CLASS TEST

S.No.: 01SKCE_ABCD_22032025

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ENGINEERING MECHANICS

CIVIL ENGINEERING

Date of Test : 22/03/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)
During inelastic collision only linear momentum is conserved.

2. (c)

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

$$\omega_0 = 0$$

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

$$\therefore \quad \text{Number of revolutions} = \frac{100}{2\pi} = 15.92$$

3. (b)

$$e = \frac{\text{Velocity of separation}}{\text{Velocity of approach}}$$

For perfectly elastic body, $e = 1$ and no dissipation of energy occurs.

4. (c)

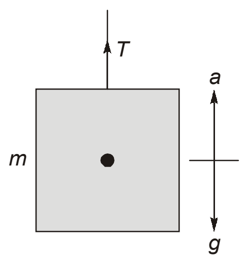
$$\text{Kinetic energy, } KE = \frac{1}{2}I\omega^2$$

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

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

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

5. (d)



$T = m(a + g) = 400(3 + 10) = 5200$ N

6. (a)
Given: Velocity of first particle, $u_1 = 10$ m/s
Angle of projection for first particle, $\alpha_1 = 60°$
Angle of projection for second particle, $\alpha_2 = 30°$
Velocity of second particle, $u_2 = ?$
Given, Time of flight is same.

$$t_1 = t_2$$

$$\frac{2u_1 \sin\alpha_1}{g} = \left(\frac{2u_2 \sin\alpha_2}{g}\right)$$

$$u_2 = \frac{10 \times \sin 60°}{(\sin 30°)} = \frac{10 \times \frac{\sqrt{3}}{2}}{\frac{1}{2}} = 10 \times \sqrt{3}$$

$$u_2 = 17.32 \text{ m/s}$$

7. (b)

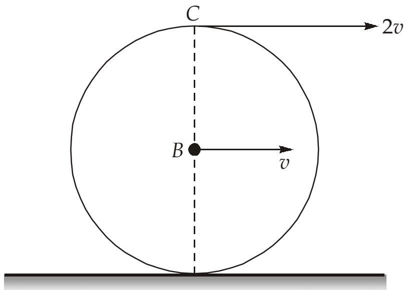
Given: Velocity, $v = 54$ kmph $= (54) \times \frac{5}{18} = 15$ m/s

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:

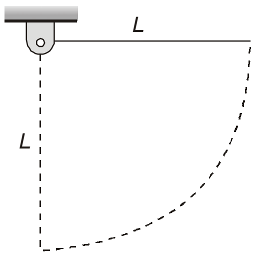
We know that the velocity of the top of the wheel (C) = $2v = 2 \times 15 = 30$ m/s



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

8. (b)



Applying conservation of energy,

$$mgL = \frac{mgL}{2} + \frac{1}{2} I\omega^2$$

$$\Rightarrow \quad I\omega^2 = mgL$$

$$\Rightarrow \quad \frac{mL^2}{3}\omega^2 = mgL$$ [The moment of inertia about the end of the rod is $\frac{mL^2}{3}$]

$$\therefore \quad \omega = \sqrt{\frac{3g}{L}}$$

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)

Given: $$\vec{F} = 10\hat{i} + 5\hat{j} + \hat{k} \text{ (N)}$$

$$x = \sqrt{106}\text{ m}$$

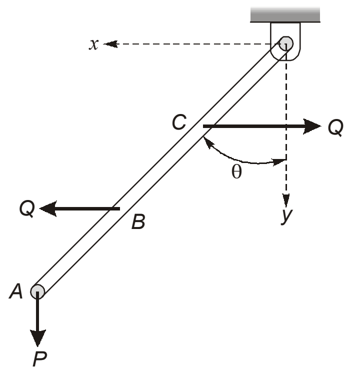
Now, $$\vec{A} \times \vec{B} = (3\hat{i} + 4\hat{j}) \times (3\hat{j} + \hat{k}) = 4\hat{i} - 3\hat{j} + 9\hat{k}$$

Now, $$W = \left[(10\hat{i} + 5\hat{j} + \hat{k}) \times \sqrt{106}\right] \cdot \frac{(4\hat{i} - 3\hat{j} + 9\hat{k})}{\sqrt{4^2 + 3^2 + 9^2}}$$

or $$W = 40 - 15 + 9$$

∴ $$W = 34 \text{ Nm}$$

11. (c)



We have
$$\left.\begin{aligned} x_C &= a\sin\theta \\ \delta x_C &= a\cos\theta\,\delta\theta \end{aligned}\right\}$$

$$\left.\begin{aligned} x_B &= 2a\sin\theta \\ \delta x_B &= 2a\cos\theta\,\delta\theta \end{aligned}\right\}$$

$$\left.\begin{aligned} y_A &= 3a\cos\theta \\ \delta y_A &= -3a\sin\theta\,\delta\theta \end{aligned}\right\}$$

Virtual work: We note that P tends to increase y_A and Q at B tends to increase x_B, while Q at C tends to decrease x_c. From principle of virtual work, work done by external forces is equal to change in internal energy of the system.

