CLASS TEST

S.No.: 02SKME_JKLMN_04082025

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ENGINEERING MECHANICS

MECHANICAL ENGINEERING

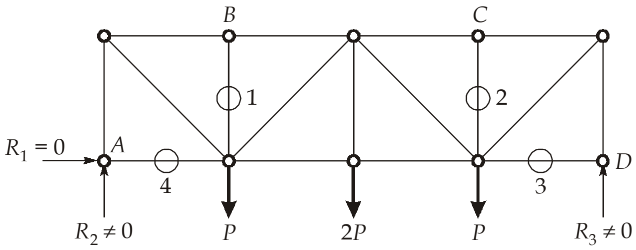
Date of Test : 04/08/2025

ANSWER KEY

1.	(c)	7.	(b)	13.	(b)	19.	(b)	25.	(a)
2.	(d)	8.	(b)	14.	(b)	20.	(c)	26.	(a)
3.	(c)	9.	(d)	15.	(b)	21.	(a)	27.	(a)
4.	(c)	10.	(b)	16.	(a)	22.	(a)	28.	(c)
5.	(d)	11.	(b)	17.	(c)	23.	(b)	29.	(a)
6.	(b)	12.	(a)	18.	(b)	24.	(b)	30.	(c)

DETAILED EXPLANATIONS

1. (c)



- At joint B and C, three members are hinged and out of these three, two members are collinear. So, the force in the third member must be zero to attain static equillibrium. (Members 1 and 2)
- At joint A and B, two perpendicular members are hinged and a force is acting which is along only one member. So, the force in the other member must be zero to attain static equillibrium. (Members 3 and 4)

2. (d)

At the instance when the particle changes its direction of motion, the speed will be zero and acceleration will not be zero.

$$s = \frac{t^4}{4} - 128t^2$$

$$v = \frac{ds}{dt} = t^3 - 256t$$

When, $v = 0$, $\quad t^3 - 256t = 0$

$\Rightarrow \quad t(t^2 - 256) = 0$

$\Rightarrow \quad t = 0, 16, -16$

$t \neq -16$s (Time is always positive)

$t \neq 0$ s (Because particle starts to move at that moment)

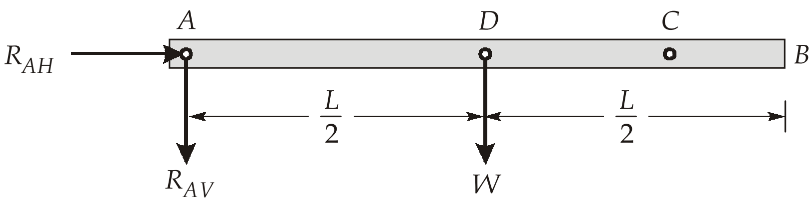
$\Rightarrow \quad t = 16$ seconds

3. (c)

When mass distribution is uniform in a body then its centroid and centre of mass coincides.

Note: In addition to the above it must also be placed under uniform gravitational field.

4. (c)



Moment of inertia of the rod about point A,

$$I_A = \frac{\frac{W}{g}(L)^2}{12} + \frac{W}{g}\left(\frac{L}{2}\right)^2 = \frac{1}{3} \times \frac{W}{g} \times L^2$$

The net torque about point A,

$$\Sigma T_A = I_A \alpha_A$$

$$W \times \frac{L}{2} = \frac{1}{3} \times \frac{W}{g} \times L^2 \alpha_A$$

$$\Rightarrow \quad \alpha_A = \frac{3g}{2L}$$

Hence, the angular acceleration of the rod at the instant is $\frac{3g}{2L}$

Now, using Newton's second law of motion.

$$\Sigma F_{\text{external, vertical}} = m a_{\text{cm, vertical}}$$

$$W - R_{AV} = \left(\frac{W}{g}\right) \times r_{cm} \times \alpha$$

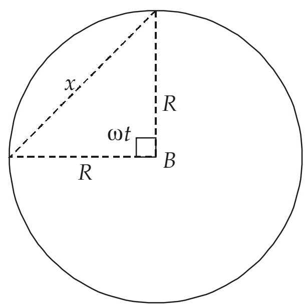
$$\Rightarrow \quad W - R_{AV} = \left(\frac{W}{g}\right) \times \frac{L}{2} \times \frac{3g}{2L}$$

$$\Rightarrow \quad R_{AV} = W - \frac{3W}{4} = \frac{W}{4}$$

Hence, the vertical reaction at hinge point A at the instant is $\frac{W}{4}$.

