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ENGINEERING MECHANICS

CIVIL ENGINEERING

Date of Test : 20/05/2026

ANSWER KEY >

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

DETAILED EXPLANATIONS

1. (c)

The reaction on the block (R) = 20 kg f

The horizontal force needed to move the block

$$= \mu R = 0.22 \times 20$$

$$= 4.4 \text{ kg f}$$

2. (d)

$$\text{Acceleration (a)} = \frac{dv}{dt} = 3t^2 - 2t$$

at $t = 3 \text{ sec.}$

$$a = 3 \times 3 \times 3 - 2 \times 3 = 21 \text{ m/s}^2$$

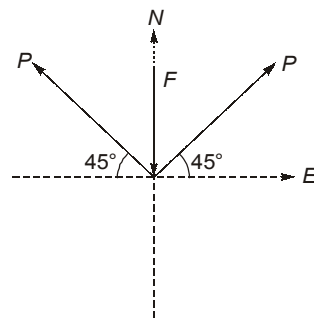
3. (b)

4. (c)

For perfectly elastic collision $e = 1.0$

5. (a)

Considering equilibrium of forces in N-S direction



$$\left(\frac{P}{\sqrt{2}}\right) + \left(\frac{P}{\sqrt{2}}\right) - F = 0$$

$$F = \frac{2P}{\sqrt{2}} = \sqrt{2}P$$

6. (b)

$$R_2 \cos 45^\circ = R_1$$

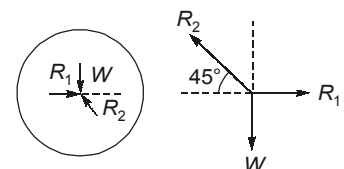
$$R_2 \sin 45^\circ = W$$

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

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

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

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



7. (d)

8. (b)

When body is at rest, for equilibrium,

$$N = 490.5 \text{ N}$$

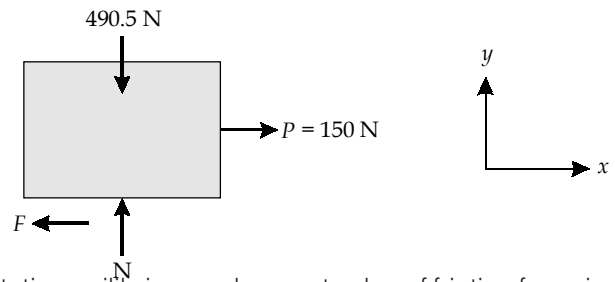
$$\text{Applied force, } P = 150 \text{ N}$$

Maximum static friction force,

$$\begin{aligned} F_{\max} &= \mu s N \\ &= 0.5 (490.5) \\ &= 245.25 \text{ N} \end{aligned}$$

Because $P < F_{\max}$, we conclude that the block is in static equilibrium and correct value of friction force is,

$$F = 150 \text{ N}$$



9. (a)

As the rod reaches its lowest position, the center of mass is lowered by a distance l . Its gravitational potential energy is decreased by $mg l$.

Rotation occurs about the horizontal axis through the clamped end.

$$\text{Moment of inertia, } I = \frac{ml^2}{3}$$

Now, by work energy theorem;

$$\text{Total work done} = \text{Change in kinetic energy}$$

$$(\Delta W)_{mgl} = (KE)_f - (KE)_i$$

$$mgl = \frac{1}{2} I \omega^2 - 0$$

$$\frac{1}{2} I \omega^2 = (mgl)$$

$$\frac{1}{2} \left(\frac{ml^2}{3} \right) \omega^2 = (mgl)$$

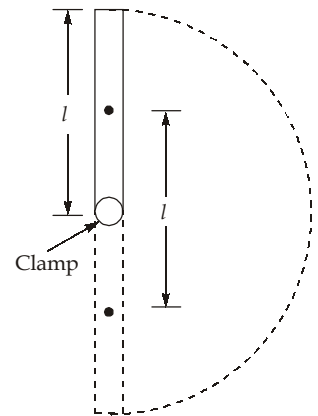
$$\omega^2 = \frac{6g}{l}$$

$$\omega = \sqrt{\frac{6g}{l}}$$

Linear speed of the free end at given instant, $v = l\omega$

$$V = l \times \sqrt{\frac{6g}{l}}$$

$$V = \sqrt{6gl}$$



10. (d)

