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SFI GEC PALAKKAD

Course Code: EST100

Course Name: ENGINEERING MECHANICS

(2019-Scheme)

Max. Marks: 100 Duration: 3 Hours

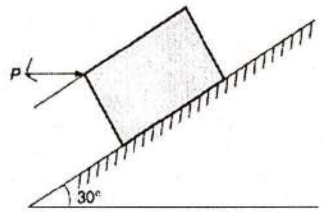
PART A

(Answer all questions, each carries 3 marks.)

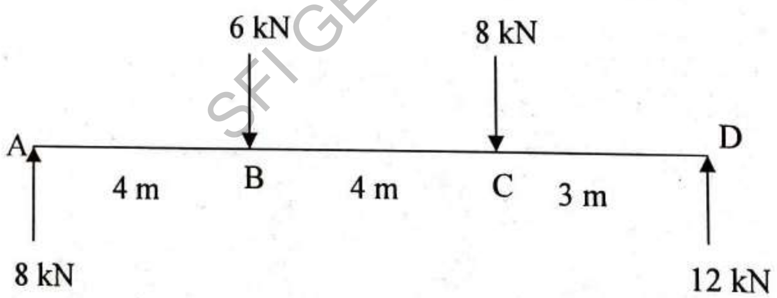
1 State and explain Lami's theorem. (3)

2 What is meant by Free body diagram? Explain with an example. (3)

3 A small block of weight 1000 N as shown in Figure, is placed on a 30° inclined plane with μ= 0.25. Determine the horizontal force to be applied for impending motion down the plane (3)

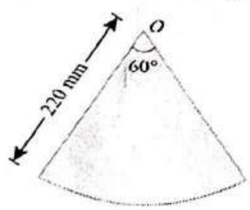


4 A rigid bar AD is acted upon by forces as shown in figure below. Reduce the force system to a single force- system and locate the point of application of the single force. (3)



5 Find the moment about C(-2,3,5) of the force F= $4\hat{i} + 4\hat{j} - 1\hat{k}$ passing through the point A (1,-2,4). (3)

6 Find the centre of gravity of lamina from O. (3)



7 A 50 kg mass has a velocity of 10m/s horizontally on a smooth surface. Determine the magnitude of horizontal force required to bring the mass to rest in 5 seconds. (3)

8	A body is projected at an angle such that its horizontal displacement is 3 times that of maximum height. Find the angle of projection.	(3)
9	A motor car is uniformly accelerated from 40 kmph to 50 kmph over a distance of 300m. If the wheels are 1 m diameter, find the angular acceleration of wheels.	(3)
10	Differentiate between curvilinear motion and projectile motion.	(3)

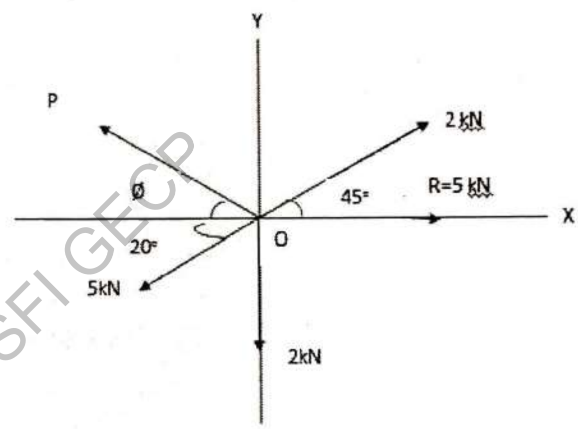
PART B

(Answer one full question from each module, each question carries 14 marks)

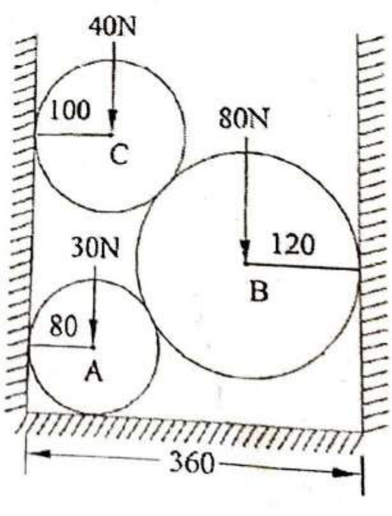
Module-I

11 a) A rope 9m long is connected at A and B, two points on the same level, 8m apart. A load of 300N is suspended from a point C on the rope 3m from A. What load connected to point D, on the rope, 2m from B is necessary to keep portion CD parallel to AB. (5)

b) The resultant of a system of four forces is 5kN directed towards right along X-axis. Find the force P and its direction Ø. (9)

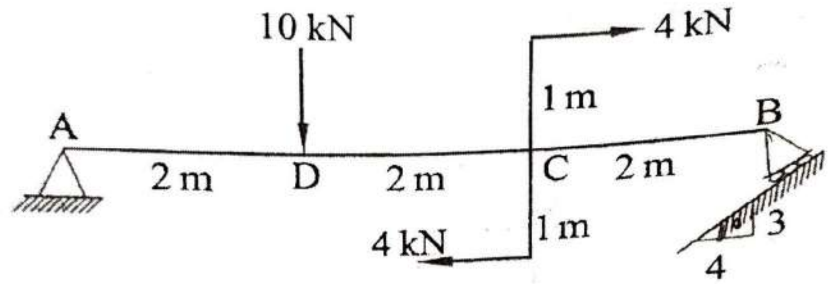


12 Three cylinders are piled in a rectangular ditch as in Fig. Neglecting friction, determine the reaction between cylinder A and vertical wall. (14)



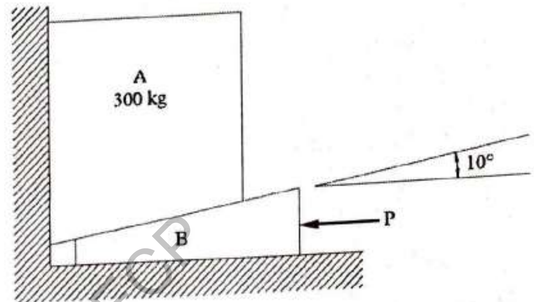
Module-II

13 a) A beam 6 m long is loaded as shown. Calculate the reactions at A and B. (7)



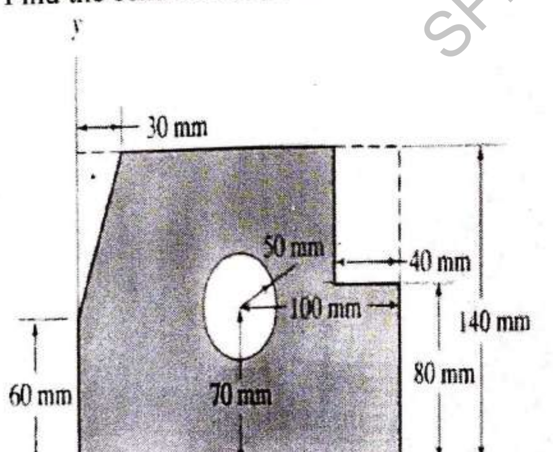
b) The uniform ladder is of mass 10kg and 2-m long, leaning against a vertical wall. The coefficient of static friction at A(wall) is 0.6 and at B (floor) is 0.4. Determine the smallest angle, for which the ladder can remain in the equilibrium. (7)