∴ $$\delta U = P\delta y_A + Q\delta x_B - Q\delta x_C = 0$$

⇒ $$-P(3a \sin\theta\,\delta\theta) + Q(2a\cos\theta\,\delta\theta) - Q(a\cos\theta\,\delta\theta) = 0$$

⇒ $$Q\cos\theta = 3P\sin\theta$$

⇒ $$Q = 3P\tan\theta$$

Alternatively,

$$\Sigma M_D = 0 \qquad (\because \text{ End } D \text{ is hinged})$$

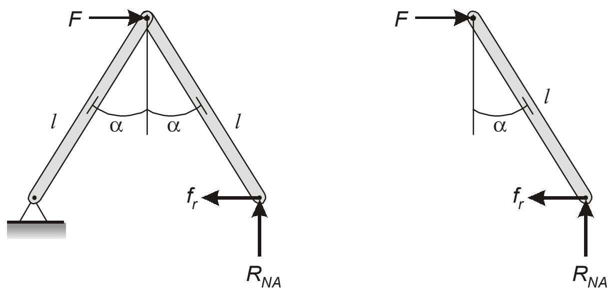
⇒ $$P(3a\sin\theta) + Q(a\cos\theta) = Q(2a\cos\theta)$$

⇒ $$3P\sin\theta = Q\cos\theta$$

⇒ $$Q = 3P\tan\theta$$

12. (a)

Note that the condition of impending slip does not necessarily apply. The moments about the left pin support must be zero.



$$\Sigma M = 0,$$

$$\Rightarrow \quad -Fl\cos\alpha + 2R_{NA}\, l\sin\alpha = 0$$

$$\Rightarrow \quad R_{NA} = \frac{F}{2\tan\alpha} \qquad \text{...(i)}$$

Isolate the right bar and take moments about the upper pin joint:

$$\Sigma M = 0,$$

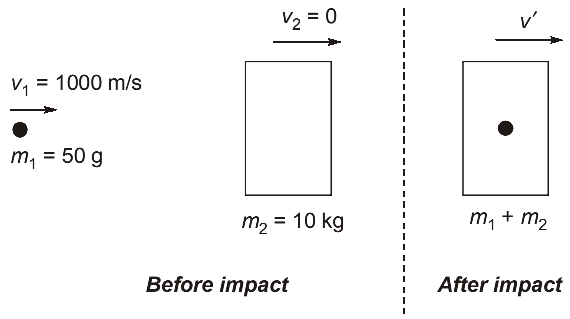
$$\Rightarrow \quad R_{NA}\, l\sin\alpha - f_r\, l\cos\alpha = 0$$

$$\Rightarrow \quad f_r = R_{NA}\tan\alpha$$

Substituting R_{NA} from equation (i), we get

$$f_r = R_{NA}\tan\alpha = \frac{F\tan\alpha}{2\tan\alpha} = \frac{F}{2}$$

13. (a)



Applying the law of conservation of linear momentum,

$$\text{Initial momentum} = \text{Final momentum}$$

$$m_1v_1 + m_2v_2 = (m_1 + m_2)v'$$

$$\Rightarrow \quad v' = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$$

$$= \frac{50 \times 1000 + 0}{10000 + 50}$$

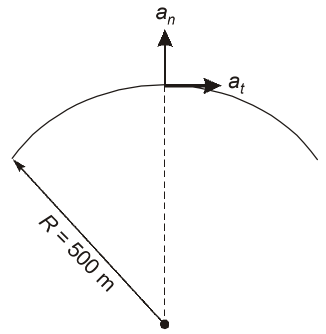
$$= 4.98 \text{ m/s}$$

Change in kinetic energy,

$$\Delta KE = \frac{1}{2} \times 0.05 \times 1000^2 - \frac{1}{2} \times 10.05 \times 4.98^2$$

$$= 24875.38 \text{ Joules} \simeq 24.9 \text{ kJ}$$

14. (b)



$$\text{Speed after 20 sec} = \frac{72}{3.6} = 20 \text{ m/s}$$

$$\text{Initial speed} = 0 \text{ m/s}$$

$$\therefore \text{Tangential acceleration, } a_t = \frac{20-0}{20} = 1 \text{ m/s}^2$$

