CLASS TEST

S.No. : 02 IG_CE_H_210423

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 : 21/04/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

$$I_P = I_x + I_y = \frac{bd^3}{12} + \frac{db^3}{12}$$

$$= \frac{bd}{12}\left(b^2 + d^2\right)$$

$$= \frac{2 \times 5}{12}\left(2^2 + 5^2\right) = 24.167 \text{ cm}^4$$

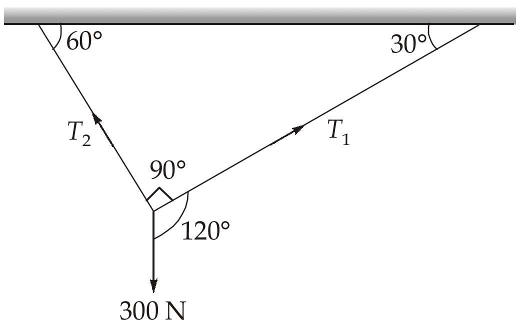
2. (c)

$$\text{Time period, } T = 2\pi\sqrt{\frac{l}{g}}$$

$$\therefore \quad \frac{T_A}{T_B} = \sqrt{\frac{l_A}{l_B}} = \frac{1}{2}$$

3. (d)

Using Lami's Theorem

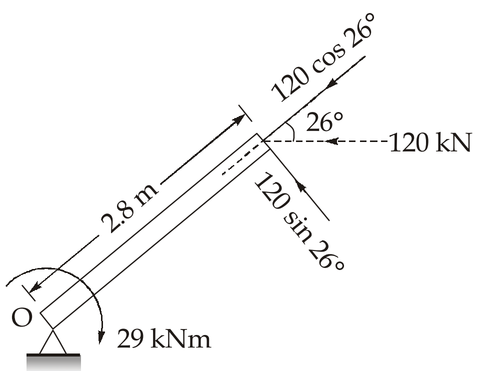


$$\frac{T_2}{\sin 120°} = \frac{T_1}{\sin\{360° - (90° + 120°)\}}$$

$$\Rightarrow \quad \frac{T_2}{T_1} = \frac{\sin 120°}{\sin 150°} = \frac{\sqrt{3}/2}{1/2} = \sqrt{3}$$

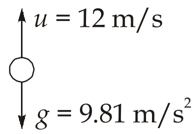
$$\Rightarrow \quad \frac{T_1}{T_2} = \frac{1}{\sqrt{3}} = 0.577$$

4. (c)



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

5. **(c)**

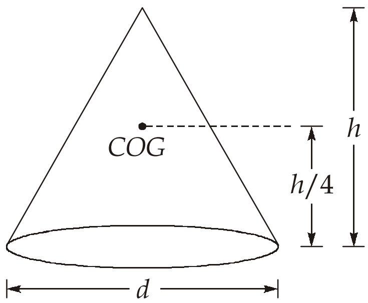


$$v = u + gt$$

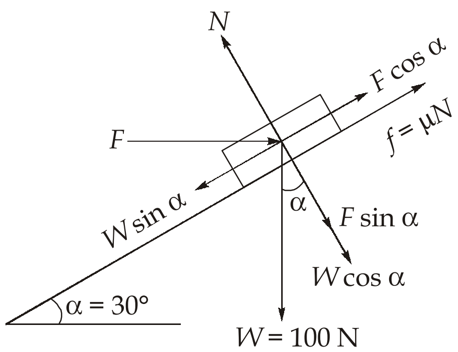
$$\Rightarrow \quad v = (-12) + 9.81 \times 2$$

$$= 7.62 \text{ m/sec}$$

6. **(c)**



7. **(b)**



$$N = W\cos\alpha + F\sin\alpha$$

$$W\sin\alpha = F\cos\alpha + f$$

$$\Rightarrow \quad W\sin\alpha = F\cos\alpha + \mu\,(W\cos\alpha + F\sin\alpha)$$

$$\Rightarrow \quad F\,(\cos\alpha + \mu\sin\alpha) = W\,(\sin\alpha - \mu\cos\alpha)$$

$$\Rightarrow \quad F = \frac{W(\sin\alpha - \mu\cos\alpha)}{\cos\alpha + \mu\sin\alpha}$$

$$= \frac{100(\sin 30° - 0.25 \times \cos 30°)}{\cos 30° + 0.25 \times \sin 30°}$$

$$= 28.606 \simeq 28.61 \text{ N}$$

8. **(c)**

$$\Sigma H = 25 - 20 = 5 \text{ kN } (\rightarrow)$$

$$\Sigma V = 50 + 35 = 85 \text{ kN } (\downarrow)$$

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

$$= \sqrt{5^2 + 85^2}$$

$$= 85.147 \text{ kN}$$

9. (d)

