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Web: www.madeeasy.in | E-mail: info@madeeasy.in | Ph: 011-45124612

ENGINEERING MECHANICS

MECHANICAL ENGINEERING

Date of Test : 18/10/2026

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

1. (d)

Given: Mass of elevator = 500 kg

Mass of operator = 100 kg

Upward acceleration = 3 m/s^2

$$\begin{aligned}\text{Total tension in the cable of the elevator} &= (m_1 + m_2)(g + a) \\ &= (500 + 100)(10 + 3) = 600 \times 13\end{aligned}$$

$$\text{Total tension in the cable of the elevator} = 7800 \text{ N} = 7.8 \text{ kN}$$

2. (a)

Given: Velocity of first particle, $u_1 = 10 \text{ m/s}$

Angle of projection for first particle, $\alpha_1 = 60^\circ$

Angle of projection for second particle, $\alpha_2 = 30^\circ$

Velocity of second particle, $u_2 = ?$

Given, Time of flight is same.

$$\begin{aligned}t_1 &= t_2 \\ \frac{2u_1 \sin \alpha_1}{g} &= \left(\frac{2u_2 \sin \alpha_2}{g} \right) \\ u_2 &= \frac{10 \times \sin 60^\circ}{(\sin 30^\circ)} = \frac{10 \times \frac{\sqrt{3}}{2}}{\frac{1}{2}} = 10 \times \sqrt{3} \\ u_2 &= 17.32 \text{ m/s}\end{aligned}$$

3. (b)

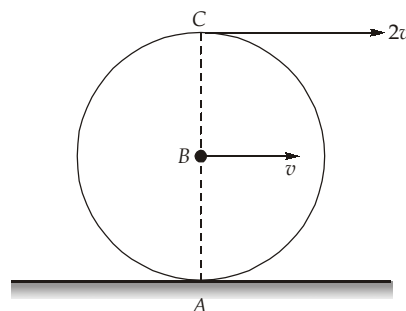
$$\text{Given: Velocity, } v = 54 \text{ kmph} = (54) \times \frac{5}{18} = 15 \text{ m/s}$$

Diameter, $d = 1 \text{ m}$

Radius, $r = 0.5 \text{ m}$

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

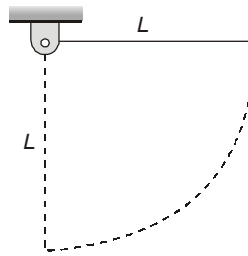
We know that the velocity of the top of the wheel (C) = $2v = 2 \times 15 = 30 \text{ m/s}$



Velocity of the person sitting in the carriage, $v = 15 \text{ m/s}$

Velocity of the top of the wheel relative to the person sitting in the carriage = $30 - 15 = 15 \text{ m/s}$

4. (b)



Applying conservation of energy,

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

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

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

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

5. (b)

$$\begin{aligned} \bar{y} &= \frac{y_1 A_1 + y_2 A_2}{A_1 + A_2} \\ &= \frac{\frac{4a}{3\pi} \times \frac{\pi}{4} a^2 + \frac{a}{2} (a^2)}{\frac{\pi}{4} a^2 + a^2} \\ &= \frac{\frac{a^3}{3} + \frac{a^3}{2}}{\left(1 + \frac{\pi}{4}\right) a^2} = 0.47a \end{aligned}$$

6. (b)

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

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

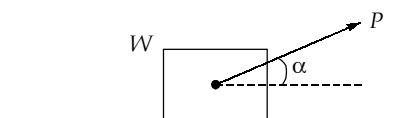
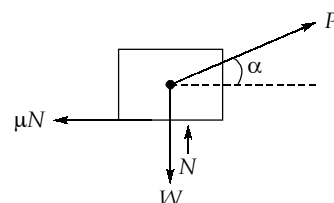
$$W = 10(4 - 2) + 0.5 \int_2^4 \ln x dx$$

