CLASS TEST

S.No. : 03IGCE-B+D-07072023

MADE EASY

India's Best Institute for IES, GATE & PSUs

Delhi | Bhopal | Hyderabad | Jaipur | Pune | Bhubaneswar | Kolkata

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

ENGINEERING MECHANICS

CIVIL ENGINEERING

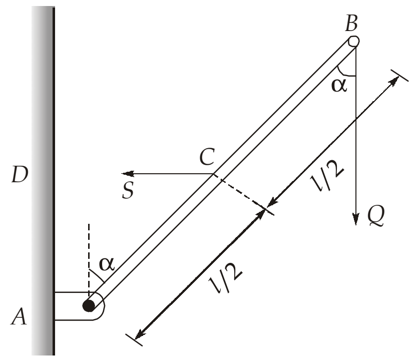
Date of Test : 07/07/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)



Taking moments about *A*

$$\Sigma M_A = 0$$

$$\Rightarrow \quad S \times \frac{l}{2} \cos\alpha = Ql \sin\alpha$$

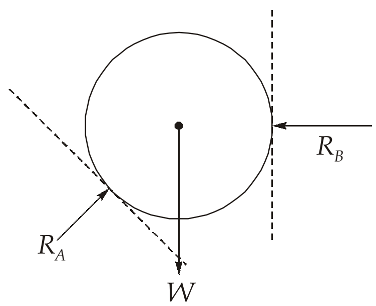
where *S* is tension developed in the string

$$\Rightarrow \quad S = \frac{Ql \sin\alpha}{\frac{l}{2}\cos\alpha}$$

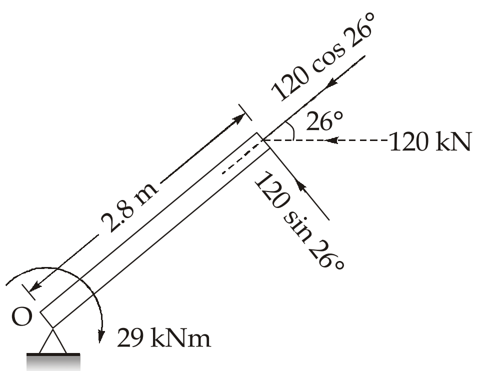
$$\Rightarrow \quad S = 2\,Q \tan\alpha$$

2. (d)

FBD of cylinder



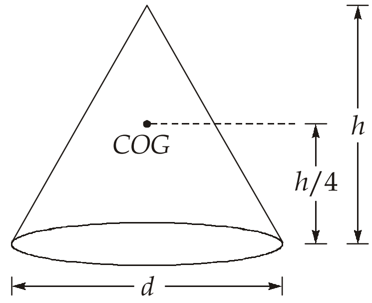
3. (c)



$$M_o = 120 \sin 26° \times 2.8 \text{ (CW)} - 29 \text{ (ACW)}$$
$$= 118.2927 \text{ kNm (CW)}$$

Reactive moment will be opposite of M_o i.e., ACW.

4. (c)

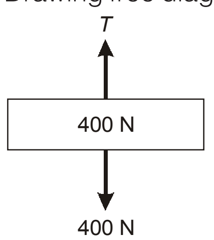


5. (b)

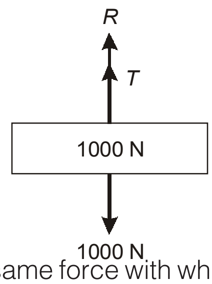
$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$
$$\omega_0 = 0$$
$$\theta = \frac{1}{2}\times 3\times 10^2 = 150 \text{ rad}$$
$$\therefore \text{ Number of revolutions} = \frac{150}{2\pi} = 23.87$$

6. (b)

Drawing free diagram of blocks, we have,



$\Rightarrow \quad T = 400$ N



$$T + R = 1000$$
$$\therefore \quad 400 + R = 1000$$
$$R = 600 \text{ N}$$

This is the reaction from the ground and it is the same force with which the 1000 N block press against the floor.

7. (b)

The velocity of point Q is zero, as the point Q is in contact with the surface.

