CLASS TEST

S.No.: 01SKCE_E_28032025

MADE EASY

Leading Institute for IES, GATE & PSUs

Delhi | Bhopal | Hyderabad | Jaipur | Pune | Kolkata

Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

ENGINEERING MECHANICS

CIVIL ENGINEERING

Date of Test : 28/03/2025

ANSWER KEY

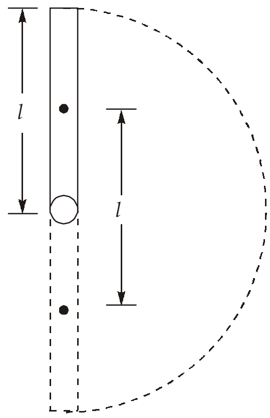
1.	(a)	7.	(d)	13.	(c)	19.	(c)	25.	(b)
2.	(a)	8.	(d)	14.	(d)	20.	(d)	26.	(c)
3.	(d)	9.	(b)	15.	(b)	21.	(b)	27.	(b)
4.	(b)	10.	(d)	16.	(a)	22.	(d)	28.	(b)
5.	(b)	11.	(c)	17.	(c)	23.	(b)	29.	(d)
6.	(c)	12.	(c)	18.	(a)	24.	(c)	30.	(c)

DETAILED EXPLANATIONS

1. (a)

As the rod reaches it lowest position, the center of mass is lowered by a distance l. Its gravitational potential energy is decreased by mgl.

Rotation occurs about the horizontal axis through the clamped end.



$$\text{Moment of inertia, } I = \frac{ml^2}{3}$$

Now, by energy conservation;

$$\frac{1}{2}I\omega^2 = (mgl)$$

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

$$\omega^2 = \frac{6g}{l}$$

$$\omega = \sqrt{\frac{6g}{l}}$$

Linear speed of the free end at given instant, $v = l\omega$

$$V = l\times\sqrt{\frac{6g}{l}}$$

$$V = \sqrt{6gl}$$

2. (a)

The acceleration of the centre of mass,

$$a_{cm} = \left(\frac{F}{m+m}\right) = \frac{F}{2m}$$

The change in position of the centre of mass at time t,

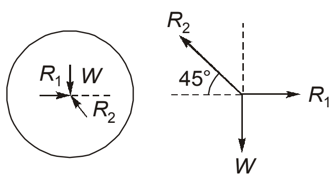
$$x = \frac{1}{2}(a_{cm})\times t^2 = \frac{1}{2}\times\left(\frac{F}{2m}\right)\times t^2 = \frac{Ft^2}{4m} \quad \text{(initial velocity is zero)}$$

3. (d)

$$\text{Rate of change of speed} = \frac{\vec{v}\cdot\vec{a}}{|\vec{v}|} = \frac{(\hat{i}+2\hat{j}+3\hat{k})\cdot(2\hat{i}+3\hat{j})}{\sqrt{1+4+9}} \simeq 2.14 \text{ m/s}^2$$

Note: Rate of change of speed means the component of acceleration in the direction of velocity.

4. (b)



$$R_2 \cos 45° = R_1$$
$$R_2 \sin 45° = W$$
$$\Rightarrow \quad R_2 = W\sqrt{2}$$
$$\therefore \quad R_1 = W\sqrt{2}\times\frac{1}{\sqrt{2}} = W$$
$$W = 50 \text{ N}$$
$$\therefore \quad R_1 = 50 \text{ N}$$

5. (b)

As per given information,

$$h = 40 \text{ m}, u = 50 \text{ m/s}$$

Let the speed be 'v' when it strike to the ground

Apply law of conservation of energy

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

$$m \times 10 \times 40 + \frac{1}{2} \times m \times (50)^2 = \frac{1}{2} \times m \times v^2$$

$$400 + 1250 = \frac{v^2}{2}$$

$$v = 57.44 \text{ m/s}$$

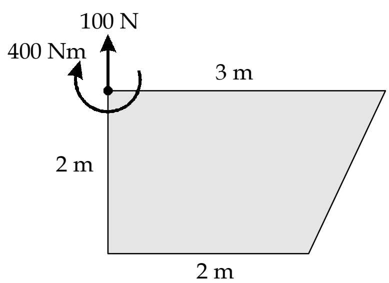
6. (c)

Force in member AH should be zero, as the AH is corner member with only two member connected to each other at 90°. Hence in both member AH and GH force is zero.

