CLASS TEST

S.No.: 03SKCE_J+K_290625

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ENGINEERING MECHANICS

CIVIL ENGINEERING

Date of Test : 29/06/2025

ANSWER KEY

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

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. (a)

During inelatic collision, only linear momentum is conserved.

3. (a)

Change in the stored energy of rubber band = $F\,dx$

$$\Rightarrow \quad dE = 300x^2 dx$$

$$\text{Integrating,} \quad \int_0^E dE = \int_0^{0.1} 300x^2\,dx$$

$$\Rightarrow \quad E = 300\times \left.\frac{x^3}{3}\right|_0^{0.1} = 0.1\text{ Joule}$$

4. (c)

$$\text{Kinetic energy, } KE = \frac{1}{2}I\omega^2$$

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

$$\omega = \frac{2\pi N}{60} = \frac{2\times\pi\times 600}{60} = 62.83\text{ rad/sec}$$

$$\therefore \quad KE = \frac{1}{2}\times 0.4\times(62.83)^2 \simeq 790\text{ Joules}$$

5. (c)

$$F = 100\sqrt{2^2+3^2+(3.464)^2} \simeq 500\text{ N}$$

$$\cos\alpha = \frac{200}{500} = 0.4$$

$$\alpha = \cos^{-1}0.4 = 66.42^\circ$$

6. (c)

Let, S be the distance by which a pile will move under a single blow of hammer.

Work done by hammer = Work done by the ground resistance

$$\frac{1}{2}(12+4)V^2 = 200\times S$$

$$\Rightarrow \quad 8\times 4^2 = 200\times S$$

$$\Rightarrow \quad 128 = 200\times S$$

$$\Rightarrow \quad S = 0.64\text{ m}$$

7. (d)

Given: Mass of elevator = 500 kg

Mass of operator = 100 kg

Upward acceleration = 3 m/s^2

Total tension in the cable of the elevator = $(m_1 + m_2)(g + a) = (500 + 100)(10 + 3) = 600 \times 13$

Total tension in the cable of the elevator = 7800 N = 7.8 kN

8. (b)

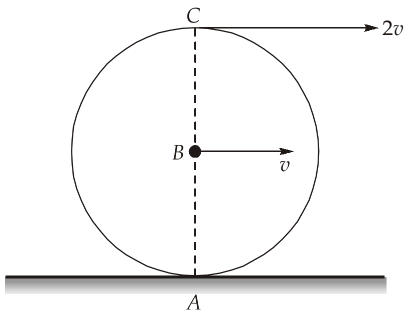
Given: Velocity, $v = 54 \text{ kmph} = (54)\times\frac{5}{18} = 15$ m/s

Diameter, d = 1 m

Radius, r = 0.5 m

(i) Velocity of the top of the wheel relative to the person sitting in the carriage:

We know that the velocity of the top of the wheel (C) = $2v = 2 \times 15 = 30$ m/s



Velocity of the person sitting in the carriage, v = 15 m/s

Velocity of the top of the wheel relative to the person sitting in the carriage = 30 – 15 = 15 m/s

9. (b)

Work done, $dW = F\cdot dx = (10 + 0.5 \ln x)dx$

Thus, $$\int_0^W dW = \int_2^4 (10+0.5\ln x)dx$$

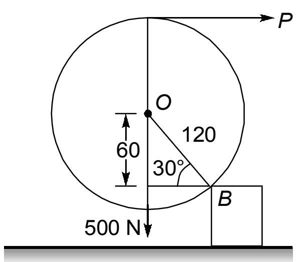
$$W = 10(4-2) + 0.5\int_2^4 \ln x\, dx$$

$$W = 20 + 0.5\,(x\ln x - x)_2^4$$

$$W = 20 + 0.5(4\ln 4 - 4 - 2\ln 2 + 2)$$

$$W = 21.079 \text{ J}$$

10. (a)

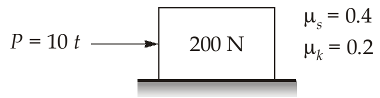


Taking moment about B,

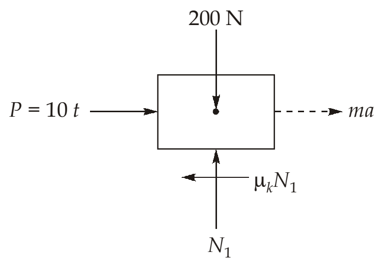
$$P \times (60 + 120) = 500 \times 120\cos 30°$$

$$\therefore \quad P = 288.68 \text{ N}$$

11. (a)



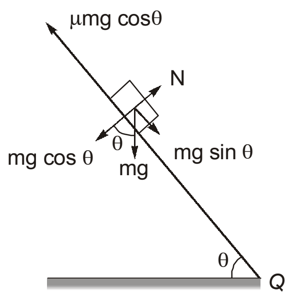
Free body diagram of the block just after limiting condition is shown below.



