CLASS TEST

S.No. : 03 IG_CE_E_010522

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ENGINEERING MECHANICS

CIVIL ENGINEERING

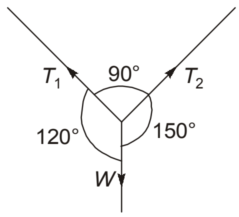
Date of Test : 01/05/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)
Applying Lami's Theorem,

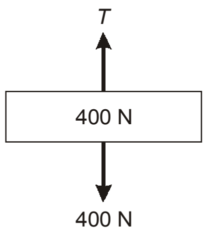


$$\frac{T_1}{\sin 150°} = \frac{T_2}{\sin 120°} = \frac{W}{\sin 90°}$$

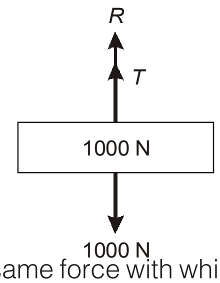
$$\therefore \quad \frac{T_1}{T_2} = \frac{\sin 150°}{\sin 120°}$$

$$\therefore \quad \frac{T_1}{T_2} = 0.577$$

2. (b)
Drawing free diagram of blocks, we have,



$$T = 400 \text{ N}$$



$$T + R = 1000$$

$$\therefore \quad 400 + R = 1000$$

$$R = 600 \text{ N}$$

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

3. (c)

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

$$\frac{d\omega}{dt} = 9 - 6t = 0, \; t = 1.5 \text{ s}$$

$$\omega_{max} = 12 + 9 \times 1.5 - 3 \times 1.5^2$$

$$= 12 + 13.5 - 6.75$$

$$= 18.75 \text{ rad/s}$$

4. (b)
The velocity of point Q is zero, as the point Q is in contact with the surface.

5. (a)

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

$$I_0 = \frac{mL^2}{3}$$

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

6. (a)

$$a = \frac{f}{m} = -\frac{bv}{m}$$

but, $$a = v\frac{dv}{dx}$$

$\therefore$ $$\frac{vdv}{dx} = -\frac{bv}{m}$$ (at time infinity means steady state)

$$\int_u^0 dv = -\frac{b}{m}\int_0^x dx$$

$$-u = -\frac{b}{m}\times x$$

$\Rightarrow$ $$x = mu/b$$

7. (b)

Resolving the forces in horizontal and vertical components.

Horizontal components, $\Sigma F_X = 60\cos30° - 80\cos45° = -4.607$

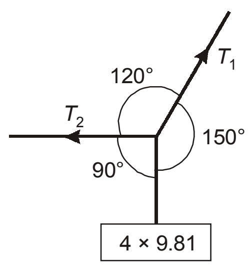
Vertical components, $\Sigma F_Y = 80\sin45° + 60\sin30° = 86.568$

$$\text{Resultant, } R = \sqrt{(\Sigma F_X)^2 + (\Sigma F_Y)^2} = \sqrt{(-4.607)^2 + (86.568)^2}$$

$$= 86.69 \text{ N}$$

8. (a)

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



$\therefore$ $$\frac{T_1}{\sin 90°} = \frac{4\times9.81}{\sin(120°)}$$

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

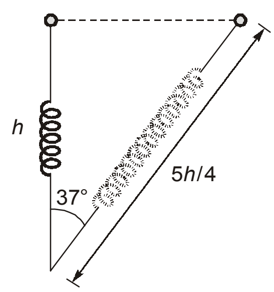
$$\frac{T_2}{\sin 150°} = \frac{4\times9.81}{\sin 120°}$$

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

9. (b)

$\therefore$ The kinetic energy of the ring will be given by the potential energy of spring.