Angle of the bank,

$$\tan\theta = \frac{v^2}{gr} = \frac{25^2}{9.81 \times 200} = 0.3186$$

$$[v(\text{m/sec}) = 90\ (\text{km/hr}) \times \frac{5}{18} = 25\ \text{m/sec}]$$

$$\therefore \quad \theta = 17.7°$$

10. (b)

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

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

∴ Maximum deceleration with speed can be decreased is

$$\text{Tangential acceleration, } a_t = \sqrt{a^2 - a_r^2} = \sqrt{(2)^2 - (1.6)^2}$$

$$= \sqrt{4 - 2.56} = \sqrt{1.44} = 1.2\ \text{m/s}^2$$

11. (d)

Using energy principle,

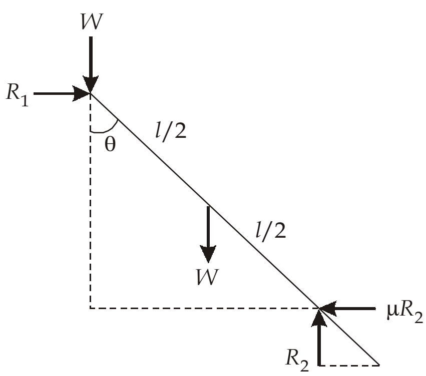
Initial energy = Final energy + Work done by air resistance

$$\Rightarrow \quad mgh_1 = mgh_2 + \frac{1}{2}mv^2 + W_{air}$$

$$\therefore \quad W_{air} = 5 \times 10 \times 20 - \frac{1}{2} \times 5 \times 10^2 = 750\ \text{J}$$

12. (b)

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



$$R_2 = W + W$$

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

For moment equilibrium

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

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

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

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

13. (a)

Applying conservation of angular momentum,

$$I\omega = I'\omega'$$

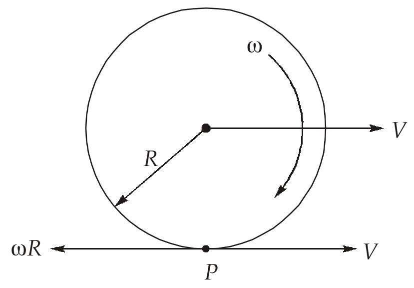
$$\Rightarrow \quad MR^2 \times \omega = \left(MR^2 + 2mR^2\right)\omega'$$

$$\Rightarrow \quad 5 \times (0.3)^2 \times 15 = \left(5 \times 0.3^2 + 2 \times 0.1 \times 0.3^2\right) \times \omega'$$

$$\Rightarrow \quad \omega' = 14.42 \text{ rad/s}$$

14. (b)

Point of contact is instantaneous centre of rotation where velocity is zero.



Net velocity at P (V_p) = $V - \omega R = 0$ ($\therefore$ In pure rolling $V = \omega R$)

15. (a)

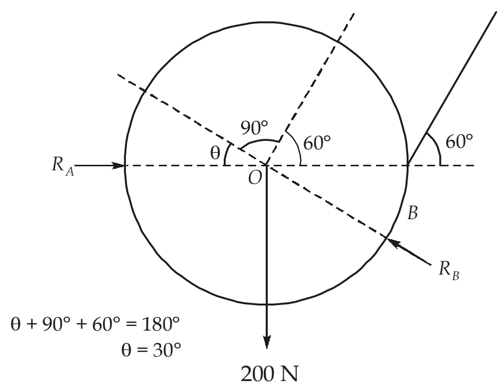
$$\text{KE} = \frac{1}{2}Iw^2$$

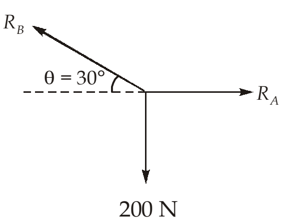
$$I = \frac{mr^2}{2} = \frac{20 \times 0.2^2}{2} = 0.4 \text{ kgm}^2$$

$$w = \frac{2\pi N}{60} = \frac{2 \times 3.14 \times 500}{60} = 52.33 \text{ rad/s}$$

$$\therefore \quad \text{KE} = \frac{1}{2} \times 0.4 \times 52.33^2 = 547.69 J$$

