സഹായി

SFI GEC PALAKKAD

Reg No.: Name:

00EST100121904

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Second Semester B.Tech Degree Examination July 2021 (2019 scheme)

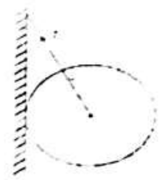
Course Code: EST100
Course Name: ENGINEERING MECHANICS
(2019 Scheme)

Max. Marks: 100 Duration: 3 Hours

PART A

(Answer all questions, each carries 3 marks.)

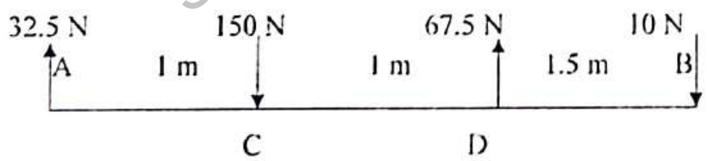
1 Define free body diagram. Draw free body diagram of a spherical ball of weight W supported by a string and resting against a wall as shown in figure. (3)



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

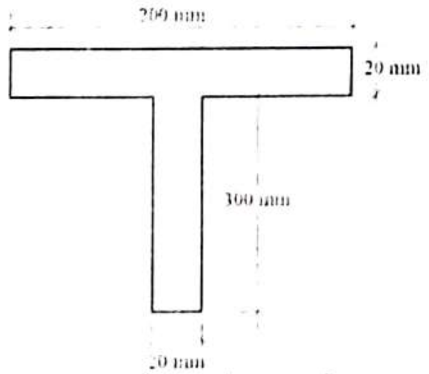
3 Weights 60N and 80N are suspended at the ends A and B respectively, of a uniform beam AB of weight 100 N and 6m long. At what distance from A the beam should be supported so that it remains horizontal. (3)

4 A system of parallel forces is acting on a rigid bar as shown. Reduce this system to a single force. (3)



5 State Pappus Guldinus theorems. (3)

6 Find the centroid of the T section shown. (3)



7 A block of mass 10 kg is suspended by an inextensible string passing over a smooth frictionless pulley. If the mass is pulled up at an acceleration of 1 m/s^2, calculate the tension in the string. (3)

8 Calculate the increase in reaction under the feet of person of weight 600 N in a lift, if the lift accelerates upward with an acceleration $1 m/s^2$. (3)

9 A body moving with simple harmonic motion, has an amplitude of 1m and period of oscillation is 2 seconds. Find the velocity and acceleration of the body at t = 0.4 second, when time is measured from the mean position. (3)

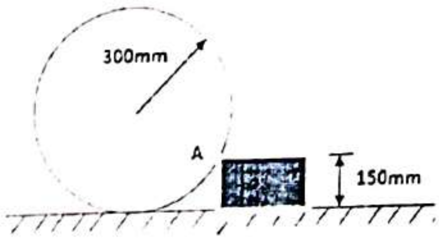
10 Explain concept of instantaneous centre. Also state its significance. (3)

PART B

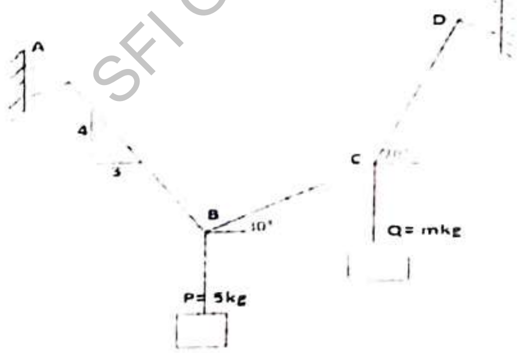
(Answer one full question from each module, each question carries 14 marks)

Module-I

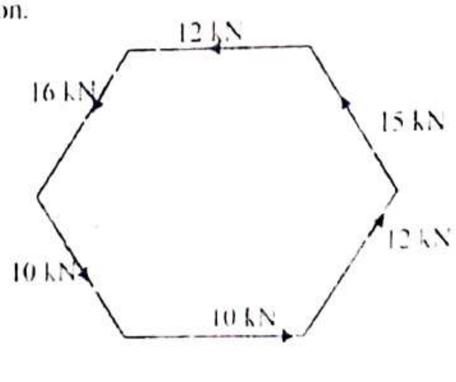
11 A roller of radius 300 mm and weight 1000N is to be pulled over a rectangular block of height 150mm as shown in fig. Determine (i) the horizontal force required to be applied through the centre and (ii) the required horizontal force when it is applied through the top end of vertical diameter. (14)



12 a) A block P= 5kg and block Q of mass M kg are suspended through a chord which is in equilibrium as shown in Fig. Determine the mass of the block Q. (5)

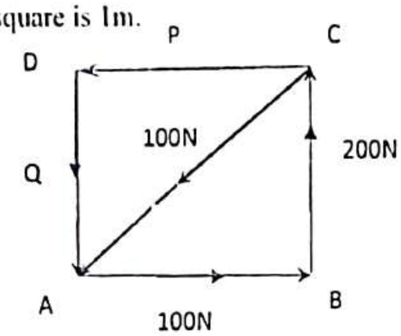


b) Six forces of magnitude 10 kN, 12 kN, 15 kN, 12 kN, 16 kN, and 10 kN are acting along the sides of the regular hexagon of side 2 m in order. Find the resultant force and its direction. (9)

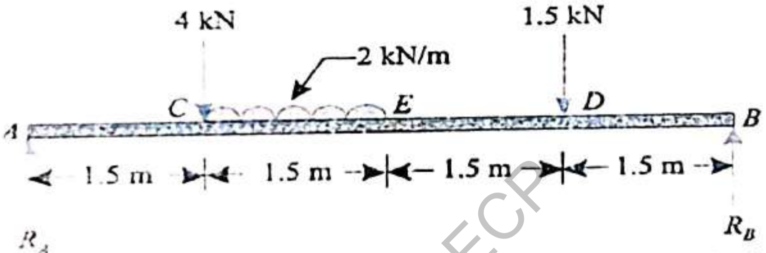


Module-II

13 a) A square ABCD has forces acting along its sides as shown in figure below. Find the values of P and Q, if the system reduces to a couple. Also find magnitude of the couple if the side of the square is 1m. (6)



b) A simply supported beam AB of span 6m is loaded as shown in figure. Determine the reactions at A and B. (8)