$\therefore$ Let V be the speed of the ring when the spring becomes vertical



$$\frac{1}{2}mV^2 = \frac{1}{2}k[X]^2$$

$$X = \frac{5h}{4} - h = \frac{h}{4}$$

$$mV^2 = k\left[\frac{h}{4}\right]^2$$

$$V = \frac{h}{4}\sqrt{\frac{k}{m}}$$

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. (d)

$$\omega_0 = 8000 \text{ rpm} = 837.33 \text{ rad/s}$$
$$t = 5 \text{ min} = 300 \text{ s}$$

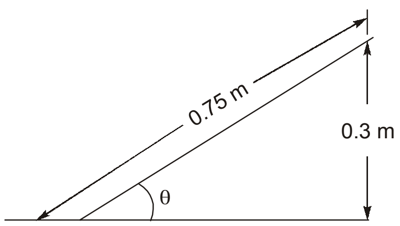
$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\alpha = \frac{\omega - \omega_0}{t} = -\frac{837.33}{300} = -2.791 \text{ rad/s}^2$$

$$\theta = 837.33 \times 300 - 0.5 \times 2.791 \times (300)^2 = 125604 \text{ rad}$$

∴ Number of revolutions $= \dfrac{\theta}{2\pi} = 19990.49 \simeq 19991$

12. (a)



Coefficient of friction $= \mu$

$$\mu = \tan\theta$$

From figure, $$\sin\theta = \frac{0.3}{0.75} = 0.4$$

$$\Rightarrow \quad \theta = \sin^{-1}(0.4)$$

$$\therefore \quad \theta = 23.57°$$

$$\mu = \tan\theta$$

$$\tan 23.57° = 0.436$$

or

$$mg\sin\theta = (f_s)_{max} = \mu N$$

$$N = mg\cos\theta$$

$$\tan\theta = \mu$$

$$\mu = 0.436$$

13. (d)

For no tipping or prevent overturning

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

where $W \rightarrow$ weight of block

and $b \rightarrow$ width of block

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

and for slipping without tipping

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

$$P > \mu W \quad ...(2)$$

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.

14. (c)

$$I = 2000 \times 0.25^2 = 125 \text{ kg-m}^2$$

$$\text{for retardation, } \omega = \omega_0 + \alpha t$$

$$\omega = 0$$

$$\omega_0 = \frac{2\pi N}{60} = \frac{2\pi \times 3000}{60}$$

$$t = 10 \text{ min} = 600 \text{ sec}$$

$$\alpha = \frac{2\pi \times 3000}{60 \times 600} = 0.5236 \text{ rad/s}$$

So, average frictional torque,

$$I\alpha = 65.44 \text{ Nm}$$

15. (c)

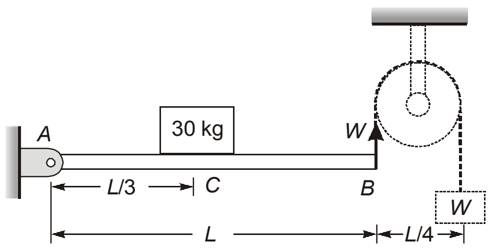
$$\text{Resistance} = mg + W = 200 \times 9.81 + 100$$
$$= 2062 \text{ N}$$

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

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

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

16. (c)



W is the tension in the string.
Taking moments from end A

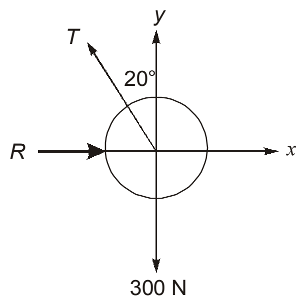
$$W \times L = 30 \times 9.81 \times L/3$$
$$W = 98.1 \text{ N}$$

17. (b)

$$a = -t$$
$$dV = -tdt$$
$$V = -\frac{t^2}{2} + C_1$$
$$7.5 = 0 + C_1$$
$$\therefore \quad C_1 = 7.5$$
$$V = -\frac{t^2}{2} + 7.5$$
$$V_{\text{at 3s}} = \frac{-3^2}{2} + 7.5 = 3 \text{ m/s}$$
$$V_{\text{at 3s}} = 3 \text{ m/s}$$

18. (c)

