of acceleration due to gravity due to rotation of earth is given by

$g' = g - R\omega^2\cos\phi$

At equator, $\phi = 0$

$\Rightarrow\ g' = g - R\omega^2$

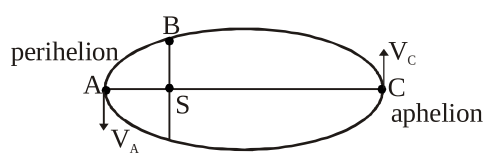
Weight of person at equator, $mg' = mg - mR\omega^2$

$\Rightarrow\ \frac{3}{5}mg = mg - mR\omega^2$

$\Rightarrow\ \omega^2=\frac{2g}{5R}$ or $\omega=\sqrt{\frac{2g}{5R}}$

NEET / AIPMT

Q.1 (2)



Point A is perihelion and C is aphelion.
So, $V_A > V_B > V_C$
So, $K_A > K_B > K_C$

Q.2 (4)
If Universal Gravitational constant becomes ten times, then $G' = 10\,G$
So, acceleration due to gravity increases.
i.e. (4) is wrong option.

Q.3 (3)
work done = $u_f - u_i$

$$\Rightarrow\frac{-GmM}{(R+h)}-\frac{-GmM}{R}$$

Now h = R

$$w=\frac{-GmM}{2R}+\frac{GmM}{R}=\frac{GmM}{2R}$$

Now $g=\frac{Gm}{R^2}$

So $w=\frac{mgR^2}{2R}=\frac{mgR}{2}$

Q.4 (4)

g at a depth $d = g\left(1-\frac{d}{R}\right)$

$d = \frac{R}{2}$

$g' = \frac{g}{2}$

$w' = \frac{w}{2}$

$w' = 100N$

Q.5 (1)
Q.6 (3)
Q.7 (3)
Q.8 (3)
Q.9 (1)

. Gravitational constant = $[M^{-1}L^{3}T^{-2}]$
Gravitational potential energy = $[ML^{2}T^{-2}]$
Gravitational potenital = $[L^{2}T^{-2}]$
Gravitational intensity = $[LT^{-2}]$

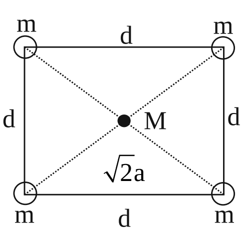
Q.10 (1)

$I_g = \frac{F}{m}$

$= \frac{3}{60\times10^{-3}} = 50\ N/kg$

JEE MAIN

Q.1 (1)



$U = -\frac{Gm^2}{d}\times4 - \frac{Gm^2}{\sqrt{2}d}\times2 - \frac{GMm}{d}\times4\sqrt{2}$

$U = -\frac{Gm^2}{d}\left[(4+\sqrt{2})m + 4\sqrt{2}M\right]$

Q.2 (2)

$mg_h = mg\left(\frac{R}{R+h}\right)^2$

$\frac{g}{3} = g\left(\frac{R}{R+h}\right)^2$

$\frac{1}{\sqrt{3}} = \frac{R}{R+h}$

$R + h = \sqrt{3}R$

$h = \left(\sqrt{3}-1\right)R$

$= 0.732\times6400\ km$
$= 4685\ km$

Q.3 (4)
According to Kepler's 3rd law

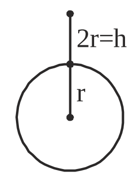
$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3$

$\left(\frac{1}{T}\right)^2 = \left(\frac{R}{3R}\right)^3 = \frac{1}{27}$

$T^2 = 27$

$T = 3\sqrt{3}$ years

Q.4 (4)



m = mass of earth

$g = \frac{Gm}{r^2}$ (At surface of earth)

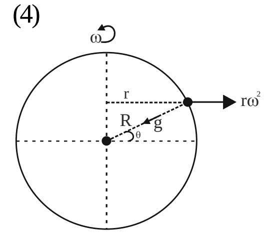
$g' = \frac{Gm}{(r+h)^2}$

$g' = \frac{Gm}{(3r)^2}$

$g' = \frac{Gm}{9r^2}$

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

Q.5 (2)
Q.6 (1)
Q.7 (6)
Q.8 (4)



Effective acceleration due to gravity is the resultant of g & $r\omega^2$ whose direction & magnitude depends upon θ. hence assertion is false.

When θ = 0° (at equator), effective acceleration is radially inward.

Q.9 (1)

Since it is universal law so it hold good for any pair of bodies.

The value of g at centre is zero

So, Statement I and Statement II are true.

Q.10 (3)

Given $T_A = 2T_B$

We know that Time period of Revolution

$T^2 \propto r^3$

$$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3 \text{ - Gravitation}$$

$$\left(\frac{2T_B}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$$

$$\Rightarrow 4r_B^3 = r_A^3$$

Q.11 (3)

$$F = \frac{Gm^2}{r^2}$$

$$F' = \frac{G\left(\frac{4m}{3}\right)\times\left(\frac{2m}{3}\right)}{r^2}$$

$$F' = \frac{8}{9}F$$

Q.12 (1)

$$V_{e(A)} = 12\frac{km}{s}$$

$$r_B = \frac{1}{2}r_A$$

Density $_{(B)}$ = 4(Density)$_A$

$\rho_B = 4\rho_A$

$$V_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2G\frac{4}{3}\pi R^3\rho}{R}}$$

$$V_e = R\sqrt{\rho}$$

$$\therefore \frac{V_{e(B)}}{V_{e(A)}} = \frac{r_B}{r_A}\sqrt{\frac{\rho_B}{\rho_A}} = \frac{1}{2}\sqrt{4} = \frac{1}{2}\times 2 = 1$$

$$\therefore V_{e(B)} = V_{e(A)} = 12 \text{ km/s}$$

Q.13 (2)

We know that

(Time period)^2 α (Radius of orbit)^3

$$\Rightarrow \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{R_1}{R_2}\right)^3$$

$$\therefore R_2 = 3R_1$$

$$\Rightarrow \frac{7^2}{T_2^2} = \frac{R_1^3}{27R_1^3}$$

$$\Rightarrow T_2^2 = 27\times 49$$

$$\Rightarrow T_2 \approx 36 \text{ hrs.}$$

Q.14 (2)

d = 13 m

$$F_0 = \frac{Gm^2}{d^2}$$

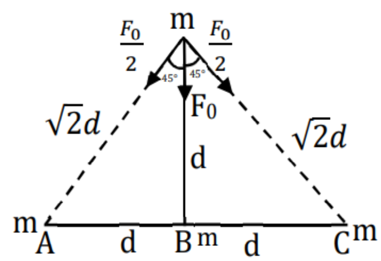
$$F = F_0 + 2\,\frac{F_0}{2}\cos 45^\circ$$

$$F = F_0\left(1+\frac{1}{\sqrt{2}}\right)$$

$$F = \frac{Gm^2}{d^2}\left(1+\frac{1}{\sqrt{2}}\right)$$

$$F = \frac{G(100)^2}{(13)^2}\left(1+\frac{1}{\sqrt{2}}\right)$$

$F \approx 100G$



Q.15 (1)

$$\frac{g'}{g} = \left(\frac{R}{r}\right)^2$$

$$g' = g\left(\frac{R}{\frac{5}{4}R}\right)^2 \qquad = g\left(\frac{4R}{5R}\right)^2$$

$$g' = \frac{16}{25}g$$

$$\Delta g = g - g'$$

$$= g - \frac{16}{25}g$$

$$= \frac{9}{25}g$$

$$\frac{\Delta g}{g} \times 100\% = \frac{9}{25} \times 100 = 36\%$$

Q.16 (1)

$$g' = g\left(1 - \frac{2h}{R}\right)$$

$$g' = g\left(1 - \frac{2 \times 32}{6400}\right) = \frac{g(99)}{100}$$

$$\frac{mg - mg'}{mg} \times 100 = \frac{g - g'}{g} \times 100$$

$$= \frac{g - \frac{99g}{100}}{g} \times 100 = \frac{1}{100} \times 100 = 1\%$$

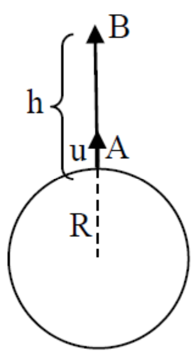
Q.17 (1)

Escape velocity of a body on any planet of mass M and radius R is given by following equation -

$V_{esc} = \sqrt{\frac{2GM}{R}}$, where G is universal gravitational constant.

Let projected velocity of body be u.

Then $u = \frac{1}{3}\sqrt{\frac{2GM}{R}}$



Let the maximum height attained by the body be *h*.

Then appying law of conservation of energy,

$E_A = E_B$

$$K_A + U_A = K_B + U_B$$

$$\Rightarrow \frac{1}{2}mu^2 - \frac{GMm}{R} = 0 - \frac{GMm}{R+h}$$

$$\Rightarrow \frac{1}{2}m \times \frac{1}{9} \times \frac{2GM}{R} - \frac{GMm}{R} = -\frac{GMm}{R+h}$$

$$\Rightarrow \frac{GMm}{9R} - \frac{GMm}{R} = -\frac{GMm}{R+h}$$

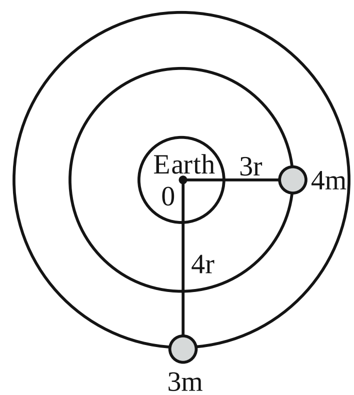
$$\Rightarrow \frac{-8GMm}{9R} = -\frac{GMm}{R+h}$$

$$\Rightarrow 8(R+h) = 9R$$

$$\Rightarrow 8h = R$$

$$\Rightarrow h = \frac{R}{8} = \frac{6400}{8} = 800km$$

Q.18 (2)



$$T.E. = \frac{-GMm}{2r}$$

$$\frac{T.E._A}{T.E._B} = \frac{m_A}{m_B} \times \frac{r_B}{r_A}$$

$$= \frac{4}{3} \cdot \frac{4r}{3r}$$

$$\frac{T.E._A}{T.E._B} = \frac{16}{9}$$

Q.19 (2)

Escape velocity Ve = $\sqrt{\frac{2GM}{R}}$

As V = $\lambda V_e = \lambda\sqrt{\frac{2GM}{R}}$

Initial total energy = $\frac{1}{2}mv^2 - \frac{GMm}{R}$ ...(1)

$$= \frac{1}{2}m\lambda^2 . \frac{2GM}{R} - \frac{GMm}{R}$$

Find total energy = $\frac{1}{2}m(0)^2 - \frac{GMm}{x}$ ...(2)

By energy conservation (1) = (2)

$$\frac{1}{2}m\lambda^2\frac{2Gm}{R}-\frac{GMm}{R}=0-\frac{GMm}{x}$$

$$\frac{1}{x}=\frac{1}{R}-\frac{\lambda^2}{R}\text{ Hence}$$

$$x=\frac{R}{1-\lambda^2}$$

Q.20 (4)

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

$$M=\text{constant } g<\frac{1}{R^2}$$

$$100\frac{\Delta g}{g}=-2\frac{\Delta R}{R}100$$

% change = – 2[–2]
% change in g = 4%
increase by 4%

Q.21 (2)

$$g\left(1-\frac{2h}{R}\right)=g\left(1-\frac{d}{R}\right)$$

$$\frac{2h}{R}=\frac{d}{R}$$

$\alpha h = d$
$\alpha = 2$

Q.22 (1)

$$U_i=\frac{-GMm}{R}$$

$$U_f=-\frac{GMm}{4R}$$

$$\Delta U=U_f-U_i=\frac{3GMm}{4R}$$

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

$$=\frac{3}{4}\times1\times10\times64\times10^5$$

$= 48MJ$

MECHANICAL PROPERTIES OF SOLIDS

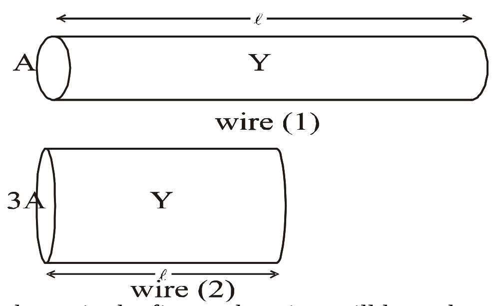
EXERCISE-I (MHT CET LEVEL)

Q.1 (2)
Maximum possible strain =0.2/100

$$\therefore A = \frac{F}{Y \times strain}$$

$$= \frac{10^4 \times 100}{(7\times10^9)\times0.2} = 7.1\times10^{-4} m^2$$

Q.2 (3)



As shown in the figure, the wires will have the same Young's modulus (same material and the length of the wire of area of cross- section 3A will be $\frac{\ell}{3}$ same volume as wire 1).

For wire 1, $Y = \frac{\frac{F}{A}}{\frac{\Delta x}{\ell}}$....(i)

For wire 2, $Y = \frac{\frac{F'}{3A}}{\frac{\Delta x}{\left(\frac{\ell}{3}\right)}}$....(ii)

From (i) and (ii), $\frac{F}{A}\times\frac{\ell}{\Delta x} = \frac{F'}{3A}\times\frac{\ell}{3\Delta x}$

$\Rightarrow F' = 9F$

Q.3 (3)

$$Y = \frac{\frac{F}{A}}{\frac{\Delta\ell}{\ell}} = \frac{\frac{50\times10^{-6}}{0.5\times10^{-3}}}{2} = \frac{\frac{250\times9.8}{50\times10^{-6}}}{2}\times\frac{2}{0.5\times10^{-3}}$$

$\Rightarrow 19.6\times10^{10} N/m^2$

Q.4 (3)
For a perfectly rigid body strain produced is zero for the given force applied, so Y = stress/strain = ∞

Q.5 (2)
Yougs's modulus of wire does not vary with dimention fo wire. It is a constant quantity.

Q.6 (2)

Q.7 (1)

Q.8 (3)

Q.9 (3)

Q.10 (2)

Q.11 (2)

$$r\theta = \ell\phi \Rightarrow \phi = \frac{r\theta}{\ell}$$

$$\frac{6mm\times30^o}{1m} = 0.18^o$$

Q.12 (4)

Q.13 (2)
Compressibility of water, K= 45.4×10^{-11} Pa^{-1}
density of water P = $10^3 kg/m^3$ depth of ocean, h = 2700 m we have to find $\frac{\Delta V}{V}$ =?

As we know, compressibility,

$$K = \frac{1}{B} = \frac{(\Delta V/V)}{P}(P = Pgh)$$

SO, $(\Delta V/V) = KPgh$

$= 45.4\times10^{-11}\times10^3\times10\times2700$

$= 1.2258\times10^{-2}$

Q.14 (4)

Q.15 (2)

EXERCISE-II (NEET LEVEL)

Q.1 (3)

$l = \frac{FL}{YA} \Rightarrow l \propto \frac{1}{A}$

Q.2 (3)

$l = \frac{FL}{AY} \Rightarrow l \propto \frac{L}{d^2} \Rightarrow \frac{l_1}{l_2} = \frac{L_1}{L_2} \times \left(\frac{d_2}{d_1}\right)^2 = \frac{1}{2} \times \left(\frac{1}{2}\right)^2 = \frac{1}{8}$

Q.3 (3)

$l = \frac{mgL}{AY} = \frac{1 \times 10 \times 1.1}{1.1 \times 10^{11} \times 10^{-6}} m = 0.1 \text{ mm}$

Q.4 (1)

Because due to increase in temperature intermolecular forces decreases.

Q.5 (3)

Breaking Force $\propto$ Area of cross section of wire (πr^2)

If radius of wire is double then breaking force will become four times.

Q.6 (4)

Y is defined for solid only and for fluids, Y = 0

Q.7 (4)

$\text{Stress} = \frac{\text{Force}}{\text{area}} l.$

In the present case, force applied and area of cross-section of wires are same, therefore stress has to be the same.

$\text{Strain} = \frac{\text{Stress}}{Y}$

Since the Young's modulus of steel wire is greater than the copper wire, therefore, strain in case of steel wire is less than that in case of copper wire.

Q.8 (1)

In the region OA, stress $\propto$ strain i.e. Hooke's law hold good.

Q.9 (4)

As stress is shown on *x*-axis and strain on *y*-axis

So we can say that $Y = \cot\theta = \frac{1}{\tan\theta} = \frac{1}{\text{slope}}$

So elasticity of wire P is minimum and of wire R is maximum

Q.10 (3)

Graph between applied force and extension will be straight line because in elastic range,

Applied force $\propto$ extension

but the graph between extension and stored elastic energy will be parabolic in nature

As $U = 1/2\ kx^2$ or $U \propto x^2$.