14 If the coefficient of static friction equals 0.3 for all surfaces of contact, determine the smallest value of force P necessary to raise the block A of mass 300kg. Neglect the weight of the wedge B. Angle of wedge is 10^0. (14)



Module-III

15 Find the centroid of the shaded area shown. **Fig (Q15)** (14)



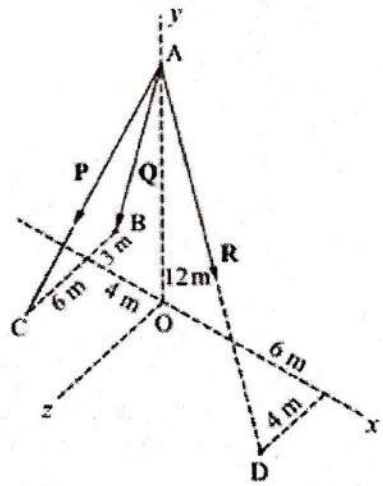


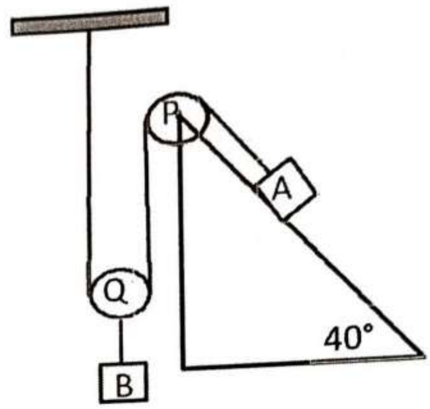
Fig (Q15) **Fig (Q16)**

16 Find the resultant of the force system shown in Fig. in which P = 280 N, Q = 260 N and R = 210 N. **Fig (Q16)** (14)

Module-IV

17 Determine the tension in the inextensible string and the acceleration of the (14)

masses. Consider the pulley as massless and coefficient of friction as 0.20. Block A=200 kg and block B=100kg

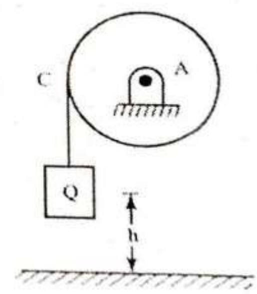


18 a) A glass ball is dropped on to a smooth horizontal floor from which it bounces to a height of 9m. On the second bounce, it rises to a height of 6m. From what height the ball was dropped and what is the coefficient of restitution between the glass and the floor? (5)

b) Two cars A and B travelling in same direction get stopped at a traffic signal. When signal turns green, car A accelerates at 0.75 m/s^2 and 1.75 seconds later, car B starts and accelerates at 1.1 m/s^2. Determine i) when and where B will overtake A and ii) the speed of each car at that time. (9)

Module-V

19 A circular disc of radius r=30cm and weight W=145N is free to rotate about its geometric axis. A flexible cord carrying a weight of Q= 45N, is wound around the circumference of the disc as shown in Fig. If the weight Q is released from rest, find (a) the time *t* required for it to fall through the height h=300cm (b) with what velocity *v* will it strike the floor? (14)



20 a) A 50N weight is suspended from a spring of constant k=8 N/cm. Neglecting the mass of the spring, find the period for small amplitudes of vertical oscillations. (5)

b) A particle performing Simple harmonic motion. When it is at distances of 10.0cm and 20.0cm from the mean position, its velocities are 1.2 m/s and 0.8 m/s respectively. Find (a) amplitude of oscillations. (b) time period of oscillations (c) its maximum velocity and (d) its maximum acceleration. (9)

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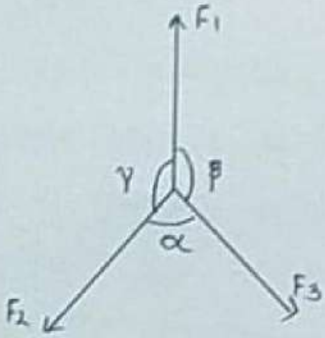
ANSWER KEY

PART - A

① Lami's theorem

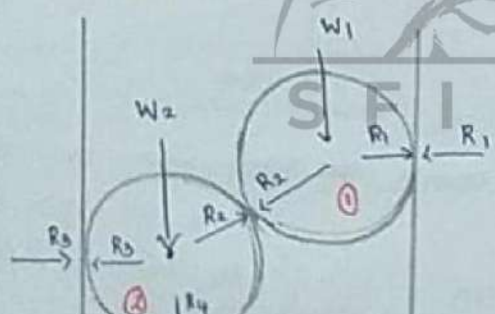
It is an another equilibrium law which states that if three forces acting at a point are in equilibrium then each force is proportional to the ~~sign~~ sine of the angle between the other two forces.



$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

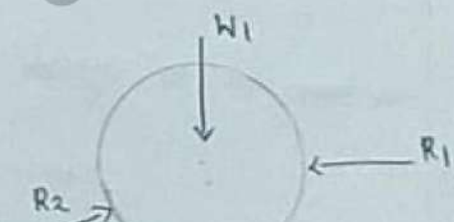
② Free-body diagram.

The sketch in which the body is completely isolated from its supports and in which all the forces acting on it are shown is called a free-body diagram.

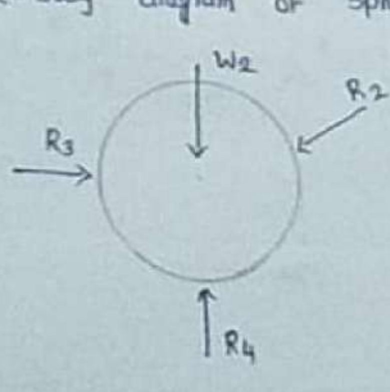


(Two spheres kept inside a cylindrical vessel)

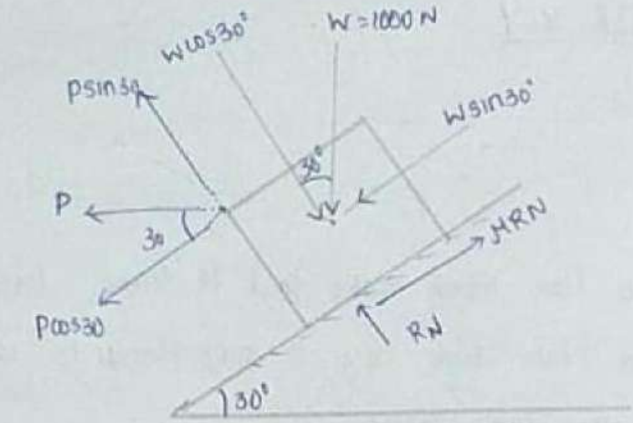
Free-body diagram of sphere-1



Free-body diagram of sphere-2



3



Resolving forces along the plane

$$\mu R_N - W\sin 30 - P\cos 30 = 0 \quad \text{——— (1)}$$

Resolving forces ⊥er to the plane

$$R_N + P\sin 30 - W\cos 30 = 0 \quad \text{——— (2)}$$

$$\Rightarrow R_N = W\cos 30 - P\sin 30 \quad \text{——— (3)}$$

Substitute (3) in (1)