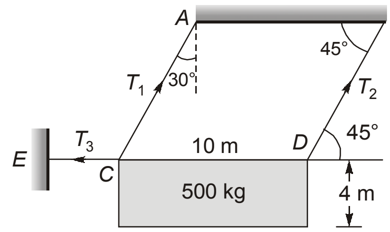
In xy direction



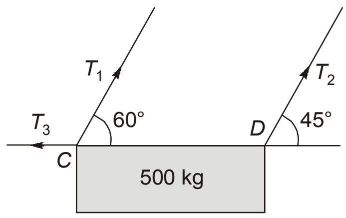
$$-T\sin 20°\, i + T\cos 20 j + Ri - 300 j = 0$$
$$(R - T\sin 20°) i + (0.947 - 300) j = 0$$

then
$$R - T\sin 20° = 0$$
$$0.94\, T - 300 = 0$$
$$(\text{Tension})\, T = \frac{300}{0.94} = 319.15\, N$$

19. (c)



Considering free body diagram of the block.



∵ The body is in equilibrium,

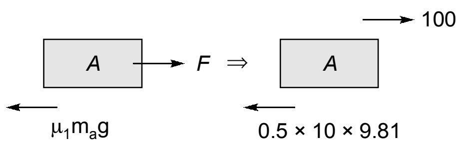
Now, taking moment about C

$$\therefore \quad T_2 \sin 45° \times 10 = 500 \times 5$$

$$T_2 = 353.55 \text{ kg}$$

20. (b)

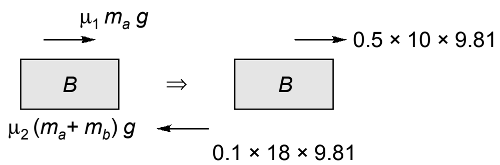
Drawing free-body diagram of A and B.



Writing equation of motion for A.

$$100 - 0.5 \times 10 \times 9.81 = 10a$$

$$\Rightarrow \quad a = 5.095 \text{ m/s}^2$$



Writing equation of motion for B.

$$49.05 - 17.658 = 8a$$

$$\Rightarrow \quad a = 3.924 \text{ m/s}^2$$

After 0.1s,

$$V_A = U_a + a_a t.$$

$$V_A = 0 + 5.095 \times 0.1$$

$$V_A = 0.5095 \text{ m/s}$$

Similarly,

$$V_B = 0 + 3.924 \times 0.1$$

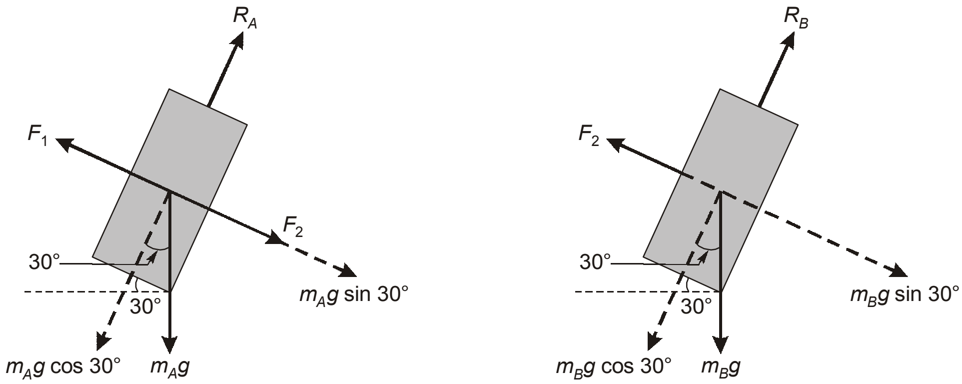
$$V_B = 0.3924$$

∴ Relative velocity of A wrt B $= V_A - V_B$

$$= 0.5095 - 0.3924 = 0.117 \text{ m/s}$$

21. (c)

The FBD of the blocks *A* and *B* are shown below



Here F_1 and F_2 are the spring forces.

