CLASS TEST

S.No.:01_CE_ABC_01042024

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ENGINEERING MECHANICS

CIVIL ENGINEERING

Date of Test : 01/04/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega_0 = 0$$

$$\theta = \frac{1}{2}\times 2\times 10^2 = 100\,\text{rad}$$

$$\therefore \quad \text{Number of revolutions} = \frac{100}{2\pi} = 15.92$$

2. (d)

$$\text{Acceleration } (a) = \frac{dv}{dt} = 3t^2 - 2t$$

at $t = 3$ sec.

$$a = 3 \times 3 \times 3 - 2 \times 3 = 21 \text{ m/s}^2$$

3. (c)

The velocity of block embedded with bullet

$$v = \frac{401\times 0.01}{4+0.01} = 1\,\text{m/s}$$

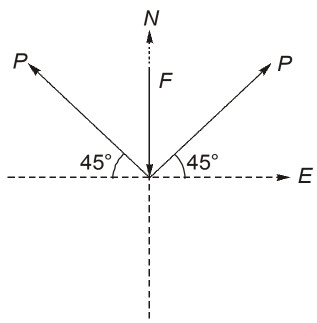
Kinetic energy loss $= kE_i - kE_f$

$$= \frac{1}{2}\times 0.01\times 401^2 - \frac{1}{2}\times 4.01\times 1^2$$

$$= 802 \text{ N} - \text{m}$$

4. (a)

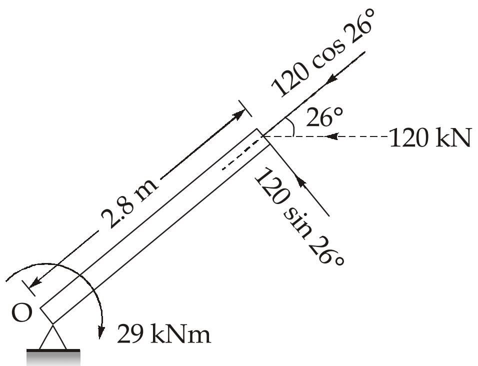
Considering equilibrium of forces in N-S direction



$$\left(\frac{P}{\sqrt{2}}\right) + \left(\frac{P}{\sqrt{2}}\right) - F = 0$$

$$F = \frac{2P}{\sqrt{2}} = \sqrt{2}P$$

5. (c)



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

6. (c)

$$\Sigma H = 25 - 20 = 5 \text{ kN } (\rightarrow)$$
$$\Sigma V = 50 + 35 = 85 \text{ kN } (\downarrow)$$

$\therefore$ Resultant force $= \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$

$$= \sqrt{5^2 + 85^2}$$
$$= 85.147 \text{ kN}$$

7. (d)

For perfectly elastic spheres $e = 1$

Using momentum equation.

$$m\vec{v}_2 + m\vec{v}_1 = 2m\vec{u} + m\vec{u} = 3m\vec{u}$$

$$\vec{v}_2 - \vec{v}_1 = 3\vec{u}$$

Using Newton's Law of collision of elastic bodies

$$\vec{v}_2 - \vec{v}_1 = e(2\vec{u} - \vec{u})\vec{u} \qquad (\therefore e = 1)$$

Solving

$$\vec{v}_2 = 2\vec{u}$$
$$\vec{v}_1 = \vec{u}$$

8. (c)

$$\omega = 12 + 9t - 3t^2$$

$$\frac{d\omega}{dt} = 9 - 6t = 0$$

$$\Rightarrow \quad t = 1.5\text{s}$$

$$\frac{d^2\omega}{dt^2} = -6 < 0$$

Hence, at t = 1.5 sec maximum value of angular velocity will occur

$$\therefore \quad \omega_{max} = 12 + 9 \times 1.5 - 3 \times 1.5^2$$
$$= 12 + 13.5 - 6.75$$
$$= 18.75 \text{ rad/s}$$

9. (c)

Let the shortest distance between ships will occur at time thereafter the ship A passes point O.

The distance of ship A from O = 20 t

The distance of ship B from O = 20 (2 – t)

The distance between ships

$$D = \sqrt{(20t)^2 + \{20(2-t)\}^2}$$

For shortest distance

$$\frac{dD}{dt} = 0 \quad \text{or} \quad \frac{d(D^2)}{dt} = 0$$
$$2 \times 20t - 20(2-t) \times 2 = 0$$
$$t = 1 \text{ hrs}$$