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

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

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

7. (b)



$$\Sigma V = 0 \quad W - P \sin \alpha = N \quad \dots(i)$$

$$P \cos \alpha - \mu N = 0$$

$$P \cos \alpha = \mu N \quad \dots(ii)$$

From (i) and (ii),

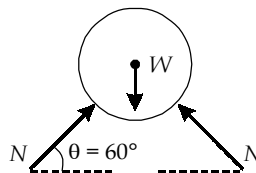
$$P = \frac{\mu W}{\cos \alpha + \mu \sin \alpha}$$

$$P_{\min} = \frac{\mu W}{\sqrt{1 + \mu^2}} = \frac{5/12}{13/12} \times 550$$

$$= \frac{5}{13} \times 550 = 211.54 \text{ N}$$

8. (c)

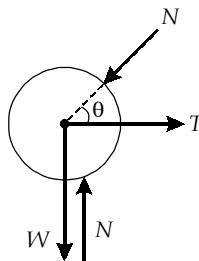
Vertical equilibrium of top cylinder



$$2N \sin \theta = W$$

$$N = \frac{W}{2 \sin \theta}$$

Horizontal equilibrium of bottom cylinder



$$N \cos \theta = T$$

$$T = \frac{W \cos \theta}{2 \sin \theta} = \frac{100}{2 \times \tan 60^\circ}$$

$$= \frac{100}{2\sqrt{3}} = 28.87 \text{ N}$$

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

or $W = 40 - 15 + 9$

$$\therefore W = 34 \text{ Nm}$$

10. (d)

Between point (1) and (2)

$$\Delta KE + \Delta PE = W$$

$$0 + mg(2 - 10) = W$$

$$W = -5 \times 9.81 \times 8$$

$$= -392.4 \text{ N-m}$$

11. (a)

Given: Mass of first ball = m kgMass of second ball = $2m$ kgInitial velocity of first mass = u m/sInitial velocity of second mass = $\frac{u}{7}$ m/sCoefficient of restitution, $e = 0.75$ Let, Velocity of the first ball after impact = v_1 m/sVelocity of the second ball after impact = v_2 m/s

By momentum conservation,

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$mu + 2m \times \frac{u}{7} = mv_1 + 2mv_2$$

$$\frac{9u}{7} = (v_1 + 2v_2) \quad \dots(i)$$

We also know that, $(v_2 - v_1) = e(u_1 - u_2)$

$$(v_2 - v_1) = 0.75 \left(u - \frac{u}{7} \right)$$

$$v_2 - v_1 = \frac{9u}{14} \quad \dots(ii)$$

Multiplying equation (ii) by 2,

$$2v_2 - 2v_1 = \frac{9u}{7} \quad \dots(iii)$$

$$v_1 + 2v_2 = \frac{9u}{7} \quad \text{from eq.(i)}$$

By equation (iii) - (i), $v_1 = 0$ m/s

12. (a)

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

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

13. (b)

Energy in spring = Energy supplied to block

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

$$100 \times (0.05)^2 = \frac{10}{1000} \times v^2$$

$$v = 5 \text{ m/s}$$

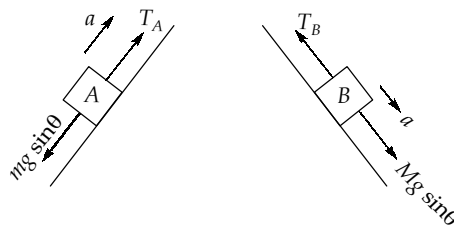
$$\text{Range of block} = v \times t$$

$$\text{Time of flight, } t = \frac{3.16}{5}$$

$$h = \frac{1}{2}gt^2$$

$$h = \frac{1}{2} \times 10 \times \left(\frac{3.16}{5}\right)^2 = 2 \text{ m}$$

14. (c)