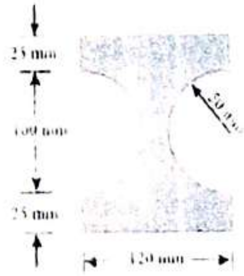


14 a) A rough inclined plane, rises 1 cm for every 5 cm along the inclined length. Calculate the effort required to drag a body weighing 100 N up the plane, when the effort is applied parallel to the plane ($\mu = 0.25$) (5)

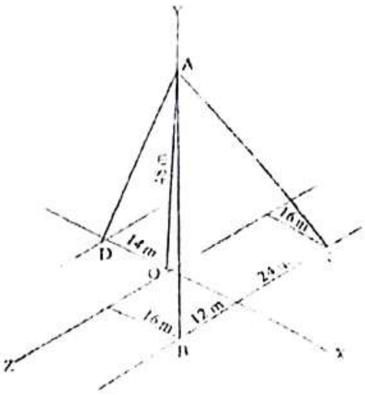
b) A uniform ladder weighing 300N is resting against a wall with which it makes 30° with the vertical. A man weighing 750N climbs up the ladder. At what position along the ladder from the bottom end does the ladder slips? The coefficient of friction is 0.20. (9)

Module-III

15 The cross section of a cast iron beam is shown in figure. Determine the moments of inertia of the section about the horizontal and vertical axes passing through the centroid. (14)



16. A post is held in vertical position by three cables AB, AC and AD as shown in figure. If the tension in cable AB is 40 N, calculate the tension in AC and AD, so that the resultant of three forces at A is vertical. (14)



Module-IV

17 a) In the motion of a projectile, in what proportion will the maximum range be increased if the initial velocity is increased by 10%? (5)

b) A train weighing 1700 kN without the engine starts to move with constant acceleration along a straight horizontal track and in the first 60 seconds acquires a velocity of 54 km/hr. Determine the tension in the coupling between the train and the engine if the total resistance to motion due to friction and air resistance is constant and equal to 0.005 times the weight of the train. (9)

18 a) A ball of mass 'm' is dropped from rest from the top of a tower of height H. Write the equations of kinematics for the motion of the ball under free fall at any instant 't' of the motion. (4)

b) Three spherical balls of mass 2kg, 6kg and 12kg are moving in the same direction with velocities 12m/s, 4 m/s and 2 m/s respectively. If the ball of mass 2 kg impinges with the ball of mass 6kg, which in turn impinges with the ball of mass 12kg, prove that the balls of masses 2kg and 6kg will be brought to rest by the impacts. Assume to be perfectly elastic. (10)

Module-V

19 An inextensible rope passing over a smooth pulley has two blocks of mass 20 kg and 30 kg attached to its two ends. The mass of the pulley is 10 kg and radius of gyration 0.3m. Determine the tension on the rope and the acceleration of the masses. (14)

20 In a particular SHM performed by a particle of mass m, the amplitude is 1.57m and time period of oscillation is 5s. i) Calculate velocity and acceleration of particle at 0.53m away from centre ii) Determine magnitude and location of maximum velocity and maximum acceleration of particle iii) Also determine the time required by the particle to pass two points 1.35 m away and 0.53 m away from the central point of oscillation. Both the points lie on the same side of the central point. (14)

*****

$2\times12 + 8\times16 =$

$24 + 128$

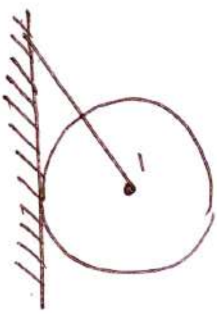
152

ENGINEERING MECHANICS

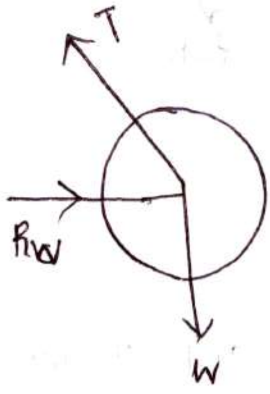
JULY - 2021 [2019 SCHEME]

1) Free Body Diagram.

A free body diagram (FBD) is a diagrammatic representation of a single body or a system of bodies isolated from its surroundings and shown under the action of all forces and moments due to external actions on the body. It can be drawn for any single member of the system, any sub system or for the entire system, whether it is in equilibrium, in a uniform motion or in dynamic state of motion

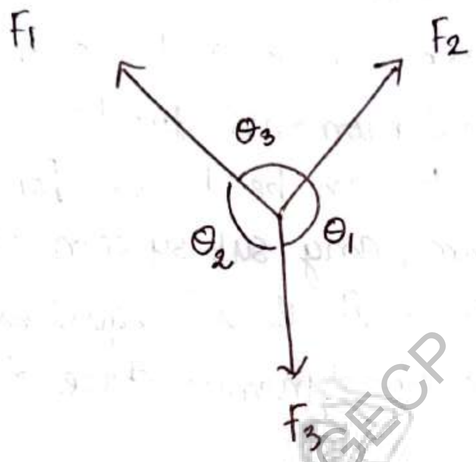


FBD



2) Lami's Theorm

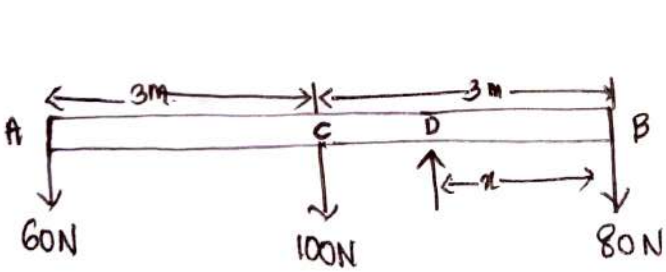
It states that three coplanar concurrent forces acting on a body be in equilibrium, then each force is propotional to the sine of the angle between the other two forces



Mathematically

$$\frac{F_1}{\sin\theta_1} = \frac{F_2}{\sin\theta_2} = \frac{F_3}{\sin\theta_3}.$$

3)



Given,

Weight of the rod = 100N

Length of the rod = 6m and weight of the bodies supported at A and B = 60N and 80N

Let x = Distance between B and the point where the beam should be supported.