16. (a)





Using Lami's theorem

$$\frac{R_A}{\sin 120°} = \frac{200}{\sin 150°} = \frac{R_B}{\sin 90°}$$

$$\therefore \quad R_A = 200 \times \frac{\sin 120°}{\sin 150°} = 346.41 \text{ N}$$

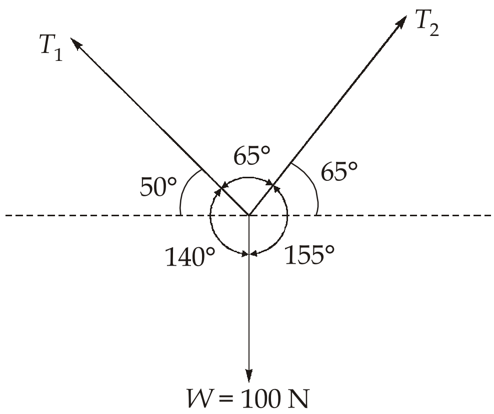
$$R_B = \frac{200 \times \sin 90°}{\sin 150°} = 400 \text{ N}$$

$$\therefore \quad R_A + R_B = 400 + 34641$$

$$= 746.41 \text{ N} \simeq 746.4 \text{ N}$$

17. (b)

Free body diagram



Weight of the light fixture, $W =$ 100 N

Lettension in the cable AB = T_1

andtension in the cable BC = T_2

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

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

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

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

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

18. (c)

$$v = u + at \text{(time taken to reach max heights } \frac{5}{2} = 2.5 \text{ sec)}$$

At the highest point, $v = 0$

$\therefore \quad u = (=)\ (gt) = gt (\because a = -g)$

$\Rightarrow \quad u = 9.81 \times 2.5$

$$= 24.525 \text{ m/sec}$$

Now, $v^2 = u^2 + 2\,ah$

$\Rightarrow$ $0 = u^2 - 2\,gh$

$\Rightarrow$ $24.525^2 = 2 \times 9.81 \times h$

$\Rightarrow$ $h = 30.66$ m

19. (c)

Given,initial velocity of train (u) = 0 (because it starts from rest)

Acceleration = a

Distance covered in 1st second = S_1

Distance covered in 2nd second = S_2

and distance covered in 3rd second = S_3

We know that distance covered by the train in 1st second,

$$S_1 = u + \frac{a}{2}(2n_1 - 1) = 0 + \frac{a}{2}[(2 \times 1) - 1] = \frac{a}{2} \quad \text{...(i)}$$

Similarly distance covered in 2nd second,

$$S_2 = u + \frac{a}{2}(2n_2 - 1) = 0 + \frac{a}{2}[(2 \times 2) - 1] = \frac{3a}{2} \quad \text{...(ii)}$$

and distance covered in 3rd second,

$$S_3 = u + \frac{a}{2}(2n_3 - 1) = 0 + \frac{a}{2}[(2 \times 3) - 1] = \frac{5a}{2} \quad \text{..(iii)}$$

$\therefore$Ratio of distances $S_1 : S_2 : S_3 = \frac{a}{2} : \frac{3a}{2} : \frac{5a}{2} = 1 : 3 : 5$

20. (d)

$$S = t^3 - 2t^2 + 3$$

$$V = \frac{dS}{dt} = 3t^2 - 4t$$

$$a = \frac{dV}{dt} = \frac{d^2S}{dt^2} = 6t - 4$$

$\therefore$ $a_{t = 5 \text{ sec}} = 6 \times 5 - 4$

$= 26 \text{ m/sec}^2$

21. (c)

Variable acceleration, $\frac{dv}{dt} = \alpha - \beta v$(where $\alpha = 4$ and $\beta = 0.05$)

$\Rightarrow$ $\frac{dv}{\alpha - \beta v} = dt$

Integrating, $\frac{\ln(\alpha - \beta v)}{-\beta} = t + C$(where C is constant of integration)