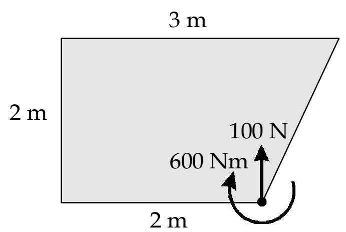
7. (d)

8. (d)

Force-couple system,



Equivalent force couple system,



9. (b)

When body is at rest, for equilibrium,

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

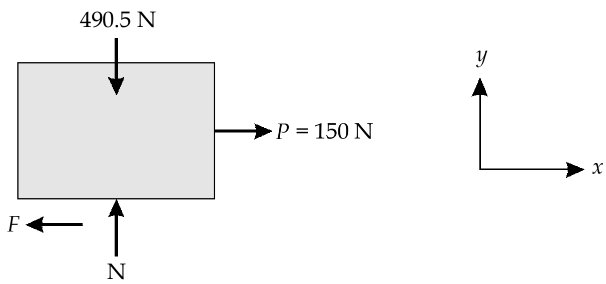
$$\text{Applied force, } P = 150 \text{ N}$$

Maximum static friction force,

$$F_{max} = \mu_s N$$

$$= 0.5\ (490.5)$$

$$= 245.25 \text{ N}$$



Because $P < F_{max}$, we conclude that the block is in static equilibrium and correct value of friction force is,

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

10. **(d)**

Let u, v, w be the components of velocity in x, y and z direction respectively.

$$u = \frac{dx}{dt} = 2\cos t$$

Similarly,
$$v = -3\sin t$$
$$w = \sqrt{5}\cos t$$
$$V = \sqrt{u^2+v^2+w^2} = \sqrt{(2\cos t)^2+(-3\sin t)^2+\left(\sqrt{5}\cos t\right)^2}$$
$$V = \sqrt{4\cos^2 t+9\sin^2 t+5\cos^2 t}$$
$$V = \sqrt{9\left(\sin^2 t+\cos^2 t\right)} = 3\,\text{units}$$

11. **(c)**

Given: Span = 10 m

Let, R_A and R_B are reaction at supports A and B respectively. The perpendicular distance between the support A and the line of action of the loads at D is

$$AD = \frac{10}{2\times\cos 30^\circ} = \frac{5}{\cos 30^\circ} = 5.77\text{ m}$$

The perpendicular distance between the support A and the line of action of the load at C.

$$AC = \frac{AD}{2} = \frac{5.77}{2} = 2.885\text{ m}$$

Taking moment about A,

$$R_B \times 10 = (4\times 2.885)+(2\times 5.77) \Rightarrow R_B = 2.308\text{ kN}$$
$$\text{Total wind load} = 2+4+2 = 8\text{ kN}$$

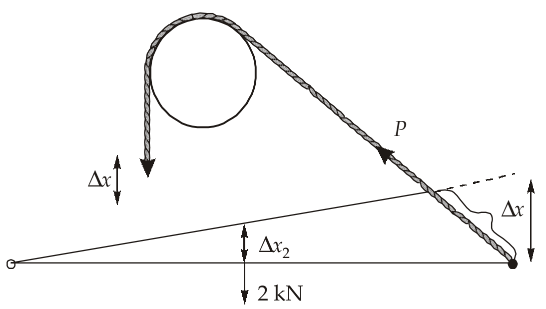
Horizontal component of total load, $(F_H)_{net}$ = 8 cos60° = 4 kN

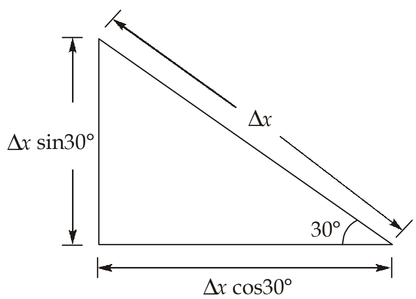
Vertical component of total load = 8 sin60° = 6.928 kN

Balance vertical reaction at A, $(R_A)_y$ = 4.620 kN

$$\text{Total reaction at } A,\ R_A = \sqrt{(R_A)_x^2+(R_A)_y^2} = \sqrt{4^2+4.62^2} = 6.111\text{ kN}$$

12. **(c)**





$$\delta x_2 = \frac{\Delta x\sin 30^\circ}{2}$$
$$F_2 = 2\text{ kN}$$
$$\delta x_1 = \Delta x\sin 30^\circ$$
$$F_1 = P\sin 30^\circ$$

$$F_1 \times \Delta x_1 = F_2 \times \Delta x_2$$

$$P\sin 30° \times \Delta x \sin 30° = 2 \times \frac{\Delta x \sin 30°}{2}$$

$$\Rightarrow \qquad P = 2 \text{ kN}$$

13. (c)

Given: $h_o = 1$ m = 100 cm; $h_1 = 81$ cm

Let, coefficient of restitution is e.