We know that for the beam to rest horizontally, the moments of the weights should be equal

Now taking moments of the weights about D and equating the same

$$80x = 60(6-x) + 100(3-x)$$

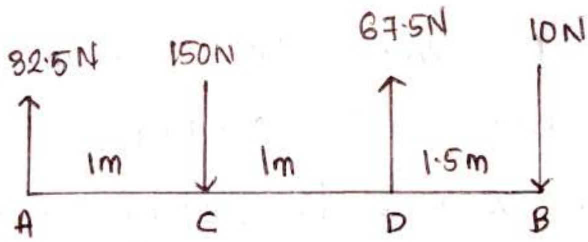
$$= 360 - 60x + 300 - 100x$$

$$= 660 - 160x$$

$$240x = 660$$

$$x = \frac{660}{240} = 2.75\,m$$

4)



Resultant of force system

$$= 32.5 + 67.5 - 150 - 10$$

$$= -60N$$

$$= 60N \text{ [Downward]}$$

Taking moment about A

$$\Sigma M_A = 150\times1 + (-67.5\times2) + (10\times3.5)$$

$$= 150 - 135 + 35$$

$$= 50 \text{ Nm (clockwise)}$$

$$Rx = \Sigma M_A$$

$$60x = 50$$

$$x = 1.2 \text{ m.}$$

Resultant force is 1.2 m towards right of A in downward direction

5) Theorm of Pappus Guldinus

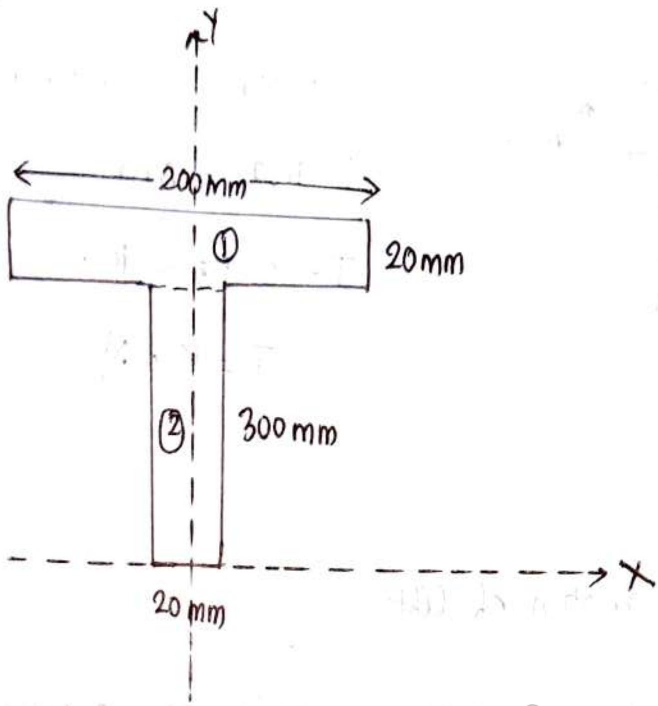
Theorm-1

The area of the surface generated by revolving a plane curve about a non intersecting axis in the plane of the curve is equal to the product of length of the curve and the distance travelled by centroid of the curve while the surface being generated.

Theorm-2

The volume of the body generated by revolving a plane area about non-intersecting axis in the plane of area is equal to the product of area and the distance travelled by the centroid of the plane area while the body is being generated.

6.



$a_1 = 200 \times 20 = 4000\ mm^2$

$a_2 = 300 \times 20 = 6000\ mm^2$

$\bar{X} = 0$ Since there is an axis of symmetry wrt to Y axis

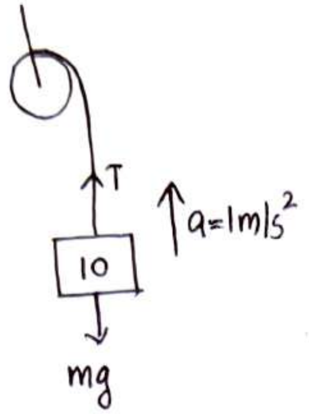
$y_1 = 300 + \frac{20}{2} = 310$

$y_2 = \frac{300}{2} = 150$

$$\bar{y} = \frac{4000 \times 310 + 6000 \times 150}{4000 + 6000} = \underline{\underline{214\ mm}}$$

Centroid $= (0, 214\ mm)$

7.



Net Force = mass x acceleration

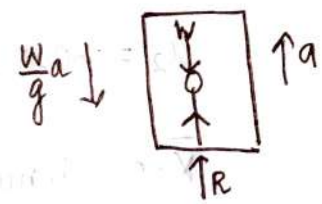
$T - mg = ma$

$T - 10 \times 9.8 = 10 \times 1$

$T = 108\ N$

8. Upward motion of lift

When the lift moves upwards with an acceleration a, the inertia force $\frac{W}{g}a$ is downwards.



For dynamic Equilibrium

$\Sigma F + F_I = 0$

$R - W - \frac{Wa}{g} = 0$

$R = W\left[1 + a/g\right]$

$= 600\left[1 + 1/9.8\right]$

$= \underline{\underline{661.22 N}}$

9) Amplitude, $r = 1m$

Timeperiod $T = 2s$.

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2} = \pi \text{ rad/s}.$$

when $t=0.4s$, $x = r\cos\omega t$

$= 1\cos(\pi \times 0.4)$

$= 0.309 \text{ m}$

$$V = \frac{dx}{dt} = \frac{d}{dt}(r\cos\omega t$$

$= -r\omega \sin\omega t$

$= -1 \times \pi \times \sin(0.4 \times \pi)$

$= -2.98 \text{ m/s}.$

$a = -\omega^2 x$

$= -\pi^2 \times 0.309$

$= -3.049 \text{ m/s}^2.$

10) Instantaneous Centre of Rotation

The motion of rotation and translation of a body may be assumed to be a motion of pure rotation about some centre. This point is called instantaneous centre of rotation.