$$\text{For the mass } m, mg - T = ma$$

$$\text{For cylinder, } T \times R = I \alpha$$

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

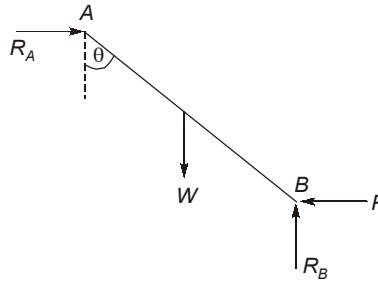
$$T = ma$$

$$\Rightarrow mg = 2ma$$

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

11. (a)

Free body diagram of ladder is



Using equilibrium equations.

$$R_A = P$$

$$\text{and } R_B = W$$

Taking moment about B.

$$R_A \cdot l \cos \theta = W \cdot \frac{l}{2} \sin \theta$$

$$R_A = \frac{1}{2} W \tan \theta = P$$

12. (c)

Shape	Area	Centroid from base
Square	$A_1 = d^2$	$y_1 = d/2$
Half circle	$A_2 = \pi d^2/8$	$y_2 = 2d/3\pi$

The centroid of hatched position from base.

$$\bar{y} = \frac{A_1 y_1 - A_2 y_2}{A_1 - A_2}$$

$$= \frac{d^2 \cdot \frac{d}{2} - \frac{\pi d^2}{8} \cdot \frac{2d}{3\pi}}{d^2 - \frac{\pi d^2}{8}} = \frac{10d}{3(8 - \pi)}$$

13. (b)

FBD

$$\Sigma F_y = 0$$

$$W = R_S \cos \theta$$

$$R_S = \frac{100 \times 10}{\sqrt{75}}$$

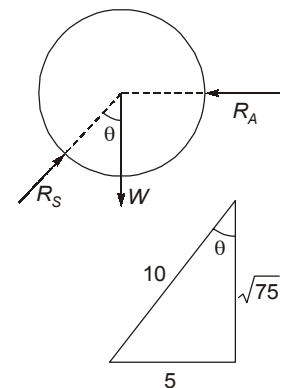
$$\cos \theta = \frac{\sqrt{75}}{10}$$

$$\sin \theta = \frac{5}{10}$$

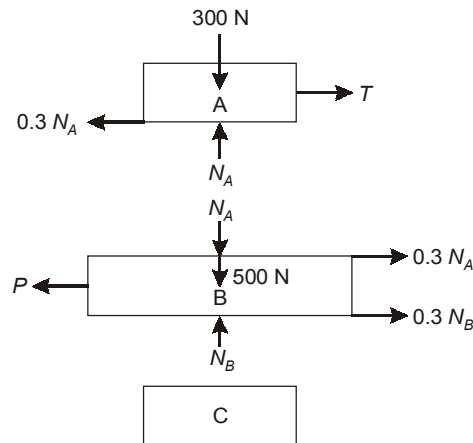
$$\Sigma F_x = 0$$

$$R_S \sin \theta = R_A$$

$$\therefore R_A = \frac{1000}{\sqrt{75}} \times \frac{5}{10} = 57.735 \text{ N}$$



14. (a)



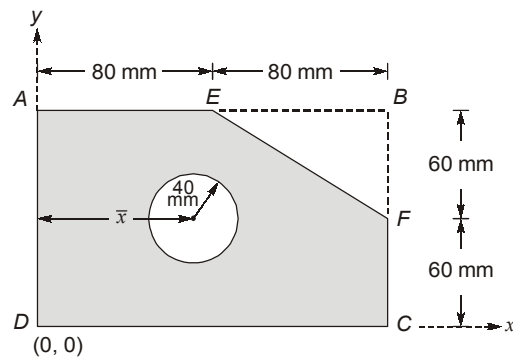
Considering first FBD of block A:

$$\begin{aligned} \Rightarrow \Sigma F_y &= 0 \\ N_A &= 300 \text{ N} \\ \Rightarrow \Sigma F_x &= 0 \\ \Rightarrow T &= 0.3 N_A = 0.3 \times 300 = 90 \text{ N} \end{aligned}$$