If initial velocity is v_o at $t = 0$ and at time $t = t$ velocity is v then

$\ln(\alpha - \beta v) - \ln(\alpha - \beta v_o) = -\beta t$

$\Rightarrow$ $\frac{\alpha - \beta v}{\alpha - \beta v_0} = e^{-\beta t}$

$\because \quad \alpha = 4;\ \beta = 0.05$

Initial velocity $= v_o = 30$ m/sec

$$\therefore \quad v = \frac{\alpha - (\alpha - \beta v_0)e^{-\beta b}}{\beta}$$

$$= \frac{4 - (4 - 0.05 \times 30)e^{-0.05\times 2}}{0.05}$$

$$= 34.758 \text{ m/s}$$

$\therefore$ At t = 2 sec, Acceleration $= \dfrac{dv}{dt}$

$$= 4 - 0.05v$$
$$= 4 - 0.05\ (34.758)$$
$$= 2.26 \text{ m/s}^2$$

22. (c)

For resultant to be in vertical direction,

$$\Sigma F_x = 0$$
$$\Rightarrow \quad 180 \cos\alpha = 100\cos\alpha + 160\cos(\alpha + 30°)$$
$$\Rightarrow \quad 80\cos\alpha = 160\cos(\alpha + 30°)$$
$$\Rightarrow \quad \cos\alpha = 2\,[\cos\alpha\cos 30° - \sin\alpha\sin 30°]$$
$$\Rightarrow \quad \cos\alpha = 1.732\cos\alpha - \sin\alpha$$
$$\Rightarrow \quad \sin\alpha = 0.732\cos\alpha$$
$$\Rightarrow \quad \tan\alpha = 0.732$$
$$\Rightarrow \quad \alpha = 36.204°$$

Resultant force in vertical direction,

$$R_y = 180\sin 36.204° + 160\sin(36.204° + 30°) + (100\sin 36.204°)$$
$$= 106.32 + 146.39 + 59.066$$
$$= 311.783 \text{ kN}$$

23. (d)

Given:

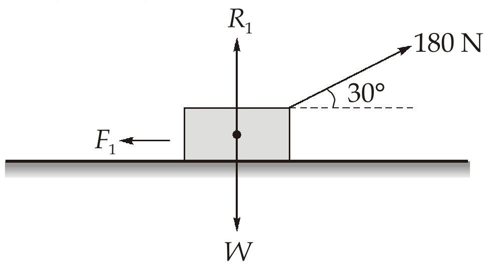
Pull = 180 N; Push = 200 N and angle at which force is inclined with horizontal plane (α) = 30°.

Let, W = Weight of the body

R = Normal reaction

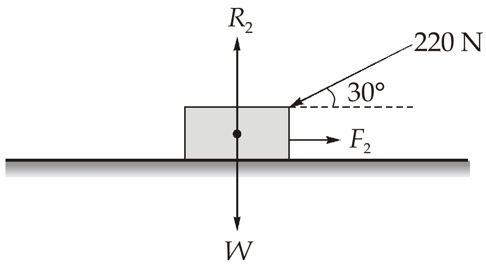
μ = Coefficient of friction

$$R_1 = W - P_1 \sin 30°$$
$$= W - 05 \times 180$$
$$= (W - 90) \text{ N}$$



$$F_1 = P_1 \cos 30°$$

$\Rightarrow \quad \mu(W - 90) = 180 \times 0.866 = 155.88 \quad ...(i)$



$$R_2 = W + P_1 \sin 30° = (W + 220 \times 0.5)$$
$$= (W + 110) \text{ N}$$
$$F_1 = P_2 \cos 30°$$

$\Rightarrow \quad \mu(W + 110) = 220 \times 0.866 = 190.52 \quad ...(ii)$

From eq. (i) and (ii)

$$\frac{W - 90}{W + 110} = \frac{155.88}{190.52} = 0.8182$$

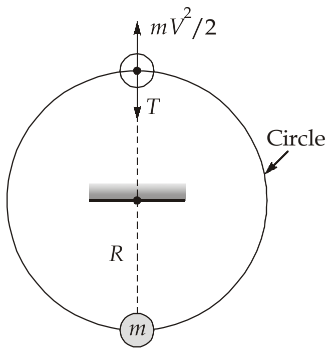
$\Rightarrow \quad W - 90 = 0.8182 W + 90.002$

$\Rightarrow \quad W = 990.1 \simeq 990 \text{ N}$

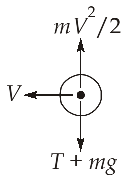
Substituting W either in eq. (i) or (ii)

$$\mu = 0.1732$$

24. (d)



FBD of mass (m) at top of swing.