Since the velocity of this point at a given instant is zero, this point is also called instantaneous centre of zero velocity. The locus of instantaneous centre as the body goes on changing its position is called centrode

PART- B

11 Case (1)

Horizontal force is applied through the centre

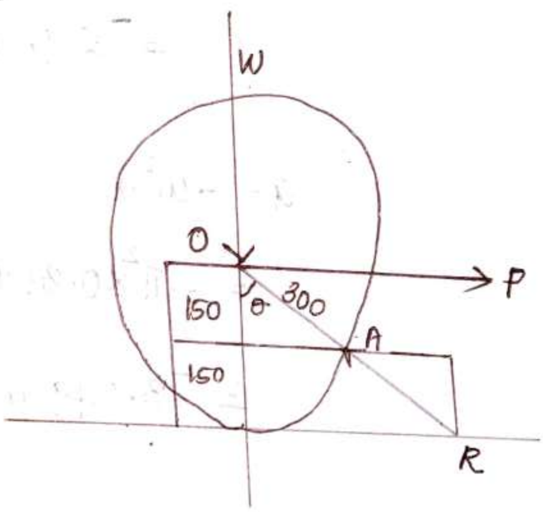
when the roller is just turned about A, the contact at B breaks and hence there is no reaction at B.

Let P be the applied force and R be the reaction at the contact point A.

$OB = OA\cos\theta + 150$

$300 = 300\cos\theta + 150$

$\theta = 60^\circ$



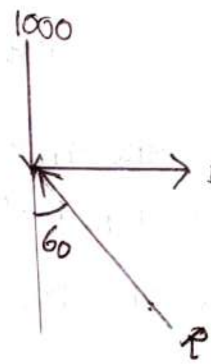
Resolving the forces Vertically

for $\Sigma F_v = 0$

$R\cos\theta - 1000 = 0$

$R\cos 60 = 1000$

$R = 2000\,N$



Resolving the forces horizontally

for $\Sigma F_H = 0$

$P - R\sin\theta = 0$

$P = R\sin 60 = 2000\sin 60 = 1732.05\,N.$

Case-II

When the force P is applied through the top end of the diameter

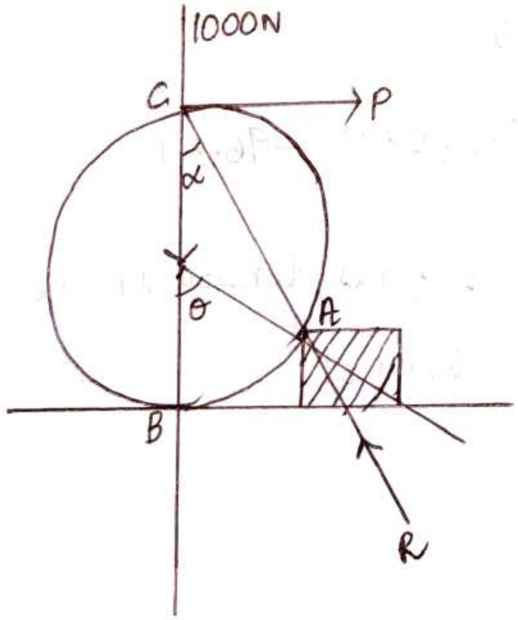
The line of action of R should intersect at C, where the line of action of other two forces intersect. Triangle OAC is an isosceles triangle with $\angle AOC = 120^\circ$

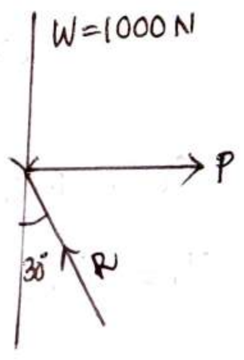
$$\alpha = \frac{180-120}{2} = 30^\circ$$

Resolving the forces vertically

for $\Sigma F_V = 0$

$R\cos 30 - W = 0$, $R = \dfrac{W}{\cos 30} = \dfrac{1000}{\cos 30} = 1154.7\,N$





Resolving the forces horizontally

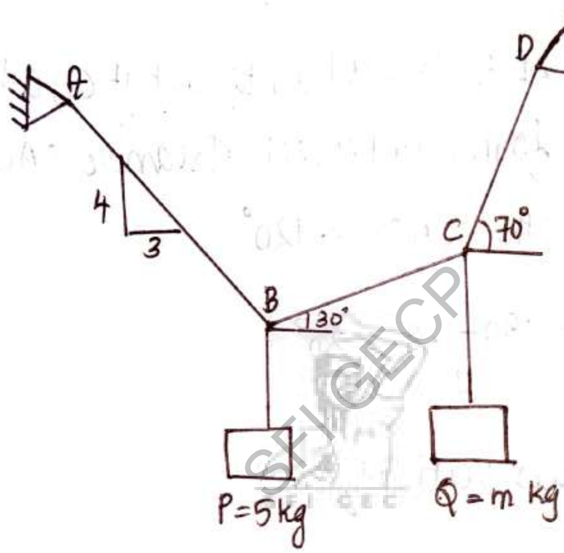
for $\Sigma F_H = 0$

$$P - R\sin 30 = 0$$

$$P = R\sin 30 = 1154.7 \times \sin 30$$

$$P = 577.35\,N$$

12.



