CLASS TEST

S.No. : 01 IG_CE_A+C_280123

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ENGINEERING MECHANICS

CIVIL ENGINEERING

Date of Test : 28/01/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

2. (c)

The reaction on the block (R) = 20 kg f

The horizontal force needed to move the block

$$= \mu R = 0.22 \times 20$$
$$= 4.4 \text{ kg f}$$

3. (d)

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

at $t = 3$ sec.

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

4. (b)

The relative velocity of shot mass = 10 m/s

Let velocity of recoil = v

Absolute velocity of shot mass = $(10 - v)$

Using momentum equation

$0.002\ (10 - v) = 1 \times v$

$$v = \frac{0.02}{1.002} = \frac{20}{1002} = \frac{10}{501} \text{ m/s}$$

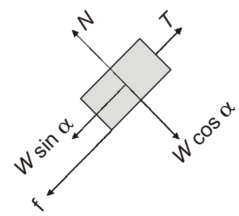
6. (d)

$$T = \frac{2m_1 m_2}{m_1 + m_2} g = \frac{2 \times 21 \times 28}{21 + 28} g = 24 \text{ gm wt}$$

7. (a)

Condition of impending motion is that the block is just about the move but maintain equilibrium.

Tension in the wire, $T = P$



$$f = \mu N$$
$$f = \mu(W \cos \alpha)$$

Balancing forces along the inclined plane

$$T = W \sin \alpha + f$$
$$T = W \sin \alpha + \mu W \cos \alpha$$

We know that $T = P$

$$P = W \sin \alpha + \mu W \cos \alpha$$

8. (a)

Velocity $v = 60$ kmph $= 16.67$ m/s

Using energy principle

$$\frac{1}{2} mv^2 = F.S.$$

$$S = \frac{mv^2}{2F} = \frac{1200 \times (16.67)^2}{2 \times 4.5 \times 1000} = 37.03 \text{ m}$$

9. (c)

The velocity of block embedded with bullet

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

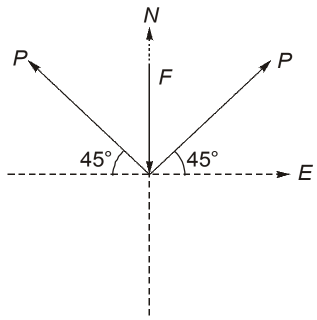
Kinetic energy loss = $kE_i - kE_f$

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

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

10. (a)

Considering equilibrium of forces in N-S direction



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

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

11. (b)

$$a_{\text{net}} = \sqrt{{a_T}^2 + {a_R}^2}$$

$$a_T = \alpha R \text{ (due of change in velocity)}$$

$$a_R = \frac{V^2}{R} \text{ (due to change in direction)}$$

$$a_R = \frac{(40)^2}{1000} = 1.6 \text{ m/s}^2$$

$$a_{\text{net}} = 2.4 \text{ m/s}^2$$

$$2.4^2 = 1.6^2 + {a_T}^2$$

$$a_T = \sqrt{2.4^2 - 1.6^2} = 1.788 \text{ m/s}^2$$

13. (c)

$$\text{Workdone} = T\,.\,\theta$$

$$= \left(30\hat{i} - 20\hat{j} + 100\hat{k}\right).\left(2\hat{i} + 3\hat{j} + 6\hat{k}\right)$$

$$= 30 \times 2 - 20 \times 3 + 100 \times 6$$

$$= 60 - 60 + 600 = 600 \text{ units}$$

14. (c)

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

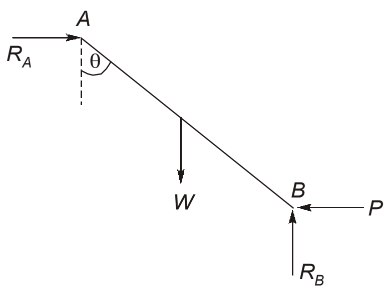
The centroid of hatched position from base.

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

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

15. (a)

Free body diagram of ladder is



Using equilibrium equations.

$$R_A = P$$

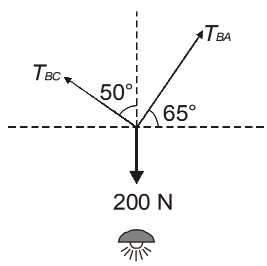
and $R_B = W$

Taking moment about B.