$$\Rightarrow \mu(W\cos 30 - P\sin 30) - W\sin 30 - P\cos 30 = 0$$

$$\Rightarrow \mu W\cos 30 - \mu P\sin 30 - W\sin 30 - P\cos 30 = 0$$

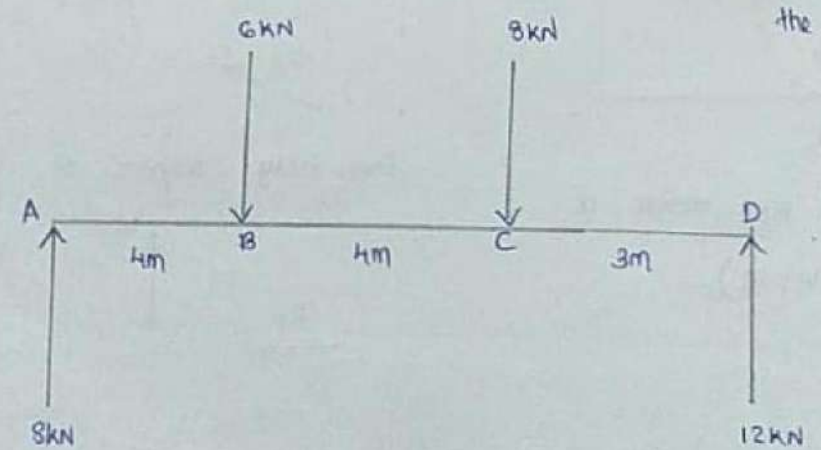
$$\Rightarrow (.25 \times 1000 \times \cos 30) - (.25 \times P\sin 30) - (1000\sin 30) - P\cos 30 = 0$$

$$\Rightarrow 216.51 - 500 = P(.25\sin 30 + \cos 30)$$

$$P = \frac{-283.49}{.25\sin 30 + \cos 30} = \underline{\underline{-286.06\,N}}$$

So from this the direction of P is towards ~~left~~ Right. when the value of P is less than 286.06N the block will move downword.

4



$\Sigma F_H = 0$

$\Sigma F_V = 8 + 12 - 6 - 8 = \underline{\underline{6KN}}$ (upword)

$R = \sqrt{\Sigma F_H^2 + \Sigma F_V^2} = \underline{\underline{6KN}}$

take Σ moment at 'A'.

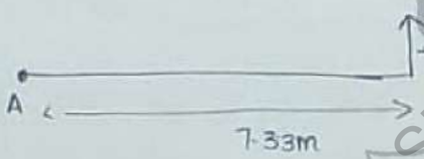
Resultant force will create a moment at 'A' will equal to moment created by the other forces at A.

$\Sigma M_A = (6\times4) + (8\times8) - (12\times11)$

$= \underline{\underline{-44kNm}}$ (Anticlockwise moment, so resultant force will also create a anticlockwise moment)

$R \times x = 44$

$x = \frac{44}{6} = \underline{\underline{7.3m}}$



(Resultant force is 7.33m away from 'A' at right side)

⑤ $F = 4\hat{i} + 4\hat{j} - 1\hat{k}$

moment $= r \times F$

position vector of point A with respect to C

$r = (x_A - x_C)\hat{i} + (y_A - y_C)\hat{j} + (z_A - z_C)\hat{k}$

$x_A = 1 \qquad x_C = -2$

$y_A = -2 \qquad y_C = 3$

$z_A = 4 \qquad z_C = 5$

$r = 3\hat{i} - 5\hat{j} - \hat{k}$

moment $= r \times F \Rightarrow (3\hat{i} - 5\hat{j} - \hat{k}) \times (4\hat{i} + 4\hat{j} - 1\hat{k})$

$$\Rightarrow \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & -5 & -1 \\ 4 & 4 & -1 \end{vmatrix}$$

$= \hat{i}(5+4) - \hat{j}(-3+4) + \hat{k}(12+20)$

$= 9\hat{i} - \hat{j} + 32\hat{k}$

(6)

(7) $m = 50kg$

$v = 0$

$u = 10m/s$

$t = 5s$

$v = u + at$

$0 = 10 + 5a$

$a = -2m/s^2$

$F = m \times a = 50 \times 2 = 100N$ (opposite to direction of motion)

(8) Horizontal displacement $= 3 \times$ (maxi height)

Range $= 3 \times$ (maxi height)

$$\frac{u^2 \sin 2\alpha}{g} = \frac{3 \times u^2 \sin^2\alpha}{2g}$$

$$2\sin\alpha\cos\alpha = \frac{3\sin^2\alpha}{4}$$

$$\frac{4}{3} = \tan\alpha \Rightarrow \alpha = 53.13^\circ$$

(9) $V = 50kmph \Rightarrow \left(50 \times \frac{5}{18}\right) m/s$, $S = 300m$

$u = 40 kmph \Rightarrow \left(40 \times \frac{5}{18}\right) m/s$

$v^2 = u^2 + 2as$

$$\left(50 \times \frac{5}{18}\right)^2 = \left(40 \times \frac{5}{18}\right)^2 + 2a \times 300$$

$a = 0.116 m/s^2$

$a = r\alpha$

radius $= 1/2$ m

Angular acceleration $\alpha = \frac{a}{r}$

$$\alpha = \frac{0.116}{(1/2)} = .231 \ rad/s^2$$

(10) <u>Curvilinear Motion</u>

=> It occurs when a particle moves along a curved path

=> The position of a particle on a space curve will be designated by the position vector, $r = r(t)$

=> It's function of time and change magnitude and direction as it moves along the curve.

<u>Projectile Motion</u>

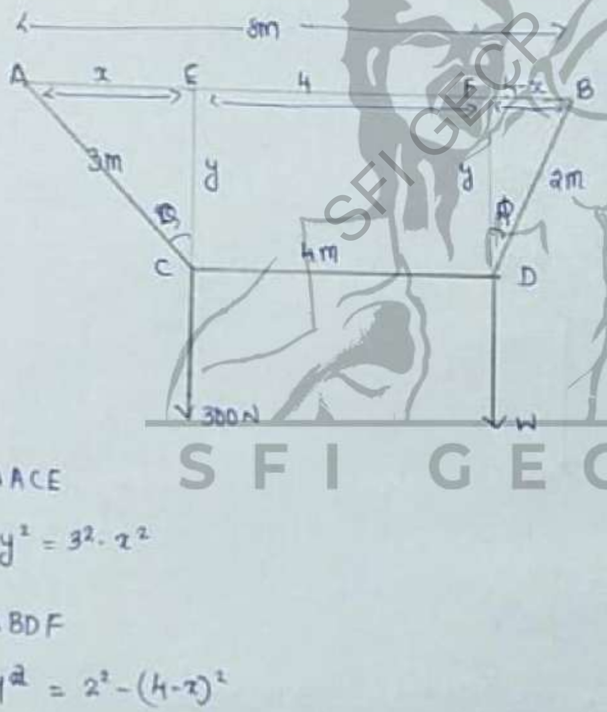
=> parabolic motion is involved

=> The horizontal component of acceleration of a projectile is zero.