Now consider FBD of block B:

$$\begin{aligned} \Rightarrow \Sigma F_y &= 0 \\ N_B &= N_A + 500 = 300 + 500 = 800 \text{ N} \\ \Rightarrow \Sigma F_x &= 0 \\ P &= 0.3 N_A + 0.3 N_B \\ \Rightarrow P &= 0.3 (300 + 800) \\ &= 330 \text{ N} \end{aligned}$$

15. (a)



S. No.	Shape	Area (mm ²)	\bar{x} (mm)	$a\bar{x}$ (mm ³)
1	ABCD	19200	80	1536000
2	Circle	-5026.55	\bar{x}	-5026.55 \bar{x}
3	ΔEBF	-2400	133.33	-320000
		$\Sigma a = 11773.45$		$\Sigma a\bar{x} = 1216000 - 5026.55\bar{x}$

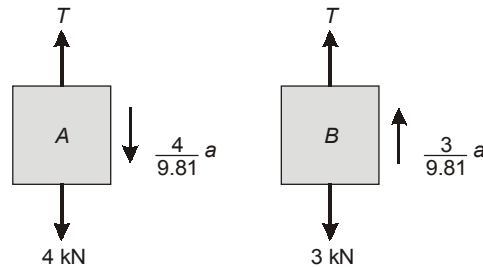
Now,

$$\bar{x} = \frac{\Sigma a\bar{x}}{\Sigma a}$$

$$\Rightarrow \bar{x} = \frac{1216000 - 5026.55\bar{x}}{11773.45}$$

$$\Rightarrow \bar{x} = 72.38 \text{ mm}$$

16. (c)



For block A,

$$T - \frac{4}{9.81}a = 4 \quad \dots(i)$$

For block B,

$$T + \frac{3}{9.81}a = 3 \quad \dots(ii)$$

For equation (i) and (ii), we get

$$\Rightarrow \frac{7a}{9.81} = -1$$

 $\therefore a = -1.401 \text{ m/s}^2$ (Because of this deceleration, the system will come to rest)

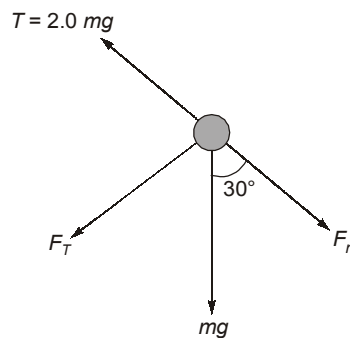
The system comes to rest when final velocity becomes zero

$$\therefore v = u + at$$

$$\Rightarrow 0 = 1.85 - 1.401t$$

$$\therefore t = 1.32 \text{ sec}$$

17. (d)



$$\text{Tangential force, } F_T = mg \sin 30^\circ = 0.5 mg$$

$$\text{Normal force, } F_n = T - mg \cos 30^\circ$$

$$\Rightarrow F_n = 2 mg - 0.866 mg$$

$$\Rightarrow F_n = 1.134 mg$$

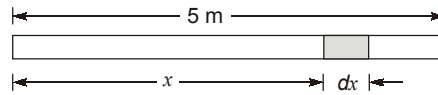
$$\text{Normal acceleration, } a_n = \frac{F_n}{m}$$

$$\Rightarrow a_n = \frac{1.134 mg}{m}$$

$$\Rightarrow a_n = 1.134 \times 9.81 = 11.125 \text{ m/s}^2$$

$$\begin{aligned} \therefore a_n &= \frac{V^2}{R} \\ \Rightarrow 11.125 &= \frac{V^2}{1} \\ \Rightarrow V &= 3.34 \text{ m/s} \end{aligned}$$