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

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

16. (b)

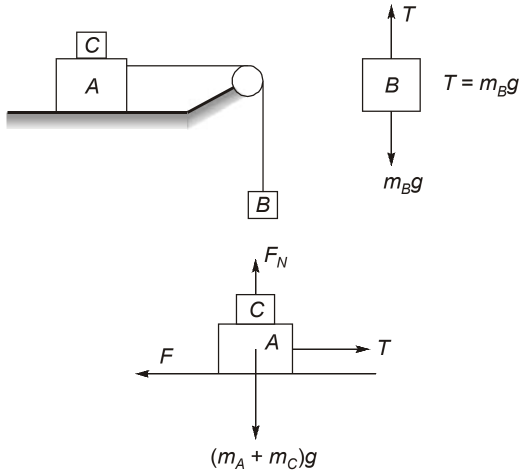


Applying Lamis theorem

$$\frac{T_{BC}}{\sin(90+65)} = \frac{200}{\sin(50+90-65)}$$

$$T_{BC} = 200 \times \frac{\sin 155}{\sin 75} = 87.5 \text{ N}$$

17. (b)



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

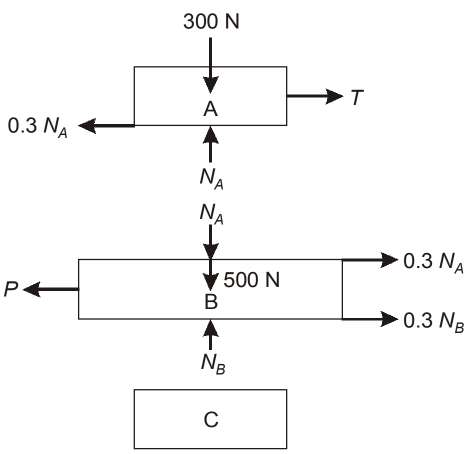
To prevent horizontal sliding

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

18. (a)

$$I = 3375 \text{ kgm}^2$$
$$T = I\alpha$$
$$\alpha = \frac{1000}{3375} = 0.296 \text{ rad/s}^2$$
$$w = w_0 + \alpha t$$
$$w = 0.296 \times 6 = 1.77 \text{ rad/s}$$
$$kE = \frac{1}{2}Iw^2 = \frac{1}{2} \times 3375 \times 1.77^2 = 5.333 \text{ kJ}$$

19. (a)



Considering first FBD of block *A*:

$$\Sigma F_y = 0$$

$\Rightarrow \quad N_A = 300\text{ N}$

$\Rightarrow \quad \Sigma F_x = 0$

$\Rightarrow \quad T = 0.3\,N_A = 0.3 \times 300 = 90\text{ N}$

Now consider FBD of block B:

$\Sigma F_y = 0$

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

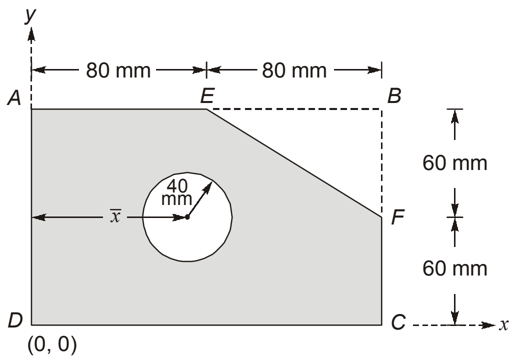
$\Sigma F_x = 0$

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

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

$= 330\text{ N}$

20. (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
		$\Sigma a = 11773.45$		$\Sigma a\bar{x} = 1216000 - 5026.55\bar{x}$

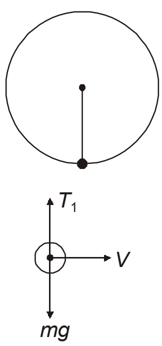
Now, $\quad \bar{x} = \dfrac{\Sigma a\bar{x}}{\Sigma a}$

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

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

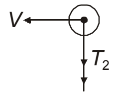
21. (b)

When the stone is at the bottom



$$T_1 = mg + \frac{mV^2}{R}$$

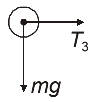
When the stone is at the top



$$T_2 + mg = \frac{mV^2}{R} - mg$$

$$T_2 = \frac{mV^2}{R} - mg$$

When the stone is at the 3 or 4



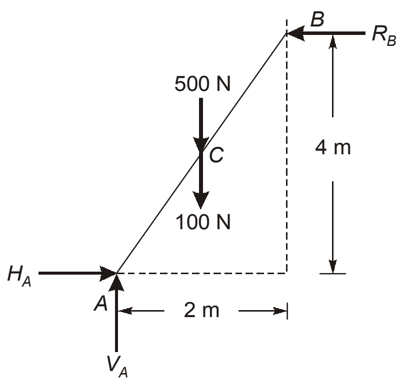
$$T_3 = \frac{mV^2}{R}$$

or
$$T_4 = \frac{mV^2}{R}$$

$$T_{max} = \max(1, 2, 3, 4)$$

$$= T_1 = mg + \frac{mV^2}{R}$$

22. (b)



$\because$ $\Sigma F_x = 0$

$\Rightarrow$ $H_A - R_B = 0$

$\therefore$ $H_A = R_B$

$\because$ $\Sigma F_y = 0$

$\Rightarrow$ $V_A - 500 - 100 = 0$

$\therefore$ $V_A = 600\text{ N}$

$\because$ $\Sigma M_A = 0$

$\Rightarrow$ $4R_B = 600 \times 1$

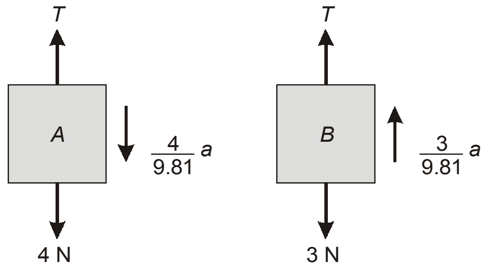
$\therefore$ $R_B = 150\text{ N}$

$\therefore$ $H_A = R_B = 150\text{ N}$

Hence, $R_A = \sqrt{V_A^2 + H_A^2} = \sqrt{600^2 + 150^2}$

$= 618.46\text{ N}$

23. (c)