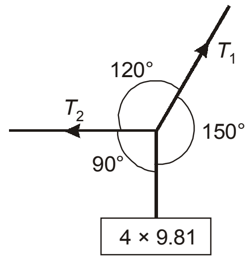
8. (a)

Torque, $\quad T = mg \times \frac{L}{2}$

$$I_0 = \frac{mL^2}{3}$$
$$\alpha = \frac{T}{I_0} = \frac{mgL}{2}\times\frac{3}{mL^2} = \frac{1.5g}{L}$$

9. (a)

As the body is in equilibrium, using Lami's theorem



$$\therefore \quad \frac{T_1}{\sin 90°} = \frac{4 \times 9.81}{\sin(120°)}$$

$$\therefore \quad T_1 = 45.310 \text{ N}$$

$$\frac{T_2}{\sin 150°} = \frac{4 \times 9.81}{\sin 120°}$$

$$\Rightarrow \quad T_2 = 22.65 \text{ N}$$

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,

$$v = -3\sin t$$

$$w = \sqrt{5}\cos t$$

$$V = \sqrt{u^2 + v^2 + w^2}$$

$$= \sqrt{(2\cos t)^2 + (-3\sin t)^2 + (\sqrt{5}\cos t)^2}$$

$$V = \sqrt{4\cos^2 t + 9\sin^2 t + 5\cos^2 t}$$

$$V = \sqrt{9(\sin^2 t + \cos^2 t)} = 3 \text{ units}$$

11. (c)

Shape	Area	Centroid from base
Square	$A_1 = d^2$	$y_1 = d/2$
Half circle	$A_2 = \pi d^2/8$	$y_2 = 2d/3\pi$

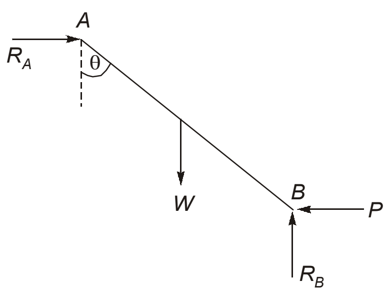
The centroid of hatched position from base.

$$\bar{y} = \frac{A_1 y_1 - A_2 y_2}{A_1 - A_2}$$

$$= \frac{d^2 \cdot \frac{d}{2} - \frac{\pi d^2}{8} \cdot \frac{2d}{3\pi}}{d^2 - \frac{\pi d^2}{8}} = \frac{10d}{3(8-\pi)}$$

12. (a)

Free body diagram of ladder is



Using equilibrium equations.

$$R_A = P$$

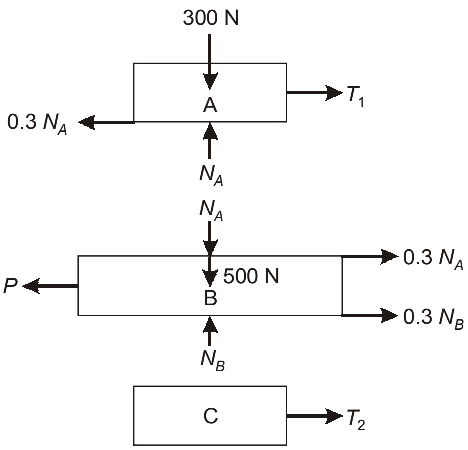
and $\quad R_B = W$

Taking moment about B.

$$R_A \cdot l\cos\theta = W \cdot \frac{l}{2}\sin\theta$$

$$R_A = \frac{1}{2}W\tan\theta = P$$

13. (a)



Considering first FBD of block A:

$$\Sigma F_y = 0$$

$\Rightarrow \quad N_A = 300$ N

$\Rightarrow \quad \Sigma F_x = 0$

$\Rightarrow \quad T = 0.3\ N_A = 0.3 \times 300 = 90$ N

Now consider FBD of block B:

$$\Sigma F_y = 0$$

$\Rightarrow \quad N_B = N_A + 500 = 300 + 500 = 800$ N

$$\Sigma F_x = 0$$

$\Rightarrow \quad P = 0.3\ N_A + 0.3\ N_B$

$\Rightarrow \quad P = 0.3\,(300 + 800)$

$= 330$ N

14. (c)

Let the initial velocity of moving vehicle is 'u'

Given; $W_1 = 2$ tonne, $W_2 = 1$ tonne

After collision skid mark length = 12 m

So velocity after collision, $(V_2) = \sqrt{2aS} = \sqrt{2 \times fg \times S}$

$$= \sqrt{2 \times 9.81 \times 0.5 \times 12} = 10.85 \text{ m/s}$$

To calculate velocity before collision, applying momentum conservation,

$$m_1 V_1 + m_2 \times 0 = (m_1 + m_2)V_2$$

$$2 \times V_1 = (2 \times 1) \times 10.85$$

$$V_1 = 16.27 \text{ m/s}$$

Now calculating initial velocity,

$\Rightarrow$ We know, $\quad V_1^2 = u^2 + 2aS$

$S = 40$ m, $\quad a = -fg = -0.5 \times 9.81 = -4.9$ m/s^2

$\Rightarrow \quad (16.27)^2 = u^2 - 4.9 \times 40 \times 2$

$u = 25.63$ m/s $= 92.25$ kmph

15. (d)