5. (d)

Angle rotated in time 't' is given as



$$\theta = \omega t$$

$$\cos\omega t = \frac{R^2 + R^2 - x^2}{2R^2}$$

$$2R^2 \cos\omega t = 2R^2 - x^2$$

$$x^2 = 2R^2(1 - \cos\omega t)$$

$$x^2 = 2R^2 \times 2\sin^2\frac{\omega t}{2}$$

$$x = 2R\sin\frac{\omega t}{2}$$

6. (b)

Acceleration of the mass is given as:

$$a = \frac{F}{m} \quad [F = \text{Constant}]$$

Using third equation of kinematics,

$$V^2 = U^2 + 2as \qquad (U = 0)$$

$$V = \sqrt{2as} = \sqrt{2\frac{F}{m}s}$$

Here, it is given that the distance travelled is also constant.

$$V \; \alpha \; \frac{1}{\sqrt{m}}$$

7. **(b)**

Since both the bodies are revolving with the same time period, therefore their angular speed will also be same.

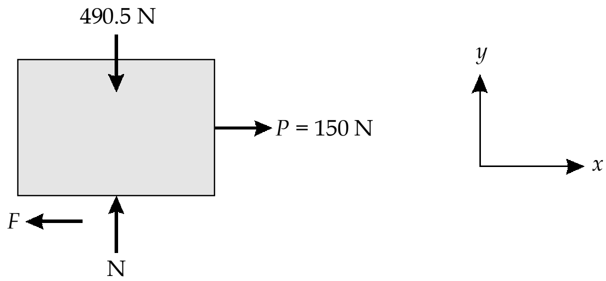
$$\frac{a_1}{a_2} = \frac{\omega_1^2 r_1}{\omega_2^3 r_2} = \frac{r_1}{r_2} = \frac{5}{10} = \frac{1}{2}$$

8. **(b)**

When body at rest, equilibrium,

$$N = 490.5 \text{ N}$$

$$F = P = 150 \text{ N}$$



Maximum static friction force,

$$F_{max} = \mu sN$$

$$= 0.5\ (490.5)$$

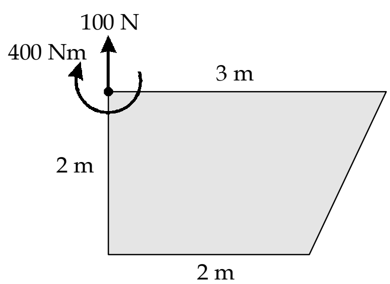
$$= 245.25 \text{ N}$$

Because F < Fmax, we conclude that the block is in static equilibrium and correct value of friction force,

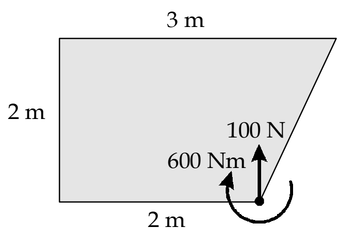
$$F = 150 \text{ N}$$

9. **(d)**

Force-couple system,

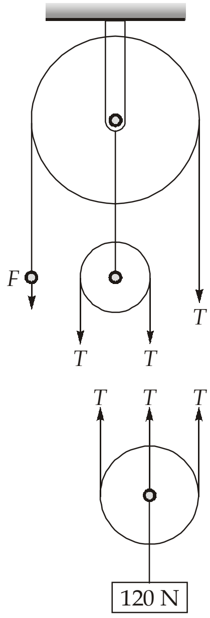


Equivalent force couple system,



10. (b)

The rope is same all over the pulley tension (T) everywhere in the rope will be same.