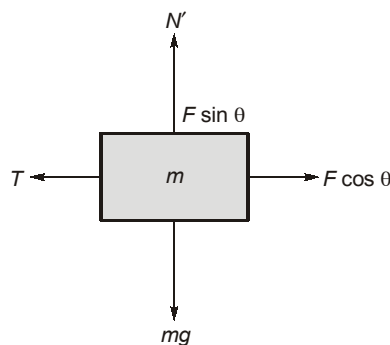
18. (b)



Let the cross-sectional area be α . The mass of an element (dm) of length dx located at a distance x away from the left end is $(0.5 + 3x)\alpha dx$. The x -coordinate of the centre of mass is given by,

$$\begin{aligned} X_{cm} &= \frac{\int x dm}{\int dm} = \frac{\int_0^5 x(0.5 + 3x)\alpha dx}{\int_0^5 (0.5 + 3x)\alpha dx} \\ &= \frac{\int_0^5 (0.5x + 3x^2)\alpha dx}{\int_0^5 (0.5x + 3x)\alpha dx} \\ &= \frac{0.5\left(\frac{5^2}{2}\right) + 3\left(\frac{5^3}{3}\right)}{0.5 \times 5 + 3\left(\frac{5^2}{2}\right)} \\ &= \frac{6.25 + 125}{2.5 + 37.5} \simeq 3.28 \text{ m} \end{aligned}$$

19. (b)



Considering free body diagram

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

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

$$[N' = mg - F \sin \theta]$$

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

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

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

20. (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

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

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

21. (b)

Apply virtual work method,

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

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

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

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

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

By principle of virtual work,

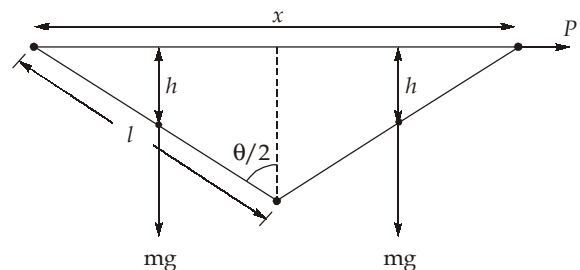
$$\Rightarrow P dx + 2mg dh = 0 = \text{WD}$$

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

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

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

$$\theta = 90^\circ$$



22. (a)

There are three forces acting on the bar AB ; pull Q at B , tension in string T and reaction at point A i.e. R_a .
 For isosceles triangle ABC ,

$$\beta = \gamma = \left(\frac{\pi - \alpha}{2}\right) = 90^\circ - \left(\frac{\alpha}{2}\right)$$

If there is no friction on pulley, tension in string BC will be P.
Taking moment about point A,

$$(P \cos \delta) \times (l \sin \alpha) + (P \sin \delta)(l \cos \alpha) = Q l \sin \alpha$$

$$P l \sin(\alpha + \delta) = Q l \sin \alpha$$

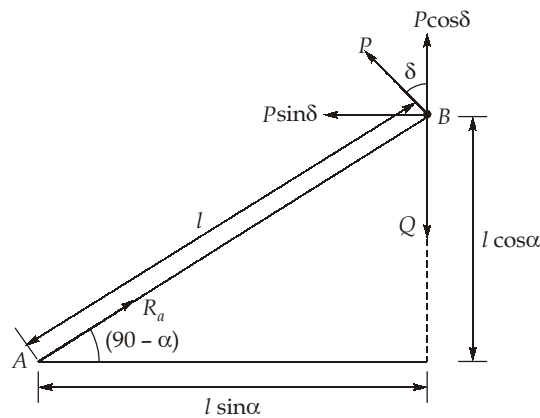
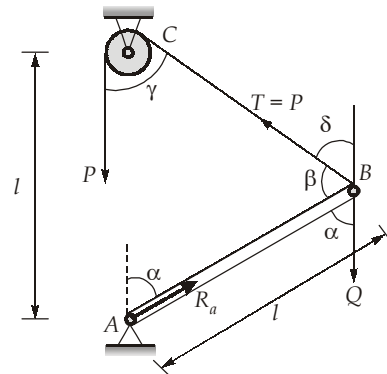
$$P \sin(180^\circ - \beta) = Q \sin \alpha$$