$$F = k\Delta z = k(x_0 - x_{\text{unstretched}})$$

$$F_1 = 1000 \times (0.3 - 0.25) = 50 \text{ N}$$

and $$F_2 = 1000 \times (0.28 - 0.25) = 30 \text{ N}$$

At equilibrium,

ΣForces along the plane for mass $A = 0$

$\Rightarrow \quad -F_1 + F_2 + m_A g \sin 30° = 0$

$$\Rightarrow \quad m_A = \frac{F_1 - F_2}{g\sin 30°} = \frac{50 - 30}{9.81 \times 0.5} = 4.08 \text{ kg}$$

and ΣForces along the plane for mass $B = 0$

$\Rightarrow \quad -F_2 + m_B\, g \sin 30° = 0$

$$\Rightarrow \quad m_B = \frac{F_2}{g\sin 30°}$$

$$= \frac{30}{9.81 \times 0.5} = 6.12 \text{ kg}$$

22. (a)

$$\text{K.E.} = \frac{1}{2} I\omega^2$$

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

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

$$\text{K.E.} = \frac{1}{2} \times 0.4 \times 52.33^2 = 547.68 \text{ J}$$

23. (d)

Let speed of car moving in opposite direction is V m/s.

From relative velocity approach

$$\frac{12}{V+50} = \frac{5}{60}$$

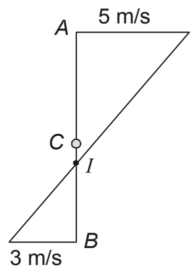
$$12 \times 60 = 5v + 250$$

$$V = 94 \text{ km/hr}$$

24. (c)

$\because$ Velocities are in opposite directions,

$\therefore$ I will lie between A and B,



$$\frac{IA}{IB} = \frac{V_a}{V_b} = \frac{5}{3}$$

$$\Rightarrow \quad \frac{0.5 - IB}{IB} = \frac{5}{3}$$

$$IB = 0.1875 \text{ m}$$

$$IA = 0.3125 \text{ m}$$

$$\omega = \frac{V_A}{IA} = \frac{5}{0.3125} = 16 \text{ rad/s}$$

Alternatively,

$$\therefore \quad V_A = V_C + R\omega$$

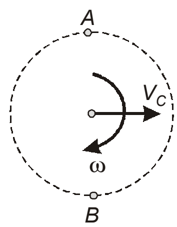
$$V_B = R\omega - V_C$$

$$\therefore \quad V_C + R\omega = 5$$

$$R\omega - V_C = 3$$

$$V_C + 0.25\,\omega = 5 \quad \text{...(a)}$$

$$0.25\,\omega - V_C = 3 \quad \text{...(b)}$$



On solving (a) and (b),

$$\omega = 16 \text{ rad/s}$$

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

where V_C = velocity of centre C.

25. (d)

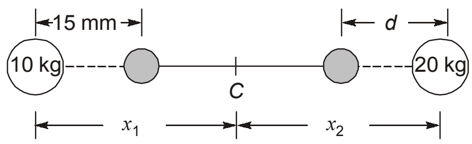
To keep centre of mass at C

$$m_1x_1 = m_2x_{2]}$$

$\rightarrow$ (Let 10 kg = m_1, 20 kg = m_2)

and $\quad m_1(x_1 - 15) = m_2(x_2 - d)$

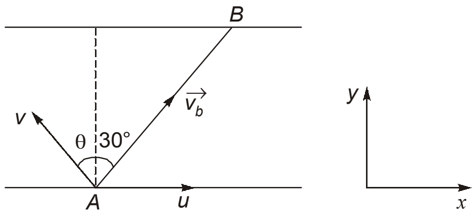
$$15\,m_1 = m_2 d$$



$$d = \frac{15 \times 10}{20} = 7.5 \text{ mm}$$

26. (d)