Q.11 (4)

Attraction will be minimum when the distance between the molecule is maximum.

Attraction will be maximum at that point where the positive slope is maximum because $F = -\frac{dU}{dx}$

Q.12 (3)

Twisting couple $C = \frac{\pi\eta r^4\theta}{2l}$

If material and length of the wires A and B are equal and equal twisting couple are applied then

$\theta \propto \frac{1}{r^4} \therefore \frac{\theta_1}{\theta_2} = \left(\frac{r_2}{r_1}\right)^4$

Q.13 (4)

$Y = 2\eta(1+\sigma)$

$2.4\eta = 2\eta(1+\sigma) \Rightarrow 1.2 = 1 + \sigma \Rightarrow \sigma = 0.2$

Q.14 (2)

Angle of shear $\phi = \frac{r\theta}{L} = \frac{4 \times 10^{-1}}{100} \times 30^o = 0.12^o$

Q.15 (3)

Isothermal elasticity $K_i = P$

Q.16 (3)

Adiabatic elasticity $K\alpha = \gamma P$

Q.17 (2)

$B = \frac{\Delta p}{\Delta V/V} l. \Rightarrow \frac{1}{B} \propto \frac{\Delta V}{V}$ [Δp = constant]

Q.18 (3)

Area of hysterisis loop gives the energy loss in the process of stretching and unstretching of rubber band and this loss will appear in the form of heating.

Q.19 (4)

Energy stored per unit volume $= \frac{1}{2} \times \text{Stress} \times \text{Strain}$

$= \frac{1}{2} \times$ Young's modulus $\times$ (Strain)^2 $\frac{1}{2} yx^2$

Q.20 (4)

$$U = \frac{1}{2}\left(\frac{YA}{L}\right) l^2\, l. \qquad \therefore\ U \propto l^2$$

$$\frac{U_2}{U_1} = \left(\frac{l_2}{l_1}\right)^2 = \left(\frac{10}{2}\right)^2 = 25 \Rightarrow U_2 = 25U_1$$

i.e. potential energy of the spring will be 25 *V*

Q.21 (1)

$$W = \frac{1}{2} F l 1$$

$$\therefore\ W \propto l \left(\text{F is constnat}\right)$$

$$\therefore\ \frac{W_1}{W_2} = \frac{l_1}{l_2} = \frac{l}{2l} = \frac{1}{2}$$

Q.22 (2)

$$W = \frac{1}{2} \times F \times l = \frac{1}{2} mgl$$

$$= \frac{1}{2} \times 10 \times 10 \times 1 \times 10^{-3} = 0.05\,J$$

Q.23 (4)

Due to tension, intermolecular distance between atoms is increased and therefore potential energy of the wire is increased and with the removal of force interatomic distance is reduced and so is the potential energy. This change in potential energy appears as heat in the wire and thereby increases the temperature.

Q.24 (1)

Increase in energy $= \frac{1}{2} \times 20 \times 1 \times 10^{-3} = 0.01J$

Q.25 (1)

Energy per unit volume $= \frac{1}{2} \times Y \times (\text{strain})^2$

$$\therefore \text{strain} = \sqrt{\frac{2E}{Y}}$$

EXERCISE-III (JEE MAIN LEVEL)

Q.1 **(1)**

d = 4mm

$Y = 9 \times 10^{10}$ N/m^2

$$\frac{F}{A} = Y \frac{\Delta \ell}{\ell}$$

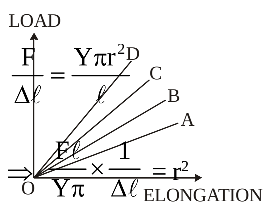
$$F = AY \frac{\Delta \ell}{\ell}$$

$$= p(2x10^{-3})^2 \text{ x } 9 \times 10^9 \text{ x } \frac{1}{100} = p \text{ x } 4 \text{ x } 10^{-6} \text{ x } 9 \times 10^7 = 360$$

p N

Q.2 **(3)**

$$\frac{F / A}{\Delta \ell / \ell} = Y$$



$$\frac{F}{\Delta \ell} = \frac{Y \pi r^2}{\ell}$$

$$\Rightarrow \frac{F \ell}{Y \pi} \times \frac{1}{\Delta \ell} = r^2$$

$\Rightarrow$ Y & l are same for all then

For same load r a $\frac{1}{\sqrt{\Delta \ell}}$

Q.3 **(3)**

$$\frac{\Delta V}{V} = \frac{\Delta P}{B} = \frac{1 \times 10^5}{1.25 \times 10^{11}} = 8 \times 10^{-7}$$

Q.4 **(3)**

On heating volume of substance increases while mass of the substance remains the same. Hence the density will decrease

Q.5 **(4)**

$$K = \frac{AY}{\ell}, K' = \frac{4AY}{\ell / 2} = 8K$$

$$\frac{U}{2} = \frac{\frac{1}{2} \times 8K \times \Delta \ell^2}{\frac{1}{2} \times K \times \Delta \ell^2} \Rightarrow U = 16\,J$$

EXERCISE-IV

Q.1 0010

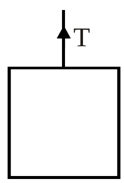
$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{mg}{A} = \frac{(\rho A\ell)g}{A} = \rho l g$$

$8 \times 10^8 = (8 \times 10^3) l\,(10)$

Q.2 0030

T – mg = ma

T = mg + ma



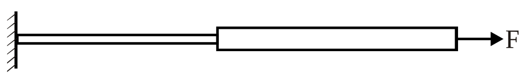
$$\frac{800(g+a)}{4\times10^{-4}} = \frac{T}{A}$$

$$= \frac{1}{3} \times 2.4 \times 10^8 = 8 \times 10^7$$

$$(g + a) = \frac{8\times10^3}{200} = 40$$

$a = 30\ m/s^2$

Q.3 8



$$\frac{F}{A_1} = y\frac{\Delta\ell_1}{\ell}$$

$$\frac{F}{A_2} = y\frac{\Delta\ell_2}{\ell}$$

$\Delta\ell_1 + \Delta\ell_2 = 10$ mm

$$\frac{F\ell}{A_1 y} + \frac{F\ell}{4A_1 y} = 10\text{ mm}$$

$$\frac{F\ell}{A_1 y} + \frac{F\ell}{4A_1 y} = 10\text{ mm} \Rightarrow \frac{F\ell}{A_1 y} = 8\text{ mm.}$$

Q.4 200

$P_0 + H\rho g = 3.7 \times 10^6$

$H \times 1.8 \times 10^3 \times 10 = 3.6 \times 10^6$

$$H = \frac{36}{18} \times 10^2 = 200$$

Q.5 5

Mg = PA ; A is sectional area

$Alqg = 10^5 A$

$$\ell = \frac{10^5}{2\times10^3\times10} = 5\text{m}$$

Q.6 0012

We know that

$$\frac{F}{A} = Y\frac{\Delta l}{l} \Rightarrow \frac{mg}{A} = Y\frac{\Delta l}{l}$$

$$\text{i.e. } m = \frac{A}{g}\,Y\,\frac{\Delta l}{l}$$

$$= \frac{\pi(0.6\times10^{-3})^2\times2\times10^{11}\times1.6\times10^{-3}}{10\times3.2}$$

$$= \frac{0.36\,\pi}{10} \times 10^2 = 3.6\,\pi \approx 11.3$$

$\therefore$ closest mass = 12 kg

Q.7 0250

F – T = 3a

T = 2a

$T = 2.5 \times 10^9 \times 4 \times 10^{-8}$

T = 100 N

T = 2a

100 = 2a

a = 50 N

F = 5 × 50

F = 250 N

Q.8 (1)

Work done against the inter molecular forces of attraction is stored in the wire in the form of elastic potential energy.

Q.9 (1)

For a perfectly plastic body, restoring force is zero. So stress strain curve is straight line parallel to strain axis. Young modulus = slope of curve = zero

Q.10 (1)

$$\text{Compressibility} = \frac{1}{K}$$

$$K = \frac{-\frac{\Delta P}{\Delta V}}{V} \propto \Delta P$$

Q.11 (1)

In a glassy solid or amorphous solid, the various bonds between particles are not equally strong. So, different bonds are broken at different temperature. Hence there is no sharp melting point.

Q.12 (1)

$$\text{Bulk modulus of elasticity} = \frac{\text{Volume stress}}{\text{Volume strain}}$$

$$\text{Modulus of rigidity} = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

Potential energy of stretched wire

$$= \frac{1}{2} Y \times \text{strain}^2 \times \text{volume}$$

$$\frac{9}{y} = \frac{3}{n} + \frac{1}{K}$$

Q.13 (3)

PREVIOUS YEAR'S

MHT CET

Q.1 (2)	**Q.2** (1)	**Q.3** (1)	**Q.4** (2)	**Q.5** (3)
Q.6 (4)	**Q.7** (4)	**Q.8** (1)	**Q.9** (2)	**Q.10** (4)
Q.11 (1)	**Q.12** (1)	**Q.13** (1)	**Q.14** (4)	**Q.15** (2)
Q.16 (2)	**Q.17** (3)	**Q.18** (2)	**Q.19** (1)	**Q.20** (3)
Q.21 (2)	**Q.22** (4)	**Q.23** (4)	**Q.24** (4)	**Q.25** (2)
Q.26 (3)	**Q.27** (4)	**Q.28** (3)	**Q.29** (3)	**Q.30** (2)
Q.31 (4)	**Q.32** (1)	**Q.33** (2)		

NEET/AIPMT

Q.1 (3)

Wire 1:

Wire 2 :

For wire 1,

$$\Delta I = \left(\frac{F}{AY}\right) 3I \qquad \text{....(i)}$$

For wire 2,

$$\frac{F'}{3A} = Y\frac{\Delta I}{I}$$

$$\Rightarrow \Delta I = \left(\frac{F'}{3AY}\right) I \qquad \text{....(ii)}$$

From equation (i) & (ii),

$$\Delta I = \left(\frac{F}{AY}\right) 3I = \left(\frac{F'}{3AY}\right) I$$

$$\Rightarrow F' = 9F$$

Q.2 (3)

$$\text{Strain} = \frac{\ell}{L}; \qquad \text{stress} = \frac{Mg}{A}$$

$$\text{Energy} = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$$

$$= \frac{1}{2} \times \frac{Mg}{A} \times \frac{\ell}{L} \times A \times L$$

$$= \frac{1}{2} Mg\ell$$

Q.3 **(3)**

Q.4 (2)

In stretching of a spring shape charges therefore shear modulus is used.

$Y_{copper} < Y_{steel}$

Q.5 (2)

$$v \propto \sqrt{\text{Tension}}$$

$$\frac{v_i}{v_f} = \sqrt{\frac{T_i}{T_f}}$$

$$\frac{v_i}{v_f} = \sqrt{\frac{T}{2T}}$$

$$\frac{v_i}{v_f} = \sqrt{\frac{1}{2}} = \frac{1}{\sqrt{2}}$$

JEE-MAIN

Q.1 (3)

Given $B = 3 \times 10^{10}\ \text{N/m}^2$

$$B = \frac{-\Delta P}{\Delta V / V}$$

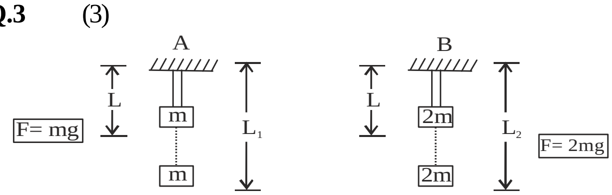
$$\Delta P = (-)\ B \times \frac{\Delta V}{V}$$

$$= 3 \times 10^{10} \times \frac{2}{100}$$

$$= 6 \times 10^{8}\ \text{Nm}^{-2}$$

Q.2 (25)

Q.3 (3)



$\Delta L = (L_1 - L)$ $\qquad$ $\Delta L = (L_2 - L)$

$F = \frac{YA}{L}\Delta L$

$\boxed{F = K\Delta L}$

For (A)

$mg = K(L_1 - L)$ .....(i)

For (B)

$2mg = K(L_2 - L)$ .....(ii)

From Eq. $\frac{(ii)}{(i)}$

$\frac{2}{1} = \frac{L_2 - L}{L_1 - L}$

$\boxed{L = 2L_1 - L_2}$

Q.4 (5)

Stress = y × strain

$\frac{F}{\pi r^2} = \frac{y\Delta\ell}{L} \Rightarrow \Delta\ell \frac{FL}{y\pi r^2}$

$\frac{\Delta\ell_1}{\Delta\ell_2} = \left(\frac{F}{4F}\right)\left(\frac{L}{4L}\right)\left(\frac{4r}{r}\right)^2$

$\frac{\Delta\ell_1}{\Delta\ell_2} = 1 \Rightarrow \Delta\ell_2 = \Delta\ell_1$

$\Delta\ell_2 = 5\,\text{cm}$

Q.5 (2)

$L = 1m$

$\Delta L = 0.4 \times 10^{-3} m$

$d = 0.4 \times 10^{-3} m$

$Y = \frac{FL}{A\Delta L} = \frac{mg(1)}{\frac{\pi d^2}{4}(0.4\times10^{-3})}$

$Y = \frac{40}{\pi(0.4\times10^{-3})^3}$

$Y = \frac{40\times7}{22\times64\times10^{-3}\times10^{-9}}$

$Y = 0.199 \times 10^{-12}\ N/m^2$

$\frac{\Delta Y}{Y} = \frac{\Delta F}{F} + \frac{\Delta L}{L} + \frac{\Delta A}{A} + \frac{\Delta(\Delta L}{\Delta L}$

$= \frac{\Delta L}{L} + 2\frac{\Delta d}{d}$

$= \frac{0.02}{0.4} + 2\times\frac{0.01}{0.4}$

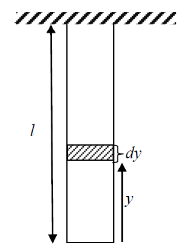
$\frac{\Delta Y}{Y} = \frac{0.1}{2} + \frac{0.1}{2} = 0.1$

$\Delta Y = 0.1 \times Y = 0.1 \times 0.199 \times 10^{11}$

$\boxed{\Delta Y = 1.99\times10^{10}}\ \therefore\ \boxed{x = 2}$

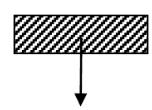
$\simeq 2\times10^{10}$

Q.6 (25)



According to Hook's law, $\frac{F}{A} = Y\frac{\Delta l}{l}$

Net pulling force on the elemental mass will be due the mass lower to it.



F (Force due to lower weight)

$F = \frac{m}{l}yg$

Let elongation in this elemental mass be d (Δl)

Then,

$\frac{F}{A} = y\frac{d(\Delta l)}{l}$

$\Rightarrow \frac{mgy}{lA} = Y\frac{\Delta l}{dy}$

$\Rightarrow \Delta l = \frac{mgy}{lAY}dy$

$\Rightarrow l = \int_0^1 \frac{mgy}{LAY}dy$

$= \frac{mg}{lAY}\int_0^1 ydy$

$= \frac{mg}{lAY}\left[\frac{Y^2}{2}\right]_0^1$

$= \frac{mgl}{2AY}$

$= \frac{20\times10\times20}{2\times0.4\times2\times10^{11}}$

$= 25\times10^{-9}$

Q.7 (48)

$\eta = 25\times10^9\ N/m^2$

Area = 60 cm × 15 cm

= 900 cm^2

$\text{Stress} = \frac{F}{\text{Area}} = \frac{18\times10^4}{900\times10^{-4}}$

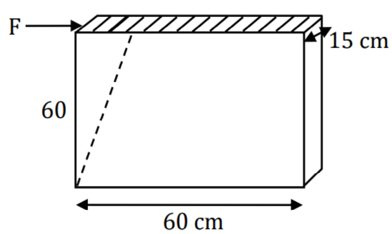
= 2 × 10^6

$\eta = \frac{\text{Stress}}{Q} = \frac{\text{Stress}}{(\frac{x}{h})}$

$25\times10^9 = \frac{2\times10^6}{x}\times60$

$x = \frac{2\times60\times10^6}{25\times10^9} = 12\times4\times\frac{10^5}{10^9} = 48\times10^{-4}\text{cm}$

$\boxed{x = 48\mu m}$



Q.8 (4)

Given $\Delta l_1 + \Delta l_2 = 1.4\times10^{-3}$m

Or

$\Delta l_5 + \Delta l_c = 1.4\times10^{-3}$

Or

$$\frac{F(3.2)}{\frac{22}{7}(1.4\times10^{-3})^2\times2\times10^{11}} + \frac{F(4.4)}{\frac{22}{7}(1.4\times10^{-3})^2\times1.1\times10^{11}} = 1.4\times10^{-3}$$

$$\text{or } F\left(\frac{3.2}{2}\right) + \frac{F(4.4)}{1.1} = 1.4\times1.4\times1.4\times10^2\times\frac{22}{7}$$

Or F(5.6) = 8.6 × 10^2

Solving F = 154 N

Q.9 (2)

Let us take wire (2) and now

$$Y = \frac{FL}{A\Delta x} \text{ or } = \frac{L}{A}\left(\frac{F}{\Delta x}\right)$$

Putting values $Y = \frac{2\times2}{.5\times10^{-5}(2\times10^{-3})^2}$

Solving Y = 2 × 10^{11}

Q.10 (3)

$F = \gamma A\left(\frac{\Delta\ell}{\ell}\right)$

$= 2\times10^{11}\times10^{-4}\left(\frac{2\ell-\ell}{\ell}\right)$

= 2 × 10^{7}N

Q.11 (30)

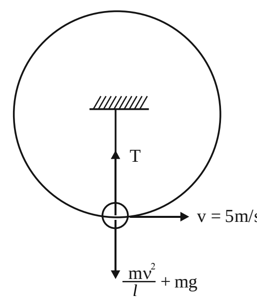
A = 4mm^2 l = 0.5 m m_{body} = 2 kg

$\gamma = 10^{11}$ N/m^2 g = 10 m/s^2

$\text{strain} = \frac{\text{stress}}{\gamma}$

$= \frac{F}{Ay}$

F = tension in string



$F = \frac{mv^2}{\iota} + mg$

$f = \frac{2\times5^2}{0.5} + 2\times10 = 120\ N$

$\text{Strain} = \frac{120}{4\times10^{-6}\times10^{11}}$

= 30 × 10^{-5}

Q.12 (1)

Y depends on material of wire

Q.13 (50)

$T = \frac{mv^2}{\ell} = \frac{10\times v^2}{0.5} = 20v^2$

T_{max} = Breaking stress × Area

= 5 × 10^8 × 10^{-14} = 5 × 10^4

20V^2 = 5 × 10^4

$V = \sqrt{\frac{1}{4}10^4} = 50m/s$

MECHANICAL PROPERTIES OF FLUIDS

EXERCISE-I (MHT CET LEVEL)

Q.1 (3)

Q.2 (3)

Q.3 (4)

Q.4 (2)

Ice is less denser than water. When ice melts, the volume occupied by water is less than that of ice. Due to which the level of water goes down.