$$P \sin \left[180 - 90 + \frac{\alpha}{2} \right] = Q \sin \alpha$$

$$P \cos \frac{\alpha}{2} = 2Q \sin \frac{\alpha}{2} \cos \frac{\alpha}{2}$$

$$\left(\cos \frac{\alpha}{2} \right) \left[P - 2Q \sin \frac{\alpha}{2} \right] = 0$$

or $\sin \frac{\alpha}{2} = \frac{P}{2Q}$



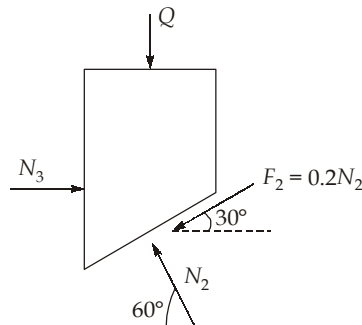
$$\alpha = 2 \sin^{-1} \left(\frac{P}{2Q} \right) = 2 \sin^{-1} \left(\frac{900}{2 \times 2200} \right) = 23.6057^\circ$$

$$\alpha = 23.6057 \times \left(\frac{\pi}{180} \right) = 0.412 \text{ radian}$$

23. (d)

From Newton's first law,

$$\Sigma F_y = 0$$



$$N_2 \sin 60^\circ - 0.2N_2 \sin 30^\circ - Q = 0$$

$$Q = 0.766 N_2$$

$$\Sigma F_x = 0$$

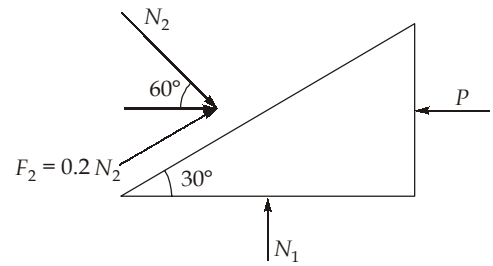
$$N_2 \cos 60^\circ + 0.2N_2 \cos 30^\circ - P = 0$$

$$P = 0.673 N_2$$

$$\frac{P}{Q} = \frac{0.673}{0.766}$$

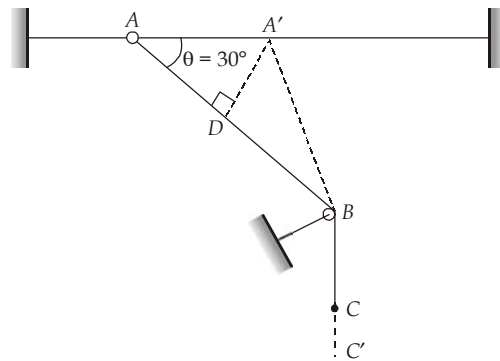
$$P = 0.878Q \approx 0.9Q$$

$$\alpha = 0.9$$



24. (b)

Suppose in small time interval Δt , the ring is displaced from A to A' and the block from C to C'.



Now

$$AB + BC = A'B + BC'$$

$$\Rightarrow AD + DB + BC = A'B + BC'$$

$$\Rightarrow AD = BC' - BC$$

$$[\because A'B \approx DB]$$

$$\Rightarrow AD = CC'$$

$$\left[\cos\theta = \frac{AD}{AA'} \right]$$

$$\Rightarrow \frac{AA' \cos\theta}{\Delta t} = \frac{CC'}{\Delta t}$$

$$\Rightarrow V \cos\theta = V'$$

$$\Rightarrow V' = 10 \times \cos 30^\circ = 8.66 \text{ km/hr}$$

25. (a)

Let speed of car moving in opposite direction is V km/hr.