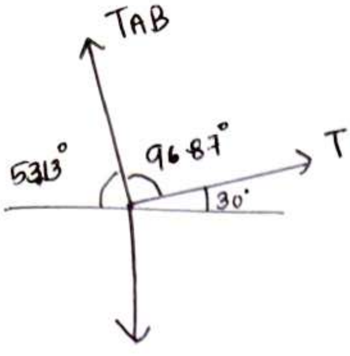
Inclination of chord AB with horizontal is

$$\tan^{-1}(4/3) = 53.13^\circ$$

$$\theta = 53.13^\circ$$

$$\angle ABC = 180 - (30 + 53.13) = 96.87$$

Point B is acted upon 3 forces, tension in the chord T_{AB}, T_{BC} and weight $W \times 9.81$



$P = 5 \times 9.81 N.$

Applying Lamis Theorm

$$\frac{5 \times 9.81}{\sin 96.87} = \frac{T_{AB}}{\sin 120} = \frac{T_{BC}}{\sin 143.13}$$

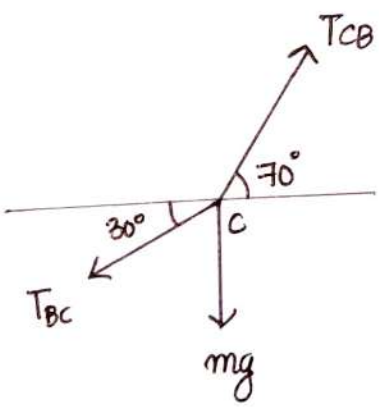
$$T_{AB} = \frac{5 \times 9.81}{\sin 96.87} \times \sin 120 = 42.79 N$$

$$T_{BC} = \frac{5 \times 9.81}{\sin 96.87} \times \sin 143.13$$

$$= 29.64 N$$

Consider the equilibrium of point c

Applying Lamis Theorm



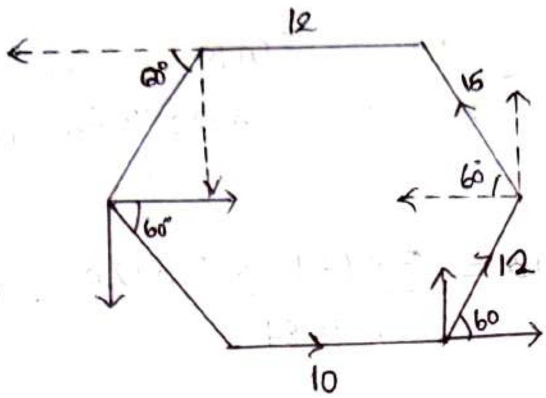
$$\frac{5 \times 9.81}{\sin 96.87} = \frac{T_{AB}}{\sin 120} = \frac{T_{BC}}{\sin 143.13}$$

$$\frac{T_{BC}}{\sin 160} = \frac{mg}{\sin 140}$$

$$mg = \frac{T_{BC}}{\sin 160} \times \sin 140 = \frac{29.64}{\sin 160} \times \sin 140 = 55.7 N$$

$$\text{Mass of } Q = \frac{55.7}{9.8} = 5.68 kg.$$

12b



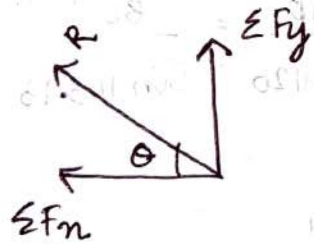
$$\Sigma F_x = 10 + 12\cos 60 - 15\cos 60 - 12 - 16\cos 60 + 10\cos 60$$

$$= -6.5\ KN$$

$$\Sigma F_y = 12\sin 60 + 15\sin 60 - 16\sin 60 - 10\sin 60$$

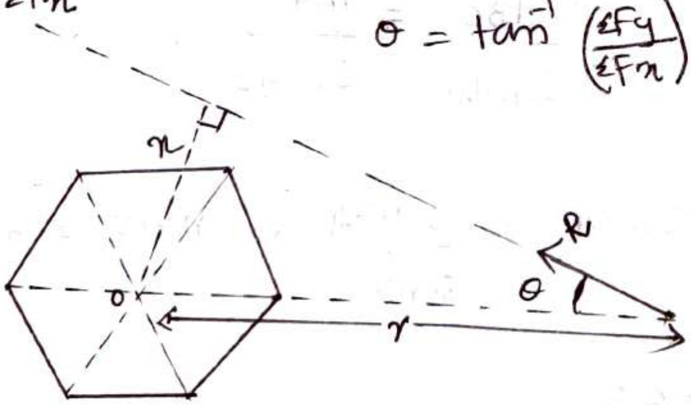
$$= 0.86\ KN$$

$$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2} = \sqrt{(6.5)^2 + (0.86)^2} = 6.55\ N$$



$$\tan\theta = \frac{\Sigma F_y}{\Sigma F_x}$$

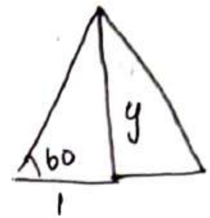
$$\theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right) = 7.56.$$



let $\perp$r distance from centre O to R be x

$\Sigma M_0 = 10y + 12y + 15y + 12y + 16y + 10y = 129.9$

$\Sigma M_0 = Rx = 129.9$



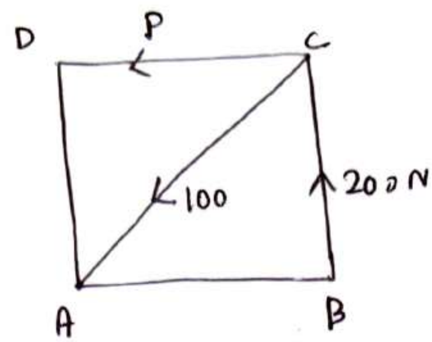
$x = \frac{129.9}{6.55} = 19.8\ m$

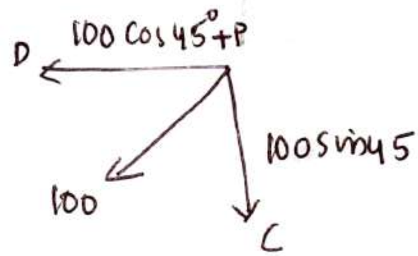
$\frac{x}{\sin\theta} = r = 150.49\ m$

R is at a horizontal distance 150·49 from O inclined at an angle 7·56°

value of R = 6·55 kN

13 a)