Now,
$$\Sigma F_y = 0$$
$$\Rightarrow \quad N_1 - 200 = 0$$
$$\Rightarrow \quad N_1 = 200\text{ N}$$
$$\Sigma F_x = 0$$
$$\Rightarrow \quad P - \mu_k N_1 - ma = 0$$
$$\Rightarrow \quad 10t - 0.2 \times 200 = m\left(\frac{dV}{dt}\right) \qquad [\because N = 200\text{ N}]$$
$$\Rightarrow \quad \left(\frac{dV}{dt}\right) = \frac{1}{m}(10t - 40)$$
$$\Rightarrow \quad dV = \frac{1}{m}(10t - 40)dt$$

On integrating both sides.
$$\int_0^V dV = \frac{1}{m}\int_0^8 (10t - 40)dt$$
$$\Rightarrow \quad V = \frac{1}{m}\left(\frac{10t^2}{2} - 40t\right)_0^8$$
$$\Rightarrow \quad V = \frac{1}{m}(320 - 40 \times 8)$$
$$\Rightarrow \quad V = 0\text{ m/s}$$

12. (a)



From Newton's second law
$$mg\sin\theta - \mu mg\cos\theta = ma$$
$$\therefore \quad a = g(\sin\theta - \mu\cos\theta)$$

$$\Rightarrow \qquad a = g\cos\theta\,(\tan\theta - \mu)$$

Now,
$$s = ut + \frac{1}{2}at^2$$

$$\Rightarrow \qquad s = 0 + \frac{1}{2}g\cos\theta(\tan\theta - \mu)\cdot t^2$$

$$\therefore \qquad t = \sqrt{\frac{2s}{g\cos\theta\,(\tan\theta - \mu)}}$$

13. (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

$$\frac{dD}{dt} = 0 \quad \text{or} \quad \frac{d(D^2)}{dt} = 0$$

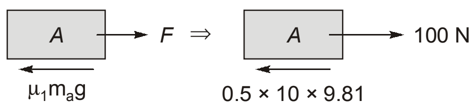
$$2 \times 20t - 20(2-t) \times 2 = 0$$

$$t = 1 \text{ hrs}$$

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

14. (b)

Free body diagram of *A*:

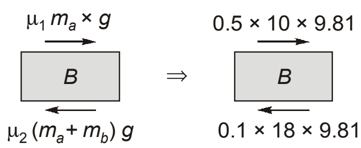


Writing equation of motion for A.

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

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

Free body diagram of *B*:



Writing equation of motion for *B*.

$$49.05 - 17.658 = 8\,a$$

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

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,
$$V_B = 0 + 3.924 \times 0.1$$
$$V_B = 0.3924 \text{ m/s}$$

$\therefore$ Relative velocity of *A* w.r.t. *B* $= V_A - V_B$

$$= 0.5095 - 0.3924 \simeq 0.12 \text{ m/s}$$

15. (c)

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

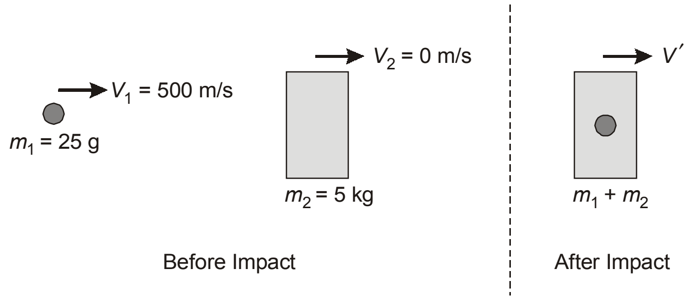
$$\Rightarrow \quad 10.5g = 2.5V^2 + \frac{1}{2}\times 10000\times(0.1)^2$$

$$\Rightarrow \quad 10.5\times 9.81 = 2.5\ V^2 + 50$$

$$\Rightarrow \quad V^2 = 21.202$$

$$\therefore \quad V = 4.6\ \text{m/s}$$

16. (d)



$$V' = \frac{0.025\times 500}{5+0.025} = \frac{12.5}{5.025} = 2.488\,\text{m/s}$$