$$T_B = Mg \sin \theta - Ma$$

$$T_A = ma + mg \sin \theta$$

$$I_{\text{pulley}} = \frac{1}{2}mr^2$$

$$T_B r - T_A r = \frac{Ia}{r}$$

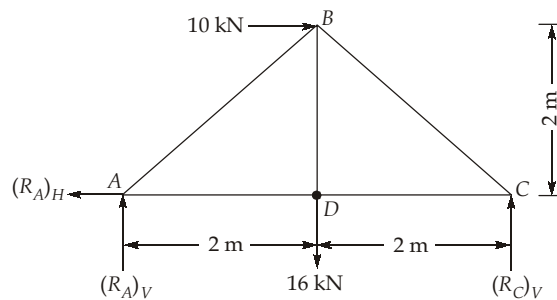
$$Mg \sin \theta - Ma - (ma + mg \sin \theta) = \frac{1}{2}mr^2 \frac{a}{r^2}$$

$$(M - m)g \sin \theta = \left(M + \frac{3}{2}m\right)a$$

$$a = \frac{2(M - m)g \sin \theta}{2M + 3m}$$

15. (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,

$$(R_C)_V \times 4 = (16 \times 2) + (10 \times 2) = 52$$

$$\Rightarrow (R_C)_V = 13 \text{ kN}$$

Now, $\Sigma F_y = 0$

$$\Rightarrow (R_A)_V + (R_C)_V = 16$$

$$\Rightarrow (R_A)_V = 16 - 13 = 3 \text{ kN}$$

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

16. (b)

Assume, Initial angular velocity = ω_0

Angular acceleration = α

Condition I:

Angular velocity after 4 sec = ω

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

$$\omega = \omega_0 + 4\alpha$$

...(i)

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

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

$$100 = 4\omega_0 + 8\alpha$$

...(ii)

Condition II:

$$\theta = \omega \times t$$

{ $\because \alpha = 0$ in 2nd case}

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

$$20 = \omega_0 + 4\alpha$$

...(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, $\omega_0 = 30 \text{ rad/s}$

17. (c)

Given:

Mass, $m = 80000 \text{ kg}$,

Resistance = 2% of $(80000 \times 10) \text{ N}$

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

$$\begin{aligned}\text{Available force} &= \text{Tractive force} - \text{Resistance} \\ &= (26 - 16) = 10 \text{ kN}\end{aligned}$$

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

Final velocity of the train, $v = 10 \text{ m/s}$

$$\begin{aligned}\therefore v &= u + at \\ 10 &= 0 + \left(\frac{1}{8} \times t\right) \\ t &= 80 \text{ s}\end{aligned}$$

18. (b)

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

We know that,

$$\begin{aligned}v \frac{dv}{ds} &= a \\ \frac{v dv}{ds} &= \left(\frac{5}{v+3}\right) \\ v(v+3)dv &= 5ds\end{aligned}$$

Integrating on both sides,

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

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

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

$$\therefore c_1 = 0$$

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

at, $v = 30 \text{ m/s}$

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

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

$$9000 + 1350 = 5s$$

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

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

19. (d)

Conservation of linear momentum,

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$2 \times 10 + 1 \times 4 = 2v_1 + v_2$$

$$2v_1 + v_2 = 24$$

...(i)

As collision is perfectly elastic,

So,

$$v_2 - v_1 = u_1 - u_2$$

$$v_2 - v_1 = 6$$

$$v_2 = 6 + v_1$$

$$2v_1 + 6 + v_1 = 24 \quad \text{from (i)}$$

$$3v_1 = 18$$

$$v_1 = 6$$

$$v_2 = 6 + 6$$

$$= 12 \text{ m/s}$$

20. (b)

Given: Angle of inclination, $\alpha = 30^\circ$; Deceleration, $a = 1 \text{ m/s}^2$; Weight of block, $W = 5 \text{ kN}$