=> The vertical acceleration of a particle is constant because of gravity.

=> The horizontal and vertical motions of a projectile are independent, but they share the same time.

(11) a)



From ΔACE

$$y^2 = 3^2 - x^2$$

From ΔBDF

$$y^2 = 2^2 - (4-x)^2$$

$$3^2 - x^2 = 2^2 - (4-x)^2$$

$$9 - x^2 = 4 - 16 - x^2 + 8x$$

$$8x = 21$$

$$\underline{x = 2.625m}$$

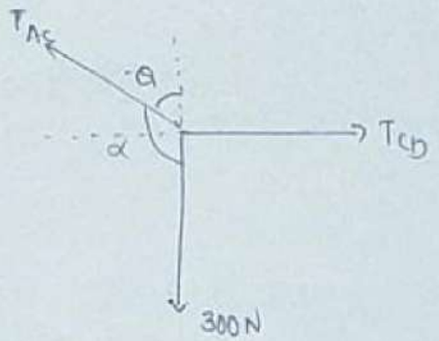
$$\sin\theta = \frac{x}{3} = \frac{2.625}{3} = .875$$

$$\underline{\theta = 61.04^\circ}$$

$\sin\phi = \frac{4-x}{2} = \frac{4-2.625}{2} = .6875$ ⓐ

$\phi = 43.43^\circ$

⇒ Apply Lami's theorem at point 'C'.



$$\frac{T_{AC}}{\sin 90} = \frac{300}{\sin(90+\theta)} = \frac{T_{CD}}{\sin\alpha}$$

$\alpha = 90 + 28.96$

118.96

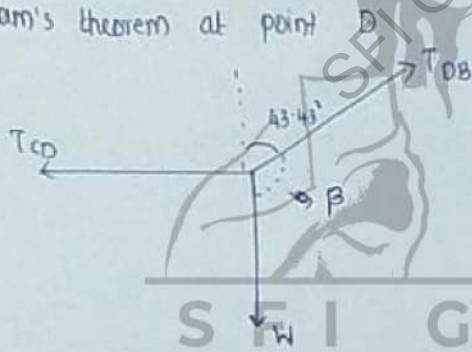
$$T_{AC} = \frac{300}{\sin(90+61.04)}$$

$T_{AC} = 619.58\,N$

$$\frac{300}{\sin(151.04)} = \frac{T_{CD}}{\sin(118.96)}$$

$T_{CD} = 542.11\,N$

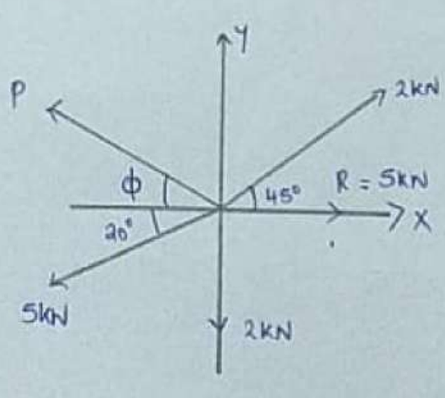
⇒ Apply Lami's theorem at point D



$$\frac{T_{CD}}{\sin\beta} = \frac{W}{\sin(90+43.43)}$$

$$W = \frac{T_{CD}\times\sin(133.43)}{\sin(136.57)} = 572.66\,N$$

ⓑ



$\Sigma F_H = 2\cos 45 + {}^-P\cos\phi + 5\cos 200$

$\Sigma F_V = 2\sin 45 + P\sin\phi + 5\sin 200 - 2 = 0$

$R = \sqrt{\Sigma F_H^2 + \Sigma F_V^2}$

$R^2 = \Sigma F_H^2 + \Sigma F_V^2$

$25 = (2\cos 45)^2 - (P\cos\phi)^2 + (5\cos 200)^2 + (2\sin 45)^2 + (P\sin\phi)^2 + (5\sin 200)^2 - (2^2)$

$25 = \cancel{2} - P^2\cos^2\phi + 22.08 + \cancel{2} + P^2\sin^2\phi + 2.92 - \cancel{4}$

$25 = 25 - P^2\cos^2\phi + P^2\sin^2\phi$

$P^2\sin^2\phi = P^2\cos^2\phi$

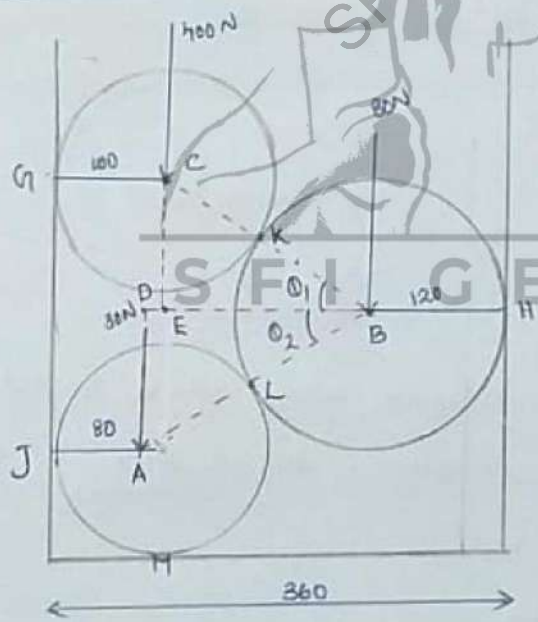
$\therefore \underline{\phi = 45^\circ}$

Resultant in horizontal direction, so $\Sigma F_V = 0$

$2\sin 45 + P\sin 45 + 5\sin 200 - 2 = 0$

$\underline{P = 3.45\text{ N}}$

(12)



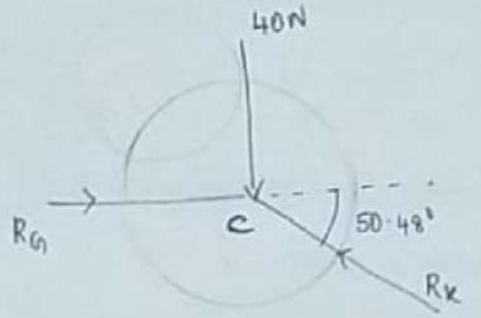
$\cos\theta_1 = \frac{BE}{BC} = \frac{360 - 120 - 100}{120 + 100} = \frac{140}{220}$

$\underline{\theta_1 = 50.48^\circ}$

$\cos\theta_2 = \frac{BD}{AB} = \frac{360 - 120 - 80}{120 + 80} = \frac{160}{200}$

