CLASS TEST

S.No. : 01SP_ME_D_110422

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ENGINEERING MECHANICS

MECHANICAL ENGINEERING

Date of Test : 11/04/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (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)

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

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

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

2. (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, $$v = -3\sin t$$

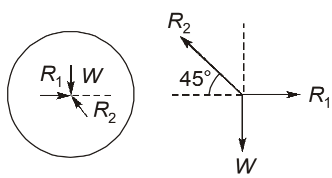
$$w = \sqrt{5}\cos t$$

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

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

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

3. (b)



$$R_2 \cos 45° = R_1$$

$$R_2 \sin 45° = W$$

$\Rightarrow$ $$R_2 = W\sqrt{2}$$

$\therefore$ $$R_1 = W\sqrt{2} \times \frac{1}{\sqrt{2}} = W$$

$$W = 50\text{ N}$$

$\therefore$ $$R_1 = 50\text{ N}$$

4. (b)

For a perfect truss, the condition is

$$m = 2j - 3$$

where, $m \rightarrow$ number of members

$j \rightarrow$ number of joints

5. (d)

For no tipping or prevent overturning

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

where $W \rightarrow$ weight of block

and $b \rightarrow$ width of block

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

and for slipping without tipping

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

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

From (1) and (2)

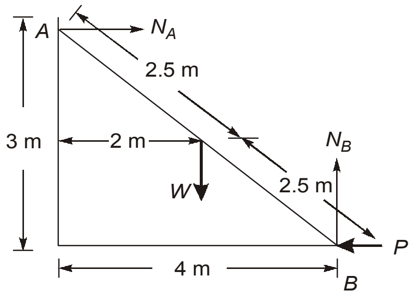
$$h < \frac{b}{2\mu}$$

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

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

Option (d) is correct.

6. (d)



Considering equilibrium of ladder

$$N_A = P \qquad \left[\because \vec{F}_H = 0\right]$$

$$W = N_B \qquad \left[\because \vec{F}_V = 0\right]$$

$$\Sigma M_B = 0$$

$$N_A \times 3 - W \times 2 = 0$$

$$W = \frac{N_A \times 3}{2} = \frac{P \times 3}{2} = \frac{400 \times 3}{2} = 600 \text{ N}$$

8. (d)

For the mass m, $mg - T = ma$

For cylinder, $T \times R = I\alpha$

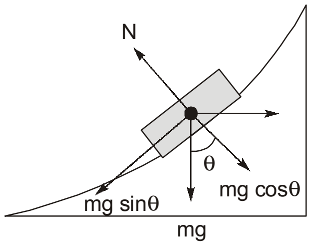
$$T \times R = mR^2 \times \frac{a}{R}$$

$$T = ma$$

$$\Rightarrow \quad mg = 2ma$$

$$\Rightarrow \quad a = \frac{g}{2}\text{ms}^{-2}$$

9. (b)



$$\tan\theta = \frac{dy}{dx} = \frac{x^2}{2}$$

Now, $$mg\sin\theta = \mu mg\cos\theta$$

$\Rightarrow$ $$\tan\theta = \mu$$

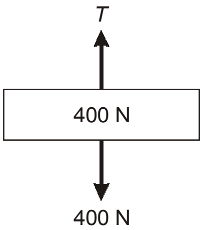
$\Rightarrow$ $$\frac{x^2}{2} = 0.5$$

$\Rightarrow$ $$x = 1$$

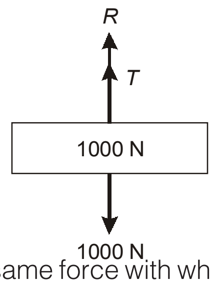
$$y = \frac{1}{6}\text{m}$$

10. (b)