Coefficient of friction, $\mu = 0.3$

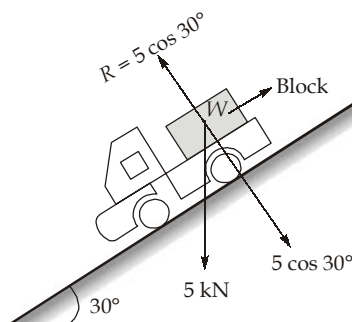
$\therefore$ As truck is decelerated, the load will tend to slip forward (i.e. downward)

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,

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



$\therefore$ Total force that will cause slipping:

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

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

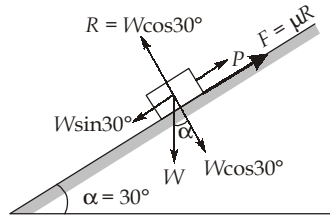
$$= 1.5 \times 0.866 \text{ kN} = 1.30 \text{ kN}$$

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

21. (c)

Given: Weight of body, $W = 1000 \text{ N}$

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



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, $W \sin 30^\circ = P + \mu R$

$$P = W \sin 30^\circ - \mu W \cos 30^\circ$$

$$[\because \mu = \tan \phi = \tan 15^\circ]$$

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

$$= 1000 \times 0.268$$

Minimum force required for equilibrium, $P = 268 \text{ N}$

Alternate:

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

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

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

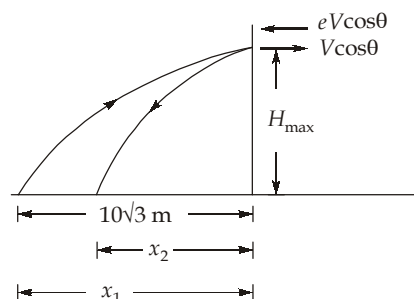
22. (b)

$$\text{Range} = \frac{2V \sin \theta \times V \cos \theta}{g}$$

$$= \frac{2 \times 20 \times \frac{1}{2} \times 20 \times \sqrt{3}}{2 \times 10}$$

$$= 20\sqrt{3} \text{ m}$$

So, ball has only horizontal velocity when striking with wall.



After collision, ball velocity = $eV \cos \theta$

$$= 0.8 \times 20 \times \frac{\sqrt{3}}{2} = 8\sqrt{3} \text{ m/s}$$

$$H_{\max} = \frac{V^2 \sin^2 \theta}{2g}$$

From this height ball comes down in time ' t '.

$$H_{\max} = V_y t + \frac{1}{2} g t^2$$

$$t^2 = \frac{2H_{\max}}{g} = \frac{V^2 \sin^2 \theta}{g^2}$$

$$t = \frac{V \sin \theta}{g}$$

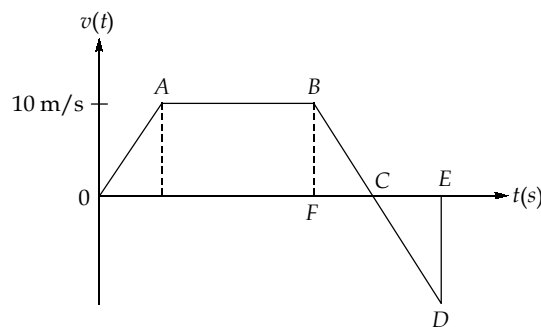
Horizontal range after bounce,

$$x_2 = (eV \cos \theta) \times t$$

$$x_2 = \frac{V \sin \theta}{g} \times eV \cos \theta$$

$$x_1 - x_2 = 2\sqrt{3} \text{ m}$$

23. (d)