Equating potential and kinetic energy

$$\frac{1}{2}mw^2y^2 = \frac{1}{2}mw^2(a^2 - y^2)$$

$$\Rightarrow \quad y^2 = a^2 - y^2$$

$$a^2 = 2y^2$$

$$a = \sqrt{2}y$$

amplitude = 4 cm

$$y = \frac{4}{\sqrt{2}} = 2\sqrt{2} \text{ cm}$$

16. (b)

Mass of the block is m, therefore, stretch in the spring (x) is given by,

$$mg = kx$$

$$\Rightarrow \quad x = \frac{mg}{k}$$

Total mechanical energy of the system just after the blow is,

$$T_i = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$

$$\Rightarrow \quad T_i = \frac{1}{2}mv^2 + \frac{1}{2}k\left(\frac{mg}{k}\right)^2$$

$$\Rightarrow \quad T_i = \frac{1}{2}mv^2 + \frac{m^2g^2}{2k}$$

If the block descends through a height 'h' before coming to an instantaneous rest then the elastic potential energy becomes $\frac{1}{2}k\left(\frac{mg}{k} + h\right)^2$ and the gravitational potential energy will be $-mgh$.

$$\therefore \quad T_f = \frac{1}{2}k\left(\frac{mg}{k} + h\right)^2 - mgh$$

On applying conservation of energy, we get

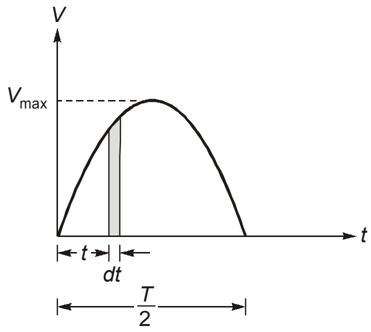
$$T_i = T_f$$

$$\Rightarrow \quad \frac{1}{2}mv^2 + \frac{m^2g^2}{2k} = \frac{1}{2}k\left(\frac{mg}{k} + h\right)^2 - mgh$$

$$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{1}{2}kh^2$$

$$\Rightarrow \quad h = v\sqrt{\frac{m}{k}}$$

17. (a)



Velocity at any instant, $V = V_{max} \sin\left(\frac{2\pi t}{T}\right)$

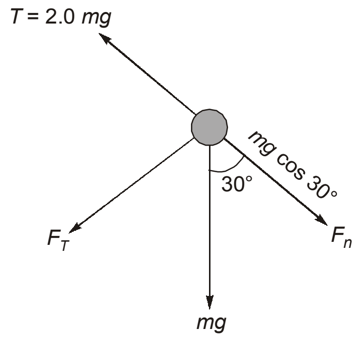
Consider the distance travelled through a small interval dt

$$dS = Vdt = V_{max} \sin\left(\frac{2\pi t}{T}\right) dt$$

$$\Rightarrow \quad S = \int_0^{T/2} V_{max} \sin\left(\frac{2\pi t}{T}\right) dt$$

$$= V_{max} \frac{T}{2\pi}\left[-\cos\left(\frac{2\pi t}{T}\right)\right]_0^{T/2} = V_{max}\frac{T}{\pi}$$

18. (d)



Tangential force, $F_T = mg \sin 30° = 0.5\, mg$

Normal force, $F_n = T - mg \cos 30°$

$\Rightarrow \quad F_n = 2\, mg - 0.866\, mg$

$\Rightarrow \quad F_n = 1.134\, mg$

Normal acceleration, $a_n = \frac{F_n}{m}$

$\Rightarrow \quad a_n = \frac{1.134\, mg}{m}$

$\Rightarrow \quad a_n = 1.134 \times 9.81 = 11.125 \text{ m/s}^2$

$\because \quad a_n = \frac{V^2}{R}$

$\Rightarrow \quad 11.125 = \frac{V^2}{1}$

$\Rightarrow \quad V = 3.34$ m/s

19. (a)