$\theta_2 = 36.87°$

consider the free body diagram of cylinder C

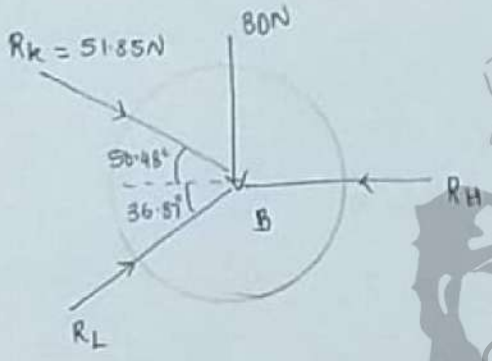


$\Sigma F_V = 0$,

$R_K \sin 50.48 - 40 = 0$

$R_K = 51.48\,N$

consider the free body diagram of cylinder B



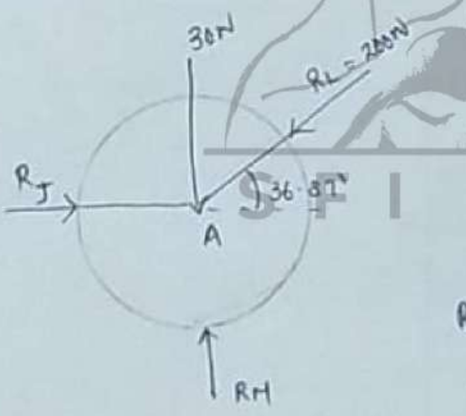
$\Sigma F_V = 0$

$R_L \sin 36.87 - 80 - 51.85 \sin 50.48 = 0$

$R_L = \dfrac{51.85 \sin 50.48 + 80}{\sin 36.87}$

$R_L = 200\,N$

consider the free body diagram of cylinder A.



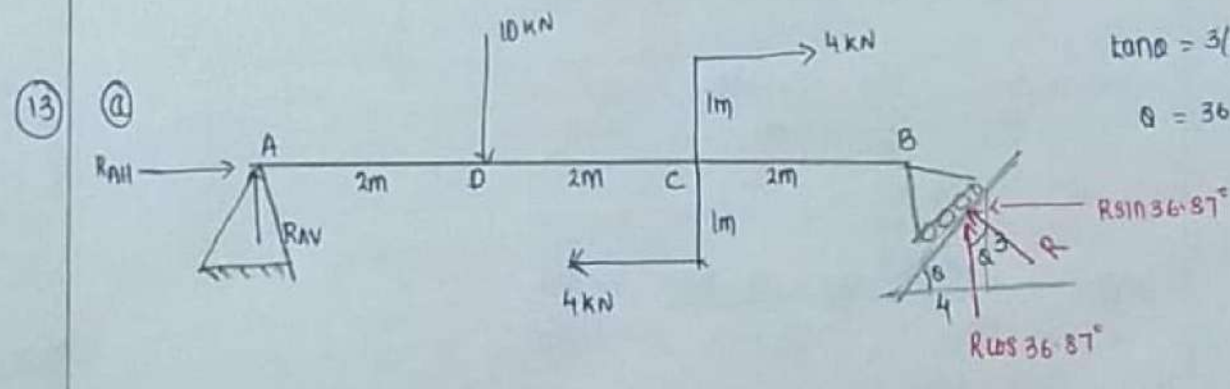
$\Sigma F_H = 0$

$R_J - 200 \cos 36.87 = 0$

$R_J = 160\,N$

Reaction between cylinder A and the vertical wall is 160N.

13 (a)



$\tan\theta = 3/4$

$\theta = 36.87°$

$\Sigma F_H = R_{AH} + 4 - 4 - R\sin 36.87$

$\therefore R_{AH} = R\sin 36.87$ ——(1)

$\Sigma F_V = R_{AV} - 10 + R\cos 36.87$ ——(2)

$\Sigma M_A = (10\times2) + (4\times1) + (4\times1) - R\cos(36.37)\times 6$

$\Rightarrow R\cos(36.87)\times 6 = 28$

$\underline{R = 5.833N}$

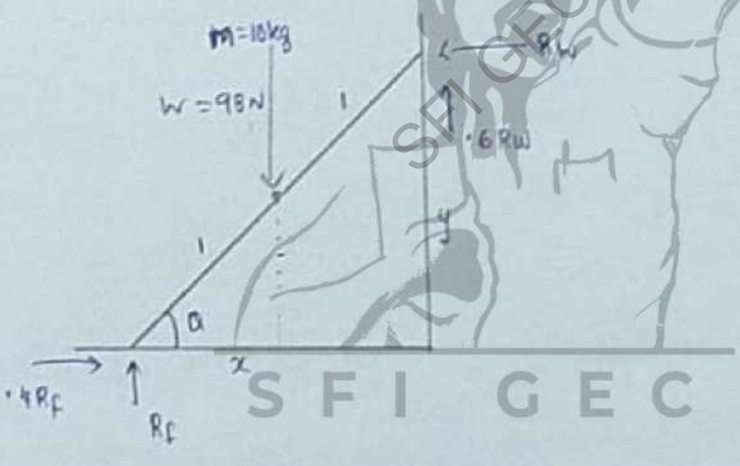
(1) $\Rightarrow R_{AH} = 3.50N$

(2) $\Rightarrow R_{AV} = 5.32N$

Reaction at A = 6.37 N $\Rightarrow \left(\sqrt{3.50^2 + 5.32^2} = 6.37N\right)$

Reaction at B = 5.833N

(b)



For equilibrium condition ΣF_H & ΣF_V is zero.

$\Sigma F_V \Rightarrow R_f + .6R_W - 10\times9.8 = 0$

$R_f + .6R_W = 98$ ——(1)

$\Sigma F_H \Rightarrow .4R_f - R_W = 0$

$R_W = .4R_f$ ——(2)

sub (2) in (1), $\Rightarrow R_f + .6\times(.4R_f) = 98$

$1.24R_f = 98$, $\underline{\underline{R_f = 79N}}$

$\therefore R_W = \underline{\underline{31.6N}}$

$\Sigma M_A = 0,$

$$= 10\cos\theta + {}^{-}R_w\, 2\sin\theta + {}^{-}.6R_w\, 2\cos\theta$$

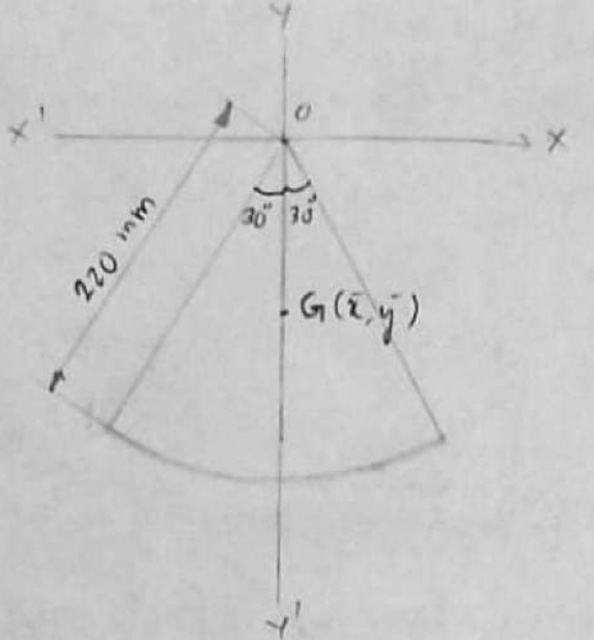
$$0 = 10\cos\theta - 63.2\sin\theta - 37.92\cos\theta$$