Shortest distance = $20\sqrt{2}$ km

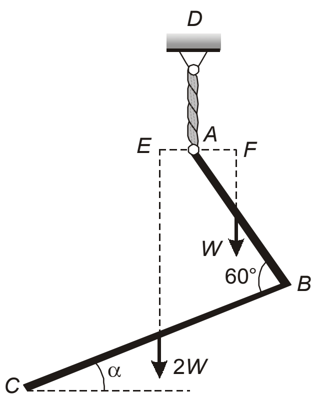
10. (c)

$$5g(2.1) = \frac{1}{2} \times 5 \times V^2 + \frac{1}{2} k\delta^2 \qquad [\because \quad k = 10000 \text{ N/m}]$$

$$\Rightarrow \quad 10.5g = 2.5V^2 + \frac{1}{2} \times 10000 \times (0.1)^2$$
$$\Rightarrow \quad 10.5 \times 9.81 = 2.5\, V^2 + 50$$
$$\Rightarrow \quad V^2 = 21.202$$
$$\therefore \quad V = 4.6 \text{ m/s}$$

11. (d)

Considering both bars together as a free body, we see that they are in equilibrium under the action of three parallel forces i.e. weights W and $2W$ and the vertical reaction exerted by the string AD.



For equilibrium condition,

$$\Sigma M_A = 0$$

$$\Rightarrow \qquad 2W \times AE - W \times AF = 0$$

$$\therefore \qquad AF = 2AE \qquad \text{...(i)}$$

Now, from the geometry of the system,

$$AF = \frac{L}{2}\cos(60^\circ - \alpha) \qquad \text{...(ii)}$$

and

$$AE = (L\cos\alpha - L\cos(60^\circ - \alpha)) \qquad \text{...(iii)}$$

From equations (i), (ii) and (iii), we get

$$\frac{L}{2}\cos(60^\circ - \alpha) = 2\,(L\cos\alpha - L\cos(60^\circ - \alpha))$$

$$\tan\alpha = \frac{\sqrt{3}}{5}$$

$$\alpha = 19.11^\circ$$

12. (a)

Since no external torque has acted, angular momentum will be conserved.

Applying conservation of angular momentum,

$$\therefore \qquad I\omega = I'\omega'$$

$$MR^2 \times \omega = (MR^2 + 2mR^2)\omega'$$

$$5 \times (0.2)^2 \times 10 = [5 \times (0.2)^2 + 2 \times 0.5 \times (0.2)^2]\omega'$$

$$\Rightarrow \qquad \omega' = 8.333 \text{ rad s}^{-1}$$

13. (d)

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

$$r = 2\hat{i} - 3\hat{j} + \hat{k}$$

$$\text{Angular momentum} = H = r \times I$$

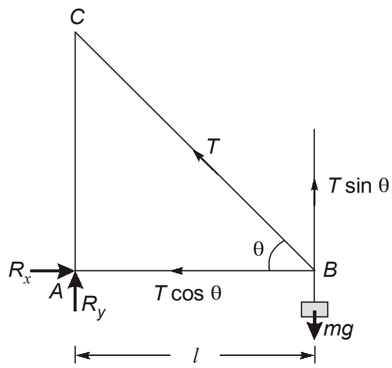
$$= (2\hat{i} - 3\hat{j} + \hat{k}) \times (-2\hat{i} - \hat{j} + \hat{k}) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & -3 & 2 \\ -2 & -1 & 1 \end{vmatrix}$$

$$= \hat{i}(-3 + 2) - \hat{j}(2 + 4) + \hat{k}(-2 - 6)$$

$$= \hat{i}(-1) - 6\hat{j} - 8\hat{k} = -\hat{i} - 6\hat{j} - 8\hat{k}$$

$$|H| = \sqrt{1^2 + 6^2 + 8^2} = 10.01 \text{ kg m}^2/\text{s} \simeq 10 \text{ kg m}^2/\text{s}$$

14. (c)



$$T\sin\theta + R_y = mg$$
$$T\cos\theta = R_x$$

Now, $$\tan\theta = \frac{125}{275}$$
$$\theta = 24.44°$$

Taking moments about *A*,
$$l \times T\sin\theta = l \times mg$$
$$\Rightarrow \quad T = \frac{35 \times 9.81}{\sin 24.44°} = 829.87 \text{ N}$$

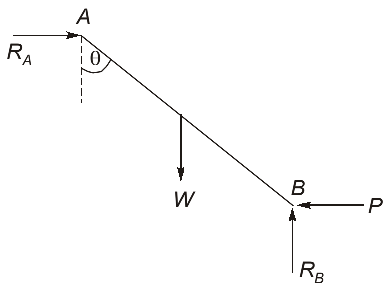
15. (c)

16. (d)

17. (c)

18. (a)

Free body diagram of ladder is



Using equilibrium equations.