For block A,

$$4 - T = \frac{4}{9.81}a \quad \text{...(i)}$$

For block B,

$$T - 3 = \frac{3}{9.81}a \quad \text{...(ii)}$$

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

$$\Rightarrow \quad \frac{7a}{9.81} = +1$$

$$\therefore \quad a = +1.401 \text{ m/s}^2$$

(This acceleration is opposite to direction of initial velocity of A. Thus it will cause retardation and the system will come to rest)

The system comes to rest when final velocity becomes zero

$$\therefore \quad v = u + at$$

$$\Rightarrow \quad 0 = 1.85 - 1.401t$$

$$\therefore \quad t = 1.32 \text{ sec}$$

24. (b)

Let, H be the height of tower and t be the time taken to reach the ground.

$$\because \quad H = \frac{1}{2}at^2 \qquad (\because \quad u = 0)$$

$$\Rightarrow \quad H = \frac{1}{2}(9.81)t^2 \quad \text{...(i)}$$

$$\text{and} \quad \frac{3H}{4} = \frac{1}{2}(9.81)(t-1)^2 \quad \text{...(ii)}$$

Using equation (i) and (iii), we get,

$$\Rightarrow \quad \frac{3}{4}\times\frac{1}{2}(9.81)t^2 = \frac{1}{2}(9.81)(t-1)^2$$

$$\Rightarrow \quad t^2 - 8t + 4 = 0$$

$$\Rightarrow \quad t = 7.46 \text{ or } 0.54 \text{ seconds}$$

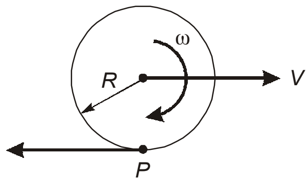
$$\therefore \quad t = 7.46 \text{ seconds}$$ ($\because$ 0.54 seconds is not possible because time is more than one second)

Hence, Height of tower, $H = \frac{1}{2}\times 9.81\times(7.46)^2$

$$= 272.97 \text{ m} \simeq 273 \text{ m}$$

25. (d)

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



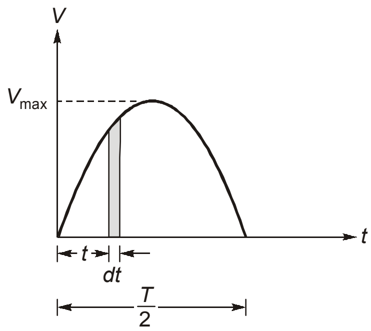
The wheel rolls without slipping only if there is no horizontal movement of the wheel at the contact point P (with respect to the surface/ground). Thus, the contact point P must also have zero horizontal movement (with respect to the surface/ground).

26. (a)

$$
\begin{aligned}
x\text{-component of the resultant} &= 5\cos 37° + 3\cos 0° + 2\cos 90° \\
&= 3.99 + 3 + 0 \\
&= 6.99 \\
y\text{-component of the resultant} &= 5\sin 37° + 3\sin 0° + 2\sin 90° \\
&= 3.01 + 2 \\
&= 5.01
\end{aligned}
$$

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

27. (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

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

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

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

$$= V_{max}\frac{T}{\pi}$$

28. (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,

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

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

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

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 $-mgh$.

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

On applying conservation of energy, we get

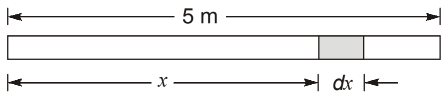
$$T_i = T_f$$

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

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

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

29. (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,

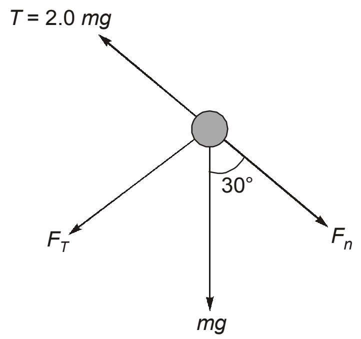
$$X_{cm} = \frac{\int x dm}{\int dm} = \frac{\int_0^5 x(0.5+3x)\alpha dx}{\int_0^5 (0.5+3x)\alpha dx}$$

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

$$= \frac{0.5\left(\frac{5^2}{2}\right)+3\left(\frac{5^3}{3}\right)}{0.5\times 5+3\left(\frac{5^2}{2}\right)}$$

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

30. (d)



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

$$\text{Normal force, } F_n = T - mg \cos 30°$$

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

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

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

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

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

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

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

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

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