Triangles BCF and CED are similar, therefore

$$\frac{BF}{ED} = \frac{CF}{CE}$$

$$\frac{10}{ED} = \frac{5}{15}$$

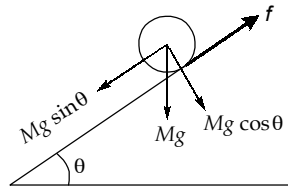
$$ED = 30$$

Total area of the velocity time graph will give us the total displacement

$$\begin{aligned} \text{Area} &= \frac{1}{2} \times (30 + 20) \times 10 - \frac{1}{2} \times 15 \times 30 \\ &= 250 - 225 \\ &= 25 \text{ m} \end{aligned}$$

$$\text{Average velocity} = \frac{25}{45} = 0.55 \text{ m/s}$$

24. (a)



Let the friction force be ' f '

$$\text{So, } Mg \sin \theta - f = Ma$$

$$f = Mg \sin \theta - Ma$$

$$\text{and } fR = I\alpha = I \frac{a}{R}$$

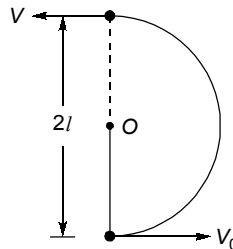
$$f = \frac{Ia}{R^2}$$

$$\frac{Ia}{R^2} = Mg \sin \theta - Ma$$

$$\therefore a = \frac{g \sin \theta}{\left(1 + \frac{I}{MR^2}\right)}$$

25. (d)

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



By energy conservation,

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

$$\text{or, } mV^2 = mV_0^2 - 4mgl \quad \dots(1)$$

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

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

$$mV^2 = mgl + Tl$$

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

For minimum V_0 , T should be zero

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

26. (b)

$$F = 100 - 2V$$

At terminal speed $F = 0$

$$\text{So, } V_t = 50 \text{ m/s}$$

$$50\% \text{ of } V_t = 25 \text{ m/s}$$

$$m \frac{dV}{dt} = F = 100 - 2V$$

$$m \int_0^{25} \frac{dV}{100 - 2V} = \int_0^t dt$$

$$t = \frac{m}{2} \ln \left(\frac{100 - 2 \times 0}{100 - 2 \times 25} \right)$$

$$= \frac{4}{2} \ln 2 = 1.386 \text{ s}$$

27. (a)

Work done by force, $F = \Delta KE + \Delta PE$

$$\int_0^{10} F \cdot dx = \frac{1}{2} m V^2 + \frac{1}{2} m r^2 \left(\frac{V}{r} \right)^2 + 2 \times 10 \times \frac{10}{2}$$

$$200 = 2V^2 + 2V^2 + 100$$

$$100 = 4V^2$$

$$V^2 = \frac{100}{4}$$

$$V = 5 \text{ m/s}$$

28. (b)

$$\Sigma F_H = 0$$

$$P + 150 - R = 0$$

$$R = P + 150$$

$$\Sigma M_{\text{support}} = 0$$

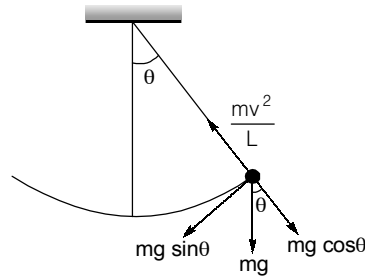
$$100 \times 1 - 150 \times 2 - P \times 4 = 0$$

$$4P = -200$$

$$P = -50 \text{ kN}$$

$$R = -50 + 150 = 100 \text{ kN}$$

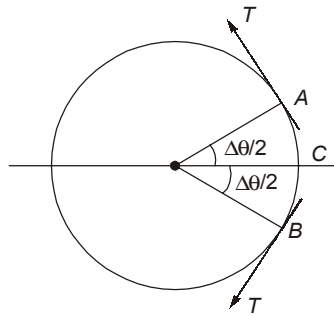
29. (a)



$$\Rightarrow T - mg \cos \theta = \frac{mv^2}{L}$$

$$\Rightarrow T = m \left(g \cos \theta + \frac{v^2}{L} \right)$$

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.

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

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

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

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

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

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