Change in kinetic energy,

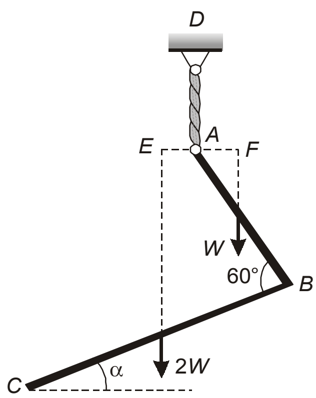
$$\Delta KE = \frac{1}{2}\times 0.025\times 500^2 - \frac{1}{2}\times 5.025\times 2.488^2$$

$$= 3125 - 15.55 = 3109.45\ \text{J}$$

$$\text{Percentage of energy lost} = \frac{3109.45}{3125}\times 100 = 99.5\%$$

17. (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,

$$\Sigma M_A = 0$$

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

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

Now, from the geometry of the system,

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

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

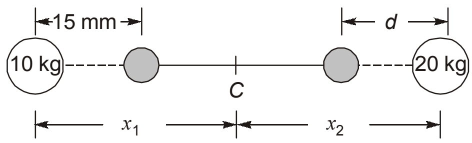
From equations (i), (ii) and (iii), we get

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

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

$$\alpha = 19.11^\circ$$

18. (c)



To keep centre of mass at C

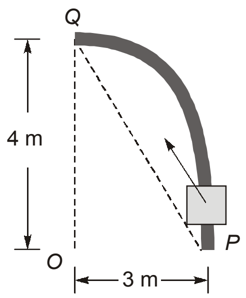
$$m_1 x_1 = m_2 x_2 \quad \rightarrow \quad (\text{Let } 10 \text{ kg} = m_1,\ 20 \text{ kg} = m_2)$$

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

$$15\, m_1 = m_2 d$$

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

19. (b)



$$\text{Change in Kinetic Energy} = \text{Total work done} = W_{18} + W_{mg}$$

$$= F.S. - mg \times s'$$

$$= 18 \times PQ - 1 \times 10 \times OQ$$

$$= 18 \times 5 - 10 \times 4 \qquad \left[PQ = \sqrt{4^2 + 3^2} = 5\text{m}\right]$$

$$= 50 \text{ J}$$

Change in kinetic energy is positive hence increase in kinetic energy is 50 J.

20. (a)

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

Applying conservation of angular momentum,

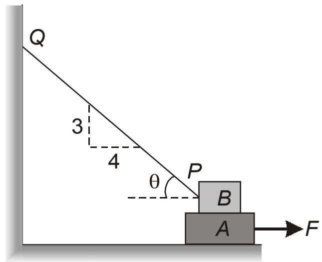
$$\therefore \quad I\omega = I'\omega'$$

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

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

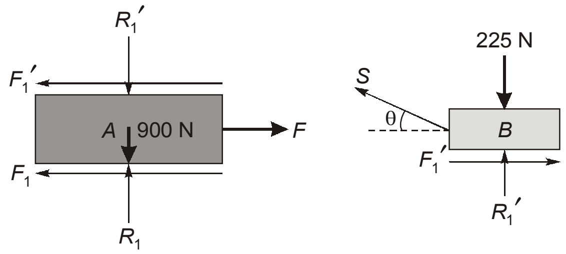
$$\Rightarrow \quad \omega' = 8.333 \text{ rad s}^{-1}$$

21. (a)



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

The free body diagrams of the blocks are shown below.



$$F_1 = \mu R_1 \text{ and } F_1' = \mu R_1' \quad \text{...(i)}$$

From equilibrium of block *A*,

$$F - F_1 - F_1' = 0 \quad \text{...(ii)}$$

and

$$R_1 - W_1 - R_1' = 0 \quad \text{...(iii)}$$

$$\Rightarrow \quad R_1 = \frac{F_1}{\mu} = W_1 + \frac{F_1'}{\mu} \quad \text{...(iv)}$$