$\Sigma F_x = 0$

$100 - P - 100 \cos 45 = 0$

$P = 100 - \frac{100}{\sqrt{2}} = 29.2 N$

$\Sigma F_y = 0$

$200 - 100 \sin 45 - Q = 0$

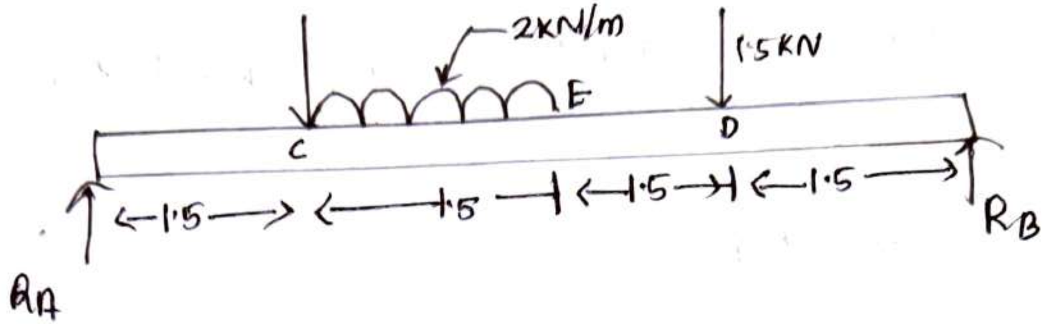
$Q = 200 - 100 \sin 45$

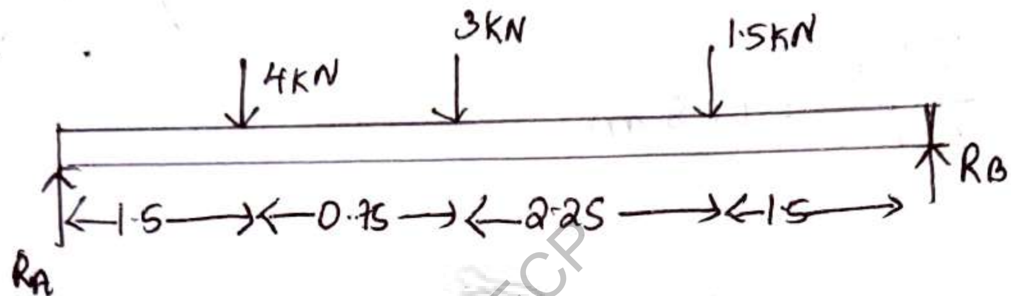
$= 129.2 N$

$M_A = ?$ $\quad x = 1$

$M_A = 200 \times 1 + 29.2 \times 1 = \underline{\underline{229.2 Nm}}$

13 b)





$R_A + R_B = 4+3+1.5 = 8.5\ KN$

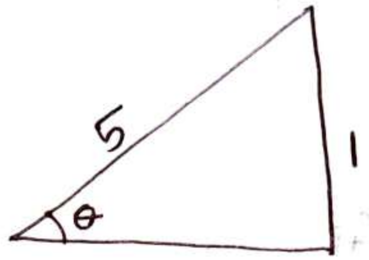
Taking moment about A

$4 \times 1.5 + 3 \times 2.25 + 1.5 \times 4.5 = R_B \times 6$

$R_B = \frac{6 + 6.75 + 6.75}{6} = 3.25\ KN$

$R_A = 8.5 - 3.25 = 5.25\ KN$

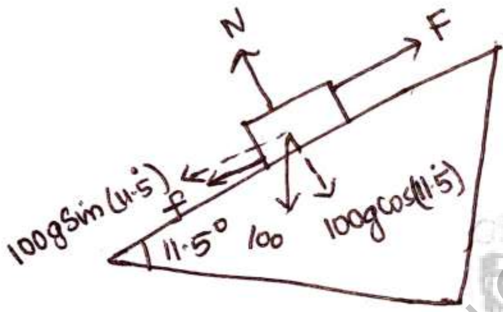
14a)



$\sin\theta = 1/5$

$\theta = \sin^{-1}(1/5)$

$= 11.5^\circ$.



F → Force/Effort required to drag a body

~~Newton~~ $\Sigma F_V = 0$

$N = 100g\cos(11.5^\circ)$

$= 100 \times 9.8 \times \cos(11.5^\circ) = 960.1\ N$

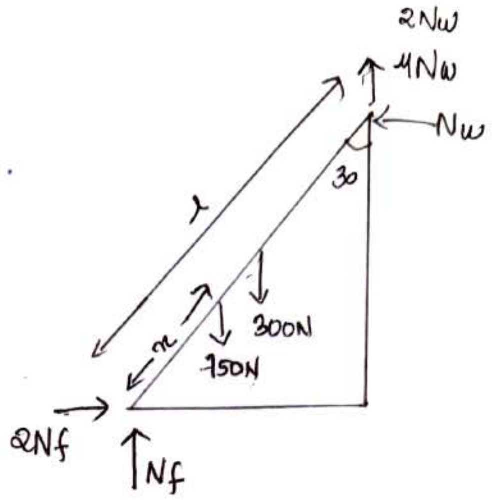
frictional force $f = \mu_s N = 0.25 \times 960.1 = 240.02N$

$F = f + 100g\sin(11.5^\circ)$

$= 240.02 + 100 \times 9.8 \times \frac{1}{5}$

$= 436.02\ N$

14 b)



$\Sigma F_V = 0$

$1050 = N_f + 2N_w$ —— ①

$2N_f = N_w$

$(\Sigma F_H = 0)$

$\frac{1}{5} N_f = N_w$

$5 N_w = N_f$ —— ②

$1050 = 5.2 \times N_w$

$N_w = \underline{\underline{201.92}}$

taking A as moment centre

$-(750 \times x \cos 60) - (300 \times \frac{l}{2} \cos 30)$
$+ 2N_w l \cos 60 + N_w l \sin 30$
$= 0$

$-375x - 75l + 20.192l + 174.86l = 0$

$-375x + 120l = 0$

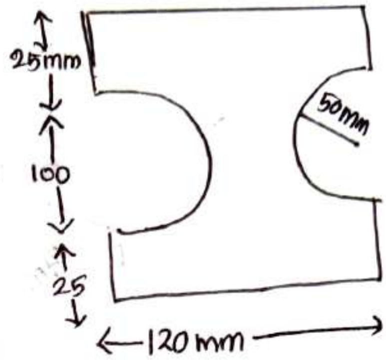
$120l = 375x$

$x = 0.32l$.

let $l = 1$

$\underline{\underline{x = 0.32m}}$.