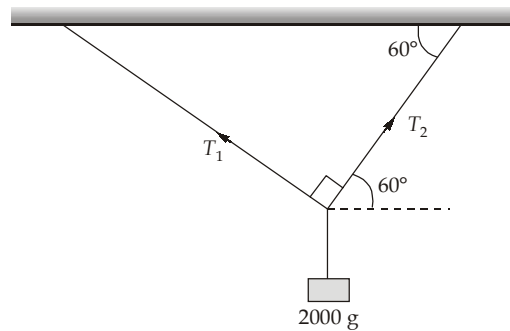
From relative velocity approach, velocity of opposite direction car = $V + 80$

$$\therefore \frac{\text{Distance}}{\text{Velocity}} = \text{Time}$$

$$\Rightarrow \frac{20}{V + 80} = \frac{8}{60}$$

$$\Rightarrow V = 70 \text{ kmph} = 19.44 \text{ m/s}$$

26. (c)



Using Lami's theorem, $\frac{T_1}{\sin(90^\circ + 60^\circ)} = \frac{T_2}{\sin(360^\circ - (90^\circ + 60^\circ + 90^\circ))}$

$$\Rightarrow \frac{T_1}{\sin 150^\circ} = \frac{T_2}{\sin 120^\circ}$$

$$\Rightarrow \frac{T_1}{T_2} = 0.577$$

27. (b)

Resolving the forces in horizontal and vertical components.

In x-direction,

$$\Rightarrow \Sigma F_x = 100 \cos 45^\circ - 40 \cos 60^\circ$$

$$\Rightarrow \Sigma F_x = 70.71 - 20$$

$$\Rightarrow \Sigma F_x = 50.71 \text{ N}$$

In y-direction,

$$\Sigma F_y = 40 \sin 60^\circ + 100 \sin 45^\circ$$

$$\Rightarrow \Sigma F_y = 105.35 \text{ N}$$

∴ Resultant of given forces, $R = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$

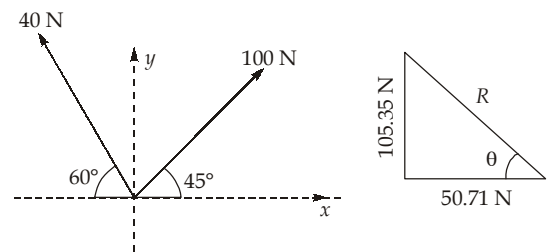
$$\Rightarrow R = \sqrt{(50.71)^2 + (105.35)^2}$$

$$\Rightarrow R = 116.92 \text{ N}$$

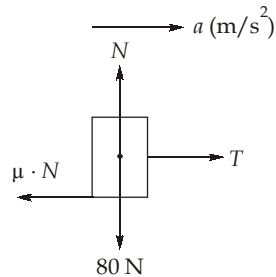
$$\Rightarrow \theta = \tan^{-1} \left(\frac{F_y}{F_x} \right)$$

$$\Rightarrow \theta = \tan^{-1} \left(\frac{105.35}{50.71} \right)$$

$$\Rightarrow \theta = 64.3^\circ \text{ from x-axis}$$



28. (a)
FBD of 80 N block,



$$\Rightarrow \Sigma F_y = 0,$$

$$N = 80 \text{ N}$$

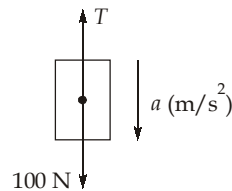
$$\Rightarrow \Sigma F_x = ma,$$

$$T - \mu N = ma$$

$$\Rightarrow T - 0.2(80) = \frac{80 \cdot a}{g} \quad [\because W = mg]$$

$$\Rightarrow T - 16 = \frac{80a}{g} \quad \dots(i)$$

FBD of 100 N block,



$$\Rightarrow \Sigma F_y = ma$$

$$100 - T = ma$$

$$\Rightarrow 100 - T = \frac{100 \cdot a}{g} \quad \dots(ii)$$

From equation (i) and (ii),

$$100 - \left(16 + \frac{80a}{g}\right) = \frac{100a}{g}$$

$$\Rightarrow 84 = \frac{180a}{g}$$

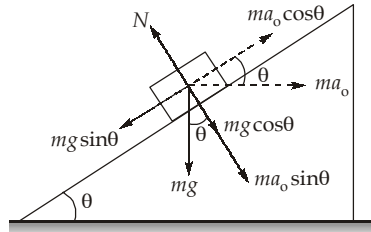
$$\Rightarrow a = \frac{7g}{15} \text{ m/s}^2$$

$$\therefore T = 16 + \frac{80}{g} \left(\frac{7g}{15}\right) = 53.33 \text{ N}$$

29. (a)

Let the acceleration of system be a_0 in the left direction due to applied force P .