Apply, $\quad T + mg = \dfrac{mV^2}{R}$

Given that string slackens as the block reaches the top

$\therefore \quad T = 0$

$\Rightarrow \quad mg = \dfrac{mV^2}{R}$

$\Rightarrow \quad V = \sqrt{Rg}$

25. (a)

$$y = \frac{x^2}{200}$$

$$\therefore \quad \frac{dy}{dx} = \frac{x}{100}$$

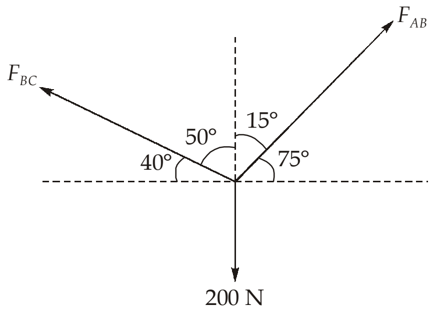
$$\frac{d^2y}{dx^2} = \frac{1}{R} = \frac{1}{100}$$

where R = Radius of curvature

Normal acceleration, $a_n = \frac{V^2}{R} = \frac{5^2}{100} = 0.25 \text{ m/s}^2$

26. (a)

Applying Lame's theorem



$$\frac{F_{BC}}{\sin(90° + 75°)} = \frac{200}{\sin 65°}$$

$$\Rightarrow \quad F_{BC} = 57.12 \text{ kN}$$

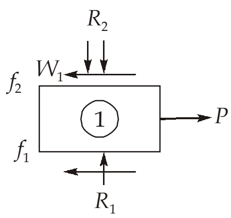
Again, $\frac{F_{AB}}{\sin(90° + 40°)} = \frac{200}{\sin 65°}$

$$\Rightarrow \quad F_{AB} = 169.05 \text{ kN}$$

27. (c)

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

Block (1)

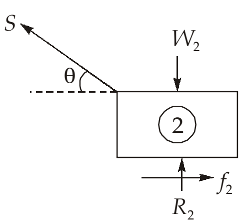


$$P = f_1 + f_2 \quad \text{...(i)}$$

$$\Rightarrow \quad R_1 = R_2 + W_1 \quad \text{...(ii)}$$

$$\Rightarrow \quad \frac{f_1}{\mu} = W_1 + \frac{f_2}{\mu}$$

Block (2)



$$S\cos\theta = f_2 \quad \text{...(iii)}$$

$$S \sin\theta + R_2 = W_2$$

$$\Rightarrow \quad S \sin\theta = W_2 - R_2 \quad \text{...(iv)}$$

Dividing eq. (iv) ÷ (iii)

$$\tan\theta = \frac{W_2 - R_2}{f_2}$$

$$\Rightarrow \quad f_2 \tan\theta + \frac{f_2}{\mu} = W_2$$

$$\Rightarrow \quad f_2 = \frac{W_2}{\tan\theta + \frac{1}{\mu}} = \frac{25}{\frac{3}{4} + \frac{1}{0.3}} = 6.122 \text{ kN}$$

$$\therefore \quad R_2 = \frac{f_2}{\mu} = 20.41 \text{ kN}$$

From eq. (i)

$$R_1 = R + W_1$$
$$= 20.41 + 90 = 110.41 \text{ kN}$$

$$\therefore \quad P = f_1 + f_2$$
$$= \mu (R_1 + R_2)$$
$$= 0.3\,(110.41 + 20.41) = 39.25 \text{ kN}$$

28. (c)

$$T = m\,(a + g)$$
$$= 500\,(2 + 10)$$
$$= 6000 \text{ N}$$

29. (d)

∵ Wheel starts from rest

$$\therefore \quad \theta = w_0 t + \frac{1}{2}\alpha t^2$$

$$w_0 = 0$$

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

$$\text{Number of revolutions} = \frac{100}{2\pi} = 15.92 \text{ rev.}$$

30. (c)

Centroid from base,

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

$$= \frac{d^2 \times \frac{d}{2} - \frac{\pi}{8} d^2 \times \frac{2d}{3\pi}}{d^2 - \frac{\pi d^2}{8}}$$

$$= \frac{5 \times 8d}{12(8 - \pi)} = \frac{10d}{3(8 - \pi)}$$

■■■■