Q.5 (2)

Retardation of ball due to buoyant force

$$=\frac{\rho_w V_g-\rho_s V_g}{\rho_s v}=\frac{0.4-1}{0.4}g$$

$=-1.5$ g

Approach velocity of ball $=\sqrt{2gh}$

$v^2-u^2=2ax$

$\Rightarrow 0^2-2\times g(9)=2(-1.5\,g).x$

x=6 cm

Q.6 (2)

Q.7 (4)

Q.8 (4)

Q.9 (3)

Q.10 (2)

Q.11 (1)

Q.12 (1)

Q.13 (3)

According to principle of continuity

$$v_y=\frac{v_x A_x}{A_x}=\frac{10(m/s)\times 2(cm^2)}{25\times 10^{-2}(cm^2)}=80m/s$$

Q.14 (1)

According to Bernouli's theorem

$$P_1+\frac{1}{2}\rho v_1^2=P_2+\frac{1}{2}\rho v_2^2....(i)$$

According to the condition,

$$P_1-P_2=3\times 10^5,\frac{A_1}{A_2}=5$$

From equation of continuity,

$A_1v_1 = A_2v_2$

so, $\frac{A_1}{A_2}=\frac{A_2}{A_1}=5\Rightarrow v_2=5v_1$

From equation(i)

$$P_1-P_2=\frac{1}{2}\rho\left(v_2^2-v_1^2\right)$$

or $3\times 10^5=\frac{1}{2}\times 1000\left(25v_1^2-v_1^2\right)$

$600=24v_1^2\Rightarrow v_1^2=25$

$\therefore$ $v_1 = 5$ m/s

Q.15 (2)

Q.16 (1)

Q.17 (1)

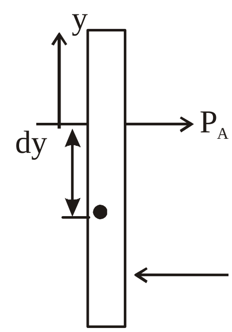
Q.18 (3)

The net force acting on the gate element of width dy a depth y from the surface of the fluid, is.

$dy=\left(p_0+\rho gy-p_0\right)\times 1dy$

$=\rho g y dy$

Torque about the hinge is



$$d\tau=pgydy\times\left(\frac{l}{2}-y\right)$$

Net torque experienced by the gate is

$$\tau_{net}=\int d\tau+F\times\frac{\ell}{2}$$

$$=\int_0^{\ell}\rho g\ ydy\left(\frac{\ell}{2}-y\right)+F\times\frac{\ell}{2}=0$$

$$\Rightarrow F=\frac{\rho g}{6}$$

i.e., The force F required to hold the gate stationary is $\frac{pg}{6}$

Q.19 (4)

Apparent weight

$= V(\rho-\sigma)g = l\times b\times h\times(5-1)\times g$

$= 5\times 5\times 5\times 4\times g$ Dyne $= 4\times 5\times 5\times 5$ gf.

Q.20 (1)

Fraction of volume immersed in the liquid $V_{in}=\left(\frac{\rho}{\sigma}\right)V$

i.e. it depends upon the densities of the block and liquid. So there will be no change in it if system moves upward or downward with constant velocity or some acceleration.

Q.21 (2)
Bernoulli's theorem for unit mass of liquid

$$\frac{P}{\rho}+\frac{1}{2}v^2 = \text{constant}$$

As the liquid starts flowing, it pressure energy decreases

$$\frac{1}{2}v^2=\frac{P_1-P_2}{\rho}\Rightarrow\frac{1}{2}v^2=\frac{3.5\times10^5-3\times10^5}{10^3}$$

$$\Rightarrow v^2=\frac{2\times0.5\times10^5}{10^3}\Rightarrow v^2=100\Rightarrow v=10\ m/s$$

Q.22 (1)
From the Bernoulli's theorem

$$P_1-P_2=\frac{1}{2}\rho\left(v_2^2-v_1^2\right)=\frac{1}{2}\times1.3\times\left[(120)^2-(90)^2\right]$$

= 4095 N/m^2 or Pascal

Q.23 (3)

$$F=\frac{2AT}{d}=\frac{2\times\pi\times(0.05)^2\times73\times10^{-3}}{0.01\times10^{-3}}$$

$$=36.5\pi\approx115\,\text{newton}$$

Q.24 (2)

$$\Delta W = s\times\Delta A = 0.06\times4\pi\left(r_2^2-r_1^2\right)$$

$$=0.003168\,J$$

Q.25 (1)
$W = T\Delta A = 4\pi R^2T(n^{1/3}-1)$
$= 4\times3.14\times(10^{-2})^2\times460\times10^{-3}[10^{6/3}-1]$
$= 0.057$

Q.26 (1)
On increasing the temperature, angle of contact decreases

Q.27 (1)
Q.28 (1)
Q.29 (4)

Capillary rise, $h\propto\frac{1}{r}$

$\Rightarrow$ h is greater if radius is smaller

Q.30 (2)
Viscosity is also termed as liquid friction. Due to viscosity, the adjacent layers of a liquid resist, the relative motion between them.

Q.31 (1)

EXERCISE-II (NEET LEVEL)

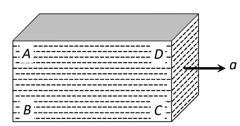
Q.1 (3)
As the both points are at the surface of liquid and these points are in the open atmosphere. So both point possess similar pressure and equal to 1 atm. Hence the pressure difference will be zero.

Q.2 (3)

Volume of ice $=\frac{M}{\rho}$, volume of water $=\frac{M}{\sigma}$.

$\therefore$ Change in volume $=\frac{M}{\rho}-\frac{M}{\sigma}=M\left(\frac{1}{\rho}-\frac{1}{\sigma}\right)$

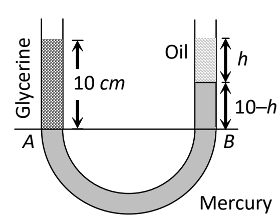
Q.3 (1)



Due to acceleration towards right, there will be a pseudo force in a left direction. So the pressure will be more on rear side (Points A and B) in comparison with front side (Point D and C)

Q.4 (4)
Pressure = hρg i.e. pressure at the bottom is independent of the area of the bottom of the tank. It depends on the height of water upto which the tank is filled with water. As in both the tanks, the levels of water are the same, pressure at the bottom is also the same.

Q.5 (4)



At the condition of equilibrium
Pressure at point A = Pressure at point B
$P_A = P_B \Rightarrow 10 \times 1.3 \times g = h \times 0.8 \times g + (10 - h) \times 13.6 \times g$
By solving we get h = 9.6 cm

Q.6 (2)
Let specific gravities of concrete and saw dust are ρ_1 and ρ_2 respectively.
According to principle of floatation weight of whole sphere = upthrust on the sphere

$$\frac{4}{3}\pi(R^3 - r^3)\rho_1 g + \frac{4}{3}\pi r^3 \rho_2 g = \frac{4}{3}\pi R^3 \times 1 \times g$$

$$\Rightarrow R^3\rho_1 - r^3\rho_1 + r^3\rho_2 = R^3$$

$$\Rightarrow R^3(\rho_1 - 1) = r^3(\rho_1 - \rho_2) \Rightarrow \frac{R^3}{r^3} = \frac{\rho_1 - \rho_2}{\rho_1 - 1}$$

$$\Rightarrow \frac{R^3 - r^3}{r^3} = \frac{\rho_1 - \rho_2 - \rho_1 + 1}{\rho_1 - 1}$$

$$\Rightarrow \frac{(R^3 - r^3)\rho_1}{r^2\rho_2} = \left(\frac{1-\rho_2}{\rho_1 - 1}\right)\frac{\rho_1}{\rho_2}$$

$$\Rightarrow \frac{\text{Mass of concrete}}{\text{Mass of saw dust}} = \left(\frac{1-0.3}{2.4-1}\right) \times \frac{2.4}{0.3} = 4$$

Q.7 (2)

$$V\rho g = \frac{V}{2}\sigma g$$

$$\therefore \rho = \frac{\sigma}{2}(\sigma = \text{density of water})$$

Q.8 (2)

For streamline flow, Reynold's number $N_R \propto \frac{r\rho}{\eta}$ should be less. For less value of N_R, radius and density should be small and viscosity should be high.

Q.9 (1)
$d_A = 2\text{cm}$ and $d_B = 4$ cm $\therefore r_A = 1\text{cm}$ and $r_B = 2$ cm
From equation of continuity, av = constant
$\therefore$

$$\therefore \frac{\nu_A}{\nu_B} = \frac{\alpha_B}{\alpha_A} = \frac{\pi(r_B)^2}{\pi(r_A)^2} = \left(\frac{2}{1}\right)^2 \Rightarrow \nu_A = 4\nu_B$$

Q.10 (3)
If the liquid is incompressible then mass of liquid entering through left end, should be equal to mass of liquid coming out from the right end.
$\therefore M = m_1 + m_2 \Rightarrow A\nu_1 = A\nu_2 + 1.5A \cdot \nu$
$\Rightarrow A \times 3 = 4 \times 1.5 + 1.5A.\nu \Rightarrow \nu = 1$ m/s

Q.11 (1)

Pressure at the bottom of tank $P = h\rho g = 3\times10^5 \frac{N}{m^2}$

Pressure due to liquid column
$P_l = 3 \times 10^5 - 1 \times 10^5 = 2 \times 10^5$
and velocity of water $\nu = \sqrt{2gh}$

$$\therefore \nu = \sqrt{\frac{2P_l}{\rho}} = \sqrt{\frac{2\times2\times10^5}{10^3}} = \sqrt{400} \text{ m/s}$$

Q.12 (1)
As speed of air above wing is greater,
$\therefore$ pressure is smaller above wing.

Q.13 (2)

Horizontal range will be maximum when $h = \frac{H}{2} = \frac{90}{2} =$ 45 cm i.e. hole 3.

Q.14 (4)
Upthrust – weight of body = apparent weight
$VDg - Vdg = Vd\alpha$,

Where a = retardation of body $\therefore \alpha = \left(\frac{D-d}{d}\right)g$

The velocity gained after fall from h height in air, $\nu = \sqrt{2gh}$
Hence, time to come in rest,

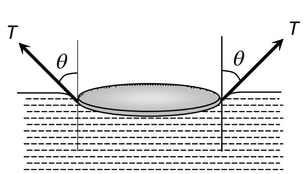
$$t = \frac{\nu}{\alpha} = \frac{\sqrt{2gh} \times d}{(D-d)g} = \sqrt{\frac{2h}{g}} \times \frac{d}{(D-d)}$$

Q.15 (4)
Soap helps to lower the surface tension of solution, thus soap get stick to the dust particles and grease and these are removed by action of water.

Q.16 (1)
Weight of spiders or insects can be balanced by vertical component of force due to surface tension.

Q.17 (4)
$T = T_0(1 - \alpha t)$

Q.18 (3)



Weight of metal disc = total upward force

= upthrust force + force due to surface tension
= weight of displaced water + T cos θ (2π r)
= W + 2π rT cos θ

Q.19 (1)

$$T = \frac{F}{2l} = \frac{2\times10^{-2}}{2\times10\times10^{-2}} = 0.1\ N/m$$

Q.20 (1)
Energy needed = Increment in surface energy
= (surface energy of *n* small drops) – (surface energy of one big drop)
$= n4\pi r^2T - 4\pi R^2T = 4\pi T(nr^2 - R^2)$

Q.21 (1)
When two droplets merge with each other, their surface energy decreases.
W = T(ΔA)= (negative) i.e. energy is released.

Q.22 (3)
Work done to increase the diameter of bubble from d to D

$$W = 2\pi\left(D^2 - d^2\right)T = 2\pi\left[(2D)^2 - (D)^2\right]T = 6\pi D^2T$$

Q.23 (3)

$$W = 8\pi T(r_2^2 - r_1^2) = 8\pi T\left[\left(\frac{2}{\sqrt{\pi}}\right)^2 - \left(\frac{1}{\sqrt{\pi}}\right)^2\right]$$

$$\therefore\ W = 8\times\pi\times30\times\frac{3}{\pi} = 720\text{ erg}$$

Q.24 (3)
$W = 8\pi RT^1$.
$\therefore$ $W \propto R^2$ (T is constant)
If radius becomes double then work done will become four times.

Q.25 (3)
This happens due to viscosity.

Q.26 (2)

Q.27 (2)

Q.28 (2)

Q.29 (3)
Angle of contact is acute.

Q.30 (2)
Both liquids water and alcohol have same nature (i.e. wet the solid). Hence angle of contact for both is acute.

Q.31 (3)

$$h = \frac{2T\cos\theta}{r\rho g} \Rightarrow h \propto \frac{1}{r} \Rightarrow \frac{h_2}{h_1} = \frac{r_1}{r_2} = \frac{2}{3}$$

$$\left(\because r_1 = r, r_2 = +50\ \%\ of r = \frac{3}{2}r\right)$$

New mass m_2

$$\pi r_2^2 h_2\rho = \pi\left(\frac{3}{2}r_1\right)^2\left(\frac{2}{3}h_1\right)\rho = \frac{3}{2}\left(\pi r_1^2 h_1\right)\rho = \frac{3}{2}m$$

Q.32 (c)

$$h = \frac{2T\cos\theta}{r\rho g} \Rightarrow h \propto \frac{1}{r} \Rightarrow \frac{h_2}{h_1} = \frac{r_1}{r_2} = \frac{2}{3}$$

$$\left(\because r_1 = r, r_2 = +50\ \%\ of r = \frac{3}{2}r\right)$$

New mass m_2

$$\pi r_2^2 h_2\rho = \pi\left(\frac{3}{2}r_1\right)^2\left(\frac{2}{3}h_1\right)\rho = \frac{3}{2}\left(\pi r_1^2 h_1\right)\rho = \frac{3}{2}m$$

Q.33 (3)
Concept of excess pressure

Q.34 (3)

Since $\Delta P \propto \frac{1}{R}$

Q.35 (2)
As soap bubble has two free surfaces.

Q.36 (2)

$$S = \frac{rhdg}{2\cos\theta} \Rightarrow 1$$

Pressure difference $= hdg = \frac{2S}{r}\cos\theta$

Q.37 (3)

$$r^2 = r_1^2 + r_2^2$$

$$\boxed{r = 5cm}$$

Q.38 (3)

$$\Delta P = \frac{2T}{R} = \frac{2\times70\times10^{-3}}{1\times10^{-3}} = 140\ N/m^2$$

Q.39 (b)

EXERCISE-III (JEE MAIN LEVEL)

Q.1 **(1)**
F = [rgh] [A]
= (1000) (10) (6) (10) (8).