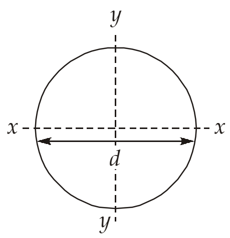


Hence, $F = T$

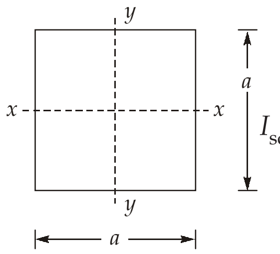
and $3T = 120$

$$\Rightarrow \quad F = T = \frac{120}{3} = 40 \text{ N}$$

11. (b)



$$I_{\text{circle}} = I_{xx} = I_{yy} = \frac{\pi}{64} d^4$$



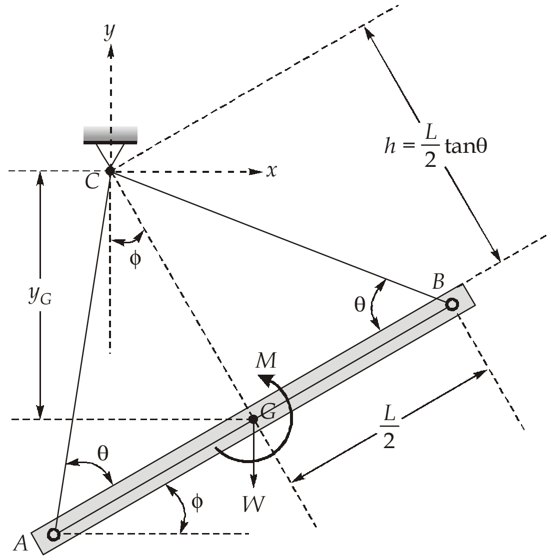
$$I_{\text{square}} = I_{xx} = I_{yy} = \frac{a^4}{12}$$

Since both have same area,

$$A = a^2 = \frac{\pi}{4} d^2$$

$$\frac{I_{\text{circle}}}{I_{\text{square}}} = \frac{\left(\frac{\pi}{64} \cdot d^4\right)}{\left(\frac{a^4}{12}\right)} = \frac{\left(\frac{\pi}{64} d^4\right)}{\frac{1}{12}\left(\frac{\pi}{4} d^2\right)^2} = 0.954929 \approx 0.955$$

12. (a)



Considering the fixed point C as origin of rectangular coordinate system.
Point G:

$$x_G = \frac{L}{2}\tan\theta\sin\phi$$

$$\delta x_G = -h\cos\phi = -\frac{L}{2}\tan\theta\cos\phi$$

$$\Rightarrow \quad \delta x_G = 0$$

and $$\delta y_G = \frac{L}{2}\tan\theta\sin\phi\,\delta\phi$$

Using the method of virtual work;

(Virtual work)$_W$ + (Virtual work)$_M$ = 0

$$(-W)\,(\delta y_G) + (M)\,(\delta\phi) = 0$$

$$\Rightarrow (-W)\left(\frac{L}{2}\tan\theta\sin\phi\,\delta\phi\right) + M\,\delta\phi = 0$$

$$\Rightarrow \quad -\frac{WL}{2}\tan\theta\sin\phi + M = 0$$

$$\Rightarrow \quad M = \frac{WL}{2}\tan\theta\sin\phi$$

13. (b)

$$x^3y = c \Rightarrow y = \frac{c}{x^3}$$

$$\Rightarrow \quad \dot{y} = \frac{-3c}{x^4}\dot{x}$$

Total kinetic energy (T):

$$T = \frac{1}{2}m\dot{x}^2 + \frac{1}{2}m\dot{y}^2 = \frac{1}{2}m\dot{x}^2 + \frac{1}{2}m\left(\frac{-3c}{x^4}\dot{x}^2\right)$$

$$= \frac{1}{2}m\dot{x}^2 + \frac{9}{2}mc^2\frac{\dot{x}^2}{x^8}$$

Total potential energy (V):

$$V = mgy = mg\frac{c}{x^3}$$

The Lagrangian (L) for the particle is given by:

$$L = T - V$$

$$= \left[\frac{1}{2}m\dot{x}^2 + \frac{9}{2}mc^2\frac{\dot{x}^2}{x^8}\right] - \left[mg\frac{c}{x^3}\right] = \frac{1}{2}m\dot{x}^2 + \frac{9}{2}\frac{mc^2}{x^8}\dot{x}^2 - mg\frac{c}{x^3}$$

14. (b)

Under static equillibrium:

$\Sigma F_V = 0;$ $\quad N_B = W$

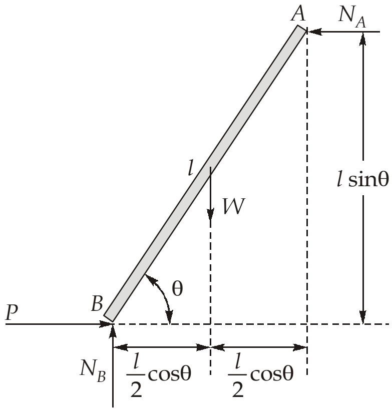
$\Sigma F_H = 0;$ $\quad N_A = P$

$\Sigma M_B = 0;$ $\quad N_A\, l\sin\theta = W\frac{l}{2}\cos\theta$

$$\Rightarrow \quad P\sin\theta = \frac{W}{2}\cos\theta$$

$$\Rightarrow \quad W = 2P\tan\theta = 2(50)\tan 60°$$

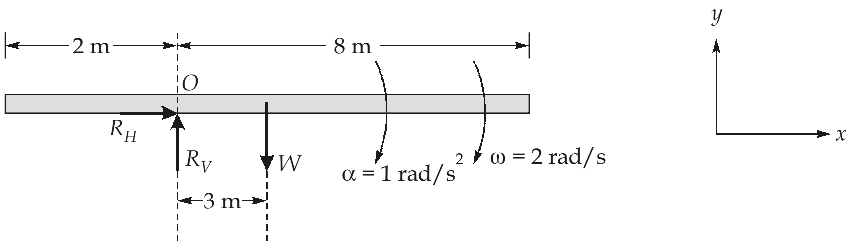
$$= 100\sqrt{3}\text{ N}$$



15. (b)

Mass of rod, $m = 5$ kg

Length of rod, $L = 10$ m



$\Sigma F_{ext,x} = ma_{cm,x}$

$$\Rightarrow \quad R_H = mr_{cm}\,\omega^2 = 5 \times 3 \times 2^2 = 60\text{ N}$$

$\Sigma F_{ext,y} = ma_{cm,y}$

$$\Rightarrow \quad mg - R_V = mr_{cm}\,\alpha$$

$$R_V = mg - mr_{cm}\,\alpha$$

$$= 5 \times (9.81) - 5 \times 3 \times 1 = 34.05\text{ N}$$

Net reaction at hinge, $R = \sqrt{R_H^2 + R_V^2} = \sqrt{(60)^2 + (34.05)^2}$

$$= 68.9884\text{ N} \approx 69\text{ N}$$

16. (a)

Given: $P = 5t$, $\mu_s = 0.5$, $\mu_k = 0.4$, $N = mg = 100$ N

$$(f_s)_{max} = \mu_s N = 0.5 \times 100 = 50\text{ N}$$

P becomes 50 N at $t = 10$ s

$\Rightarrow$ From $t = 0$ to $t = 10$s, there is no motion.

From $t = 10$s to $t = 20$s, there will be kinetic friction.

$$f_k = \mu_k N = 0.4 \times 100 = 40\text{ N}$$

$$P(t = 20\text{s}) = P_{max} = 100\text{ N}$$

$$P(t = 10s) = P_{min} = 50 \text{ N}$$

Since, the force P increases linearly with time during time, t = 10s to t = 20s, so average concept is valid here.

$$P_{avg} = \frac{P_{max} + P_{min}}{2} = \frac{100 + 50}{2} = 75 \text{ N}$$

$$\text{Average resultant force} = P_{avg} - f_k = 75 - 40 = 35 \text{ N}$$

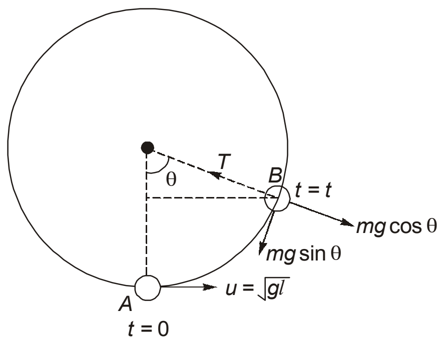
$$\text{Average acceleration} = \frac{35 \times 9.81}{100} = 3.4335 \text{ m/s}^2$$

$$v = \cancel{u}^{o} + at$$

$$= at = (3.4335) \times (20 - 10) = 34.335 \text{ m/s}$$

$$\approx 34.34 \text{ m/s}$$

17. (c)