Drawing free diagram of blocks, we have,



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



$$T + R = 1000$$

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

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

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

11. (c)

$$a = \frac{dv}{dt}$$

Let resisting force,

$\Rightarrow$ $$F = Kv^2$$

Let m is mass of bullet

$\therefore$ $$a = \frac{F}{m} = \frac{Kv^2}{m}$$

$$\frac{dv}{dt} = \frac{Kv^2}{m}$$

$$\frac{1}{v^{-2}}dv = \frac{K}{m}\cdot dt$$

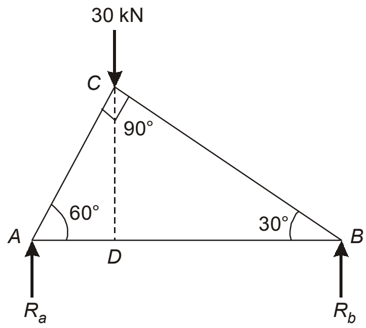
$$\left[\frac{v^{-1}}{-1}\right]_u^v = \frac{K}{m}\int_0^t dt$$

$$\Rightarrow \quad \left[\frac{v-u}{uv}\right] = \frac{K}{m}t$$

$$\Rightarrow \quad t = \frac{(u-v)}{uv} \times \frac{-m}{K}$$

$$\therefore \quad t \propto (u-v)(uv)^{-1}$$

12. (b)



$$AC = AB\cos 60° = 2.5 \text{ m}$$

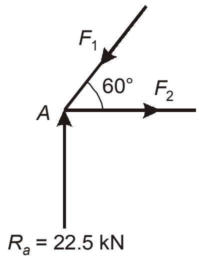
$$AD = AC\cos 60° = 2.5 \times 0.5 = 1.25$$

∴ Taking moments about A,

$$R_b \times 5 = 30 \times 1.25$$

$$R_b = 7.5 \text{ kN}, \quad R_a = 30 - 7.5 = 22.5 \text{ kN}$$

Considering joint A,



$$\Sigma F_x = 0, \quad F_2 - F_1\cos 60° = 0$$

$$F_1\sin 60° - R_a = 0$$

$$F_1 = \frac{R_a}{\sin 60°} = \frac{22.5}{\sin 60°} = 25.97 \text{ kN} \quad \text{(compressive)}$$

$$F_2 = F_1\cos 60° = 12.99 \text{ kN} \quad \text{(tensile)}$$

∴ AB is in tension.

13. (a)

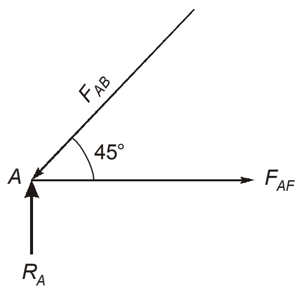
Reaction at A is R_A

Taking moments from point E,

$$W \times \frac{a}{2} + Wa = 2a \cdot R_A$$

$$\therefore \quad R_A = 0.75\text{ W}$$

Joint A



$$F_{AB}\sin 45° = R_A$$

$$F_{AB} = 1.06\,W \text{ (compressive)}$$

14. (c)

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

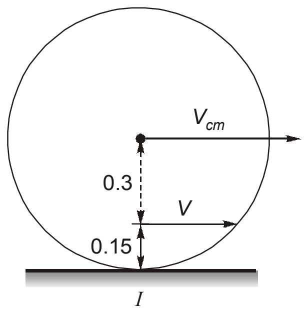
$$= 2062 \text{ N}$$

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

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

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

15. (a)



$$V_{cm} = 0.45\,\omega$$

$$\omega = \frac{3}{0.45} \text{ rad/s}$$

$$V = 0.15\ \omega = \frac{0.15 \times 3}{0.45}$$

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

16. (d)

$$\omega_0 = 8000 \text{ rpm} = 837.33 \text{ rad/s}$$

$$t = 5 \text{ min} = 300 \text{ s}$$

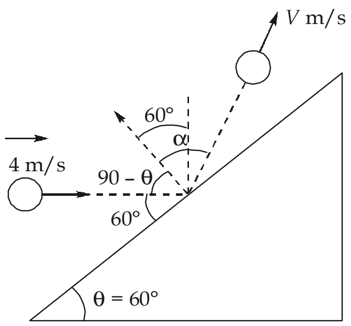
$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

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

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

$$\therefore \quad \text{Number of revolutions} = \frac{\theta}{2\pi} = 19990 \simeq 20000$$

17. (b)



Since the impact is occuring normal to the incline, there will be no change in velocity along the incline so,

$$4\cos(60°) = V\sin\alpha$$

$$V\sin\alpha = 2 \qquad \text{...(i)}$$

Now,

$$\text{Coefficient of restitution} = \frac{\text{Velocity of separation along the line of impact}}{\text{Velocity of approach along the line of impact}}$$

$$e = \frac{V\cos\alpha}{4\sin(60°)}$$

$$0.5 = \frac{V\cos\alpha}{4\sin(60°)}$$

$$V\cos\alpha = 1.732 \quad \text{...(ii)}$$

Dividing (i) by (ii)