Q.2 **(2)**
$W_A > W_B$ as mass of water in A is more than in B
$P_A = P_B$
Area of A = Area of B
or $P_A \text{Area}_A = P_B \text{Area}_B$
or $F_A = F_B$.

Q.3 **(2)**
Given $A = 2 \times 10^{-3}$, h = 0.4 m, r = 900 Kg/m^3
F = mg = Vrg = (pr^{2}h)rg
$= 2 \times 10^{-3} \times 0.4 \times 900 \times 10$
= 7.2 N

Q.4 **(1)**
F = mg
F = 10 N

Q.5 **(1)**
At same depth pressure is same. So ratio $P_1 : P_2 = 1 : 1$.

Q.6 **(1)**
$$\frac{m_1 g}{A_1} = \frac{m_2 g}{A_2}$$
Solving, $m_2 = 3.75$ kg.

Q.7 **(3)**
Given m = 12 kg, A = 800 cm^2, r = 1000 kg/m^3
P = rgh
$$\frac{mg}{A} = rgh$$
$$\frac{12\times10}{800\times10^{-4}} = 1000 \times 10 \times h \quad \Rightarrow \quad \frac{12}{80} = h$$
$$h = \frac{1200}{80} = 15 \text{ cm}$$

Q.8 **(2)**
F_b = rVg – rvg = 0

Q.9 **(1)**
mg = 60 ....(i)
mg – $r_i$vg = 40 ....(ii)
$$\frac{mg - \rho_\ell v g}{mg} = \frac{2}{3} \text{ or } \frac{\rho_0}{\rho_\ell} = 3$$
where r_0 = density of the block and r_l = density of the liquid.

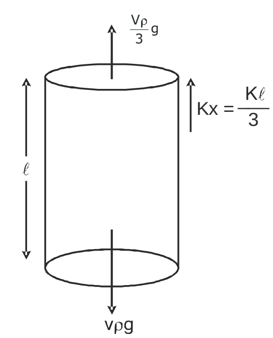
Q.10 **(3)**
$$10^3 \times \frac{4}{5} + 13.5 \times 10^3 \times \frac{1}{5} = r \times 1$$
or r = 3.5×10^3 kg/m^3

Q.11 **(3)**
$[36 - r_l v_l]g = [48 - r_l v_2]g$
$$\left[36 - \rho_i\left(\frac{36}{9}\right)\right]g = \left[48 - \rho_i\left(\frac{48}{\rho_0}\right)\right]g$$
Solving, $r_0 = 3$.

Q.12 **(3)**
As, weight = Buoyant force
mg = [100 × 6 × 0.6 g] + (100 × 1 × 4)g
∴ m = 760 gm.

Q.13 **(2)**
$W - v \times 1 \times g = W_1$
$W - v \times x \times g = W_2$
$\Rightarrow W - (W - W_1) \times x = W_2$
$$x = \frac{W - W_2}{W - W_1}$$

Q.14 **(2)**
V = A.ℓ.
$$\text{Now } \frac{A\ell\rho g}{3} + \frac{K\ell}{3} = A\ell\rho$$
K = 2ρAg



Q.15 **(2)**
Apparent weight ($W_{app.}$) = W – V ρ_ℓ g
Since, $W_{app. (Ram)} > W_{app. (Shyam)}$
$\Rightarrow W_{(Ram)} > W_{(Shyam)}$
Therefore, from given passage shyam has more fat than Ram.

Q.16 **(2)**
$V_1 > V_2 \Rightarrow W_{app. (1)} < W_{app. (2)}$
(Since $W_{app.}$ = W – V ρ_ℓ g)
Hence (2)

Q.17 **(3)**

R = vt

$= \sqrt{2gD}\sqrt{\frac{2(H-D)}{g}}$

$= 2\sqrt{D(H-D)}$.

Q.18 **(2)**

$F_{thrust} = \rho a v^2$

$F_{net} = F_1 - F_2 = a\rho[2g(h_1 - h_2)]$

$= a\rho(2gh)$

or $F \propto h$

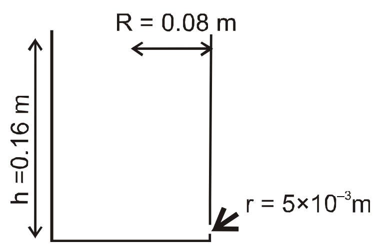
Q.19 **(1)**

$A_1 v_1 = A_2 v_2$

$\pi R^2\, dh/dt = \pi r^2 v$ ....(i)

$v = \sqrt{2gh}$ ....(ii)

from equation (ii) put the value of v in equation (i)



$\pi R^2\, dh/dt = \pi r^2\sqrt{2gh}$

$\Rightarrow \int \frac{R^2 dh}{r^2\sqrt{2gh}} = \int dt$

$\frac{R^2}{r^2\sqrt{2g}}\int_h^0 \frac{dh}{\sqrt{h}} = \int_0^t dt$

on solving

t = 46.26 second.

Q.20 **(2)**

$A_1V_1 = A_2V_2$

$0.02 \times 2 = 0.01 \times V_2$

$V_2 = 4$ m/sec.

$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$

$4 \times 10^4 + \frac{1}{2} \times 1000 \times 2^2$

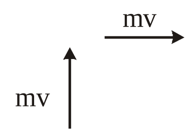
$= P_2 + \frac{1}{2} \times 1000 \times 4^2 \Rightarrow P_2 = 3.4 \times 10^4\ N/m^2$

Q.21 **(4)**

Force exerted by the water on the corner

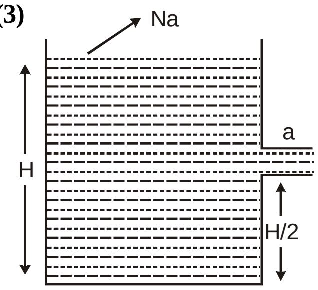
= change in momentum in 1 sec

$= \sqrt{2}$ mv



$= \sqrt{2}\rho vL$

Q.22 **(3)**



Force $= \rho a\left(\sqrt{2gh/2}\right)^2$

acceleration $= \frac{\rho agh}{\rho Na.H} = g/N$

Q.23 **(2)**

$\rho AV^2 = 1000 \times 2 \times 10^{-4} \times (10)^2$

= 20 N

Q.24 **(2)**

$A_1V_1 = A_2V_2$ (Given $\frac{r_1}{r_2} = \frac{3}{2}$)

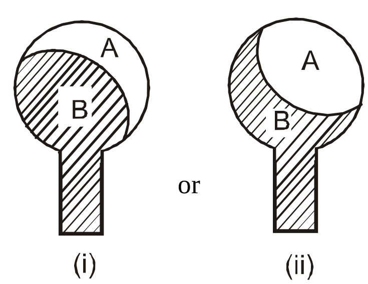
$\frac{v_1}{v_2} = \frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2} = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$

Q.25 **(3)**

$\frac{dV}{dt} = A\sqrt{2gh}$

Q.26 (2)

After the portion A is punctured' the thread has 2 options as shown in the figures.



Clearly, due to surface tension , the soap film wants to minimize the surface area which is happening in option (ii).
Hence the thread will become concave towards A.

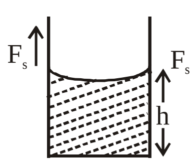
Q.27 (3)
We know that surface energy
$U_S = T \times \text{Area}$.
Here. as 2 films are formed because of ring. so
$U_S = T \times 2 \times (A)$

$= 5\ \frac{N}{m} \times 2 \times 0.02\ m^2 = 0.2\ J$

Q.28 (4)
In the satellite, g_{eff} becomes zero but the surface tension still prevails. Hence the water will experience only surface Tension force which will push it fully outward.

Q.29 (2)
Water will rise to a height more than h when downward force (mg_{eff}) becomes lesser than mg.
so in a lift accelerating downwards, g_{eff} is $(g - a_0)$. Hence capillary rise is more.
On the poles g_{eff} is even more than g. Hence the capillary will even drop.

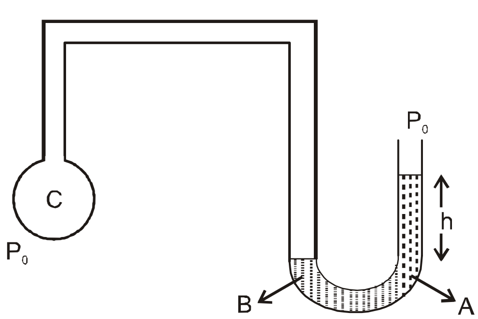
Q.30 (2)



By balancing forces
$T \times (2\ \ell) \times (\cos\theta) = d\ x\ \ell\ h\ g$

we get $h = \frac{2T\ \cos\theta}{xdg}$.

Q.31 (4)



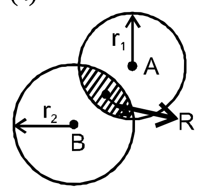
P_A has to be equal to P_B. $P_A = P_0 + \rho gh$ .....(i)

Now $P_C - P_0 = \frac{4\sigma}{r}$
$\because$ soap bubble has 2 films
and $P_C = P_B \because$ same air is filled

$\Rightarrow P_0 + \frac{4\sigma}{r} = P_0 + \rho gh$ ....(ii)

get $\sigma = \frac{\rho ghr}{4}$

Q.32 (4)



Equating pressures on the shaded portion :

$$\frac{4\sigma}{r_1} - \frac{4\sigma}{r_2} = \frac{4\sigma}{R}$$

get $R = \frac{r_2 r_1}{r_2 - r_1}$

Q.33 (2)

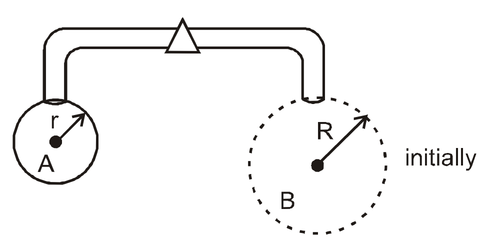
By equating volume : $\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3$

get r = R/2.

Now pressure difference in A = $\frac{4\sigma}{R}$

and that in B = $\frac{4\sigma}{R/2}$ = 2 × pressure difference in A.

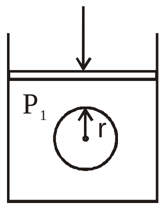
Q.34 (3)

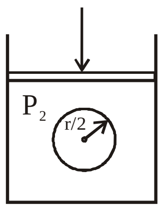


$P_A = P_0 + \frac{4\sigma}{r}$; $P_B = P_0 + \frac{4\sigma}{R}$ {P_0 = atmospheric pressure}.
Clearly $P_A > P_B$; so air will flow from A to B.

As r decreases; pressure will become more and hence more flow of air from A to B.
Ultimately bubble A collapses and B becomes bigger in size.

Q.35 (1)

Before


After


Lets say, initially, the pressure due to air inside the bubble is P_{air}.

$\Rightarrow P_{air} - P_1 = \dfrac{4T}{r}$ ....(i)

Finally, the radius becomes half ; so volume becomes $\dfrac{1}{8}$ th and hence pressure becomes $8P_{air}$.

So, $8P_{air} - P_2 = \dfrac{4T}{r/2}$ ....(ii)

Solving (i) and (ii)

get $P_2 = 8P_1 + \dfrac{24r}{r}$.

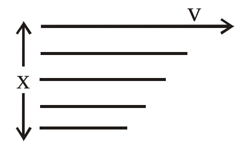
Q.36 (4)
When the excess pressure at the hole becomes equal to the pressure of water height ;then only water will start coming out of the holes : [atm pressure on both sides is same].

$\Rightarrow \rho hg = \dfrac{2\sigma}{r}$

$\Rightarrow h = \dfrac{2\sigma}{\rho r g}$

$$= \frac{2 \times 70 \times 10^{-3} \times \frac{N}{m}}{1000 \frac{kg}{m^3} \times \left(\frac{0.1}{2}\right) \times 10^{-3} \times 10} = 0.28 \text{ } \mathbf{m.}$$

Q.37 (3)



$800 = \eta A.\dfrac{1.5}{x}$

$2400 = \eta A \dfrac{v}{x}$

v = 4.5 cm /sec.

Q.38 (2)

$2\dfrac{4}{3}\pi r^3 = \dfrac{4}{3}\pi R^3$

$R = 2^{1/3}.\ r$

$v \propto r^2$

$v \propto 4^{1/3}$

Q.39 (4)

$V_T = \dfrac{2}{9}\dfrac{r^2 g}{\eta}(\rho - \sigma)$

$= \dfrac{2}{9}\dfrac{(0.003)^2 \times 10}{1.260}$ (1260)

$v_T = 0.02$ m /sec.

$\therefore$ Time $= \dfrac{0.1}{0.02} = 5$ sec.

EXERCISE-IV

Q.1 [0050]

$1 = \sqrt{2gh}\, t$

$h = \dfrac{1}{2}gt^2$

$t = \sqrt{\dfrac{2h}{g}}$ þ $1 = \sqrt{2g(1-h)} \times \sqrt{\dfrac{2h}{g}}$

þ h = 0.5 m = 50 cm

Q.2 [0006]
$A_1 v_1 = A_2 v_2$

$3 \times 30 = N \times 3 \times 10^{-7} \times 0.05$

$\dfrac{3 \times 10^8}{0.05} = N$

$N = 6 \times 10^9$

Q.3 [2375]

$A_1v_1 = A_2v_2$

$10 \times 5 = 5 \times v_2$

$v_2 = 10$ m/s

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} = \frac{v_2}{\rho g} + \frac{v_2^2}{2g}$$

$$\frac{p_1}{10^4} + \frac{25}{20} = \frac{2\times10^5}{10^4} + \frac{100}{20}$$

$$\frac{p_1}{10^4} = 25 - 1.25 = 23.75$$

$p_1 = 2375 \times 10^2$ Pa

Q.4 [0800]

In both cases, Weight = Bouyant force

Initially, $\rho_b Vg = \rho_w \left(\frac{2}{3}V\right) g \Rightarrow \rho_b = \frac{2}{3}\rho_w$

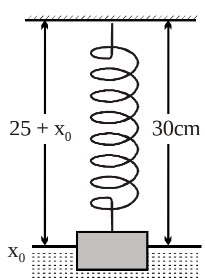
After wards, $\rho_b Vg = \rho_{oil} \left(\frac{5V}{6}\right) g$

$$\Rightarrow \frac{2}{3}\rho_w = \rho_{oil} \times \frac{5}{6}$$

$$\Rightarrow \rho_{oil} = \frac{4}{5}\rho_w = \frac{4}{5} \times 100 = 800 \text{ kg/m}^3.$$

Q.5 [5]

$30 - (25 + x_0) = 5 - x_0$



$$V = \frac{32}{0.4} = 80 \text{ cc}$$

$A = 16 \text{ cm}^2$

$kx_0 + 10^3 \times 16 \times 10^{-4} \times x_0 \times 10 = 32 \times 10^{-3} \times 10$

$x_0 (48 + 16) = 32 \times 10^{-2}$

$$x_0 = \frac{32}{64} \text{ cm} = 5 \text{ mm}$$

Q.6 [0400]

$P_L \times 6 \times 10^2 \text{ g} = 600 \text{ g}$

$mg + 600 \text{ g} = P_L \times 1000 \text{ g}$

$m = 1000 - 600 = 400$ gm

Q.7 [0004]

$$p = \frac{2s}{r} = \frac{BdV}{V}$$

$$V = \frac{4}{3}\pi r^3$$

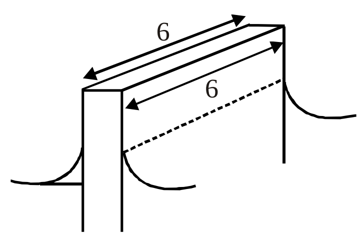
$dV = 4\pi r^2 dr$

$$\frac{2s}{r} = B \times \frac{4\pi r^2 dr}{4/3\pi r^3}$$

$$dr = \frac{2s}{3B} = \frac{2 \times 0.075}{3 \times 1.25 \times 10^8} = \frac{0.15}{3 \times 1.25} \times 10^{-8} = 4\text{Å}]$$

Q.8 [0073]

App. wt. = weight in air



$mg - B + F_{surface} = mg$

$\Rightarrow B = F_{surface}$

$10^3 \times 3 \times 1.5 \times 0.2 \times 10^{-6} \times 10$

$$= S \times \frac{6}{100} \times 2 + S \times \frac{0.2}{100} \times 2$$

$$S = \frac{9 \times 10^{-3}}{12.4} \times 100 = \frac{9000}{124} \text{ N/m}$$

$\simeq 72.59$ m N/m $\simeq 73$

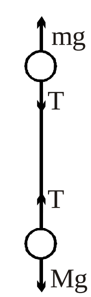
Q.9 [8]

$Mg - T - 6\pi\eta r_1 v = 0$

$mg + T - 6\pi\eta r_2 v = 0$

$$\frac{\frac{4}{3}\pi\left(r_1^3 + r_2^2\right) \times \rho g}{6\pi\eta(r_1 + r_2)} = v$$

$$v = \frac{2}{9}(r_1^2 - r_1 r_2 + r_2^2)\frac{\rho g}{\eta}$$



$$T = Mg - 6^2\pi\eta r_1 \times \frac{2}{9}(r_1^2 - r_1r_2 + r_2^2)\frac{\rho g}{\eta}$$

$$= \frac{4}{3}\pi r_1^3 \times \rho g - \frac{4\pi}{3}\rho g\,[r_1^3 - r_1^2r_2 + r_2^2r_1]$$

$$= \frac{4}{3}\pi gr\,[r_1^2 r_2 - r_2^2 r_1]$$

$$= \frac{4}{3}\pi gr_1^2\left[r_2 - \frac{r_2^2}{r_1}\right]$$

$$\frac{dT}{dr_2} = 0 \Rightarrow \frac{4}{3}\pi gr_1^2\left[1 - \frac{2r_2}{r_1}\right] = 0$$

$r_1 = 2r_2$

$$\frac{M}{m} = 8$$

Q.10 [50]

$$6\pi\eta rv = B = \frac{4}{3}\pi r^3 P_L\, g$$

$$\eta = \frac{2}{9}r^2\frac{P_L g}{v}$$

$$= \frac{2}{9} \times \frac{(0.9)^2 \times 1.75 \times 1000}{0.7} = 50 \text{ poise}$$

Q.11 (1)
As per the Bernoulli theorem, when wind velocity increases the pressure decreases over the wings and increases under the wings. This pressure difference provide the necessary lift.