Let $T = mg$ at angle θ shown in figure

$$h = l(1 - \cos\theta) \quad ...(1)$$

Apply conservation of mechanical energy between points A and B,

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

$$u^2 = gl \quad ...(2)$$

v = Speed of particle in position on B

$$v^2 = u^2 - 2gh \quad ...(3)$$

$$T - mg\cos\theta = \frac{mv^2}{l}$$

$$mg - mg\cos\theta = \frac{mv^2}{l}$$

$$\Rightarrow \quad v^2 = gl(1 - \cos\theta) \quad ...(4)$$

Substituting the values of v^2, u^2 and h from equations (4), (2) and (1) in equation (3).

$$gl(1 - \cos\theta) = gl - 2gl(1 - \cos\theta)$$

$$\cos\theta = \frac{2}{3}$$

$$\theta = \cos^{-1}\left(\frac{2}{3}\right)$$

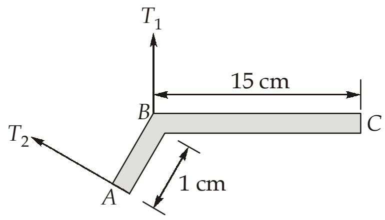
Substituting $\cos\theta = \frac{2}{3}$ in equation (4),

$$v = \sqrt{\frac{gl}{3}}$$

18. (b)

Given: Coefficient of friction, $\mu_k = 0.20$, Contact angle, $\theta = \frac{240}{180}\pi = 4.189 \text{ rad}$, Torque, $\tau = 200$ N-m

Since, the drum is rotating in the clockwise direction. The frictional resistance acting on the drum will be in the clockwise direction. Therefore, tension T_2 will act on the left end of the band and tension T_1 at the right end.



$$\text{Torque, } \tau = (T_2 - T_1)r$$
$$200 = (T_2 - T_1) \times 0.25$$
$$T_2 - T_1 = 800 \text{ N} \quad \text{... (i)}$$

Also,
$$\frac{T_2}{T_1} = e^{\mu_k \theta} = e^{0.2 \times 4.189}$$
$$T_1 = 0.433 T_2 \quad \text{... (ii)}$$

Solving equation (i) and (ii),

$$T_2 = \frac{800}{(1 - 0.433)} = 1410.93 \text{ N}$$

Taking moment about the point B,
$\Sigma M_B = 0$,

$$-T_2 \times 1 + P \times 15 = 0$$
$$P = \frac{T_2 \times 1}{15} = \frac{1410.93 \times 1}{15} = 94.06 \text{ N}$$

19. (b)

Given: Pitch (P) = 12 mm, Mean radius (r) = $\frac{80}{2} = 40 \text{ mm}$, Coefficient of static friction (μ_s) = 0.15,

Coefficient of kinetic friction (μ_k) = 0.10, Lever length (a) = 600 mm, Weight to be lifted (W) = 25 kN.
Since, the screw is single threaded, lead (C) = Pitch(P) = 12 mm.
Determination of helix angle,

$$\tan\theta = \frac{L}{2\pi r} = \frac{12}{2\pi \times 40} = 0.0477$$
$$\theta = \tan^{-1}(0.0477) = 2.733°$$

Force required to just lift a weight of 25 kN.

$$\tan\phi_s = \mu_s$$
$$\phi_s = \tan^{-1}(\mu_s) = \tan^{-1}(0.15)$$
$$\phi_s = 8.53°$$
$$\phi_s + \theta = 8.53° + 2.733° = 11.263°$$
$$\tan(\phi_s + \theta) = \tan(11.263) = 0.199$$

Therefore, the force required to just raise the load is given as:

$$P = \frac{Wr}{a}\tan(\phi_s + \theta)$$

$$= \frac{25000 \times 0.04}{0.6} \times 0.199 = 331.67 \text{ N}$$

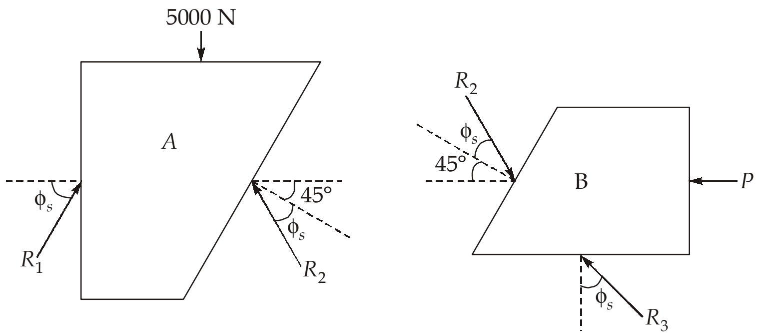
20. (c)

Coefficient of friction, μ_s = 0.2.