$$27.92\cos\theta = -63.2\sin\theta$$

$$0.4417 = \tan\theta$$

$$\underline{\theta = 23.83^\circ}$$

6



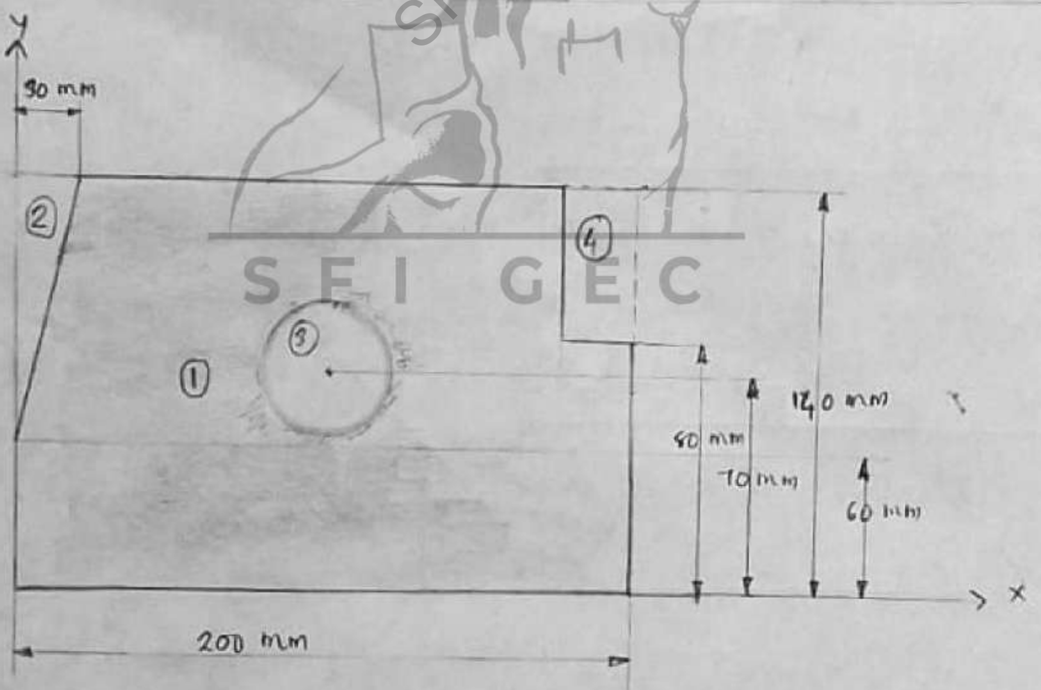
The area is symmetrical w.r.t Y axis $\Rightarrow \bar{x} = 0$

We've, $\bar{y} = \dfrac{-4R\sin(\alpha/2)}{3\alpha}$ where, $R = 220$ mm, $\alpha = 60° = \frac{\pi}{3}$ ra

$$\Rightarrow \bar{y} = \frac{-4 \times 220 \times \sin(\pi/6)}{3 \times \pi/3} = \frac{-440}{\pi} = -140 \text{ mm}$$

$\therefore$ Centre of gravity $= (\bar{x}, \bar{y}) \Rightarrow \underline{\underline{(0, -140 \text{ mm})}}$

15.



Centroid of the shaded area $= (\bar{x}, \bar{y})$

$$\bar{x} = \frac{a_1x_1 - (a_2x_2 + a_3x_3 + a_4x_4)}{a_1 - (a_2 + a_3 + a_4)}, \quad \bar{y} = \frac{a_1y_1 - (a_2y_2 + a_3y_3 + a_4y_4)}{a_1 - (a_2 + a_3 + a_4)}$$

$x_1 = 100$ mm, $x_2 = \frac{30}{3} = 10$ mm, $x_3 = 100$ mm, $x_4 = 180$ mm

$y_1 = 70$ mm, $y_2 = 140 - \frac{80}{3} = \frac{340}{3}$ mm, $y_3 = 70$ mm, $y_4 = 80 + 30 = 110$ mm

$a_1 = 200 \times 140 = 28000 \text{ mm}^2$, $a_2 = \frac{1}{2} \times 80 \times 30 = 1200 \text{ mm}^2$

$a_3 = \pi \times 50^2 = 2500\pi \text{ mm}^2$, $a_4 = 60 \times 40 = 2400 \text{ mm}^2$

Substitute the above values in the respective equations, we get,

$\bar{x} = \underline{\underline{94.9223 \text{ mm}}}$, $\bar{y} = \underline{\underline{61.0535 \text{ mm}}}$

16 The points are $O(0,0,0)$, $A(0,12,0)$, $B(-4,0,-3)$, $C(-4,0,6)$, $D(6,0,4)$

$\vec{AB} = -4i - 12j - 3k$, $|\vec{AB}| = \sqrt{4^2 + 12^2 + 3^2} = \sqrt{169} = 13$

Unit vector along AB,

$\hat{n}_{AB} = -\frac{4}{13} i - \frac{12}{13} j - \frac{3}{13} k$

$\vec{AC} = -4i - 12j + 6k$, $|\vec{AC}| = \sqrt{4^2 + 12^2 + 6^2} = \sqrt{196} = 14$

Unit vector along AC,

$\hat{n}_{AC} = -\frac{4}{14} i - \frac{12}{14} j + \frac{6}{14} k$

$\vec{AD} = 6i - 12j + 4k$, $|\vec{AD}| = \sqrt{6^2 + 12^2 + 4^2} = \sqrt{196} = 14$

Unit vector along AD,

$\hat{n}_{AD} = \frac{6}{14} i - \frac{12}{14} j + \frac{4}{14} k$

$\vec{P} = |\vec{P}| . \hat{n}_{AC} = (280 \times -\frac{4}{14}) i - (280 \times \frac{12}{14}) j + (280 \times \frac{6}{14}) k$

$\Rightarrow \vec{P} = \underline{-80i - 240j + 120k}$

$\vec{Q} = |\vec{Q}| \hat{n}_{AB} = (-\frac{260 \times 4}{13}) i - (\frac{260 \times 12}{13}) j - (\frac{260 \times 3}{13}) k$

$\Rightarrow \vec{Q} = \underline{-80i - 240j - 60k}$

$\vec{R} = |\vec{R}| \hat{n}_{AD} = (210 \times \frac{6}{14}) i - (210 \times \frac{12}{14}) j + (210 \times \frac{4}{14}) k$

$\Rightarrow \vec{R} = \underline{90i - 180j + 60k}$

$\Sigma F_x = -80 - 50 + 90 = -70\ N$

$\Sigma F_y = -240 - 240 - 180 - 660\ N$

$\Sigma F_z = 120 - 60 + 60 = 120\ N$

$\therefore$ Resultant, $\vec{R}_1 = \Sigma F_x i + \Sigma F_y j + \Sigma F_z k$

$\Rightarrow \vec{R}_1 = \underline{\underline{-70 i + 660 j + 120 k}}$

Magnitude of the resultant,

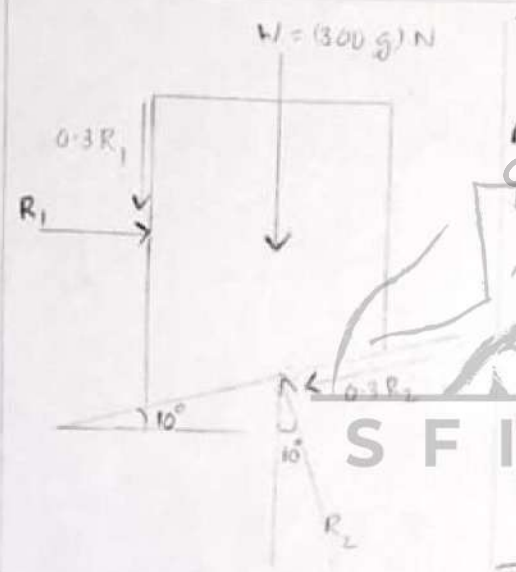
$|\vec{R}_1| = \sqrt{70^2 + 660^2 + 120^2} = \underline{\underline{674.4627\ N}}$