Q.12 (3)
Cloth has narrow spaces in form of capillaries. Small angle of contact makes cosθ.
Larger due to which capillary rise will be more and the detergent will penetrate more in the narrow pores of the clothes.

Q.13 (1)

$$\text{Pressure} \propto \frac{1}{\text{area}}$$

Paper pins have pointed ends.
Smaller the area greater the pressure which is required for punching through the surface.

Q.14 (2)
Open-tube manometer is used for measuring pressure difference.
1 bar = 10^5 Pascal

Q.15 (4)
(a) Bernoulli's equation → Principle of mechanical energy
(b) Continuity equation → AV = constant
(c) Pressure head → $\frac{P}{\rho g}$
(d) Velocity head → $\frac{v^2}{2g}$

Q.16 (3)
Viscosity = $[M^1L^{-1}T^{-1}]$
Terminal velocity = $[M^0L^1T^{-1}]$
Surface tension = $[M^1L^0T^{-2}]$
Surface energy = $[M^1L^2T^{-2}]$

PREVIOUS YEAR'S

MHT CET

Q.1 (3)	**Q.2** (4)	**Q.3** (1)	**Q.4** (1)	**Q.5** (3)
Q.6 (Bouns)	**Q.7** (1)	**Q.8** (4)	**Q.9** (4)	**Q.10** (3)
Q.11 (2)	**Q.12** (3)	**Q.13** (2)	**Q.14** (4)	**Q.15** (3)
Q.16 (1)	**Q.17** (3)	**Q.18** (3)	**Q.19** (1)	**Q.20** (4)
Q.21 (1)	**Q.22** (2)	**Q.23** (1)	**Q.24** (3)	**Q.25** (2)
Q.26 (4)	**Q.27** (3)	**Q.28** (4)	**Q.29** (3)	**Q.30** (3)
Q.31 (1)	**Q.32** (2)	**Q.33** (2)	**Q.34** (2)	**Q.35** (1)
Q.36 (3)	**Q.37** (4)	**Q.38** (1)	**Q.39** (2)	**Q.40** (1)
Q.41 (3)	**Q.42** (1)	**Q.43** (3)	**Q.44** (4)	**Q.45** (3)
Q.46 (2)	**Q.47** (2)			

NEET/AIPMT

Q.1 (1)

$$V = \sqrt{2gh} = \sqrt{2 \times 10 \times 2} = 2 \times 3.14 = 6.324\text{m / sec}$$

$$\frac{d(\text{vol})}{dt} = AV = \left(2 \times 10^6\right) \times 6.324 = 12.6 \times 10^{-6}$$

Q.2 (3)

Pressure inside soap bubble $P_0 + \frac{4T}{R}$

pressure at a point Z_0 below surface of water $= P_0 + \rho g Z_0$

P_0 is atmospheric pressure

$$\frac{4T}{R} = \rho g Z_0$$

$$Z_0 = \frac{4T}{\rho g R}$$

$$Z_0 = \frac{4 \times 2.5 \times 10^{-2}}{10^3 \times 10 \times 1 \times 10^{-3}}$$

$$Z_0 = 1\text{cm}$$

Q.3 (2)
Q.4 (4)
Q.5 (4)

$$P = P_0 + \frac{4T}{R}$$

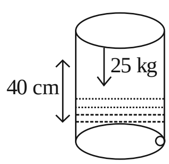
$\Rightarrow$ R increases and P decreases

JEE MAIN

Q.1 (363)
Q.2 (3)

Reynold's number is given by $\frac{\rho v d}{\eta}$

Q.3 (300)

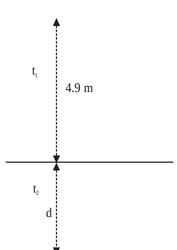


$$P_0 + \frac{250}{0.5} + \rho g(40 \times 10^{-2}) = P_0 + \frac{1}{2}\rho v^2$$

$$500 + \frac{1000 \times 10 \times 40}{100} = \frac{1}{2} \times 1000 \times v^2$$

V = 3 m/s
V = 300 cm/s

Q. 4 (2)



$$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 4.9}\,\text{m/sec}$$

$\therefore$ Total time taken by the ball to reach the bottom of the lake = $t_1 + t_2$ = 4 sec

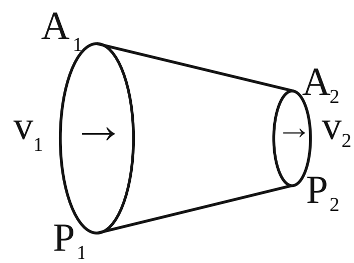
$$4.9 = \frac{1}{2} \times 9.8 \times t_1^2$$

t_1 = 1 sec and t_2 = 3 sec
since the ball is drowning with constant velocity
$d = v \times t_2$

$$d = \sqrt{2 \times 9.8 \times 4.9} \times 3\text{m}$$

$d = 9.8 \times 3\text{m} = 29.4$ m

Q.5 (24)



$$A_2 = \frac{A_1}{2}$$

$P_1 - P_2$ = 4500 Pa

$$P_1 + \frac{1}{2}\rho V_1^2 + \rho g h = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h$$

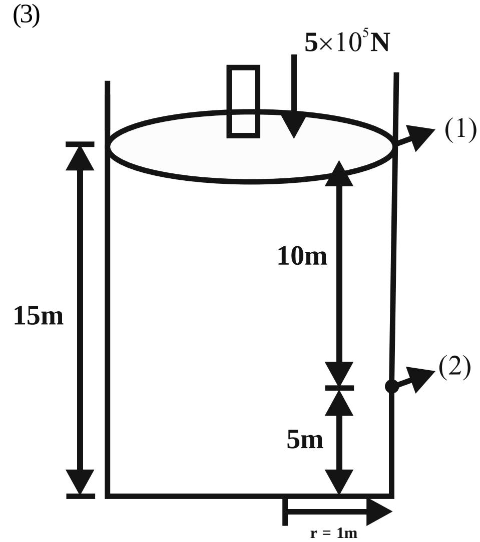
$$P_1 - P_2 = \frac{1}{2}\rho(V_2^2 - V_1^2) \quad \text{....(1)}$$

And $A_1V_1 = A_2V_2$
$\Rightarrow V_2 = 2V_1$ ....(2)

$$4500 = \frac{1}{2} \times 750 \times 3V_1^2$$

V_1 = 2 m/s
Volume flow rate = $A_1V_1 = 24 \times 10^{-3}\ m^3s^{-1}$

Q.6 (3)



Applying Boroulli equation

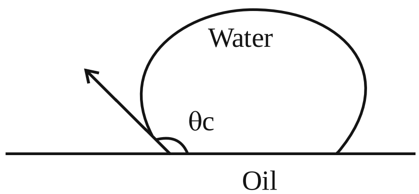
$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

$$\frac{5\times10^5}{\pi(1)^2} = 1000\times10\times10+0 = 0.01\times10^5+0+\frac{1}{2}\times1000$$

$\times\ v_2^2$

$v_2 = 17.8$ m/s

Q.7 (1)



$\theta c > 90°$

For water oil interface

Q.8 (25)

$F_v + F_B = mg$ (v = constant)

$Fv = mg - F_B$

$= \rho_B Vg - \rho_L Vg$

$= (\rho_B - \rho_L)Vg$

$$= (8-1.3)\times10^{+3}\times\frac{0.3\times10^{-3}}{8\times10^3}\times10$$

$$= \frac{6.7\times0.3}{8}\times10^{-2} \qquad (g = 10)$$

$$= \frac{67\times3}{8}\times10^{-4} = 25.125\times10^{-4}$$

Ans. 25.125

Q.9 (2)

Area of cube $= 6a^2 = 24m^2$ $a \rightarrow$ side of cube

$a^2 = 4 \Rightarrow \boxed{a = 2} \Rightarrow v_0 = 2^3 = 8$

$\Delta T = 10°C$

$\alpha = 5.0\times10^{-4}\ \frac{1}{°C}$

We know for solid materials $\gamma = 3\alpha$

So $\gamma = 3\times5\times10^{-4} = 15\times10^{-4}/°C$

$\Delta V = v_0\gamma.\Delta T$

$\Delta V = 8\times15\times10^{-4}\times10 = 1200\times10^{-4}\ m^3 = 12\times10^{-2}\times(10^2)^3\ cm^3$

$\Delta V = 12\times10^4\ cm^3$

$$\boxed{\Delta V = 1.2\times10^5 cm^3}$$

Q.10 (4)

Initial diameter of ring = 6.230 cm

Final diameter of ring should be equal to diameter of bangle

$\Rightarrow$ Final diameter of ring = 6.241 cm

Using $\frac{\Delta 1}{1} = \propto \Delta t$

or

For diameter

$$\frac{\Delta D}{D} = \propto \Delta T$$

$\Delta D \rightarrow$ change in diameter

$\Delta \rightarrow$ Initial diameter

$$\Rightarrow \frac{6.241-6.230}{6.230} = 1.4\times10^{-5}(T-27)$$

$$\Rightarrow \frac{0.011}{6.230} = 1.4\times10^{-5}(T-27)$$

$$\Rightarrow T - 27 = \frac{11\times10^5}{6230\times1.4}$$

$\Rightarrow T = 152.7°C$

Q.11 (20)

Difference of their length

$\ell_2 - \ell_2 =$ const.

$\Delta\ell_2 - \Delta\ell_1 = 0$

$\Delta\ell_2 = \Delta\ell_1$

$\ell_2\alpha_2\Delta T = \ell_1\alpha_1\Delta T$

$40\times1.8\times10^{-5} = \ell_1(1.2\times10^{-5})$

$\ell_1 = 60$ Cm

Q.12 (3)

If the electric field is in the positive direction and the positive charge is to the left of that point then the electric field will increase. But to the left of the positive charge the electric field would decrease.

If the dipole is kept at the point where the electric field is maximum then the force on it will be zero.

Q.13 (1)

Diameter of Bigger drop = 2 cm

So Radius R = 1 cm

Surface tension = 0.075 N/m

Apply conservation of volume

$V_{initial} = V_{final}$

$$\frac{4}{3}\pi R^3 = 64\times\frac{4}{3}\pi r^3$$

$$\frac{(1)^3}{64} = r^3 \Rightarrow r = \frac{1}{4}\text{cm}$$

Gain In Energy = {64[Area of small drop]- Area of Bigdrop} x T

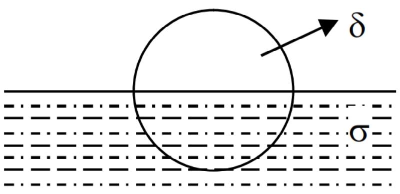
$= \{64 \times 4\pi r^2 - 4\pi R^2\} \times T$

$$= 4\pi\left\{64 \times \left(\frac{10^{-2}}{4}\right)^2 - (1\times10^{-2})^2\right\} \times 0.075$$

$= 4\pi \times 10^{-4}\{4-1\} \times 0.075$

$= 2.8 \times 10^{-4}$ J

Q.14 (1)



$S \times 2\pi r = mg - F_b$

$$= v\rho g - \frac{v\sigma}{2}g$$

$$S\times 2\pi r = vg\left(\frac{2\rho-\sigma}{2}\right)$$

$$S\times 2\pi r = \frac{4}{3}\pi r^3 g\left(\frac{2\rho-\sigma}{2}\right)$$

$$\frac{3s}{g(2\rho-\sigma)} = r^2$$

$$\frac{3(7.5\times10^{-4}\,\text{kg m/sec}^2\times\text{cm})}{(10\text{m/sec}^2)(2\rho-\sigma\times\text{kg m}^3)} = r^2 \quad (1\text{m} = 100\text{ cm})$$

$$-\frac{3\times10^2}{2\sqrt{(2\rho-\sigma)}} = r$$

$$r = \frac{15}{\sqrt{2\rho-\sigma}}$$

Q.15 (3)

Initial surface energy = T.A

$$U_i = \frac{75\times10^{-5}}{10^{-2}}\frac{N}{m}\times\left[\left(4\pi\left(1\times10^{-2}\right)^2\right)\right]$$

$= 75 \times 10^{-3} \times 4\pi \times 10^{-4} = 942 \times 10^{-7}$

But

$(\text{Volume})_i = (\text{volume})_f$

$$\frac{4}{3}\pi R^3 = 729\left(\frac{4}{3}\pi r^3\right) \qquad (r = \text{final}, R = \text{initial})$$

$$r = \frac{R}{(729)^{\frac{1}{3}}} = \frac{R}{9} = \frac{1}{9}\text{cm}$$

$$U_f = 729[TA] = 729\left[\frac{75\times10^{-5}}{10^{-2}}\frac{N}{m}\right]\left[4\pi\left(\frac{1}{9}\times10^{-2}\right)^2\right]$$

$$= 729\left[75\times10^{-3}\times\frac{4\pi\times10^{-4}}{81}\right]$$

$= 9 \times 942 \times 10^{-7}$ J

Gain in surface energy $= (9 \times 942 - 942) \times 10^{-7}$

$= 8 \times 942 \times 10^{-7}$

$= 7536 \times 10^{-7}$ J

$= 7.5 \times 10^{-4}$ J

Q.16 (2)

pressure difference

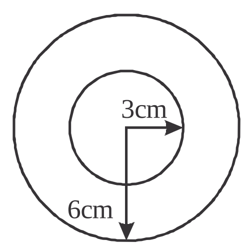
$\Delta P = P_1 + P_2$

$$\frac{4T}{R} = \frac{4T}{r_1} + \frac{4T}{r^2}$$

$$\frac{1}{2} = \frac{1}{r_1} + \frac{1}{r_2}$$

$$\frac{1}{R} = \frac{1}{3} + \frac{1}{6}$$

$R = 2$



Q.17 (3)

$$v_t = \frac{2}{9}\frac{gr^2(\rho_2-\rho_1)}{\eta}; \; v_t \propto r^2$$

(ρ_1 = density of air, ρ_2 = density of rain drops)

Q.18 (100)

Using Newton's law of viscosity

$$\tau = \eta\left|\frac{dv}{dy}\right|$$

Assuming velocity profile linear with respect to depth

$$\frac{F}{A} = \eta\frac{\Delta v}{\Delta y}$$

$$\Rightarrow 10^{-3} = 10^{-2} \times \frac{36\times1000}{h\times3600}$$

$$\Rightarrow h = 10^{-2} \times \frac{36\times1000}{10^{-3}\times3600} = 100\text{ m}$$

Q.19 (2)

$F_V = m_g - F_B$ $\quad$ (F_B = Buoyancy force)

$$= mg - \left(\frac{m}{d_1}\times d_2\right)g$$

$$= mg\left(1\times\frac{d_2}{d_1}\right)g$$

Q.20 (3)

Dimension of pressure × time

$$= \frac{\text{force}}{\text{Area}}\times\text{time}$$

$$= \frac{[MLT^{-2}]}{[l^2]}\times[T]$$

$= [ML^{-1}T^{-1}]$

Dim. of coeff. of viscosity $F = A\frac{dv}{dz}\eta$

$$\eta = \frac{f}{A}\times\frac{dz}{dv}$$

$$= \frac{MLT^{-2}}{[L^2]}\times\frac{[L]}{[LT^{-1}]}$$

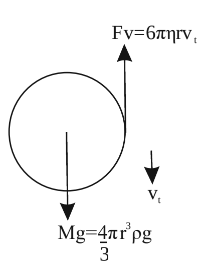
$= [ML^{-1}T^{-1}]$

A is true because

R is false coeff. of viscosity $= \frac{\text{forec}}{\text{Area}\times\text{vel.gradient}}$

Reason R : Coefficient of viscosity $= \frac{\text{Force}}{\text{velocity gradient}}$

Q.21 **(4)**



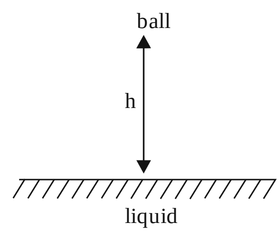
$$6\pi\eta r v_t = \frac{4}{3}\pi r^3\rho g$$

$$v_t = \frac{4}{3}\times\frac{\pi r^3\rho g}{6\pi\eta r}$$

$$= \frac{2\times10^{-12}\times10^3\times10}{9\times1.8\times10^{-5}}$$

$$= 123.4\times10^{-6}\text{ m/s}$$

Q.22 (20)



If the speed if ball does not change after entering into liquid that means the speed attained by ball was equal to terminal speed

$$= \sqrt{2gh} = \frac{2}{9}\frac{r^2}{\eta}(\sigma - \rho)g$$

$r = 0.1 \times 10^{-3}$ m $\quad$, $\quad$ $\eta = 10^{-5}$ Ns m^{-2}

$g = 10$ ms^{-2}

$$\Rightarrow \sqrt{2\times10\times h} = \frac{2}{9}\times\frac{0.01\times10^{-6}}{10^{-5}}(10^4 - 10^3)\times10$$

$$\Rightarrow \sqrt{20h} = \frac{2}{9}\times\frac{10^{-8}}{10^{-5}}\times9000\times10$$

$$\Rightarrow \sqrt{20h} = 2\times10^{-8}\times10^4\times10^5$$

$$\Rightarrow \sqrt{20h} = 20$$

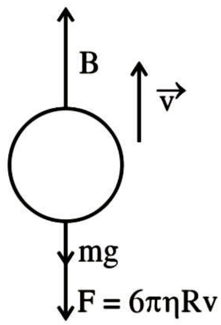
$\Rightarrow 20h = 400$

$\Rightarrow h = 20$ m

$= 20$

Q.23 (11)

As the bubble is rising steadily the net force acting on it will be zero (Because of density of air the value of mg can be neglected.)