Velocity with which ball impinges, $u = \sqrt{2gh_o} = \sqrt{2g \times 100} = 10\sqrt{2g}$ cm/s

Velocity with which the ball rebounds, $v = \sqrt{2gh_1} = \sqrt{2g \times 81} = 9\sqrt{2g}$ cm/s

We know that,

$$v = eu$$

$$9\sqrt{2g} = e\left(10\sqrt{2g}\right)$$

$$e = 0.9$$

Velocity with which which the ball impinges second time, $u_2 = \sqrt{2gh_1} = \sqrt{2g \times 81} = 9\sqrt{2g}$ cm/s

Now, velocity with which ball rebounds, $v = eu$

$$\sqrt{2gh_2} = 0.9 \times 9\sqrt{2g}$$

$$h_2 = (8.1)^2$$

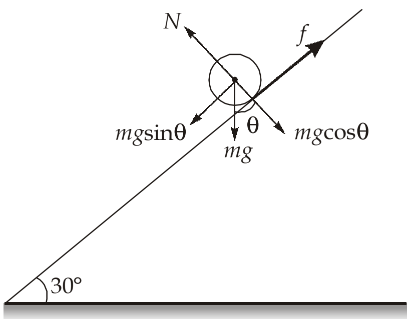
Expected height of second bounce, $h_2 = 65.61$ cm

14. (d)

Given, $m = 5$ kg, $\theta = 30°$

Let, linear acceleration of the sphere down the plane be a and radius of sphere is r.

Along the plane by Newton's II[nd] law,



$$mg\sin\theta - f = ma \qquad \text{...(1)}$$

If sphere rolls without slipping, angular acceleration about the center will be $\frac{a}{r}$.

Taking moment about center of mass,

$$f \times r = (I)\alpha$$

$$f \times r = \left(\frac{2}{5}mr^2\right) \times \left(\frac{a}{r}\right)$$

$$\text{Friction force, } f = \frac{2}{5}ma \qquad \text{...(2)}$$

By equation (1) and (2),

$$mg\sin\theta = \left(\frac{7}{5}\right)ma$$

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

$$\text{Frictional force, } f = \frac{2}{5}ma = \frac{2}{5}\times\frac{5}{7}mg\sin\theta = \frac{2}{7}mg\sin\theta$$

Maximum friction force will be $mg\cos\theta$. Where μ is coefficient of static friction.

$$\text{For pure rolling, } \mu mg\cos\theta \geq \frac{2}{7}mg\sin\theta$$

$$\mu \geq \frac{2}{7}\times\tan 30°$$

$$\Rightarrow \quad \mu \geq 0.165$$

15. **(b)**

As per given information,

m = 30 kg; r = 0.2 m

ω = 20 rad/s; T = 5 Nm

F = 10 N

$$I = \frac{1}{2}mr^2 = \frac{1}{2}\times 30\times 0.2^2 = 0.6 \text{ kg.m}^2$$

Let the disk rotate an angle of θ rad.

From work energy principle

$$T\cdot\theta + F\times r\cdot\theta = \frac{1}{2}\times I\times\omega^2 \qquad [\because \text{Workdone = change in energy}]$$

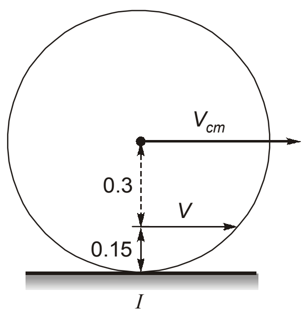
$$5\cdot\theta + 10\times 0.2\times\theta = \frac{1}{2}\times 0.6\times(20)^2$$

$$7\cdot\theta = 120$$

$$\theta = 17.14 \text{ rad}$$

$$\text{Number of revolution} = \frac{\theta}{2\pi} = \frac{17.14}{2\pi} = 2.73 \text{ rev}$$