$\theta_x = \cos^{-1}\left(\frac{-70}{674.4627}\right) = \underline{\underline{95.9572^\circ}}$

$\theta_y = \cos^{-1}\left(\frac{660}{674.4627}\right) = \underline{\underline{11.8867^\circ}}$

$\theta_z = \cos^{-1}\left(\frac{120}{674.4627}\right) = \underline{\underline{79.7514^\circ}}$

14



Consider the eq^n of the load,

Along horizontal,

$R_1 - 0.3R_2 \cos 10^\circ - R_2 \sin 10^\circ = 0$

$\Rightarrow R_1 = R_2(\sin 10^\circ + 0.3 \cos 10^\circ)$

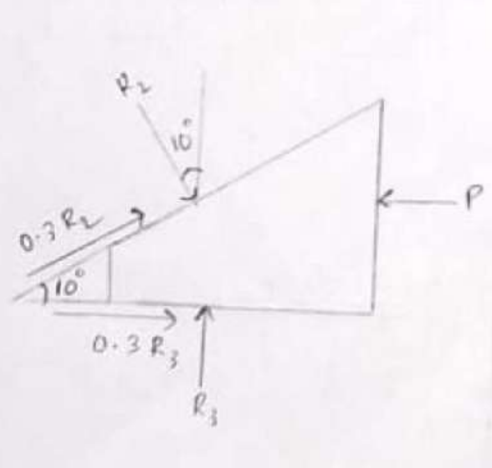
$\Rightarrow R_1 = 0.469\ R_2$ —— (1)

Along vertical

$R_2 \cos 10^\circ - 0.3 R_2 \sin 10^\circ - 2943 - 0.3 R_1 = 0$

$\Rightarrow R_2(\cos 10^\circ - 0.3 \sin 10^\circ - (0.3 \times 0.469)) = 2943$

$\Rightarrow R_2(0.792) = 2943 \Rightarrow R_2 = 3715.8466\ N$



Consider the eq^n of the wedge,

Along vertical.

$R_3 + 0.3 R_2 \sin 10^\circ - R_2 \cos 10^\circ = 0$

$\Rightarrow R_3 = R_2(\cos 10 - 0.3 \sin 10^\circ)$

$= 3715.8466 \times 0.9327$

$\Rightarrow R_3 = 3465.81\ N$

Along horizontal,

$0.3 R_2 \cos 10^\circ + R_2 \sin 10^\circ + 0.3 R_3 = P$

$\Rightarrow P = R_2 (0.3 \cos 10^\circ + \sin 10^\circ) + 0.3 R_3$

$= (0.469 \times 3715.8466) + (0.3 \times 3465.81)$

$\Rightarrow P = \underline{\underline{2782.4750 \text{ N}}}$

18.a) Assume the ball falling from a height 'h' vertically

$u = 0, \; s = h, \; a = g$

Velocity at the time of first bounce,

$v^2 = u^2 + 2as \Rightarrow v^2 = 2gh \Rightarrow v = \sqrt{2gh}$

After collision it bounces back with a velocity 'u_1'

We've, coefficient of restitution, e is the ratio of relative velocity after collision to that of before collision

$\Rightarrow u_1 = ev = e\sqrt{2gh}$

Then the ball reaches at a height of h_1 from the floor. ie $h_1 = 9m$

Let final velocity after the first bounce be v_1

$\Rightarrow v_1^2 = u_1^2 + 2as \Rightarrow 0 = e^2 2gh - 2gh_1$

$\Rightarrow e^2 2gh = 2g \times 9 \Rightarrow e^2 h = 9$ ---(1)

The ball returns back and completes its second bounce with a velocity u_2 to a height of h_2 from the floor

$v_2 = \sqrt{2gh_1} \quad u_2 = ev_2 \Rightarrow u_2 = e\sqrt{2gh_1}$

After the second bounce, at $h_2 = 6m$, velocity $v_3 = 0$

$\Rightarrow 0^2 = u_2^2 - 2gh_2 \Rightarrow e^2 2g \times 9 = 2g \times 6$

$\Rightarrow e^2 = \frac{6}{9} \Rightarrow e = \underline{\underline{0.81649}}$

$\therefore (1) \Rightarrow \frac{6h}{9} = 9 \Rightarrow h = \frac{81}{6} = \underline{\underline{13.5 \text{ m}}}$

$\therefore$ Required height, $h = \underline{\underline{13.5\text{m}}}$ and coefficient of restitution, $e = \underline{\underline{0.81649}}$

b) Let the accelerations of the cars A and B be a_1 and a_2 respectively

We've, $s = ut + \frac{1}{2}at^2$

$u = 0$ [$\because$ Initially at rest] $\Rightarrow s = \frac{1}{2}at^2$

Displacement of cars A and B are same $\Rightarrow$

$\frac{1}{2} \times 0.75\, t^2 = \frac{1}{2} \times 1.1 \times (t - 1.75)^2$ [t: Time taken by the car-A

$\Rightarrow 0.75\, t^2 = 1.1\,(t^2 - 3.5t + (1.75)^2)$

$\Rightarrow 0.75\, t^2 = 1.1\, t^2 - 3.85\, t + 3.36875$

$\Rightarrow 0.35\, t^2 - 3.85\, t + 3.36875 = 0$

$\therefore t = \dfrac{3.85 \pm 3.179}{0.7}$

$\Rightarrow t = 10.04\ s$ or $t = 0.9585\ s$

Since $t > 1.75\ s$, $\underline{\underline{t = 10.04\ s}}$

At $t = 10.04\ s$,

Displacement of the cars $= \frac{1}{2} \times 0.75 \times (10.04)^2 = \underline{\underline{37.8\ m}}$

Speed of car-A at $t = 10.04\ s \Rightarrow$

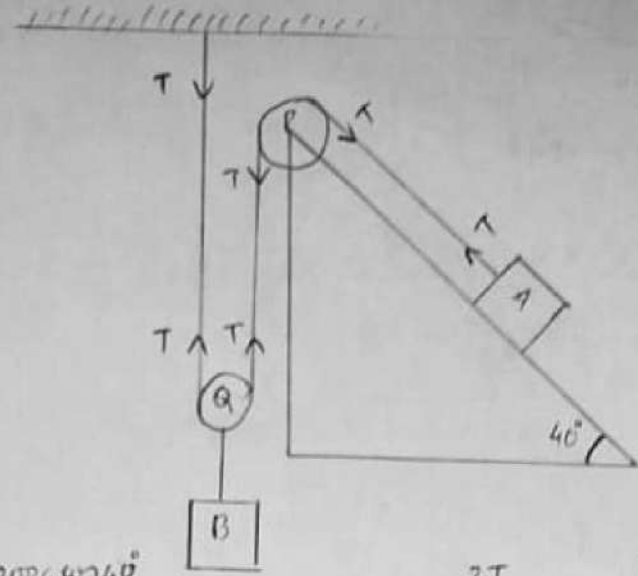
$v_A = 0 + (0.75 \times 10.04) = \underline{\underline{7.53\ ms^{-1}}}$