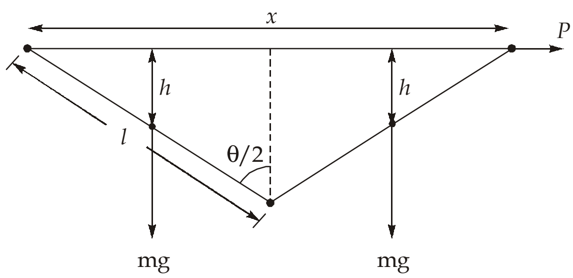
$$\tan\alpha = \frac{2}{1.732}$$

$$\alpha = 49.1074°$$

$$\text{Angle made with vertical} = 60 - 49.1074 = 10.8926°$$

18. (b)

Apply virtual work method,



$$x = 2l\sin\left(\frac{\theta}{2}\right)$$

$$h = \frac{l}{2}\cos\left(\frac{\theta}{2}\right)$$

$$\Rightarrow \quad dx = 2l\cos\left(\frac{\theta}{2}\right)\frac{d\theta}{2}$$

$$dh = -\frac{l}{2}\sin\left(\frac{\theta}{2}\right)\frac{d\theta}{2}$$

$$\Rightarrow \quad \frac{dx}{\cos\left(\frac{\theta}{2}\right)} = -\frac{dh}{\sin\left(\frac{\theta}{2}\right)} \times 4$$

By principle of virtual work,

$$\Rightarrow \quad Pdx + 2mgdh = 0 = WD$$

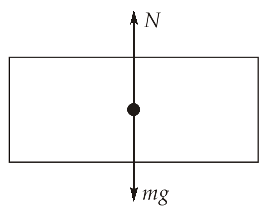
$$\Rightarrow \quad P \times dx = 2mg \times \tan\left(\frac{\theta}{2}\right) \times \frac{dx}{4}$$

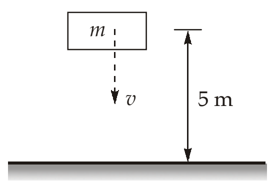
$$\Rightarrow \quad \frac{2P}{mg} = \tan\left(\frac{\theta}{2}\right)$$

$$\Rightarrow \quad \theta = 2 \times \tan^{-1}\left(\frac{2P}{mg}\right)$$

$$\theta = 90°$$

19. (d)





Initial condition

Velocity when block reaches the ground = $\sqrt{2gh}$

$$= \sqrt{2 \times 10 \times 5} = 10 \text{ m/s}$$

By momentum conservation:

$(F) \times dt$ = Momentum just after striking the ground – momentum just before striking the ground

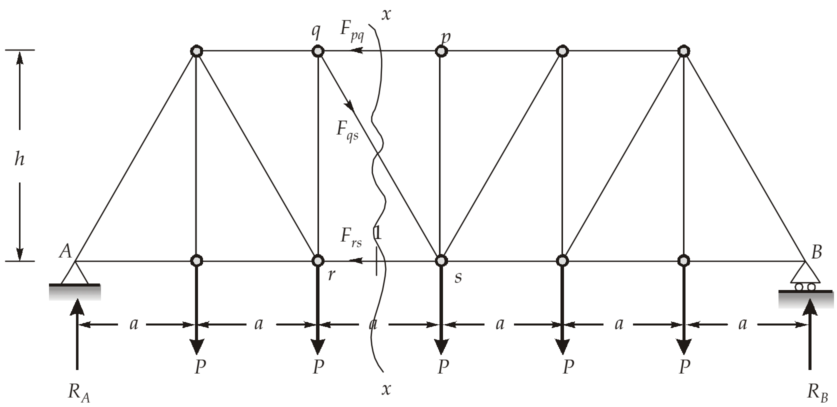
$$(N - mg) \times dt = m \times 0 - (-m \times 10)$$

$$(N - mg) = \frac{m \times 10}{dt}$$

$$N = \frac{10 \times 10}{(1/10)} + 10 \times 10$$

Force of interaction, $N = 1100$ N

20. (a)



$$\Sigma F_y = 0$$

$$R_A + R_B = 5P$$

By symmetry, $R_A = R_B = \frac{5P}{2}$

Using method of section,

Taking moment about q,

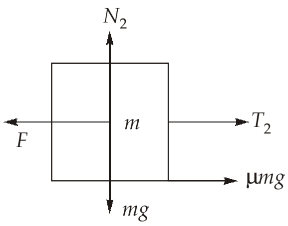
$$F_{rs} \times h = \frac{5P}{2} \times 4a - (P \times 3a) - (P \times 2a) - (P \times a)$$

$$F_{rs} \times h = 4\,Pa$$

Force in member 1 is, $F_{rs} = \frac{4Pa}{h}$ (Tensile)