15 G_1, G_2, G_3 and G are on the same horizontal XX axis



$$I_{Gxx} = I_{Gx_1xx} - I_{G_2xx} - I_{G_3xx}$$

$$= I_{G_1xx} - 2 I_{G_2xx}$$

$$= \frac{1}{2} \times 120 \times (150)^3 - 2 \times \frac{1}{8} \times \pi \times (50)^4$$

$$= 28841261.48 \, mm^4$$

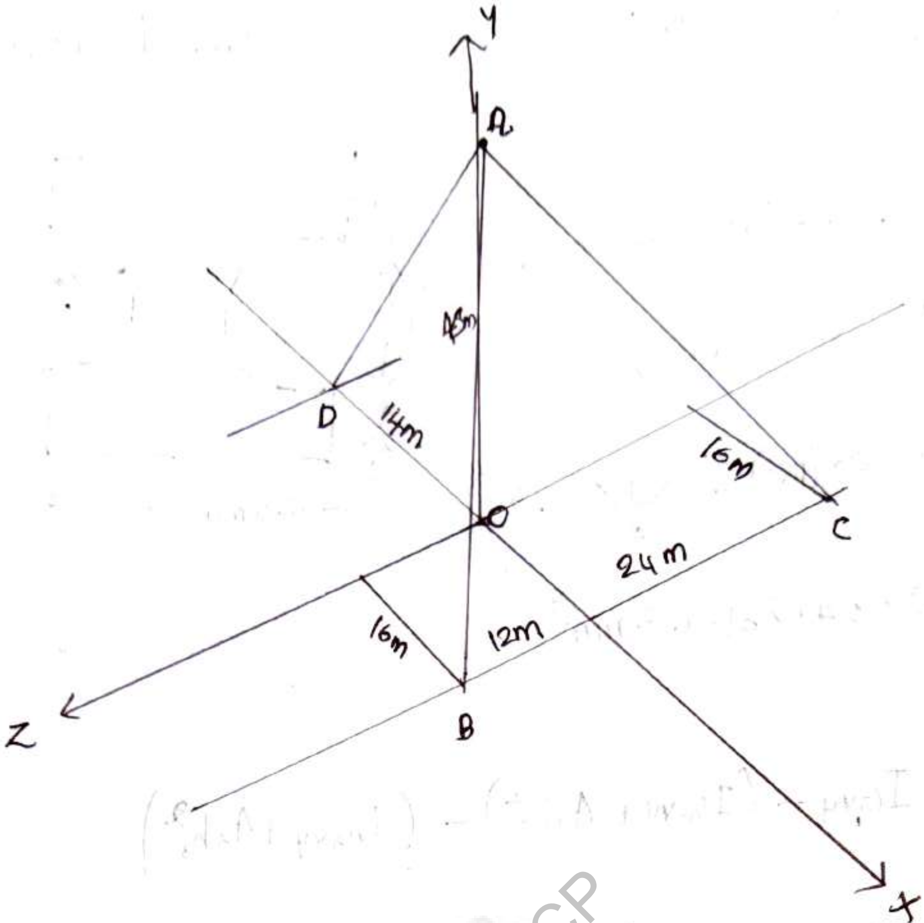
$$I_{Gyy} = I_{G_1yy} - (I_{G_2yy} + A_2 h_2^2) - (I_{G_3yy} + A_3 h_3^2)$$

$$= I_{G_1yy} - 2(I_{G_2yy} + A_2 h_2^2)$$

$$= \frac{1}{2} \times (120)^3 \times 150 - 2\left[\frac{1}{8} \times \pi \times 50^4 + \frac{\pi \times 50^2}{2} \times \left(60 - \frac{4 \times 50}{3 \times \pi}\right)^2\right]$$

$$= 216 \times 10^5 - 2(24500 + 59{,}05721.721)$$

$$= 4888856.558 \, mm^4$$



Unit vector in the direction of AB

$$= \frac{(16-0)\hat{i} + (0-48)\hat{j} + (12-0)\hat{k}}{\sqrt{16^2 + (-48)^2 + 12^2}}$$

$$= \frac{16\hat{i} - 48\hat{j} + 12\hat{k}}{52}$$

Force vector along AB $= 40\left(\frac{16\hat{i} - 48\hat{j} + 12\hat{k}}{52}\right)$

$$= 12.31\hat{i} - 36.92\hat{j} + 9.23\hat{k}$$

Unit vector in the direction of AC

$$= \frac{(16-0)\hat{i} + (0-48)\hat{j} + (0-24)\hat{k}}{\sqrt{16^2 + (-48)^2 + (-24)^2}}$$

$$= \frac{16\hat{i} - 48\hat{j} - 24\hat{k}}{56}$$

Force vector along AC $= F_{AC}\left(\frac{16\hat{i} - 48\hat{j} - 24\hat{k}}{56}\right)$

$$= 0.29 F_{AC}\hat{i} - 0.86 F_{AC}\hat{j} - 0.43 F_{AC}\hat{k}$$

Unit vector in the direction of AD

$$= \frac{(0-14)\hat{i} + (0-48\hat{j}) + (0-0)\hat{k}}{\sqrt{(-14)^2 + (-48)^2 + 0^2}}$$

$$= \frac{-14\hat{i} - 48\hat{j}}{50}$$

Force vector along AD $= F_{AD}\left(\frac{-14\hat{i} - 48\hat{j}}{50}\right)$

$$= -0.28 F_{AD}\hat{i} - 0.96 F_{AD}\hat{j}$$

Resultant force at A, $R = F_{AB} + F_{AC} + F_{AD}$

$$= (12.31\hat{i} - 36.92\hat{j} + 9.23\hat{k}) + (0.29F_{AC}\hat{i} - 0.86F_{AC}\hat{j} - 0.96F_{AC})$$

$$- (0.28F_{AD}\hat{i} - 0.96F_{AD}\hat{j} + 0\hat{k})$$

$$= (12.31 + 0.29F_{AC} - 0.28F_{AD})\hat{i}$$

$$+ (-36.96 - 0.86F_{AC} - 0.96F_{AD})\hat{j}$$

$$+ (9.23 - 0.43F_{AC} + 0)\hat{k}$$

For the resultant to the vertical, the X and Z components must be zero.