$R_A = P$

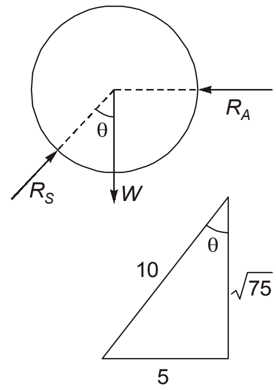
and $R_B = W$

Taking moment about *B*.

$$R_A \cdot l\cos\theta = W \cdot \frac{l}{2}\sin\theta$$
$$RA = \frac{1}{2}W\tan\theta = P$$

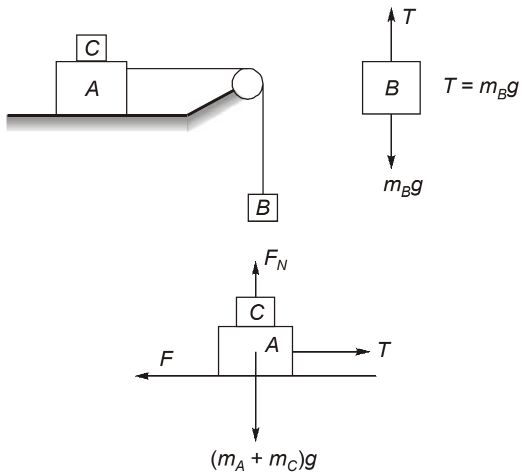
19. (b)

FBD



$$\Sigma F_y = 0$$
$$W = R_S \cos\theta$$
$$R_S = \frac{100 \times 10}{\sqrt{75}}$$
$$\cos\theta = \frac{\sqrt{75}}{10}$$
$$\sin\theta = \frac{5}{10}$$
$$\Sigma F_X = 0$$
$$R_S \sin\theta = R_A$$
$$\therefore \quad R_A = \frac{1000}{\sqrt{75}} \times \frac{5}{10} = 57.735\text{ N}$$

20. (b)

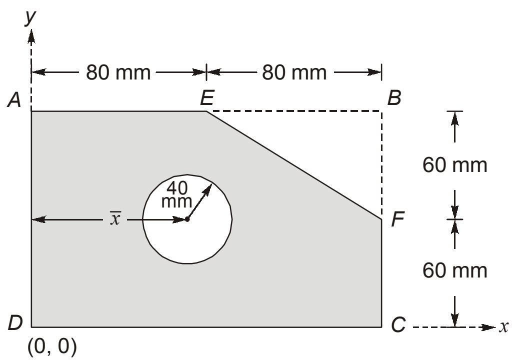


$$F_N = (m_A + m_C)g$$
$$F = T = m_B g$$

To prevent horizontal sliding

$$F = \mu F_N$$
$$\mu(m_A + m_C)g = m_B g$$
$$0.2(4.4 + m_C) = 2.6$$
$$\Rightarrow \quad m_C = 8.6\text{ kg}$$

21. (a)



S. No.	Shape	Area (mm^2)	$\bar{x}$ (mm)	$a\bar{x}$ (mm^3)
1	*ABCD*	19200	80	1536000
2	Circle	–5026.55	$\bar{x}$	$-5026.55\bar{x}$
3	ΔEBF	–2400	133.33	–320000
		$\sum a = 11773.45$		$\sum a\bar{x} = 1216000 - 5026.55\bar{x}$

Now,
$$\bar{x} = \frac{\sum a\bar{x}}{\sum a}$$

$$\Rightarrow \quad \bar{x} = \frac{1216000 - 5026.55\bar{x}}{11773.45}$$

$$\Rightarrow \quad \bar{x} = 72.38 \text{ mm}$$

22. (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

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

23. (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

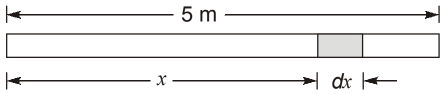
$$T_i = T_f$$

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

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

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

24. (b)



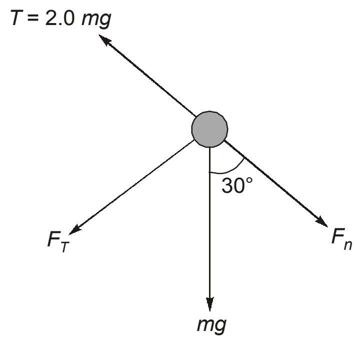
Let the cross-sectional area be α. The mass of an element (dm) of length dx located at a distance x away from the left end is $(0.5 + 3x)\alpha\, dx$. The x-coordinate of the centre of mass is given by,

$$X_{cm} = \frac{\int x\,dm}{\int dm} = \frac{\int_0^5 x(0.5+3x)\alpha\,dx}{\int_0^5 (0.5+3x)\alpha\,dx}$$

$$= \frac{\int_0^5 \left(0.5x+3x^2\right)\alpha\,dx}{\int_0^5 (0.5x+3x)\alpha\,dx} = \frac{0.5\left(\frac{5^2}{2}\right)+3\left(\frac{5^3}{3}\right)}{0.5\times 5+3\left(\frac{5^2}{2}\right)}$$

$$= \frac{6.25+125}{2.5+37.5} \simeq 3.28 \text{ m}$$

25. (d)



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

Normal force, $F_n = T - mg \cos 30°$

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

$\Rightarrow F_n = 1.134\, mg$

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

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

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

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

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

$\Rightarrow V = 3.34 \text{ m/s}$

■■■■