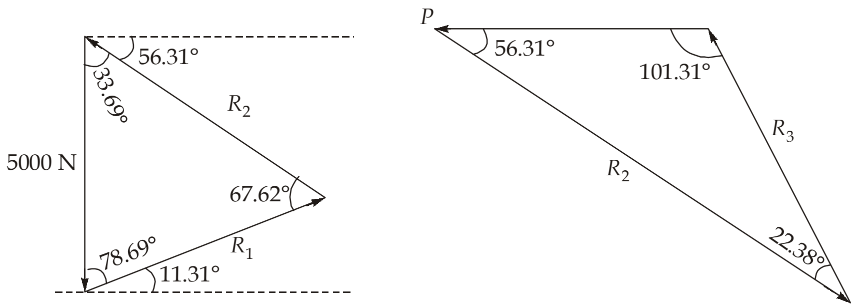
Here the force P is required to maintain the equilibrium. The direction of impending motion of the block A is downwards and that of block B is rightwards.

The free body-diagrams of the block are:

[Angle of friction: $\phi_s = \tan^{-1}\mu$, $\phi_s = \tan^{-1}(0.2)$, $\phi_s = 11.31°$]



Making force triangles for A and B



Applying Lami's theorem for block A

$$\frac{5000}{\sin 67.62°} = \frac{R_1}{\sin 33.69°} = \frac{R_2}{\sin(78.69°)}$$

$$\therefore \quad R_2 = 5000 \times \frac{\sin(78.69°)}{\sin(67.62°)} = 5302.27 \text{ N}$$

From Lami's theorem for block B

$$\frac{P}{\sin(22.38°)} = \frac{R_3}{\sin(101.31°)} = \frac{R_3}{\sin(56.31°)}$$

$$\therefore \quad P = R_2 \times \frac{\sin(22.38°)}{\sin(101.31°)}$$

$$P = 5302.27 \times \frac{\sin(22.38°)}{\sin(101.31°)} = 2058.81 \text{ N}$$

21. (a)

The area under the force displacement curve will give the net work done by the force on the particle.

$$W_{net} = 10\times 2-\frac{1}{2}\times 10\times 2 = 20-10 = 10\text{ J}$$

Using work energy theorem,

$$W_{net} = \text{Change in kinetic energy}$$

$$10 = (KE)_f - KE_i$$

$$10 = \frac{1}{2}Mv^2 - 0$$

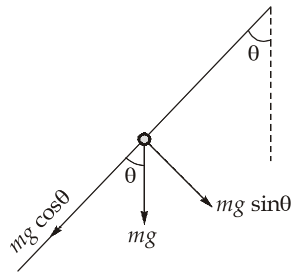
$$v = \sqrt{\frac{20}{M}} = \sqrt{\frac{20}{5}} = \sqrt{4} = 2\text{ m/s}$$

22. (a)

Value of AB is given as,

$$AB = 2R\cos\theta$$

Free-body diagram of the bead is given by



Acceleration of bead along AB is given as

$$a = \frac{F_{net}}{m} = \frac{mg\cos\theta}{m} = g\cos\theta$$

Using 2nd equation of kinematics along AB,

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

$$AB = \frac{1}{2}at^2$$

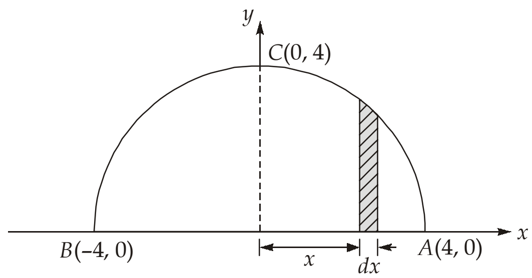
$$\therefore \quad 2R\cos\theta = \frac{1}{2}\times g\cos\theta\times t^2$$

$$\therefore \quad 2R = \frac{g}{2}t^2$$

$$t = 2\sqrt{\frac{R}{g}}$$

23. (b)

The co-ordinates of the plate on the axis are:



Let ρ be the area density of the plate,

$$\rho = \frac{m}{A} = \frac{W}{gA}$$

The mass of an element ydx at a distance x from the y-axis is,

$$dm = \frac{W}{gA}ydx$$

Using the formula for moment of inertia,

$$I_{y\text{-axis}} = \int r^2 dm = \int x^2 \frac{W}{gA} y dx$$

$$= \frac{W}{gA}\int_{-4}^{4} x^2\left(4 - \frac{x^2}{4}\right)dx = \frac{W}{gA}\int_{-4}^{4}\left(4x^2 - \frac{x^4}{4}\right)dx$$

$$= \frac{W}{gA}\left[\frac{4x^3}{3} - \frac{x^5}{20}\right]_{-4}^{4} = \frac{W}{gA}(68.26) \quad \text{... (i)}$$

Area of the plate is $A = \int\left(4 - \frac{x^2}{4}\right)dx = \left[4x - \frac{x^3}{12}\right]_{-4}^{4}$

$A = 21.33 \text{ m}^2$

Putting this value of area in equation (i)

$$I_{y\text{-axis}} = \frac{W}{g \times 21.33} \times (68.26) = 6.52 \text{ kg} - \text{m}^2$$

24. (b)

Radius of ring, r = 1 m

Side of square, a = $2r = 2 \times 1 = 2$ m

Linear density of wire, ρ = 1 kg/m

Mass of the ring, $m_r = 2\pi r\rho$

$m_r = 2\pi \times 1 \times 1 = 6.28$ kg

Moment of inertia of ring,

$I_r = m_r r^2 = 6.28 \times 1 = 6.28 \text{ kg-m}^2$

Mass of one side of square,

$m_a = 2 \times 1 = 2$kg

Moment of inertia of one side of the square about it centre.

$$I_a = \frac{ma^2}{12} = \frac{2 \times 2^2}{12} = \frac{8}{12} = \frac{2}{3} \text{ kg-m}^2$$

Using parallel axis theorem to find the moment of inertia of one side about the centre of mass of the frame.

$$I_{ac} = I_a + mr^2 = \frac{2}{3} + 2 \times 1^2$$

$$I_{ac} = \frac{2}{3} + 2 = \frac{8}{3} \text{ kg-m}^2$$

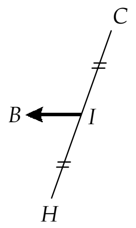
Moment of inertia of square,

$$I_s = 4I_{ac} = 4 \times \frac{8}{3} = \frac{32}{3} \text{ kg-m}^2$$

Total moment of inertia, $I = I_s + I_m = \frac{32}{3} + 6.28 = 16.95 \text{ kg-m}^2$

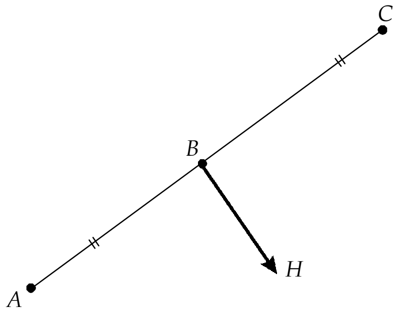
25. **(a)**

As in the given truss,



$$F_{CI} = F_{IH}$$

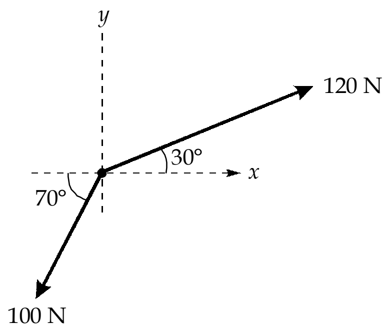
Therefore, $F_{BI} = 0$ (zero force member)



$$F_{CB} = F_{AB}$$

Therefore, $F_{BH} = 0$ (also zero force member)