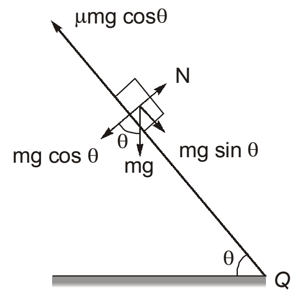
Now speed after 10 sec from start = 10 × 1 = 10 m/s

$$\text{Normal acceleration, } a_n = \frac{V^2}{R}$$

$$= \frac{10^2}{500} = 0.2 \text{ m/s}^2$$

$$\therefore \quad \text{Required ratio, } \frac{a_t}{a_n} = \frac{1}{0.2} = 5$$

15. (a)



From Newton's second law

$$mg \sin\theta - \mu mg \cos\theta = ma$$

$$\therefore \quad a = g(\sin\theta - \mu\cos\theta)$$

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

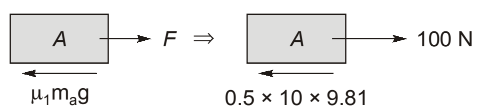
Now,
$$s = ut + \frac{1}{2}at^2$$

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

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

16. (b)

Free body diagram of *A*:

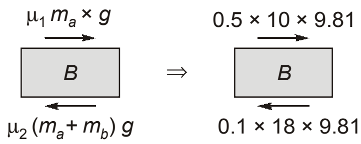


Writing equation of motion for A.

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

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

Free body diagram of *B*:



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,

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

$$V_B = 0.3924 \text{ m/s}$$

∴ Relative velocity of A w.r.t. B $= V_A - V_B$

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

17. (c)

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

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

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

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

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

18. (c)

Coefficient of restitution,

$$e = -\frac{\Delta V}{\Delta u} = -\frac{v_2 - v_1}{u_2 - u_1}$$

here,

$$u_2 = 0,$$

$$v_2 = 0$$

$$e = \frac{v_1}{u_1}$$

$$v^2 - u^2 = 2\,ah$$

when ball is dropped from height,

$$u = 0$$

Let final velocity is u_1

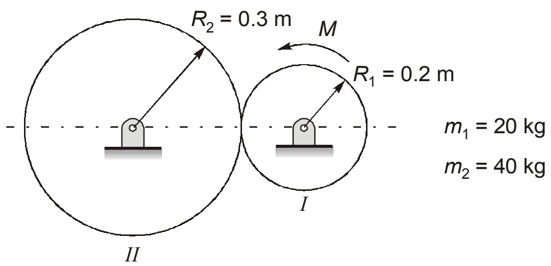
$$u_1^2 = 2ah_1$$

$$v_1^2 = 2ah_2$$

$$e^2 = \left(\frac{v_1}{u_1}\right)^2 = \frac{h_2}{h_1}$$

$$\therefore \quad h_2 = h_1 \times e^2 = 0.36 \text{ m}$$

19. (a)



$$\text{Moment of inertia, } I_2 = \frac{m_1R_1^2}{2} = \frac{20\times0.2^2}{2} = 0.4 \text{ kgm}^2$$

$$I_2 = \frac{m_2R_2^2}{2} = \frac{40\times0.3^2}{2} = 1.8 \text{ kgm}^2$$

A force of friction F acts between disc I and II which drives disc II.

$$F\times R_2 = I_2\alpha_2 \quad \text{...(1)}$$

$$R_1\alpha_1 = R_2\alpha_2$$

$$\Rightarrow \quad 0.2\times8.33 = 0.3\times\alpha_2$$

$$\alpha_2 = 5.55 \text{ m/s}^2$$

Put α_2 value in (1)