16. **(a)**



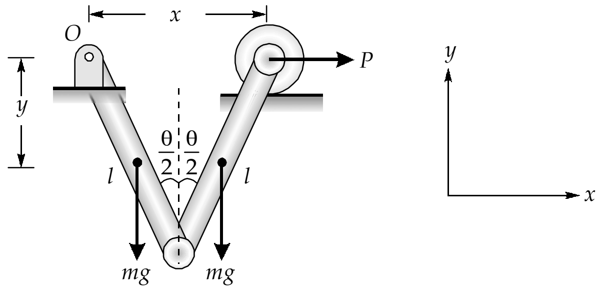
$$V_{cm} = 0.45\ \omega$$

$$\omega = \frac{3}{0.45} \text{ rad/s}$$

$$V = 0.15\ \omega = \frac{0.15\times 3}{0.45}$$

$$V = 1 \text{ m/s}$$

17. (c)



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

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

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

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

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

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

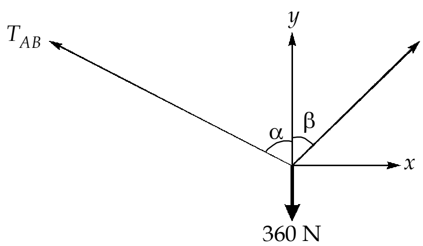
$$Pl\cos\frac{\theta}{2}\partial\theta = 2mg\times\frac{l}{4}\sin\frac{\theta}{2}\partial\theta$$

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

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

18. (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

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

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

$$\cos\beta = 0.9401$$

$$\beta = 19.9° \simeq 20°$$

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

$$\alpha = 21.7°$$

19. (c)

Moment about the point 'c'

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

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

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

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

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

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

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

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

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

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

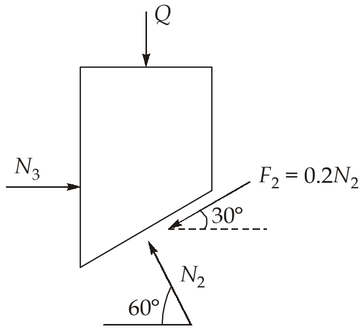
$$\text{Magnitude, } M_C = \sqrt{(557.086)^2+(742.776)^2}$$

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

20. (d)

From Newton's first law,

$\Sigma F_y = 0$



$N_2 \sin 60° - 0.2N_2 \sin 30° - Q = 0$

$$Q = 0.766\ N_2$$

$\Sigma F_X = 0$

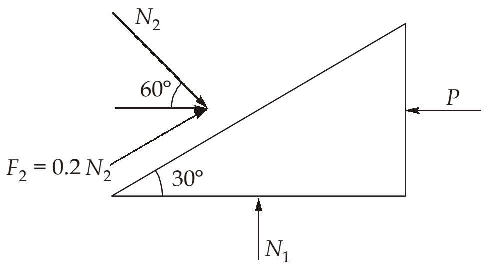
$N_2 \cos 60° + 0.2N_2 \cos 30° - P = 0$

$$P = 0.673\ N_2$$

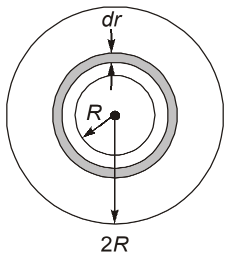
$$\frac{P}{Q} = \frac{0.673}{0.766}$$

$$P = 0.878Q \simeq 0.9Q$$

$$\alpha = 0.9$$



21. (b)



$\therefore$ I = Moment of inertia of disc

Total mass m is contained in area $3\pi R^2$

Let dm be the mass in area $2\pi r\,d\,r$

$$\therefore \quad dm = \frac{m \times 2\pi r dr}{3\pi R^2}$$

$$I = \int_R^{2R} dm\ r^2$$

$$\therefore \quad I = \frac{5}{2} mR^2$$

$$\text{K.E.} = (\text{K.E.})_{\text{translation}} + (\text{K.E.})_{\text{rotation}} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

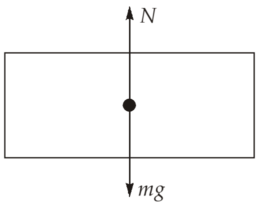
But $\quad V = 2R\omega$

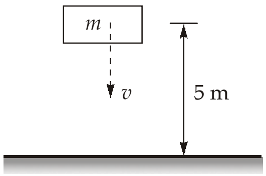
$$\therefore \quad \text{K.E.} = \frac{1}{2}mv^2 + \frac{1}{2}\times\frac{5R^2}{2}\times\frac{V^2}{4R^2} = \frac{1}{2}mv^2 + \frac{5}{16}mv^2$$

$$\text{K.E.} = \frac{8mv^2 + 5mv^2}{16} = \frac{13}{16}mv^2 = \frac{13}{16}\times 5\times(2)^2$$

$$\therefore \quad \text{K.E.} = 16.25 \text{ J}$$

22. (d)