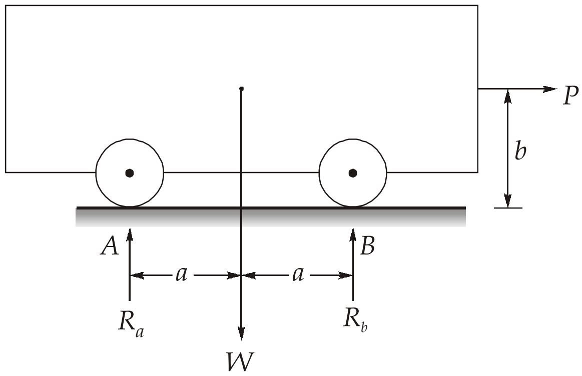
$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta} = \sqrt{90^2 + 140^2 + 2 \times 140 \times 90 \times \cos 70°} = 190.58 \text{ kN}$$

$$\tan\phi = \frac{Q\sin\theta}{P + Q\cos\theta}$$

$$= \frac{140\sin 70°}{90 + 140\cos 70°} = 0.954$$

$\therefore \quad \phi = 43°39'$

20. (d)



$$\Sigma F_V = 0$$

$$\Rightarrow \quad R_a + R_b = W$$

Taking moments about B,

$$\Sigma M_B = 0$$

$$\Rightarrow \quad R_a \times 2a + P \times b = W \times a$$

$$\Rightarrow \quad R_a = \frac{Wa - Pb}{2a}$$

$$\therefore \quad R_b = W - R_a$$

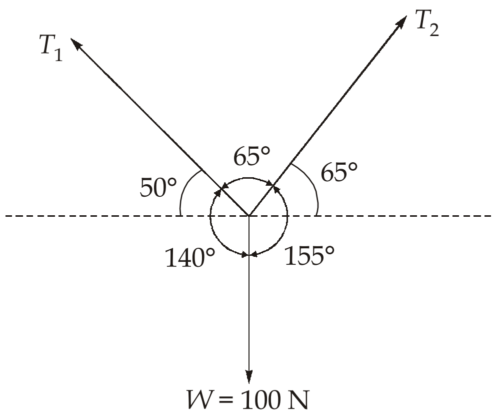
$$\Rightarrow \quad R_b = W - \left(\frac{Wa - Pb}{2a}\right)$$

$$\Rightarrow \quad R_b = \frac{Wa + Pb}{2a}$$

21. (b)

22. (b)

Free body diagram



Weight of the light fixture, W = 100 N

Let tension in the cable AB = T_1

and tension in the cable BC = T_2

Apply Lami's theorem $\dfrac{T_1}{\sin 155°} = \dfrac{T_2}{\sin 140°} = \dfrac{W}{\sin 65°}$

$$\therefore \quad \frac{T_1}{\sin 155°} = \frac{W}{\sin 65°} = \frac{100}{\sin 65°}$$

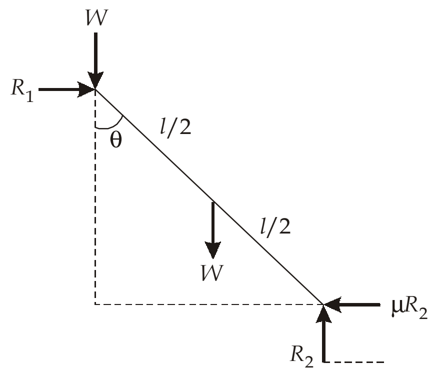
$\Rightarrow \quad T_1 = 46.63 \text{ N}$

Similarly,
$$\frac{T_2}{\sin 140^\circ} = \frac{W}{\sin 65^\circ} = \frac{100}{\sin 65^\circ}$$

$$\Rightarrow \quad T_2 = \frac{100 \times \sin 140^\circ}{\sin 65^\circ} = 70.92 \text{ N}$$

23. (c)

When man is on the top of the ladder, the free body diagram of ladder is



$$R_2 = W + W = 2W$$
$$R_1 = \mu R_2 = \mu \times 2W = 0.25 \times 2W = 0.5W$$

For moment equilibrium

$$R_1 l \cos\theta = Wl \sin\theta + 0.5\, Wl \sin\theta$$

$$\Rightarrow \quad \tan\theta = \frac{R_1}{1.5W} = \frac{0.5W}{1.5W}$$

$$\Rightarrow \quad \theta = \tan^{-1}\left(\frac{1}{3}\right)$$

So,
$$x = \left(\frac{1}{3}\right)$$

24. (d)

$$\text{Radial acceleration, } a_r = \frac{V^2}{R} = \frac{(40)^2}{1000} = 1.6 \text{ m/s}^2$$

$$\text{Total acceleration, } a = 2 \text{ m/s}^2$$

$\therefore$ Maximum deceleration with speed can be decreased is

$$\text{Tangential acceleration, } a_t = \sqrt{a^2 - a_r^2} = \sqrt{(2)^2 - (1.6)^2}$$
$$= \sqrt{4 - 2.56} = \sqrt{1.44} = 1.2 \text{ m/s}^2$$