Let v be the speed of boatman in still water



Resultant of u and v should be along AB. Components of $\vec{v}_b$ (absolute velocity of boatman) along x and y -direction are:

$$v_x = u - v\sin\theta,\ v_y = v\cos\theta$$

$$\tan 30° = \frac{v_y}{v_x}$$

$$\Rightarrow \quad 0.577 = \frac{v\cos\theta}{u - v\sin\theta}$$

$$0.577u - 0.577v\sin\theta = v\cos\theta$$

$$\Rightarrow \quad v = \frac{0.577u}{0.577\sin\theta + \cos\theta}$$

$$v = \frac{(0.577 \times \cos 30°)u}{\sin 30° \sin\theta + \cos 30° \cos\theta}$$

$$v = \frac{0.49964}{\sin(\theta + 30°)}$$

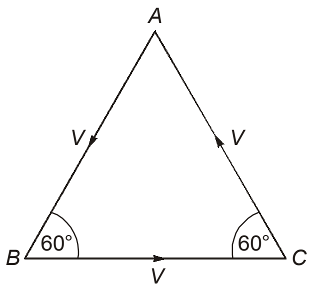
v is minimum at $\theta = 60°$,

$$\Rightarrow \quad v_{min} = 0.49964$$

$$v_{min} \simeq 0.54$$

27. (a)

Velocity of A is v along AB and velocity of particle B is along BC, its component along BA is $v\cos 60° = \frac{v}{2}$.



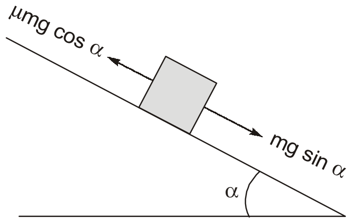
Thus separation AB decreases at the rate of

$$v + \frac{v}{2} = \frac{3v}{2}$$

Since this rate is constant, time taken in reducing separation from AB from d to zero is

$$t = \frac{d}{3v/2} = \frac{2d}{3v}$$

28. (a)



Here, $\alpha = 45°$

We have: $a = \dfrac{dV}{dt} \Rightarrow a = \dfrac{dV}{dx} \times \dfrac{dx}{dt}$

$\therefore \quad a = \dfrac{dV}{dx} \times V$

Also, $a = \dfrac{mg\sin\alpha - \mu mg\cos\alpha}{m}$

$a = g[\sin\alpha - \mu\cos\alpha]$

$\therefore \quad g[\sin\alpha - \mu\cos\alpha] = \dfrac{dV}{dx} \times V$

$\therefore \quad g[\sin\alpha \cdot dx - 5x\cos\alpha\, dx] = V \cdot dV$

On integrating,

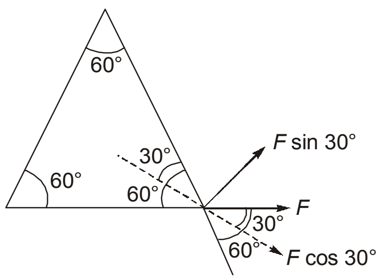
$$g\left[\sin\alpha \cdot x - 5\cos\alpha \times \frac{x^2}{2}\right] = \left[\frac{V^2}{2}\right]_0^0$$

$$g\left[\sin\alpha \cdot x - 5\cos\alpha \times \frac{x^2}{2}\right] = 0$$

$$\Rightarrow \quad \sin\alpha \cdot x = 5\cos\alpha \times \frac{x^2}{2}$$

$$x = \frac{2\tan\alpha}{5} \Rightarrow \frac{2\tan 45°}{5} = 0.4\,\text{m}$$

29. (b)



We have, Torque $= I\alpha$

$\therefore \quad 3F\sin 30° \times 0.5 = I\alpha$

$$3 \times 0.5 \times \frac{1}{2} \times 0.5 = 1.5 \times \frac{0.5^2}{2} \times \alpha$$

$\therefore \quad \alpha = 2\ \text{rad/s}^{-1}$

$\therefore \quad \omega = \omega_0 + \alpha t$

$\omega = 0 + 2 \times 1$

$\omega = 2\ \text{rad s}^{-1}$

30. (a)

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

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

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

$$\therefore \quad g = \frac{4 \times \pi^2 \times 0.8}{1.8^2} = 9.74\ \text{m/s}^2$$

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