So, B = F $\Rightarrow \frac{4\pi}{3}R^3\rho g = 6\pi\eta Rv$

Putting R = 1 mm = 10^{-3} m

$\rho = 1.75 \times 10^3$ kg/m^3

g = 10 m/s^2

v = 0.35×10^{-2} m/s

$\eta = \frac{10}{9} \simeq 1.11$ SI unit = 11 poise (CGS)

Q.24 (25)

$F_v + F_B = mg$ (v = constant)

$Fv = mg - F_B$

$= \rho_B Vg - \rho_L Vg$

$= (\rho_B - \rho_L)Vg$

$= (8-1.3) \times 10^{+3} \times \frac{0.3 \times 10^{-3}}{8 \times 10^3} \times 10$

$= \frac{6.7 \times 0.3}{8} \times 10^{-2}$ (g = 10)

$= \frac{67 \times 3}{8} \times 10^{-4} = 25.125 \times 10^{-4}$

Ans. 25.125

THERMAL PROPERTIES OF MATTER

EXERCISE-I (MHT CET LEVEL)

Q.1 (1)
Thermal stress = $Y\alpha\Delta\theta$
$= 1.2 \times 10^{11} \times 1.1 \times 10^{-5} \times (20 - 10) = 1.32 \times 10^{7}$ N/m^2

Q.2 (1)
Let final temperature of mix be T°C
Heat gained = Heat lost
$m_i C_i (T-0) + m_i L_i = m_w c_w (80 - T)$

$$1 \cdot \frac{1}{2} \cdot T + 1 \cdot \frac{336}{4.2} = 1 \cdot 1 \cdot (80 - T)$$

$$\frac{336}{4.2} = 80 - T - \frac{T}{2}$$

$$\Rightarrow \boxed{T = 0^{\circ} C}$$

Q.3 (4)
The change of state from liquid to vapour (for gas) is called vapourisation. It is observed that when liquid is heated, the temperature remains constant untill the entire amount of the liquid is converted into vapour. The temperature at which the liquid and the vapour states of the substance coexists is called its boiling point.

Q.4 (a)

Q.5 **(a)**

Q.6 **(d)**

Q.7 **(c)**

Q.8 **(d)**

Q.9 (2)

$$\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow 6000 = \frac{200 \times 0.75 \times \Delta\theta}{1}$$

$$\therefore \Delta\theta = \frac{6000 \times 1}{200 \times 0.75} = 40^{\circ} C$$

Q.10 (2)
High conductivity is desired to ensure greater transfer of heat to the food.
Low specific heat is required so that temperature of pot rises even with small amount of heat.

Q.11 (3)

Heat current in first rod (copper) $= \dfrac{390 \times A(0 - \theta)}{\ell}$

Here θ is temperature of the junction and A & ℓ are area and length of copper rod. Heat

current in second rod (steel) $= \dfrac{46 \times A(\theta - 100)}{\ell}$

In series combination, heat current remains same. So,

$$\frac{390 \times A(0 - \theta)}{\ell} = \frac{46 \times A(\theta - 100)}{\ell}$$

$$-390\theta == 46\theta - 4600$$

$$436\theta = 4600 \Rightarrow \theta = 10.6^{\circ} C$$

Q.12 (1)

$$\frac{E_1}{E_2} = \frac{\sigma\left(T_1^4 - T_0^4\right)}{\sigma\left(T_2^4 - T_0^4\right)} = \frac{(600)^4 - (300)^4}{(500)^4 - (300)^4}$$

Q.13 (1)

Q.14 (1)

Q.15 (3)

Q.16 (1)

Q.17 (2)

Q.18 **(4)**

Q.19 (3)
According to the Stefan-Boltzmann law states that power radiated by a perfectly black body is
$P = A \sigma T^4$
$\therefore P \propto T^4$

Q.20 (4)
Stefan's law for black body radiation

$$Q = \sigma e A T^4$$

$$T = \left[\frac{Q}{\sigma\left(4\pi R^2\right)}\right]^{1/4}$$

Here $e = 1$

$A = 4\pi R^2$

Q.21 (3)
According to wien's displacement law,
$\lambda_m T$ = constant.

$$\Rightarrow \lambda \propto \frac{1}{T}$$

$\therefore$ Wavelength of radiation emitted by body depends upon the temperature of its surface.

Q.22 (3)
Q.23 (1)
Q.24 (2)
Q.25 (1)
Q.26 (2)
Q.27 (3)
Q.28 (3)
Q.29 (2)
Q.30 (1)
Q.31 (3)
Total energy radiated from a body $Q = A\varepsilon\sigma T^4 t$
$\Rightarrow Q \propto AT^4 \propto r^2T^4$ $\quad(\because A = 4\pi r^2)$

$$\Rightarrow \frac{Q_P}{Q_Q} = \left(\frac{r_P}{r_Q}\right)^2\left(\frac{T_P}{T_Q}\right)^4 = \left(\frac{8}{2}\right)^2\left\{\frac{(273+127)}{(273+527)}\right\}^4 = 1$$

Q.32 (1)
According to Wein's law $\lambda_m T$ = constant

$$\Rightarrow \lambda_{m_1}T_1 = \lambda_{m_2}T_2 \Rightarrow T_2 = \frac{\lambda_{m_1}}{\lambda_{m_2}}T_1 = \frac{\lambda_0}{3\lambda_0/4}\times T_1 = \frac{4}{3}T_1$$

$$\text{Now } P \propto T^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{4/3T_1}{T_1}\right)^4 = \frac{256}{81}$$

EXERCISE-II (NEET LEVEL)

Q.1 (4)
Increase in tension of wire = YA $\alpha\Delta\theta$
$= 8 \times 10^{-6} \times 2.2 \times 10^{11} \times 10^{-2} \times 10^{-4} \times 5 = 8.8$ N

Q.2 (3)
$F = YA\alpha\Delta t = 2 \times 10^{11} \times 3\times 10^{-6} \times 10^{-5} \times (20-10) = 60$ N

Q.3 (4)

Q.4 (4)
Thermal capacity = m × c
= 40 × 0.2 = 8 cal/°C

Q.5 (2)
Resultant temperature is 0°C while ice will not melt.

Q.6 (1)
Heat gained by the water = (Heat supplied by the coil) – (Heat dissipated to environment)

$$\Rightarrow mc\Delta\theta = P_{coil}t - P_{Loss}t$$

$$\Rightarrow 2\times 4.2\times 10^3 \times (77-27) = 1000t - 160t$$

$$\Rightarrow t = \frac{4.2\times 10^5}{840} = 500s = 8\min 20s$$

Q.7 (4)
Utensil should have low thermal resistan ce $\left(R = \frac{\ell}{KA}\right)$
and low specific heat so that heat loss is less

Q.8 (3)

$$\frac{R_1}{R_2} = \frac{\frac{\ell_1}{K_1A_1}}{\frac{\ell_2}{K_2A_2}} = \frac{\frac{\ell}{K\pi(2r)^2}}{\frac{2\ell}{K\pi(3r)^2}} = \frac{9}{8}$$

$$\because I = \frac{\Delta T}{R} \Rightarrow I \propto \frac{1}{R}$$

$$\text{so } \frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{8}{9}$$

Q.9 (4)
Radius of small sphere = r Thickness of small sphere = t Radius of bigger sphere = t/4 Mass of ice melted = (volume of sphere) × (density of ice) Let K_1 and K_2 be the thermal conductivities For bigger sphere.

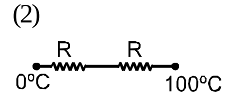
$$\frac{K_1 4\pi(2r)^2\times 100}{t/4} = \frac{\frac{4}{3}\pi(2r)^3 pL}{25\times 60}$$

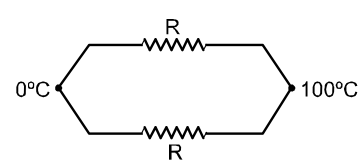
For smaller sphere,

$$\frac{K_2\times 4\pi r^2\times 100}{t} = \frac{\frac{4}{3}\pi r^3 pL}{16\times 60}$$

$$\therefore \frac{K_1}{K_2} = \frac{8}{25}$$

Q.10 **(4)**
Q.11 (2)





$$\frac{Q_1}{t_1} = i_{H_1} = \frac{100-0}{2R} = \frac{50}{R}$$

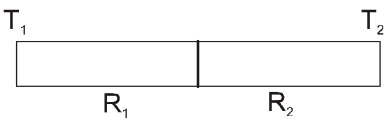
$$i_{H_2} = \frac{100}{R/2} = \frac{200}{R} = \frac{Q_2}{t_2}$$

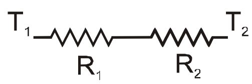
$Q_1 = Q_2 = 10$ cal.

$$\frac{50}{R}\times(2) = \frac{200}{R}\times t_2$$

$$t_2 = \frac{1}{2}\text{min.}$$

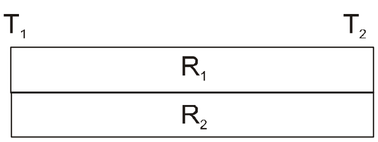
Q.12 (2)



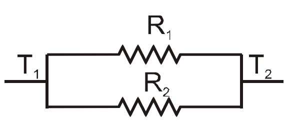
Equivalent thermal circuit 

$$R_{eq} = R_1 + R_2 = \frac{2\ell}{KA} = \frac{\ell}{K_1A} + \frac{\ell}{K_2A} \Rightarrow K = \frac{2K_1K_2}{K_1+K_2}$$

Q.13 (3)



Equivalent thermal circuit



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{K_{eq}\times 2A}{\ell} = \frac{KA}{\ell} + \frac{2KA}{\ell}$$

$$\Rightarrow K_{eq} = \frac{3}{2}K$$

Q.14 (4)

$$\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow \frac{K_A}{K_B} = \frac{A_B}{A_A} = \left(\frac{r_B}{r_B}\right)^2 = \frac{1}{4} \Rightarrow K_A = \frac{K_B}{4}$$

Q.15 (3)

Temperature of interface : $\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1} =$

$$\frac{K\times 0\times 2 + 3K\times 100\times 1}{K\times 2 + 3K\times 1} = \frac{300K}{5K} = 60°C$$

Q.16 (2)

By Newton's law of cooling

$$\frac{\theta_1-\theta_2}{t} = -k\left[\frac{\theta_1+\theta_2}{2} - \theta_2\right]...(1)$$

A sphere cools from 62°C to 50°C in 10 min,

$$\frac{62-50}{10} = -k\left[\frac{62+50}{2} - \theta_0\right] ...(2)$$

Now, sphere cools from 50°C to 42°C in next 10min.

$$\frac{50-42}{10} = -k\left[\frac{50+42}{2} - \theta_0\right]...(3)$$

Dividing eq^n, (2) by (3) we get,

$$\frac{56-\theta_0}{46-\theta_0} = 0.4\theta_0 = 10.4$$

Hence $\theta_0 = 26°C$

Q.17 (4)

Q.18 **(3)**

Q.19 (1)

Q.20 (2)

Because of uneven surfaces of mountains, most of it's parts remain under shadow. So, most of the mountains. Land is not heated up by sun rays. Besides this, sun rays fall slanting on the mountains and are spread over a larger area. So, the heat received by the mountains top per unit area is less and they are less heated compared to planes (Foot).

Q.21 (1)

Q.22 (2)

$$\lambda_{m_2} = \frac{T_1}{T_2}\times\lambda_{m_1} = \frac{2000}{3000}\times\lambda_{m_1} = \frac{2}{3}\lambda_{m_1} = \frac{2}{3}\lambda_m$$

Q.23 (1)

$$\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 \Rightarrow \frac{E}{E_2} = \left(\frac{273+0}{273+273}\right)^4 \Rightarrow E_2 = 16\,E$$

Q.24 (1)

$$E \propto T^4 \Rightarrow \frac{E_1}{E_2} = \frac{T^4}{T^4}\times 2^4 \Rightarrow E_2 = \frac{E}{16}$$

Q.25 (4)

$$\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{2}{1} = \left(\frac{420+273}{T}\right)^4 = \left(\frac{673}{T}\right)^4$$

$\Rightarrow T = 2^{1/4}\times 673 = 800$ K

Q.26 (2)
Liquid having more specific heat has slow rate of cooling because for equal masses rate of cooling $\frac{d\theta}{dt} \propto \frac{1}{c}$.

Q.27 (3)

$$\frac{60-50}{10} = K\left(\frac{60+50}{2} - 25\right) \quad \text{.....(i)}$$

$$\frac{50-\theta}{10} = K\left(\frac{50+\theta}{2} - 25\right) \quad \text{.....(ii)}$$

On dividing, we get

$$\frac{10}{50-\theta} = \frac{60}{\theta} \Rightarrow \theta = 42.85°C$$

Q.28 (3)
In first case

$$\frac{60-40}{7} = K\left[\frac{60+40}{2} - 10\right] \quad \text{.....(i)}$$

In second case

$$\frac{40-28}{t} = K\left[\frac{40+28}{2} - 10\right] \quad \text{....(ii)}$$

By solving t = 7 minutes

EXERCISE-III (JEE MAIN LEVEL)

Q.1 **(3)**
Given $L = 1$ mm, $\Delta L = 6 \times 10^{-5}$ mm
$\alpha = 12 \times 10^{-6}\ k^{-1}$
then
$\Delta L = L\alpha\,\Delta T$
6×10^{-5} mm $= (1\text{mm})\,(12 \times 10^{-6})\,\Delta T$
$\Delta T = 5°C$

Q.2 **(3)**
$I = CMR^2$
$dI = 2CMRdR = 2CMR\,[R\alpha\Delta T] = 2\alpha I\Delta T$

Q.3 **(2)**

$$F = AY\frac{\Delta L}{L} = AY\alpha\Delta T$$

$$f = K\sqrt{\frac{F}{\mu}} = K\sqrt{\frac{AY\alpha\Delta T}{\rho A}}$$

$$\Rightarrow f\ \alpha\ \sqrt{\frac{Y\alpha}{\rho}}$$

Q.4 **(3)**
$\ell_1(1 + \alpha_1\Delta T) + \ell_2(1 + \alpha_2\Delta T) = \ell_f$
$\ell_f = \ell_1 + \ell_2 + (\ell_1\alpha_1 + \ell_2\alpha_2)\Delta T$

$$\ell_f = (\ell_1 + \ell_2)\left(1 + \frac{\ell_1\alpha_1 + \ell_2\alpha_2}{\ell_1 + \ell_2}\Delta T\right).$$

Q.5 **(4)**
$\gamma_{oil} = \gamma_{vessel} \Rightarrow D.$
Volume increases but mass remains same.