26. **(a)**



$$\Sigma F_x = 120 \cos 30° - 100 \cos 70° = 69.72 \text{ N}$$

$$\Sigma F_y = 120 \sin 30° - 100 \sin 70° = -33.969 \text{ N}$$

$$\text{Resultant force, } R = \sqrt{(F_x)^2 + (F_y)^2}$$

$$= \sqrt{(69.72)^2 + (-33.969)^2} = 77.55 \text{ N} \simeq 78 \text{ N}$$

27. **(a)**

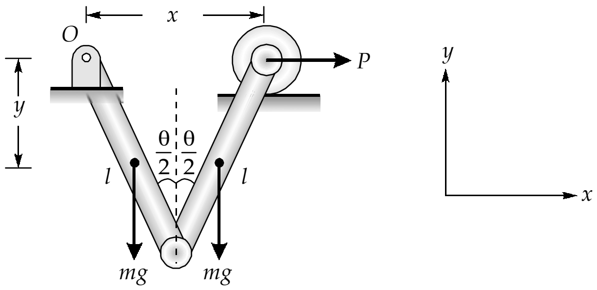
Conservation of linear momentum,

$$(m_A v_A)_i + (m_B \times v_B)_i = (m_A + m_B)v_f$$

$$15000 \times 1.5 + (-12000 \times 0.75) = 27000 \times v_f$$

$$v_f = 0.5 \text{ m/s}$$

28. (c)



$$x = 2l\sin\frac{\theta}{2}$$

$$\partial x = l\cos\frac{\theta}{2}\partial\theta$$

$$y = -\frac{l}{2}\cos\frac{\theta}{2}$$

$$\partial y = +\frac{l}{4}\sin\frac{\theta}{2}\partial\theta$$

$$+P(\partial x) + (-2mg)\cdot\partial y = 0$$

$$P\left(l\cos\frac{\theta}{2}\partial\theta\right) - 2mg\left(\frac{l}{4}\sin\frac{\theta}{2}\partial\theta\right) = 0$$

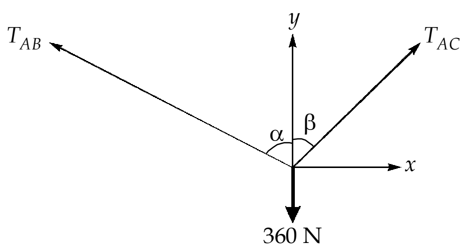
$$Pl\cos\frac{\theta}{2}\partial\theta = 2mg\times\frac{l}{4}\sin\frac{\theta}{2}\partial\theta$$

$$\tan\frac{\theta}{2} = \frac{2P}{mg}$$

$$\theta = 2\tan^{-1}\left(\frac{2P}{mg}\right)$$

29. (a)

As per given condition,



T_{AB} = 185 N
T_{AC} = 200 N

$$T_{AB}\sin\alpha = T_{AC}\sin\beta$$

$$\sin\alpha = \frac{200}{185}\sin\beta \quad \text{...(i)}$$

$$T_{AB}\cos\alpha + T_{AC}\cos\beta = 360$$

$$\cos\alpha = \frac{360}{185} - \frac{200}{185}\cos\beta \quad \text{...(ii)}$$

From equation (i) and (ii), we get

$$1 = \left(\frac{200}{185}\right)^2 + \left(\frac{360}{185}\right)^2 - \left(2 \times \frac{360 \times 200}{185^2} \cos\beta\right)$$

$$2 \times \frac{360 \times 200}{185^2} \cos\beta = 3.955$$

$$\cos\beta = 0.9401$$

$$\beta = 19.9° \simeq 20°$$

$$\sin\alpha = \frac{200}{185} \sin 20°$$

$$\alpha = 21.7°$$

30. **(c)**

Moment about the point '*c*'

$$\text{(Vector method), } M_c = \vec{r} \times \vec{F}$$

$$\text{Force vector, } \vec{F} = 500 \frac{\overrightarrow{AB}}{|\overrightarrow{AB}|}$$

$$= 500\left(\frac{2\hat{i} - 4\hat{j} + 3k}{\sqrt{(2)^2 + (-4)^2 + (3)^2}}\right)$$

$$= 92.847\left(2\hat{i} - 4\hat{j} + 3k\right)$$

$$\text{Position vector, } r_{CA} = -2\hat{i} - 0\hat{j} + 0\hat{k}$$

$$M_C = \vec{r}_{CA} \times \vec{F}$$

$$= \left(-2\hat{i}\right)[92.847\left(2\hat{i} - 4\hat{j} + 3\hat{k}\right)]$$

$$M_C = 92.847 \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -2 & 0 & 0 \\ 2 & -4 & 3 \end{vmatrix}$$

$$= 92.847\left(6\hat{j} + 8\hat{k}\right)$$

$$= 557.086\hat{j} + 742.776\hat{k}$$

$$\text{Magnitude, } M_C = \sqrt{(557.086)^2 + (742.776)^2}$$

$$M_C = 928.47 \text{ Nm}$$

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