21. (d)

FBD for M:



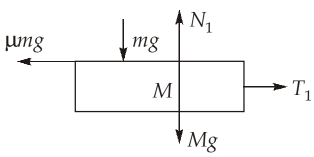
$$\Sigma F_x = 0$$

$\Rightarrow$ $T_1 = \mu mg$

$$\Sigma F_x = 0$$

$$N_1 = (M + m)g$$

FBD for m:

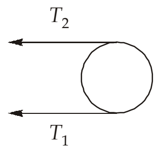


$$\Sigma F_x = 0$$

$\Rightarrow$ $F = T_2 + \mu mg$

Pulley:

Since T_2 is tension at tight side,



$$T_2 = T_1 e^{\mu\pi}$$

$$\Rightarrow \quad F = e^{\mu\pi} \times \mu mg + \mu mg$$

$$\Rightarrow \quad F = \mu mg\,(1 + e^{\mu\pi})$$

22. (a)

Initially

Maximum kinetic energy will be recovered if collision is perfectly elastic (e = 1)

Momentum conservation: $mu = mv_1 + mv_2$

$$v_1 + v_2 = u \qquad \text{...(i)}$$

$$e = 1$$

$$\Rightarrow \quad e = \frac{v_2 - v_1}{u}$$

$$v_2 - v_1 = u \qquad \text{...(ii)}$$

From (i) and (ii)

$$v_2 = u,\ v_1 = 0$$

$$kE_f = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 = 0.5$$

$$\frac{1}{2}\times 0.1 \times u^2 = 0.5$$

$$u = \sqrt{10}\ \text{m/s} \quad \text{(Minimum)}$$

Minimum kinetic energy recovered if collision is perfectly inelastic (e = 0)

$$mu = mv_1 + mv_2$$

$$v_1 + v_2 = u \qquad \text{...(iii)}$$

$$e = 0$$

$$\Rightarrow \quad 0 = \frac{v_2 - v_1}{u}$$

$$v_2 = v_1 \qquad \text{...(iv)}$$

From (iii) and (iv)

$$v_2 = v_1 = \frac{u}{2}$$

$$KE_f = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 = 0.5$$

$$\frac{1}{2}\times m\left(\frac{u^2}{4} + \frac{u^2}{4}\right) = 0.5$$

$$\frac{u^2}{2} = 10$$

$$u = \sqrt{20}\ \text{m/s} \quad \text{(Maximum)}$$

So, $$\frac{u_{\max}}{u_{\min}} = \sqrt{2} = 1.414$$

23. (d)

Let the velocity of box as it reaches point D is v.

Energy conservation between A and D

$$mg \times 100 = mg \times 60 + \frac{1}{2}mv^2$$

$$v = 28.01 \text{ m/s}$$

As the box reaches the highest point after take off, it will have velocity,

$$v_h = v\cos\theta = 28.01 \times \cos(30)$$

$$v_h = 24.26 \text{ m/s}$$

Energy conservation between A and the highest point

$$mg \times 100 = mg \times h_{max} + \frac{1}{2}m \times (24.26)^2$$

$$h_{max} = 70 \text{ m}$$

24. (b)

$$mg(\sin\theta + \mu\cos\theta) = 3mg(\sin\theta - \mu\cos\theta)$$

$$(\sin 45° + \mu\cos 45°) = 3(\sin 45 - \mu\cos 45°)$$

$$\mu = 0.5$$

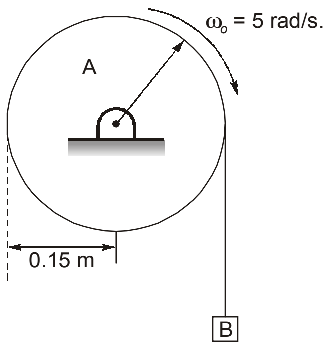
25. (b)