From the equilibrium of block *B*,

$$F_1' - S\cos\theta = 0 \quad \text{...(v)}$$

and

$$R_1' + S\sin\theta - W_2 = 0 \quad \text{...(vi)}$$

$$\Rightarrow \quad F_1' = \frac{W_2}{1/\mu + \tan\theta} \quad \text{...(vii)}$$

From equations (ii), (iv) and (vii), we get

$$F = \mu W_1 + \frac{2W_2}{\frac{1}{\mu} + \tan\theta} = 0.3 \times 900 + \frac{2 \times 225}{\frac{1}{0.3} + \frac{3}{4}} = 380.2\text{N}$$

22. (a)

$$x = 10 \sin 2t + 15 \cos 2t + 100$$

$$v = \frac{dx}{dt} = 20 \cos 2t - 30 \sin 2t$$

$$a = \frac{dv}{dt} = -40 \sin 2t - 60 \cos 2t \quad \text{...(i)}$$

For a_{max}, $\frac{da}{dt} = 0$

$\Rightarrow$ $-80 \cos 2t + 120 \sin 2t = 0$

$$\tan 2t = \frac{2}{3}$$

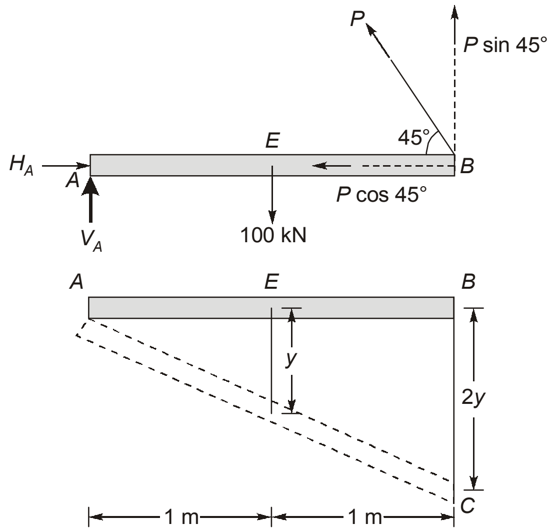
$\Rightarrow$ $2t = 33.69$

Now using equation (i), we get

$$a_{max} = -40 \sin (33.69) - 60 \times \cos (33.69) = -72.11 \text{ mm/s}^2$$

23. (c)

Free body diagram of beam AB,



Now using the principle of virtual work done, if C.G. of beam AB shifts by an amount 'y' then end B must shift by '$2y$' (using similar triangles).

$\therefore$ $100 \times y - P \sin 45° \times 2y = 0$

$\Rightarrow$ $P = 70.71$ kN

24. (a)

Considering velocities to the right as positive,

The initial momentum of the system $= \frac{W + w}{g} v_0$

The final momentum of the car $= \frac{W}{g}(v_0 + \Delta v)$

The final momentum of the man $= \frac{w}{g}(v_0 + \Delta v - u)$

Since no external forces act on the system, the law of conservation of momentum gives,

$$\frac{W+w}{g}v_0 = \frac{W}{g}(v_0+\Delta v)+\frac{w}{g}(v_0+\Delta v-u)$$

$$\Rightarrow \quad W\Delta v - wu + w\Delta v = 0$$

$$\therefore \quad \Delta v = \frac{wu}{W+w}$$

25. (b)

Assume, Initial angular velocity = ω_0

Angular acceleration = α

Condition I:

Angular velocity after 4 sec = ω

$$\omega = \omega_0 + (\alpha t)$$

$$\omega = \omega_0 + 4\alpha \quad \text{...(i)}$$

We know that, $$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$100 = (4\omega_0) + \frac{1}{2}\times\alpha\times 4^2$$

$$100 = 4\omega_0 + 8\alpha \quad \text{...(ii)}$$

Condition II:

$$\theta = \omega \times t \qquad \{\because \alpha = 0 \text{ in } 2^{nd} \text{ case}\}$$

$$80 = (\omega_0 + 4\alpha)\times 4$$

$$20 = \omega_0 + 4\alpha \quad \text{...(iii)}$$

Multiply equation (iii) by (2), $40 = 2\omega_0 + 8\alpha$ ...(iv)

By equation (ii) – equation (iv),

$$(100-40) = (4\omega_0 + 8\alpha) - (2\omega_0 + 8\alpha)$$

$$60 = 2\omega_0$$

Initial angular velocity, ω_0 = 30 rad/s

26. (c)