Initial condition

Velocity when block reaches the ground = $\sqrt{2gh}$

$$= \sqrt{2\times10\times5} = 10 \text{ m/s}$$

By momentum conservation:

$(F) \times dt$ = Momentum just after striking the ground – momentum just before striking the ground

$$(N - mg)\times dt = m\times 0 - (-m\times 10)$$

$$(N - mg) = \frac{m\times 10}{dt}$$

$$N = \frac{10\times10}{(1/10)} + 10\times10$$

Force of interaction, N = 1100 N

23. (b)

$$mg(\sin\theta + \mu\cos\theta) = 3mg(\sin\theta - \mu\cos\theta)$$

$$(\sin45^\circ + \mu\cos45^\circ) = 3(\sin45 - \mu\cos45^\circ)$$

$$\mu = 0.5$$

24. (c)

$$a = \frac{dv}{dt}$$

Let resisting force,

$\Rightarrow \quad F = Kv^2$

Let m is mass of bullet

$$\therefore \quad a = \frac{F}{m} = \frac{Kv^2}{m}$$

$$\frac{dv}{dt} = \frac{Kv^2}{m}$$

$$\frac{1}{v^{-2}}dv = \frac{K}{m}dt$$

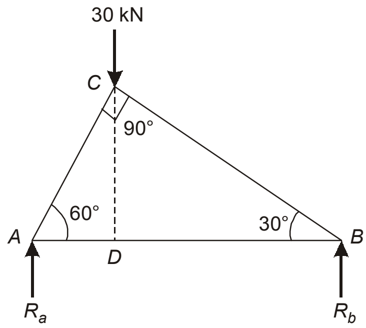
$$\left[\frac{v^{-1}}{-1}\right]_u^v = \frac{K}{m}\int_0^t dt$$

$$\Rightarrow \quad \left[\frac{v-u}{uv}\right] = \frac{K}{m}t$$

$$\Rightarrow \quad t = \frac{(u-v)}{uv}\times\frac{-m}{K}$$

$$\therefore \quad t \propto (u-v)\,(uv)^{-1}$$

25. (b)



$$AC = AB\cos 60° = 2.5\text{ m}$$

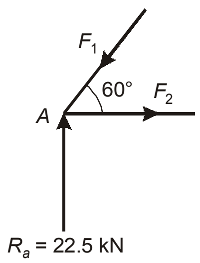
$$AD = AC\cos 60° = 2.5\times 0.5 = 1.25$$

$\therefore$ Taking moments about A,

$$R_b \times 5 = 30\times 1.25$$

$$R_b = 7.5\text{ kN},\quad R_a = 30 - 7.5 = 22.5\text{ kN}$$

Considering joint A,



$$\Sigma F_x = 0,\quad F_2 - F_1\cos 60° = 0$$

$$F_1\sin 60° - R_a = 0$$

$$F_1 = \frac{R_a}{\sin 60°} = \frac{22.5}{\sin 60°} = 25.97\text{ kN} \qquad \text{(compressive)}$$

$$F_2 = F_1\cos 60° = 12.99\text{ kN} \qquad \text{(tensile)}$$

$\therefore$ AB is in tension.

26. (c)

$$\text{Resistance} = \text{mg} + W = 200\times 9.81 + 100$$

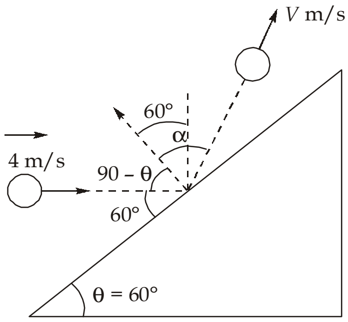
$$= 2062\text{ N}$$

$$\therefore \quad a = \frac{2062}{200}$$

$$a = 10.31\text{ m/s}^2$$

$$\frac{V^2}{2a} = S = \frac{4^2}{2\times 10.31} = 0.776\text{ m}$$

27. (b)