$$\alpha = 0.4\,t^2 + 0.6$$

$$\therefore \quad \frac{d\omega}{dt} = (0.4t^2 + 0.6t)$$

∴ Upon integration within appropriate limits, we get

$$\int_{\omega_o=5}^{\omega} d\omega = \int_6^t (0.4t^2 + 0.6)dt$$



$$\therefore \quad \omega - 5 = 0.4 \times \frac{t^3}{3} + 0.6t$$

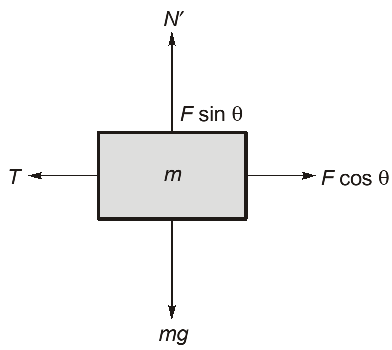
At, $t = 1.5$ sec,

$$\omega = 5 + 0.6 \times 1.5 + 0.4 \times \frac{1.5^3}{3}$$

$$\omega = 6.35$$

$$V = 0.15 \times 6.35 = 0.9525 \text{ m/s}$$

26. (b)



Considering free body diagram

$$F\cos\theta = T + \mu N'$$

$$T\cos\theta = \mu\, mg + \mu(mg - F\sin\theta) \qquad [N' = mg - F\sin\theta]$$

$$\Rightarrow \quad F = \frac{2\mu mg}{\cos\theta + \mu\sin\theta}$$

$$\Rightarrow \text{For} \quad F_{min} = \frac{2\mu mg}{\sqrt{1+\mu^2}}$$

$\because$ [Max value of $a\cos\theta + b\sin\theta$ is $\sqrt{a^2+b^2}$]

27. (c)

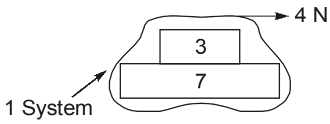
Drawing free body diagram of upper block,

$$10 - \mu_1 mg = m\,a.$$

$$10 - 0.2 \times 2 \times 10 = 2 \times a$$

$$a_1 = 3\ \text{ms}^{-2}$$

for the 3 kg block, as frictional reaction from 2 kg will act in right, the 3 kg and 7 kg block will move simultaneously, since the 7 kg block is in contact with zero friction surface. There will be no tendency of relative motion between 3 kg and 7 kg and both will move as a same system due to the action of frictional force acting on the top of 3 kg by the 2 kg block



$$4 = 10a$$

$$a = 0.4$$

$$a_2 = 0.4\ \text{ms}^{-2}$$

$$a_3 = 0.4\ \text{ms}^{-2}$$

28. (b)

Let V be the linear velocity and ω is the angular velocity.

$$\vec{V}_C = V + R\omega$$

$$\text{For pure rolling, } V = R\omega$$

$$\vec{V}_C = 2V\hat{i}$$

$$\therefore \quad \vec{V}_B = V\hat{i} \qquad \therefore \ (B) \text{ is right}$$

$$\vec{V}_A = 0$$

$$\Rightarrow \quad \vec{V}_C - \vec{V}_B = 2V\hat{i} - V\hat{i} = V\hat{i}$$

$$\vec{V}_B - \vec{V}_A = V\hat{i} - 0\hat{i} = V\hat{i}$$

29. (c)

$\therefore$ Impulse = Change in momentum

Area of graph = $m(V_f - V_i)$

$$\frac{1}{2} \times 10 \times 10 + (20 \times 14) + (\frac{1}{2} \times 15 \times 14) = m(V - O)$$

But, $m = 1$

$\Rightarrow$ $V = 435$ m/s

$$\text{Average force} = \frac{\text{Area of graph}}{\text{Total time}} = \frac{435}{45} = 9.666\,\text{N}$$

Acceleration = 9.666 m/s

$$S = \frac{1}{2} \times 9.666 \times 45^2 + (15 \times 435)$$

($\because$ Body will travel with constant velocity of 435 m/s for the next 15 seconds after the removal of force)

S = 16312.5 m = 16.312 km

30. (c)

$$W = f \times s \cos\theta$$

$$W = [200 + \mu(mg + N)] \times 10 \times \cos 180°]$$

$$W = -[200 + \mu(mg + 100)] \times 10$$

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