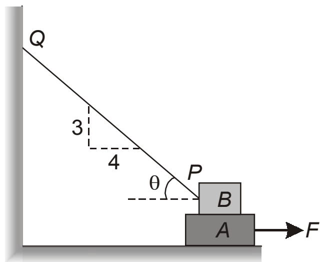
We get $F = 33.32$ N

$$M - FR_1 = I_1\alpha_1$$

$$\Rightarrow \quad M - 33.32\times0.2 = 0.4\times8.33$$

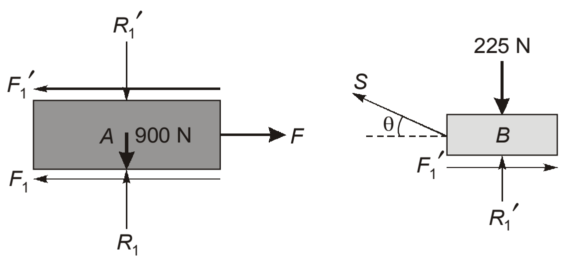
$$M = 9.996 \simeq 10 \text{ Nm}$$

20. (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 $R_1 - W_1 - R_1' = 0$ ...(iii)

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

From the equilibrium of block B,

$F_1' - S\cos\theta = 0$ ...(v)

and $R_1' + S\sin\theta - W_2 = 0$ ...(vi)

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

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

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

21. (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}, $\dfrac{da}{dt} = 0$

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

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

$\Rightarrow$ $2t = 33.69$

Now using equation (i), we get

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

22. (a)

Considering velocities to the right as positive,

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

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

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

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

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

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

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

23. (a)

Given:Speed, u = 25 m/s; diameter, d = 50 cm = 0.5 m; Radius, r = 0.25 m

We know that,
$$v^2 = u^2 + 2as$$
$$0 = (25)^2 + 2 \times a \times (25)$$
$$a = \frac{-625}{50} = -12.5 \text{ m/s}^2$$

[Here minus sign represents retardation]

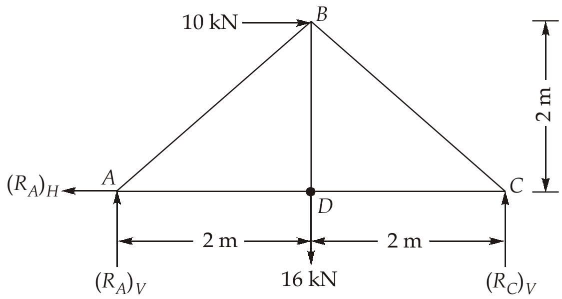
Angular retardation of the wheel,
$$\alpha = \frac{a}{r} = \frac{-12.5}{0.25} = -50 \text{ rad/s}^2$$

[Minus sign indicates retardation]

$$\alpha = 50 \text{ rad/s}^2 \text{ (Retardation)}$$

24. (c)

Let, R_A and R_C are the support reactions at A and C respectively. Support C is a roller support so there will be only vertical reaction at C.



Now,
$$\Sigma F_x = 0$$
$$(R_A)_H = 10 \text{ kN } (\leftarrow)$$

Now, Taking moment about A,
$$(R_C)_V \times 4 = (16 \times 2) + (10 \times 2) = 52$$
$$\Rightarrow \quad (R_C)_V = 13 \text{ kN}$$

Now,
$$\Sigma F_y = 0$$
$$\Rightarrow \quad (R_A)_V + (R_C)_V = 16$$
$$\Rightarrow \quad (R_A)_V = 16 - 13 = 3 \text{ kN}$$

$$\text{Reaction at } A,\ R_A = \sqrt{(R_A)_H^2 + (R_A)_V^2} = \sqrt{10^2 + 3^2} = 10.44 \text{ kN}$$

25. (c)

Given:
$$\text{Mass, } m = 80000 \text{ kg},$$
$$\text{Resistance} = 2\% \text{ of } (80000 \times 10)\text{N}$$
$$= \frac{2 \times 80000 \times 10}{100} = 16000 \text{ N} = 16 \text{ kN}$$
$$\text{Available force} = \text{Tractive force} - \text{Resistance}$$
$$= (26 - 16) = 10 \text{ kN}$$
$$\text{Acceleration of train} = \frac{\text{Available force}}{\text{mass}} = \frac{10 \times 10^3}{80 \times 10^3} = \frac{1}{8} \text{ m/s}^2$$

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

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

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

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

26. (c)

Given: m_A = 15 kg, m_B = 10 kg

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

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

For mass A, $T = m_A a$

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

Addition equation (i) and (ii)

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

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

Acceleration, a = 4 m/s^2

27. (b)

Given: Angle of inclination, α = 30°; Deceleration, a = 1 m/s^2; Weight of block, W = 5 kN