Given: Mass, m = 80000 kg,

Resistance = 2% of (80000 × 10)N

$$= \frac{2\times 80000\times 10}{100} = 16000 \text{ N} = 16 \text{ kN}$$

Available force = Tractive force – Resistance

= (26 – 16) = 10 kN

$$\text{Acceleration of train} = \frac{\text{Available force}}{\text{mass}} = \frac{10\times 10^3}{80\times 10^3} = \frac{1}{8} \text{ m/s}^2$$

Final velocity of the train, v = 10 m/s

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

$$10 = 0 + \left(\frac{1}{8}\times t\right)$$

$$t = 80 \text{ s}$$

27. (b)

Given: $a = \dfrac{5}{v+3}$, where 'v' is velocity and 's' is distance.

We know that,

$$v\frac{dv}{ds} = a$$

$$\frac{vdv}{ds} = \left(\frac{5}{v+3}\right)$$

$$v(v+3)dv = 5ds$$

Integrating on both sides,

$$\left(\frac{v^3}{3}+\frac{3v^2}{2}\right) = 5s + c_1$$

$\therefore$ at, $t = 0$, $s = 0$ and $v = 0$

$\therefore$ $$0 + 0 = 0 + c_1$$

$\therefore$ $$c_1 = 0$$

Now, $$\frac{v^3}{3}+\frac{3v^2}{2} = 5s$$

at, $v = 30$ m/s

$$\frac{(30)^3}{3}+\frac{3(30)^2}{2} = 5s$$

$$\frac{(30)^3}{3}+\frac{3\times 30^2}{2} = 5s$$

$$9000 + 1350 = 5s$$

$$s = \frac{10350}{5}$$

$$s = 2070\text{ m}$$

28. (c)

Given: $m_A = 15$ kg, $m_B = 10$ kg

For mass B, $$m_B g - T = m_B a$$

$$10g - T = 10a \quad \text{...(i)}$$

For mass A, $$T = m_A a$$

$$T = 15a \quad \text{...(ii)}$$

Addition equation (i) and (ii)

$$(10g - T) + (T) = (15 + 10)a$$

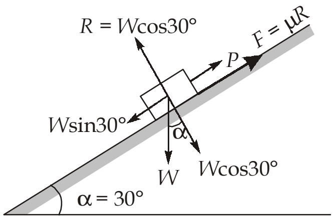
$$a = \frac{10g}{25} = \frac{10\times 10}{25} = 4\text{ m/s}^2$$

$$\text{Acceleration, } a = 4\text{ m/s}^2$$

29. (c)

Given: Weight of body, $W = 1000$ N

Angle of plane of inclination, $\alpha = 30°$, Angle of friction, $\phi = 15°$



For minimum value of P, the body will be at the point of sliding downwards. In this condition, friction force will act in upward direction parallel to the plane.

Let, F and R are friction force and normal reactions respectively.

In equilibrium condition, $W\sin 30° = P + \mu R$

$$P = W\sin 30° - \mu W\cos 30°$$

$[\because \mu = \tan\phi = \tan 15°]$

$$= W\left[0.5 - 0.268 \times \frac{\sqrt{3}}{2}\right] = W[0.5 - 0.268 \times 0.866]$$

$$= 1000 \times 0.268$$

Minimum force required for equilibrium, $P = 268$ N

Alternate:
$$P_{min} = W\frac{\sin(\alpha - \phi)}{\cos\phi}$$

$$= 1000 \times \frac{\sin(30-15)°}{\cos 15°} = 1000 \times \tan 15°$$

$$P_{min} = 268 \text{ N}$$

30. (a)

MOI of triangle about base AB,

$$I_1 = \frac{1}{12} \times (2r) \times (2r)^3 = \left(\frac{16}{12}\right)r^4$$

MOI of semi-circle about diameter, $I_2 = \left(\frac{1}{2}\right) \times \left(\frac{\pi}{64}\right) \times (2r)^4 = \left(\frac{\pi}{8}\right)r^4$

MOI of smaller circle about diameter, $I_3 = \left(\frac{\pi}{64}\right)r^4$

MOI of whole section about AB axis, $I = I_1 + I_2 - I_3$

$$= \left(\frac{4}{3} + \frac{\pi}{8} - \frac{\pi}{64}\right)r^4 = \left(\frac{4}{3} + \frac{7\pi}{64}\right)r^4 = \left(\frac{4}{3} + \frac{22}{64}\right)r^4 = 1.677\ r^4$$

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