Speed of car-B at $t = 10.04\ s \Rightarrow$

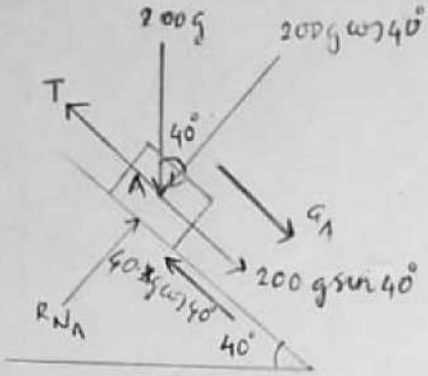
$v_B = 0 + (1.1 \times 10.04) = \underline{\underline{11.044\ ms^{-1}}}$

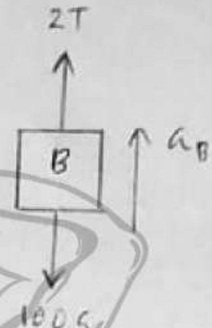
$\therefore$ Car-B will overtake car-A at $t = 10.04\ s$ and at a displacement of 37.8 m from the starting position. Speeds of car-A and car-B at that time are 7.53 ms^{-1} and 11.044 ms^{-1} respectively.

17.



$\mu = 0.2$
$a_A = 2a_B$





Consider the motion of block A.

$200g\sin 40^\circ - 40g\cos 40^\circ - T = 200\,a_A$ —(1)

Consider the motion of block B.

$2T - 100g = 100\,a_B$

$\Rightarrow 2T - 100g = 50\,a_A$

$\Rightarrow T - 50g = 25\,a_A$ —(2)

$R_{N_A} = 200g\cos 40^\circ$

$\Rightarrow$ Frictional force at the point of contact of A

$= \mu R_{N_A}$

$= 0.2 \times 200g\cos 40^\circ$

$= 40g\cos 40^\circ$ N

(1) + (2) $\Rightarrow$

$225\,a_A = g(200\sin 40^\circ - 40\cos 40^\circ - 50) \Rightarrow a_A = \underline{\underline{2.0891\ m/s^2}}$

$\therefore$ Acceleration of the block B, $a_B = \frac{1}{2}a_A = \underline{\underline{1.04455\ m/s^2}}$

$\therefore$ Tension in the string,

$T = 50g + (25 \times 2.0891) = \underline{\underline{542.7275\ N}}$

$\therefore$ Accelerations of the blocks A and B are $a_A = 2.0891\ m/s^2$ (down the plane) and $a_B = 1.04455\ m/s^2$ (upwards) respectively

Tension in the string, $T = 542.7275$ N

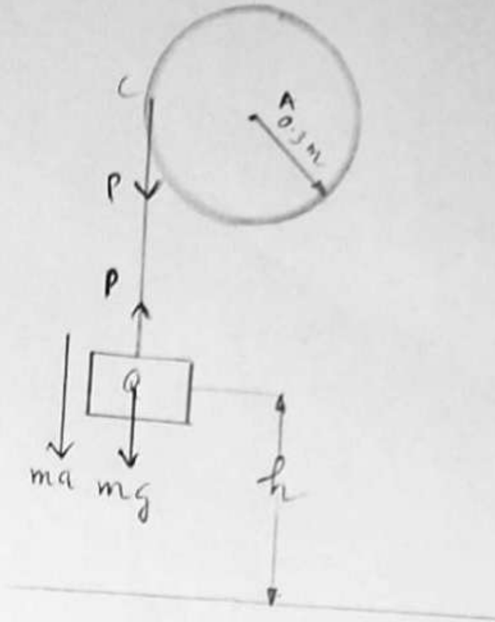
19 Let P be the tension in the string

Torque, $\tau = P \times r$

$$\tau = I\alpha = Mk^2 \times \frac{a}{r}$$

$$\Rightarrow \tau = M\frac{r^2}{2} \times \frac{a}{r} = \frac{Mar}{2}$$

$$\Rightarrow P \times r = \frac{Mar}{2} \Rightarrow P = \frac{Ma}{2}$$



Consider the vertical motion of the body Q.

$$mg - P = ma$$

$$45 - \frac{Ma}{2} = \frac{45}{g}a$$

$$\Rightarrow a\left[\frac{45}{g} + \frac{145}{2g}\right] = 45$$

$$\Rightarrow a = \frac{45 \times 9.81}{(45 + 72.5)} = \frac{45 \times 9.81}{117.5} = 3.757\ m/s^2$$

$$h = ut + \frac{1}{2}at^2$$

$$u = 0 \Rightarrow 3 = \frac{1}{2} \times 3.757\ t^2 \Rightarrow t = \sqrt{\frac{6}{3.757}} = \underline{\underline{1.263\ s}}$$

Final velocity,

$$v = u + at \Rightarrow v = 3.757 \times 1.263 = \underline{\underline{4.7478\ m/s}}$$

20. a) Given,

$m = \frac{50}{9.81}$ kg , $k = 8$ N/cm $= 800$ N/m

We've, Time period, $T = 2\pi\sqrt{\frac{m}{k}}$

$\Rightarrow \quad T = 2\pi\sqrt{\frac{50}{9.81 \times 800}} = 0.5$ s

b). We've,

Magnitude of velocity of a particle in SHM, $v = \omega\sqrt{a^2 - x^2}$

$\therefore \; 1.2 = \omega\sqrt{a^2 - (0.1)^2}$ — (1) and $0.8 = \omega\sqrt{a^2 - (0.2)^2}$ — (2)

$\frac{(1)}{(2)} \Rightarrow \frac{3}{2} = \sqrt{\frac{a^2 - (0.1)^2}{a^2 - (0.2)^2}}$

$\Rightarrow \; 9(a^2 - 0.04) = 4(a^2 - 0.01) \Rightarrow 5a^2 = -0.04 + 0.36 = 0.32$

$\Rightarrow a^2 = 0.064 \Rightarrow a = 0.252$ m $\therefore$ Amplitude $= \underline{\underline{0.252 \text{ m}}}$

$\therefore (1) \Rightarrow 1.2 = \omega\sqrt{0.064 - 0.01} \Rightarrow \omega = 5.163$ rad/s

$\therefore$ Time period, $T = \frac{2\pi}{\omega} = \underline{\underline{1.2172 \text{ s}}}$

Maximum velocity, $v_{max} = \omega a = 5.163 \times 0.252 = \underline{\underline{1.301 \text{ ms}^{-1}}}$

Maximum acceleration, $a_{max} = \omega^2 a = (5.163)^2 \times 0.252 = \underline{\underline{6.7174 \text{ ms}^{-2}}}$