Coefficient of friction, μ = 0.3

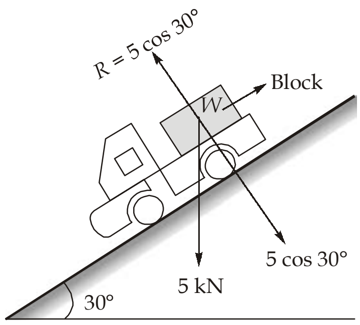
$\because$ As truck is decelerated, the load will tend to slip forward (i.e. downward)

Force due to deceleration, $F_1 = m \cdot a$

$$= \left(\frac{5 \times 10^3}{10}\right) \times 1 = 500 \text{ N}$$

Component of the load along the plane,

$$F_2 = W \sin\theta = (5 \text{ kN}) \sin 30° = 2.5 \text{ kN}$$



$\therefore$ Total force that will cause slipping:

$$F_{net} = F_1 + F_2 = 0.5 + 2.5 = 3.0 \text{ kN}$$

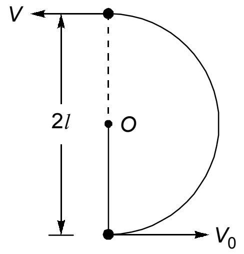
$$\text{Force of friction} = \mu W \cos\theta = 0.3 \times 5 \times \cos 30°$$

$$= 1.5 \times 0.866 \text{ kN} = 1.30 \text{ kN}$$

$$\text{Factor of safety} = \frac{\text{Force of friction}}{\text{Force causing slipping}} = \frac{1.30}{3.00} = 0.433$$

28. (d)

Let the bob is given horizontal speed V_0 at the bottom.



By energy conservation,

So, $$\frac{1}{2}mV_0^2 = \frac{1}{2}mV^2 + mg\times(2l)$$

or, $$mV^2 = mV_0^2 - 4\,mgl \qquad ...(1)$$

Also, at the top most point, force balance is,

$$mg + T = \frac{mV^2}{l}$$

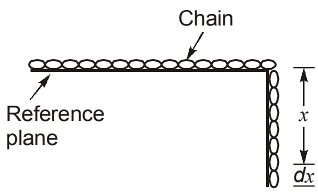
$$mV^2 = mgl + Tl$$

or $$mV_0^2 = 5\,mgl + Tl \qquad \text{(using (1))}$$

For minimum V_0, T should be zero

$\therefore$ $$V_0 = \sqrt{5gl}$$

29. (d)



The potential energy of $\frac{l}{3}$ of the chain that overhangs is

$$u_1 = \int_0^{l/3} -\frac{mgx}{l}dx = \frac{-mgl}{18}$$

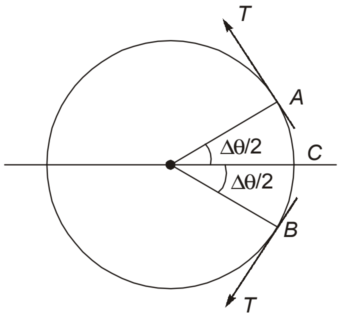
The potential energy of the full chain when it completely slips off the table is

$$u_2 = \int_0^{l} -\frac{mgx}{l}dx = \frac{-mgl}{2}$$

$$\text{The loss in } PE = \frac{-mgl}{18} - \left(\frac{-mgl}{2}\right) = \frac{4mgl}{9}$$

This should be equal to gain in kinetic energy, but the initial kE is zero. Hence this is the kE when the chain completely falls off the table.

30. (a)



Consider a small part ACB of the ring that subtends an angle $\Delta\theta$ at the centre. Let T be tension in the ring. Δm be the mass of small element.

$$\Rightarrow \quad 2T\sin\frac{\Delta\theta}{2} = \Delta m\left(\frac{v^2}{r}\right) \quad ...(1)$$

Length of arc ACB is $R\Delta\theta$.

Now, $$\Delta m = \frac{M}{2\pi R}\times R\Delta\theta = \frac{M\Delta\theta}{2\pi}$$

$$\Rightarrow \quad 2T\sin\frac{\Delta\theta}{2} = \frac{M\Delta\theta}{2\pi}\times\frac{v^2}{R}$$

$$\Rightarrow \quad T = M\times\frac{v^2}{2\pi R}\times\frac{\Delta\theta/2}{\sin(\Delta\theta/2)} = \frac{Mv^2}{2\pi R} \quad \left[\because \text{for small angle, } \sin\frac{\theta}{2} = \frac{\theta}{2}\right]$$

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