Q.6 **(3)**
$\because\ \gamma_m < \gamma_{Al}$
$\Delta V_m < \Delta V_{al}$
$\Delta\rho_m < \Delta\rho_{Al}$
$\rho_m >> \rho_{ac}$
So completely Immersed
So $W_2 > W_1$ [$\because$ Displaced mass of alchol is less]

Q.7 **(3)**

$$P\Delta V = nR\Delta T \qquad \Delta V = \frac{nR}{P}\Delta T$$

$$\Delta V = \frac{V}{T}\Delta T$$

$$\text{So}\ , \gamma = \frac{1}{T}$$

Q.8 **(3)**
$\Delta L = \Delta L_1 + \Delta L_2$
$(3L)\alpha_{net}\,\Delta t = L\alpha\Delta t = (2L)\,(2\alpha)\,\Delta t$

$$\alpha_{net} = \frac{\alpha + 4\alpha}{3} = \frac{5\alpha}{3}$$

Q.9 **(1)**
On heating the expansion will take place hence both the distances will increase.

Q.10 (4)
at 0°C
$V_{0x} = 20A$; $V_{0y} = 30A$
Now at time T y read 120°C
So. $V'_{0y} = A(120) = 30A\,(1 + \gamma_m T)$
and $V'_{0x} = Ah = 20A\,(1 + \gamma_m T)$

$$\text{Dividing}\ \frac{120}{h} = \frac{30}{20}$$

$\Rightarrow h = 80.$

Q.11 (4)

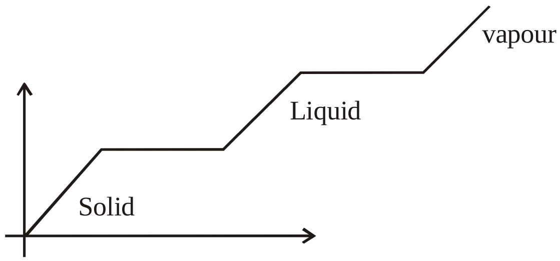
$$mc\theta = m_iL \Rightarrow m_i = \frac{mc\theta}{L}$$

Q.12 (4)
From the data given
$S_A\rho_A(8V) = (12V)\,\rho_B s_B$

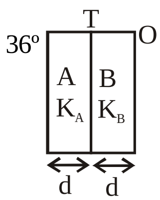
$$\frac{s_A}{s_B} = \frac{12\rho_B}{8\rho_A} = \frac{3}{2}\times\frac{2000}{1500} = 2$$

Q.13 (4)

$$\therefore dQ = msdT \Rightarrow \frac{dT}{dQ} = \frac{1}{ms}$$



Q.14 (2)



$K_A = 2K_B = 2\,K$

$$\left(\frac{36-T}{d}\right) K_A A = \left(\frac{T-0}{d}\right) K_B A$$

$(36 - T)\,2\,K = T\,K$

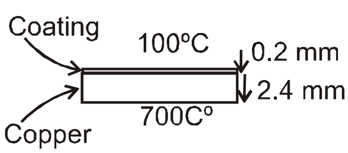
$$T = \frac{72}{3} = 24$$

ΔT = temp diff $= 36 - 24 = 12$

Q.15 (3)

$$i_H = \frac{\Delta T}{R_{eq}} = \frac{700-100}{R_1 + R_2}$$

Where $R_{eq} = R_1 + R_2 = \dfrac{0.24}{0.9\times 400} + \dfrac{0.02}{0.15\times 400}$



$$i_H = \frac{dQ}{dt} = \frac{\Delta Q}{\Delta t} = \frac{\Delta m.L}{\Delta t}$$

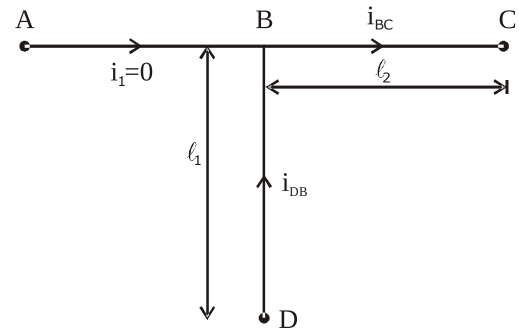
$\dfrac{\Delta m}{\Delta t} = \dfrac{i_H}{L}$ where L = 540 cal/gm ; Δt = 3600 sec.

Q.16 (4)

$$i = kA\frac{dT}{dx} \Rightarrow \frac{dT}{dx} \propto \frac{1}{K}$$

$\therefore$ i and A are same for both the layers.
$i = -kA\,(dT/dx)$
i and A are constant hence slope
$dT/dx = -i/(kA)$ is – ve but
Slope $\propto (1/k)$
Hence in air slope will be more – ve due to very less conductivity.

Q.17 (2)



$$i_{BC} = i_{DB} \Rightarrow \frac{kA(90-20)}{\ell_1} = \frac{kA(20-0)}{\ell_2}$$

$$\frac{\ell_1}{\ell_2} = \frac{7}{2}$$

Q.18 (2)
The heat current is equal to required latent heat of fusion per unit time.

$$i = \frac{dm_{ice}}{dt}\,.\,L_f = \frac{kA(100)}{\ell}$$

$$k = \frac{dm_{ice}}{dt}\cdot\frac{\ell L_f}{A(100)} = 60\ Wm^{-1}\,k^{-1}$$

Q.19 (3)
$i = -kA\ dT/dx$
Slope $dT/dx = -\,i/kA$ is – ve but due to radiation loss because of not lagged, as we move ahead current i will be less. Hence slope wil be more – ve to less – ve.

Q.20 (1)

$$T_p = \frac{100+0}{2} = 50°$$

As $T_P > T_Q$ so flow is from P to Q.

$$T_Q = \frac{30+60}{2} = 45°$$

Q.21 (3)

Initially $i = \dfrac{dm}{dt}\,.\,L_f = k\pi R^2.\,\dfrac{100}{\ell}$

Hence $\dfrac{dm}{dt} \propto \dfrac{kR^2}{\ell}$

From given condition

$$\frac{\frac{dm_2}{dt}}{\frac{dm_1}{dt}} = \frac{\frac{k}{4}\left(\frac{(2R)^2}{\ell/2}\right)}{\frac{kR^2}{\ell}}$$

$$\frac{\frac{dm_2}{dt}}{0.1} = 2 \Rightarrow \frac{dm_2}{dt} = 0.2$$

Q.22 (1)

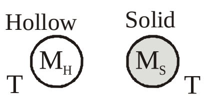
Req. is same for both the rods and same temperature same difference so $i_1 = i_2$

Q.23 (1)

$P_{emitte} = \sigma eAT^4$

since $T_1 = T_2$

$P_{absorb} = \sigma eAT_S^4$



$M_H < M_S$

So, $P_1 = P_2$ at $t = 0$

cooling rate $\left(-\frac{dT}{dt}\right) = \frac{\sigma eA}{mS}[T^4 - T_S^4]$

since $M_H < M_S$, so cooling rate will be different since cooling rate is not same so both will not have same temp at any instant t (except t = 0)

Q.24 (3)

$$-\frac{dT_p}{dt} = x\left(-\frac{dT_Q}{dt}\right)$$

$$\Rightarrow \frac{eA_p\sigma(T^4 - T_0^4)}{m_pS} = \frac{xe\sigma A_Q(T^4 - T_0^4)}{m_QS}$$

$$\Rightarrow x = \frac{A_pm_Q}{A_Qm_p} = \left(\frac{r}{3r}\right)^2 \times \left(\frac{3r}{r}\right)^3$$

$\Rightarrow x = 3$

Q.25 (2)

Initially the temperature of the substance increases and then phase change from ice to water occurs & this process continues.

Q.26 (4)

$$\text{Area} = \int y dx = \int \frac{dE}{d\lambda} \times d\lambda = \int dE$$

$$\text{Area (1)} = E = \sigma T^4 = \sigma\left(\frac{b}{\lambda}\right)^4$$

$$\frac{\text{Area}_1}{\text{Area}_2} = \left(\frac{\lambda_2}{\lambda_1}\right)^4 \Rightarrow \frac{1}{9} = \left(\frac{\lambda_2}{\lambda_1}\right)^4$$

$$\Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{3}$$

Q.27 (2)

Using relation $\lambda_{max} \propto \frac{1}{T}$

$$\frac{T_S}{T_{NS}} = \frac{\lambda_{NS_{max}}}{\lambda_{S_{max}}} = \frac{350}{510} = 0.69$$

Q.28 (2)

Using formula

$P = \sigma eAT^4$

$P_P = \varepsilon_P \sigma (1) \theta_P^4$ and $P_Q = \varepsilon_Q \sigma A \theta_Q^4$

Now $P_P = P_Q$

$$\left(\frac{\varepsilon_Q}{\varepsilon_P}\right)^{1/4} \theta_Q = \theta_P$$

Q.29 (4)

$i = ms\frac{d\theta}{dt} = msk(50° – 20°) = 10\ W$

..(1)

and $\frac{35.1 - 34.9}{60} = k(35 - 20)$

...(2)

from (1) & (2)

$$\frac{0.2}{60} = \frac{10}{ms(30)} \times 15$$

$ms = 1500\ J/°C$

Q.30 (1)

If the body cools from θ_1 to θ_2 then using formula

$$\frac{\theta_1 - \theta_2}{t} = \alpha\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$$

$$\frac{75 - 65}{5} = k\left(\frac{75 + 65}{2} - 25\right)$$

$$2 = K(70 - 25) \Rightarrow K = \frac{2}{45}$$

$$\text{Now } \frac{65 - x}{5} = k\left(\frac{65 + x}{2} - 25\right)$$

$2(65 - x) = 5k(65 + x - 50)$

$130 - 2x = 5 \times \frac{2}{45}(15 + x)$

$x = 57°c$

EXERCISE-IV

Q.1 [0023]

$$\alpha_1 = \frac{0.065}{30\times100}$$

$$\alpha_2 = \frac{0.035}{30\times100}$$

$\Delta l = l_1 a_1 \Delta T + (30 - l_1)\, \alpha_2\, \Delta T$

$$0.058 = l_1 \times \frac{0.065}{3000} + (30 - l_1) \times \frac{0.035}{3000}$$

$1.74 = 0.065\, l_1 + 1.05 - 0.035 l,$

$0.69 = +0.03 l_1$

$l_1 = 23$ cm ; $l_2 = 7$ cm

Q.2 [0200]

$\Delta\ell = \alpha\ell\Delta T$

$$\frac{\Delta\ell}{\ell} = \alpha\Delta T$$

$$\sigma_b = \frac{T}{A} = \frac{y\Delta\ell}{\ell} = y\alpha\Delta T \Rightarrow \Delta T = \frac{\sigma_b}{y\alpha} =$$

$$\frac{4\times10^8}{2\times10^{11}\times10^{-5}} = 200°C$$

Q.3 [250]

$\Delta d = d\alpha\Delta T \approx 6\times10^{-4} = 1\times12\times10^{-6}\times\Delta T$

$\Delta T = 50°C \Rightarrow T_f = 70°C$

$21\times570\times50 = m\times540\times4200 + m\times4200\times(100-70)$

$$m = \frac{21\times4500\times50}{540\times4200+4200\times30} = \frac{1}{4}\text{ kg} = 250\text{ gm}$$

Q.4 [0001]

$\Delta V = \Delta V_m - \Delta V_{pt}$

$= V(\gamma_2 - \gamma_1)\Delta T$

$$\frac{\Delta V}{V} = (18-2.7)\times10^{-5}\,\Delta T = (15.3\times10^{-5})\,\Delta T$$

$$\Delta T = \frac{(\Delta V / V)}{15.3\times10^{-5}} = 1$$

Q.5 [1000]

$$\frac{dE}{dt} = \sigma AT^4$$

$$\because \quad T^4 = \frac{(5.67\pi\times10^2)}{4\pi(0.05)^2(5.67\times10^{-8})} = 10^{12}$$

$A = 4\pi r^2$

$\Rightarrow \quad T = 1000$ K

Q.6 [1000]

$$P = \sigma AT^4,\ T = \left(\frac{P}{\sigma A}\right)^{1/4} \Rightarrow T = 1000\text{ K}$$

Q.7 [0001]

$64 = \sigma T^4 (2\pi r l)$

$r = 10^{-5}$ m = 10 mm)

Q.8 [0060]

$140\times1(80-T) = 10\times80\times2 + 20\times1\,(T-0)$

$140\times80 - 1600 = 160\,T$

$T = 60°C$

Q.9 [600]

By conservation of heat energy

$m_A S_A \Delta T_A = m_w S_w \Delta T_w$

$$m_A = \frac{m_w S_w \Delta T_w}{S_A \Delta T_A} = \frac{(60)(4200)(10)}{140\times30} = 600\text{ kg}$$

Q.10 [0004]

$25(1 + 6.96\times10^{-6}\,T) = 25.04\,[1 - 2.5\times10^{-5}\,(100-T)]$

$25 + 174\times10^{-6}\,T = 25.04 - 626\times10^{-4} + 626\times10^{-6}\,T$

$0.0226 = 452\times10^{-5}\,T$

$T = 50°$

$m_{sph}\,(0.230)\,(100-T) = m_{Ring}\,(0.092)\,(50)$

$$\frac{10m_{sph}}{m_{ring}} = 4$$

Q.11 (2)

$$F = \frac{9}{5}C + 32$$

for T = F = C

$$T = \frac{9}{5}T + 32$$

$$\frac{4}{5}T = -32$$

$T = -40°$

Q.12 (2)

According to Kirchoff's law,

$e_\lambda = E_\lambda \cdot a_\lambda$

$\Rightarrow e_\lambda \propto a_\lambda$

But $e_\lambda \neq a_\lambda$

Q.13 (2)
Rate of loss due to radiation

$Q \propto T^4$

$$\frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 = 2^4 = 16$$

Specific heat varies with the temperature

Q.14 **(2)**
Water evaporates at all temperatures
Specific heat of water is highest among all liquids.

Q.15 (2)
Factual

Q.16 (1)
(a) Stefan's Boltzman law
$E = ST^4$
(b) Kirchoff's law,
$e_\lambda = E_\lambda a_\lambda$
(c) Newton's law,

$$\frac{d\theta}{dt} \propto (\theta - \theta_0)$$

(d) Wien's displacement law,
$\lambda_m T = b$

PREVIOUS YEAR'S

MHT CET

Q.1 (4)
Q.2 (2)
Q.3 (2)
Q.4 **(4)**
Given, $h_1 = 50$ cm $T_1 = 50°C$
$h_2 = 60$ cm, $T_2 = 100°$ C
Let the density of the given liquid at STP be ρ_0, if both vertical columns balance each other, then their pressure should be equal.
i.e., $p = \rho g h$
$\Rightarrow \rho_1 g h_1 = \rho_2 g h_2$

$$\Rightarrow \frac{\rho_1}{\rho_2} = \frac{h_1}{h_2}$$

If r be the coefficient of absolute expansion of liquid,

then, $\rho_1 = \frac{\rho_0}{1+rT_1}$ and $\rho_2 = \frac{\rho_0}{1+rT_2}$

$\therefore$ From Eq. (i) we have

$$\frac{\frac{\rho_0}{1+rT_1}}{\frac{\rho_0}{1+rT_2}} = \frac{h_1}{h_2} = \frac{60}{50}$$

$$\Rightarrow \frac{1+rT_1}{1+rT_2} = \frac{6}{5} \Rightarrow 5rT_2 - 6rT_1 = 1$$

$$\Rightarrow r = \frac{1}{200} = 0.005 / °C$$

Q.5 (3)
The fractional change in time period is given by

$$\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta \Rightarrow \Delta T = \frac{T\alpha\Delta\theta}{2}$$

Here, $T = 1\text{day} = (24 \times 60 \times 60)\text{s} = 86400$ s
$\alpha = 1.2 \times 10^{-5}/°C, \Delta\theta = 20 - 15 = 5°C$

$$\therefore \quad \Delta T = \frac{86400 \times 1.2 \times 10^{-5} \times 5}{2} = 2.6\text{s}$$

Q.6 (2)
Q.7 (3)
Q.8 (1)
For the principle of calorimetry,
$m_1 s_1 \Delta T_1 = m_2 s_2 \Delta T_2$

$$540 \times s_w (80\text{-}T) = 540 \times \frac{s_w}{2} \times (T - 0)$$

where, s_w is speciffic heat of water.