Since the impact is occuring normal to the incline, there will be no change in velocity along the incline so,

$$4\cos(60°) = V\sin\alpha$$

$$V\sin\alpha = 2 \qquad \text{...(i)}$$

Now,

$$\text{Coefficient of restitution} = \frac{\text{Velocity of separation along the line of impact}}{\text{Velocity of approach along the line of impact}}$$

$$e = \frac{V\cos\alpha}{4\sin(60°)}$$

$$0.5 = \frac{V\cos\alpha}{4\sin(60°)}$$

$$V\cos\alpha = 1.732 \qquad \text{...(ii)}$$

Dividing (i) by (ii)

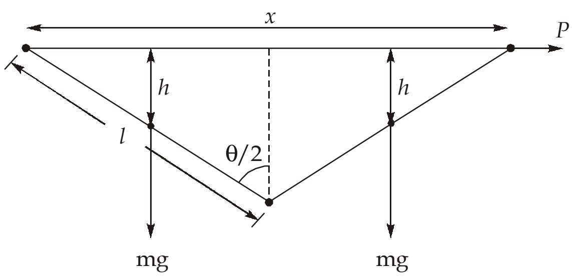
$$\tan\alpha = \frac{2}{1.732}$$

$$\alpha = 49.1074°$$

$$\text{Angle made with vertical} = 60 - 49.1074 = 10.8926°$$

28. (b)

Apply virtual work method,



$$x = 2l\sin\left(\frac{\theta}{2}\right)$$

$$h = \frac{l}{2}\cos\left(\frac{\theta}{2}\right)$$

$$\Rightarrow \quad dx = 2l\cos\left(\frac{\theta}{2}\right)\frac{d\theta}{2}$$

$$dh = -\frac{l}{2}\sin\left(\frac{\theta}{2}\right)\frac{d\theta}{2}$$

$$\Rightarrow \quad \frac{dx}{\cos\left(\frac{\theta}{2}\right)} = -\frac{dh}{\sin\left(\frac{\theta}{2}\right)} \times 4$$

By principle of virtual work,

$$\Rightarrow \quad Pdx + 2mgdh = 0 = \text{WD}$$

$$\Rightarrow \quad P \times dx = 2mg \times \tan\left(\frac{\theta}{2}\right) \times \frac{dx}{4}$$

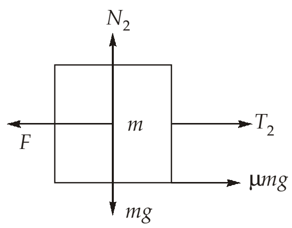
$$\Rightarrow \quad \frac{2P}{mg} = \tan\left(\frac{\theta}{2}\right)$$

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

$$\theta = 90°$$

29. (d)

FBD for M:



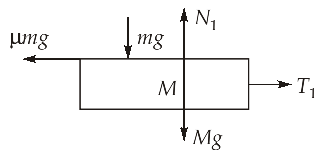
$$\Sigma F_x = 0$$

$$\Rightarrow \quad T_1 = \mu mg$$

$$\Sigma F_x = 0$$

$$N_1 = (M + m)g$$

FBD for m:

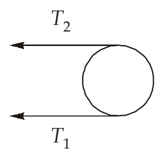


$$\Sigma F_x = 0$$

$$\Rightarrow \quad F = T_2 + \mu mg$$

Pulley:

Since T_2 is tension at tight side,



$$T_2 = T_1 e^{\mu\pi}$$

$$\Rightarrow \quad F = e^{\mu\pi} \times \mu mg + \mu mg$$

$$\Rightarrow \quad F = \mu mg\,(1 + e^{\mu\pi})$$

30. (c)

$$\therefore \quad \text{Impulse} = \text{Change in momentum}$$

$$\text{Area of graph} = m\,(V_f - V_i)$$

$$\frac{1}{2} \times 10 \times 10 + (20 \times 14) + (\frac{1}{2} \times 15 \times 14) = m\,(V - O)$$

But, $m = 1$

$$\Rightarrow \quad V = 435 \text{ m/s}$$

$$\text{Average force} = \frac{\text{Area of graph}}{\text{Total time}} = \frac{435}{45} = 9.666\,\text{N}$$

$$\text{Acceleration} = 9.666 \text{ m/s}$$

$$S = \frac{1}{2} \times 9.666 \times 45^2 + (15 \times 435)$$

($\because$ Body will travel with constant velocity of 435 m/s for the next 15 seconds after the removal of force)

$$S = 16312.5 \text{ m} = 16.312 \text{ km}$$

■■■■