25. (d)

For no tipping or prevent overturning

$$Ph < \frac{Wb}{2}$$

where W is weight of block

and b is width of block

$$h < \frac{Wb}{2P} \quad \text{...(1)}$$

and for slipping without tipping

$$P > f \text{(force of friction)}$$

$$P > \mu W \quad \text{...(2)}$$

From (1) and (2)

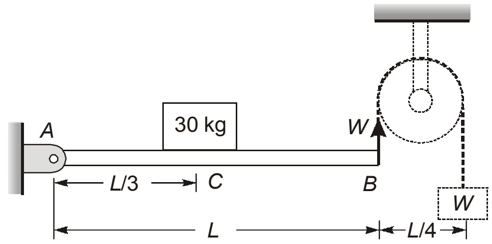
$$h < \frac{b}{2\mu}$$

$$\therefore \quad h < \frac{60}{0.6}$$

$$\therefore \quad h < 100 \text{ mm}$$

Option (d) is correct.

26. (c)



W is the tension in the string.

Taking moments from end A

$$W \times L = 30 \times 9.81 \times L/3$$

$$W = 98.1 \text{ N}$$

27. (b)

$$a = -t$$

$$dV = -tdt$$

$$V = -\frac{t^2}{2} + C_1$$

$$7.5 = 0 + C_1$$

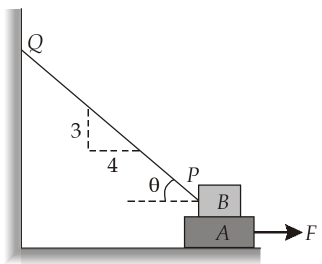
$$\therefore \quad C_1 = 7.5$$

$$V = -\frac{t^2}{2} + 7.5$$

$$V_{\text{at 3s}} = \frac{-3^2}{2} + 7.5 = 3 \text{ m/s}$$

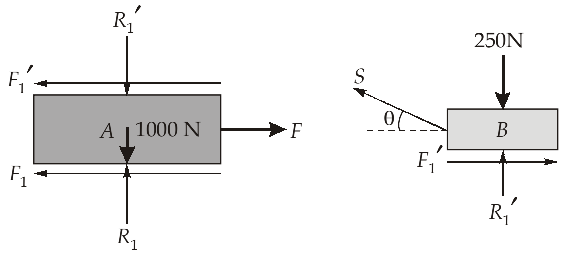
$$V_{\text{at 3s}} = 3 \text{ m/s}$$

28. (c)



$$\tan\theta = \frac{3}{4}$$

The free body diagrams of the blocks are shown below.



$$F_1 = \mu R_1 \text{ and } F_1' = \mu R_1' \quad \text{...(i)}$$

From equilibrium of block A,

$$F - F_1 - F_1' = 0 \quad \text{...(ii)}$$

and $$R_1 - W_1 - R_1' = 0 \quad \text{...(iii)}$$

But $$R_1 = \frac{F_1}{\mu} = W_1 + \frac{F_1'}{\mu} \quad \text{...(iv)}$$

From the equilibrium of block B,

$$F_1' - S\cos\theta = 0 \quad \text{...(v)}$$

and $$R_1' + S\sin\theta - W_2 = 0 \quad \text{...(vi)}$$

$\Rightarrow$ $$F_1' = \frac{W_2}{1/\mu + \tan\theta} \quad \text{...(vii)}$$

From equations (ii), (iv) and (vii), we get

$$F = \mu W_1 + \frac{2W_2}{\frac{1}{\mu} + \tan\theta} = 0.3 \times 1000 + \frac{2 \times 250}{\frac{1}{0.3} + \frac{3}{4}} = 422.45\text{N}$$

29. (a)

x-component of the resultant = 5 cos 37° + 3 cos0° + 2 cos 90°
= 3.99 + 3 + 0
= 6.99

y-component of the resultant = 5 sin 37° + 3 sin 0° + 2 sin 90°
= 3.01 + 2
= 5.01

$\therefore$ Magnitude of resultant vector = $\sqrt{6.99^2 + 5.01^2} = 8.6$

30. (a)

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

$$g = \frac{4\pi^2 L}{T^2}$$

In given problem $T = \frac{36}{20} = 1.8$ s

$\therefore$ $$g = \frac{4 \times \pi^2 \times 0.8}{1.8^2} = 9.75 \text{ m/s}^2$$

■■■■