$$F_z = (9.23 - 0.43F_{AC}) = 0$$

$$0.43F_{AC} = 9.23$$

$$F_{AC} = 21.47\,N$$

$$F_x = 12.31 + 0.29F_{AC} - 0.28F_{AD} = 0$$

$$\Rightarrow F_{AD} = 66.20\,N$$

17 (a) $R_{max} = \frac{u^2}{g}$

Here g = a constant

$R_{max} \propto u^2$

$$\frac{R_{1max}}{R_{2max}} = \frac{u_1^2}{u_2^2}$$

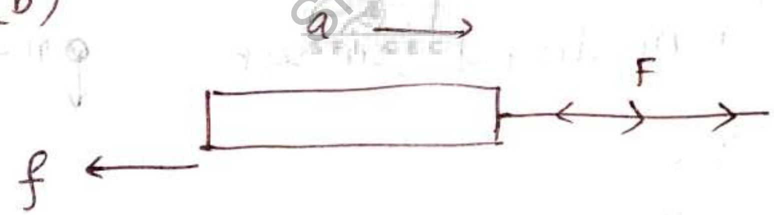
$$\frac{R_1}{R_2} = \frac{u_1^2}{(1.1u_1)^2}$$

$$R_1 = \frac{R_2}{1.21}$$

$R_2 = 1.21 R_1$

$= 21\%$

(b)



Here the tension b/w train and engine be F

at $t = 60$ $\quad V = 5\,km/hr$

$= 15\,m/s$.

$u = 0$

$V = at$, $\quad a = \frac{V}{t} = 15/60 = 0.25\,m/s^2$.

By newtons IInd law

$F = ma$.

Net $F_{net} = F - f$

$f = 0.005 \times 1700000 = 8500 N$

ie,

$m = 1700000$

$(F-f) = ma$

$F - 8500 = 1700000 \times 0.25$

$F = 51000 N$

ie, tension btw the engine & the train

$= \underline{\underline{51000 N}}$.

18 (a) for m dropped from rest

$u = 0$

$S = H$

$v = gt$

$S = \frac{1}{2} g t^2$

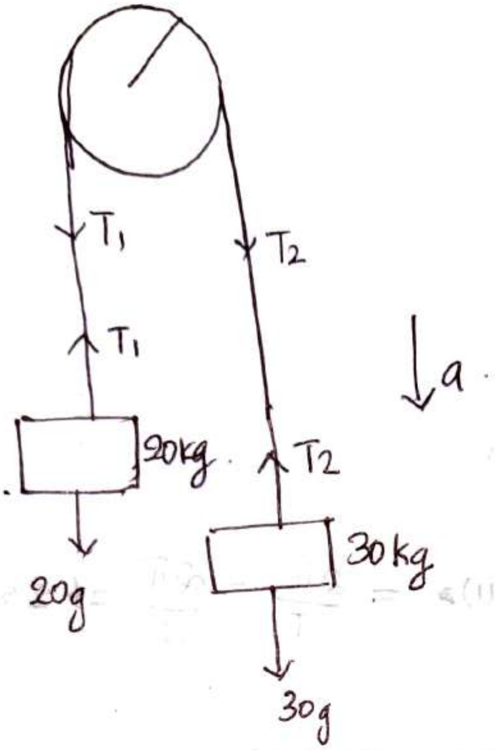
$v^2 = 2gh$

$v = \sqrt{2gh}$

b) Out of syllabus

$V_a = 0$, $V_b = 8 m/s$, $V_b = 0$ $V_c = 6 m/s$

19.



$$T_1 - 20g = 20a \quad \text{——} (1)$$

$$30g - T_2 = 30a \quad \text{——} (2)$$

Net torque

$$T_2 r - T_1 r = \frac{Mr^2}{2}\frac{a}{r}$$

$$T_2 - T_1 = \frac{Ma}{2}$$

$$T_2 - T_1 = 5a$$

(1) + (2)

$$T_1 - T_2 + 10g = 50a$$

$$T_2 - T_1 = 10g - 50a$$

$$55a = 10g$$

$$\Rightarrow a = 1.7836 \, m/s^2$$

$$T_1 = 20a + 20g = \underline{231.6 \, N}$$

$$T_2 = 30g - 30a = \underline{240.6 \, N}$$

20)

$a = 1.57\,m$

$T = 5\,s$

(i) $v = ?$ $\quad a = ?$

$V = \omega\sqrt{a^2 - x^2}$

Given $x = 0.52\,m$

$T = \frac{2\pi}{\omega}$, $\omega = \frac{2\pi}{T} = \frac{2\pi}{5} = 1.256\,rad/s.$

$V = 1.256\sqrt{(1.57)^2 - (0.53)^2}$

$= 1.256\sqrt{2.184}$

$= 1.856\,m/s.$

$a = -\omega_0^2 x$

$= -(1.256)^2(0.53)$

$= -0.836\,m/s^2.$

(ii) Max velocity

$V = \omega\sqrt{a^2 - x^2}$

$V_{max} = \omega\sqrt{a^2 - 0}$

$= \omega a = 1.256 \times (1.57)$

$= 1.97\,m/s.$

Max Acceleration $(A_{max}) = -\omega_0^2 a$

$$= -(1.256)^2(1.57)$$

$$= -2.476 \, m/s$$

Max acceleration at $x = a$

$x = 1.57 \, m$.

(iii) $x = A \sin \omega t$

$$1.35 = 1.57 \sin \left[\frac{2\pi}{5} t_1\right]$$

$$\frac{1.35}{1.57} = \sin\left[\frac{2\pi}{5} t_1\right]$$

$$0.859 = \sin\left(\frac{2\pi}{5} t_1\right)$$

$$59.2 = \frac{2\pi}{5} t_1$$

$$t_1 = 0.822 s$$

$$x = A \sin \omega t_2$$

$$\frac{0.53}{1.57} = \sin\left(\frac{2\pi}{5} t_2\right)$$

$$\frac{2\pi}{5} t_2 = 19.69^\circ$$

$t_2 = 0.272 s.$

$\therefore$ time required $= 0.822 - 0.272$

$= \underline{\underline{0.55 s}}.$