Consider the motion of rectangular block from the frame of prism which is non-inertial. A pseudo force equal to ma_0 has to be applied on rectangular block in the right direction.



To prevent sliding of rectangular block.

$$mg \sin \theta = ma_0 \cos \theta$$

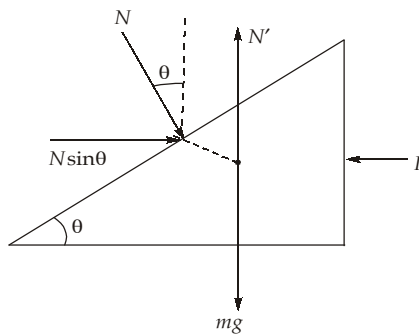
$$\Rightarrow a_0 = g \quad \dots(i)$$

Now, $N = mg \cos \theta + ma_0 \sin \theta$

$$\Rightarrow N = mg \cos 45^\circ + ma_0 \sin 45^\circ$$

$$\Rightarrow N = \sqrt{2} mg \quad \dots(ii)$$

Considering motion of prism,



$$\therefore P - N \sin \theta = ma_0$$

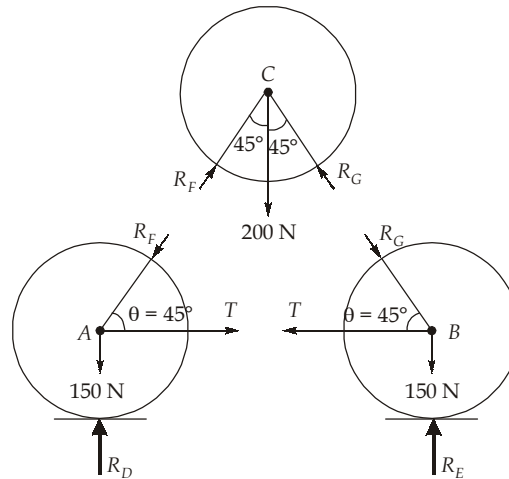
$$\Rightarrow P = ma_0 + N \sin 45^\circ$$

$$\Rightarrow P = mg + \sqrt{2} mg \times \frac{1}{\sqrt{2}} \quad \text{\{from (i) and (ii)\}}$$

$$\therefore P = 2 mg$$

30. (c)

The free body diagram of all the three cylinder are as shown below:



Consider the free body diagram of cylinder C.

Each cylinder is in equilibrium.

$$\therefore \theta = \cos^{-1}\left(\frac{170}{240}\right) = 44.9^\circ \simeq 45^\circ$$

Let, R_G and R_F are the reactive forces.

Applying equilibrium conditions:

$$\begin{aligned} \Rightarrow \Sigma F_x &= 0 \\ R_F \sin 45^\circ - R_G \sin 45^\circ &= 0 \\ R_F &= R_G \\ \Sigma F_y &= 0 \\ R_F \cos 45^\circ + R_G \cos 45^\circ &= 200 \end{aligned}$$

$$\Rightarrow R_F = R_G = \frac{200}{2 \cos 45^\circ} = 141.42 \text{ N}$$

Similarly, considering freebody diagram of cylinder A and applying equilibrium conditions,

$$\begin{aligned} \Rightarrow \Sigma F_x &= -R_F \cos 45^\circ + T = 0 \\ T &= R_F \cos 45^\circ = 141.42 \times \cos 45^\circ \\ &= 99.999 \text{ N} \\ &\simeq 100 \text{ N} \\ \Sigma F_y &= -R_F \sin 45^\circ - 150 + R_D = 0 \\ \Rightarrow R_D &= R_F \sin 45^\circ + 150 \\ &= 141.42 \times \sin 45^\circ + 150 = 250 \text{ N} \end{aligned}$$

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