$$\Rightarrow T = \frac{160}{3} °C = 53.3°C$$

Q.9 (2)
Let mass of the bullet be m gram, then total heat required for bullet to just melt down
$Q_1 = mc\Delta T + mL$
$= m \times (0.03)(327 - 27) + m \times 6$
$= 15$ m - cal
$= (16m \times 4.2)$J
Now, when bullet is struck by obstacles, the loss in its mechanical energy

$$= \frac{1}{2}\left(m \times 10^{-3}\right)v^2$$

The energy absorbed by bullet,

$$Q_2 = \frac{72}{100} \times \frac{1}{2} mv^2 \times 10^{-3}$$

$$= \frac{3}{8} mv^2 \times 10^{-3} \text{J}$$

Now, the bullet will melt if $Q_2 \geq Q_1$

i.e., $\frac{3}{8} mv^2 \times 10^{-3} \geq 15m \times 4.2$

$\Rightarrow v_{min} = 410$ m/s

Q.10 (3)
Q.11 (3)
Q.12 (2)

Q.13 (3)

Q.14 (1)

Q.15 (1)

Q.16 (2)

Q.17 (4)

Q.18 (3)

Q.19 (2)

Q.20 (3)

Q.21 (2)

Q.22 (4)

According to Newton's law of cooling,

$$\frac{T_1 - T_2}{2} = K\left(\frac{T_1 + T_2}{2} - T_0\right)$$

$$\frac{365-361}{2} = K\left[\frac{365+361}{2} - 293\right]$$

$$\Rightarrow \quad K = \frac{1}{35}$$

Again, $\frac{344-342}{t} = \frac{1}{35}\left[\frac{344+342}{2} - 293\right] = \frac{10}{7}$

t = $\frac{14}{10}\text{min} = 84\text{s}$

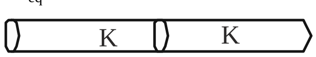
Q.23 (2)

Since, heat transfer, $Q = \frac{KA(T_1 - T_2)\times t}{L}$

The equivalent thermal resistance in series i.e joined end-to-end is

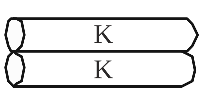
$$\frac{1}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2} = \frac{1}{K} + \frac{1}{K}$$

$$\Rightarrow \quad \frac{1}{K_{eq}} = \frac{2}{K} \Rightarrow K_{eq} = \frac{K}{2}$$



The equivalent thermal resistance in parallel i.e when they are joined one above another,

$$K'_{eq} = K_1 + K_2 = K + K = 2K$$



According to question,

$$Q_2 = Q_1$$

$$\Rightarrow \quad \frac{2Kt_2}{L} = \frac{(K/2)t_1}{2L}$$

$$\Rightarrow \quad t_2 = \frac{t_1}{8} = \frac{t}{8}\text{s} \qquad [\therefore t_1 = t]$$

Q.24 (2)

From Stefan's law, the total radiant energy emitted per second per unit surface area of a black body is proportional to the fourth power of the absolute temperature (T) of the body.

$$\therefore \quad E = \sigma T^4$$

Where σ is Stefan's constant.

Given, $E_1 = R$

$\Rightarrow T_1 = 273°C = 273 + 273 = 546\text{ K}$

and $T_2 = 0°C = 273K$

$$\therefore \frac{E_1}{E_2} = \frac{T_1^4}{T_2^4} \Rightarrow E_2 = \frac{T_2^4}{T_1^4} \times E_1$$

$$\Rightarrow E_2 = \frac{(273)^4}{(546)^4} R = \frac{R}{16}$$

Q.25 (4)

The activity of a radioactive sample is given by

$$A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{A}{A_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$

Given, $A = \frac{A_0}{32}$ and t = 1h

$$\Rightarrow \left(\frac{1}{32}\right) = \left(\frac{1}{2}\right)^{\frac{1}{T_{1/2}}} \text{ or } \left(\frac{1}{2}\right)^5 = \left(\frac{1}{2}\right)^{\frac{1}{T_{1/2}}} \Rightarrow 5 = \frac{1}{T_{1/2}}$$

$$\text{or } T_{1/2} = \frac{1}{5}\text{h} = \frac{60}{5}\text{min} = 12\text{ min}$$

NEET/AIPMT

Q.1 (2)

$V_{escape} = 11200$ m/s

On solving,

$T = 8.360 \times 10^4$ K

Q.2 (1)

We know,

$\lambda_{max} T = \text{constant}$ (Wien's law)

So, $\lambda_{max_1} T_1 = \lambda_{max_2} T_2$

$$\Rightarrow \lambda_0 T = \frac{3\lambda_0}{4} T'$$

$$\Rightarrow T' = \frac{4}{3} T$$

$$\text{So, } \frac{P_2}{P_1} = \left(\frac{T'}{T}\right)^4 = \left(\frac{4}{3}\right)^4 = \frac{256}{81}$$

Q.3 (2)

In adiabatic process $\Delta Q = 0$

Q.4 (4)

$$\ell_{Cu}^1 = \ell_{Cu}(1 + \alpha_{Cu}\Delta T) \qquad ..(i)$$

$\ell_{Al}^{1} = \ell_{Al}\left(1+\alpha_{Al}\Delta T\right)$ ..(ii)

Equation (2) - equation (1)

$\ell_{Al}^{1} - \ell_{Cu}^{1} = \ell_{Al} + \ell_{Al}\alpha_{Al}\Delta T - \left(\ell_{Cu} + \ell_{Cu}\alpha_{Cu}\Delta T\right)$

$\ell_{Al}^{1} - \ell_{Cu}^{1} = \ell_{Al} + \ell_{Cu} + \left(\ell_{Al}\alpha_{Al} - \ell_{Cu}\alpha_{Cu}\right)\Delta T$

When increases in length is not depend on temperature.

$\alpha_{Cu}\ell_{Cu} = \alpha_{Al}\ell_{Al}$

$1.7 \times 10^{-5} \times 88 = 2.2 \times 10^{-5} \times \ell_{Al}$

$\ell_{Al} = 68\text{cm}$

Q.5 **(4)**

Q.6 (1)

Q.7 (3)

V = (no. of moles) (22.4 litre)

$= \dfrac{\text{mass}}{\text{molar mass}}(22.4 \times 10^{-3}\,\text{m}^3)$

$= \dfrac{4.5\times10^{3}}{18} \times 22.4 \times 10^{-3}\,\text{m}^3$

$= 5.6\,\text{m}^3$

JEE MAIN

Q.1 (2)

Area of cube = $6a^2 = 24\text{m}^2$ a $\rightarrow$ side of cube

$a^2 = 4 \Rightarrow \boxed{a = 2} \Rightarrow v_0 = 2^3 = 8$

$\Delta T = 10°C$

$\alpha = 5.0 \times 10^{-4}\ \dfrac{1}{°C}$

We know for solid materials $\gamma = 3\alpha$

So $\gamma = 3 \times 5 \times 10^{-4} = 15 \times 10^{-4}/°C$

$\Delta V = v_0\gamma.\Delta T$

$\Delta V = 8 \times 15 \times 10^{-4} \times 10 = 1200 \times 10^{-4}\,\text{m}^3 = 12 \times 10^{-2} \times (10^2)^3\,\text{cm}^3$

$\Delta V = 12 \times 10^4\,\text{cm}^3$

$\boxed{\Delta V = 1.2\times10^{5}\,\text{cm}^3}$

Q.2 (4)

Initial diameter of ring = 6.230 cm

Final diameter of ring should be equal to diameter of bangle

$\Rightarrow$ Final diameter of ring = 6.241 cm

Using $\dfrac{\Delta 1}{1} = \propto \Delta t$

or

For diameter

$\dfrac{\Delta D}{D} = \propto \Delta T$

$\Delta D \rightarrow$ change in diameter

$\Delta \rightarrow$ Initial diameter

$\Rightarrow \dfrac{6.241 - 6.230}{6.230} = 1.4\times10^{-5}(T - 27)$

$\Rightarrow \dfrac{0.011}{6.230} = 1.4\times10^{-5}(T - 27)$

$\Rightarrow T - 27 = \dfrac{11\times10^{5}}{6230\times1.4}$

$\Rightarrow T = 152.7°C$

Q.3 (20)

Difference of their length

$\ell_2 - \ell_2 =$ const.

$\Delta\ell_2 - \Delta\ell_1 = 0$

$\Delta\ell_2 = \Delta\ell_1$

$\ell_2\,\alpha_2\Delta T = \ell_1\alpha_1\Delta T$

$40 \times 1.8 \times 10^{-5} = \ell_1(1.2\times10^{-5})$

$\ell_1 = 60\,\text{Cm}$

Q.4 (3)

$\dfrac{1}{4}\left(\dfrac{1}{2}Mv^2\right) = ms\Delta T$

$\dfrac{1}{8}\times1.5\times(60)^2 = 0.1\times420\times\Delta T$.......

$\left(s = 0.42J/g^{o}C = 0.42\times10^{3}J/kg^{o}C = 420J/kg^{o}C\right)$

$\dfrac{1}{8}\times\dfrac{15}{10}\times60\times60 = 42\times\Delta T$

$15 \times 15 \times 3 = 42\Delta T$

$\Delta T = \dfrac{225\times3}{42}$

$\Delta T = \dfrac{225}{14} = 16.07\ °C$

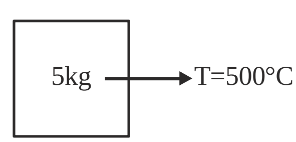
Q.5 (31)

Heat rejected per/min = $mL_f + mS\Delta T$

$= (50 \times 540) + 50\,(1)\,(100 - 20)$

$= 31000\,\text{Cal} = 31 \times 10^3\,\text{Cal}$

Q.6 (3)



$S_{cu} = 0.39\dfrac{J}{g\times°C}$

$L_f = 335\dfrac{J}{gm}$

When block is placed on ice block then heat will transferred from Cu block to ice then

$|\Delta H_{loss}| = |\Delta H_{gain}|$

$(ms_{cu}.\Delta T) = (m_{ice}L_f)$

$5000 \times 0.39 \times 500 = m_{ice} \times 335$

$$m_{ice} = \frac{25\times10^5\times0.39}{335} = \frac{9.75}{335}\times10^5$$

$$\boxed{m_{ice} = 2.9\times10^3 gm = 2.9kg}$$

Q.7 (42)

$m = 2000$ gm / min

Heat required by water / min = $mS\Delta T$

= (2000) × 4.2 × 40 J/min

= 336000 J/min

$$\left(\frac{dm}{dt}L\right) = 336000\ J/min$$

The rate of combustion $= \dfrac{dm}{dt} = \dfrac{336000}{8\times10^3}$ g / min.

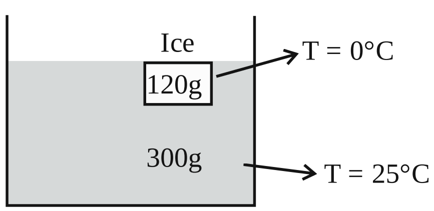
= 42 gm / min.

Q.8 (2)

$$m\times125\times200 + m\times2.5\times10^4 = \frac{1}{2}mv^2\times\frac{40}{100}$$

V = 500 m/s

Q.9 (90)



L = Latent heat of ice

Heat absorbed = Heat transmitted

m × L = m C D T

- m (left) → mass of ice which has been melted
- m (right) → mass of water
- C → specific heat capacity
- DT → charge into temperature

$(m)_{melted} \times (3.5\times10^5) = 300\times4200\times(25)$

$(m_{ice})_{melted} = 90$

Q.10 (2)

Heat will be gained by the container through conducting walls and with that heat the ice will melt.

Heat gained by container $= \dfrac{dq}{dt} = KA\dfrac{\Delta T}{x}$

And total area = 2(60 × 50 + 50 × 20 + 20 × 60) = 10400cm^2

x = 1cm

K = 0.05Wm^{-1}°C^{-1}

Now,

$$KA\frac{\Delta T}{x} = \frac{dm}{dt}L$$

$$\Rightarrow \frac{dm}{dt} = \frac{KA}{L}\frac{\Delta T}{x}$$

$$\Rightarrow \frac{dm}{dt} = \frac{0.05\times10400\times40}{3.4\times10^5\times1\times10^{-2}\times10000} \simeq 61\times10^{-5}\ kg/sec$$

Q.11 (16)

$T_i - Ts = 60$

$80 - T_s = 60 \quad \Rightarrow T_s = 20$

$T_1 - T_s = 40 \quad T_2 - T_s = 20$

$T_1 - 20 = 40 \quad T_2 - 20 = 20$

$T_1 = 60 \quad T_2 = 40$

$$\frac{\frac{80-60}{6}}{\frac{60-40}{t_2-6}} = \frac{k(50)}{k(30)} = \frac{5}{3}$$

$$\frac{10}{3}\times\frac{(t^2-6)}{20} = \frac{5}{3}$$

$t_2 - 6 = 10$

$t_2 = 16$ min.

Q.12 (3)

(1) $\dfrac{dQ}{dt} \propto K(T - T_0)$ here $\rightarrow T - T_0 = \Delta T$

$\dfrac{dQ}{dt} \propto K\Delta T$ If ΔT is twice then $\dfrac{dQ}{dt}$ will be 2 times

(2) $I \propto T_4$

$$\frac{I_P}{I_Q} = \frac{(273+10)^4}{(273+20)^4} = \left(\frac{283}{293}\right)^4 \simeq 0.92$$

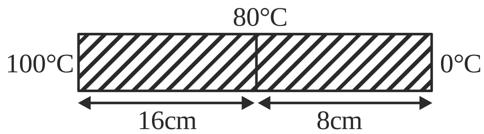
(3) $\eta = 1 - \dfrac{T_2}{T_1} = 1 - \dfrac{100}{400} = \dfrac{3}{4}$

$$\Rightarrow \eta\% = \frac{3}{4}\times100 = 75\%$$

(4) $\dfrac{dQ}{dt} \propto \Delta T$

Statements → A and C are correct

Q.13 (2)



According to given condition of steady state heat current are same in both metallic blocks, M_1 & M_2

$I_1 = I_2$ (current are same in both rod) ....(1)

$A_1 = A_2$

Formula of heat current $I = \frac{dQ}{dt} = \frac{KA(\Delta T)}{L}$ ....(2)

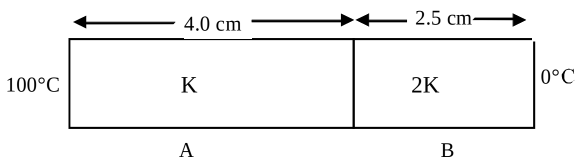
equation (1) to $\frac{K_1 A(100°C - 80°C)}{16cm} = \frac{K_2 A(80°C - 0°C)}{8cm}$

$\frac{K_1(20°C)}{16} = \frac{K_2(80)}{8}$

$\Rightarrow K_1 = 8K_2$

$K_1 = 8K$

Q.14 (21)



Area of cross section = 120 cm^2

Equivalent thermal conductivity

$\left(1 + \frac{5}{\alpha}\right)K$

$R_{eq} = R_1 + R_2$ $\qquad R = \frac{L}{kA}$

$\frac{1}{K_{eq}} \frac{(L_1 + L_2)}{A} = \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A}$

$\frac{L_1 + L_2}{K_{eq}} = \frac{L_1}{K_1} + \frac{L_2}{K_2} \Rightarrow \frac{4 + 2.5}{K_{eq}} = \frac{4}{k} + \frac{2.5}{2k}$

$\frac{6.5}{K_{eq}} = \frac{10.5}{2K}$

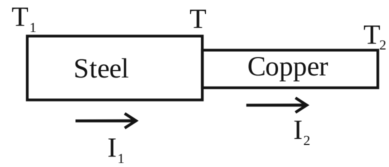
$K_{eq} = \frac{65 \times 2}{105} = \frac{130}{105} = \frac{26}{21}$

$K_{eq} = \frac{26}{21} = \left(1 + \frac{5}{21}\right)K$

$\frac{1+5}{\alpha} = 1 + \frac{5}{21}$

$\alpha = 21$

Q.15 (3)



$T_1 = 450°C$ $\qquad T_2 = 0°C$

$\frac{A_1}{A_2} = \frac{2}{1}; \frac{K_2}{K_1} = \frac{9}{1}$ and $\frac{L_1}{L_2} = \frac{2}{1}$ (given data)

In steady state $\rightarrow I_1 = I_2$

$\frac{T_1 - T}{R_1} = \frac{T - T_2}{R_2}$

$\Rightarrow \frac{(450 - T)K_1 A_1}{L_1} = \frac{(T - 0)K_2 A_2}{L_2}$

$\Rightarrow \frac{450 - T}{T} = \frac{K_2}{K_1} \cdot \frac{A_2}{A_1} \cdot \frac{L_1}{L_2}$

$\frac{450 - T}{T} = 9 \times \frac{1}{2} \times 2 = 9$

$\frac{450 - T}{T} = 9 \Rightarrow 450 - T = 9T$

$450 = 10T$

$T = 45°$