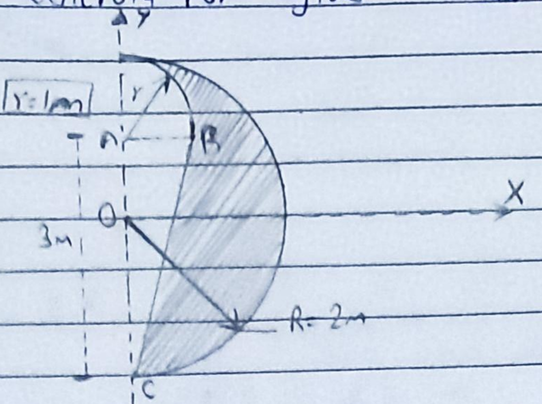
Q1 Determine the centroid for given shaded area for fig.



- Area of Semicircle $= \frac{\pi r^2}{2}$

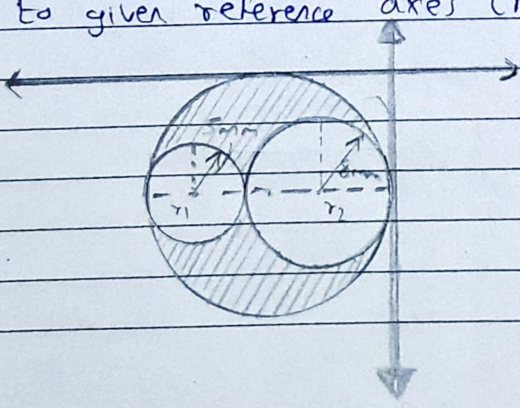
Components	Area A_i (m^2)	X_i (m)	Y_i (m)	A_iX_i (m^3)	A_iY_i (m^3)	~~$\bar{X}$=~~
Semicircle	6.28	0.85	0	5.34	0	
Quarter Circle	-0.78	0.57	1.42	-0.45	~~-0.32~~ -1.10	
Triangle	-1.5	0.33	1	-0.495	-1.5	
	$\Sigma A_i = 4$			$\Sigma A_iX_i = 4.395$	$\Sigma A_iY_i = -1.82$ ~~-1.82~~ $= -2.6$	

$\therefore X = \frac{\Sigma A_iX_i}{\Sigma A_i} = \frac{4.395}{4} = \cancel{1.57m} = 1.098$

$\therefore Y = \frac{\Sigma A_iY_i}{\Sigma A_i} = \cancel{\frac{-1.82}{4}} = \cancel{-0.61m}$ ~~-0.455~~ $\Rightarrow \frac{-2.6}{4} = 0.65$

$\boxed{\therefore \text{Centroid } (X, Y) = \cancel{(1.57, -0.61)}}$ $(1.098, -0.65)$

Q2 Determine the Centroid of the selected/shaded area shown in fig with respect to given reference axes ($r_1 = 5mm$, $r^2 = 8mm$)



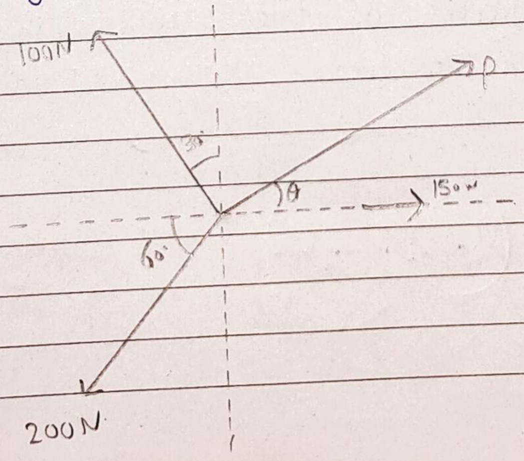
Components	Area A_i (mm)	X_1 (mm)	Y_1 (mm)	A_iX_1	A_iY_1
Circle A	-78.5	-21	~~-13~~ -13	1649.5	~~1251~~ 1020.89
Circle B	-200.96	-8	~~-13~~ -13	1608.48	~~3215~~ 2613.78
Circle C	~~580.94~~ 530.9	-16	~~-13~~ -13	~~-12861.4~~ -6901.9	~~-12861.4~~ -6901.96
	251.44 $\Sigma A_1 =$ ~~524.38~~			ΣA_iX_1 = ~~3643.8~~ = 36439	ΣA_iY_1 = ~~-8890.1~~ = -3268.07

$$X = \frac{\Sigma A_i X_1}{\Sigma A_1} = \cancel{\frac{-9605.2}{524.38}} = \cancel{-18.31\,mm} \Rightarrow \frac{3643.9}{251.44} = -14.499$$

$$Y = \frac{\Sigma A_i Y_i}{\Sigma A_1} = \cancel{\frac{-8890.1}{524.38}} = \cancel{-16\,mm} \Rightarrow \frac{-3268.07}{251.44} = -13$$

$$\boxed{\text{Centroid }(X, Y) = \cancel{(-18.31, -16)}} = (-14.49, -13)$$

Q3 A system of four forces shown in figure has resultant 50N along +ve axis. Determine magnitude & Direction of unknown force P.



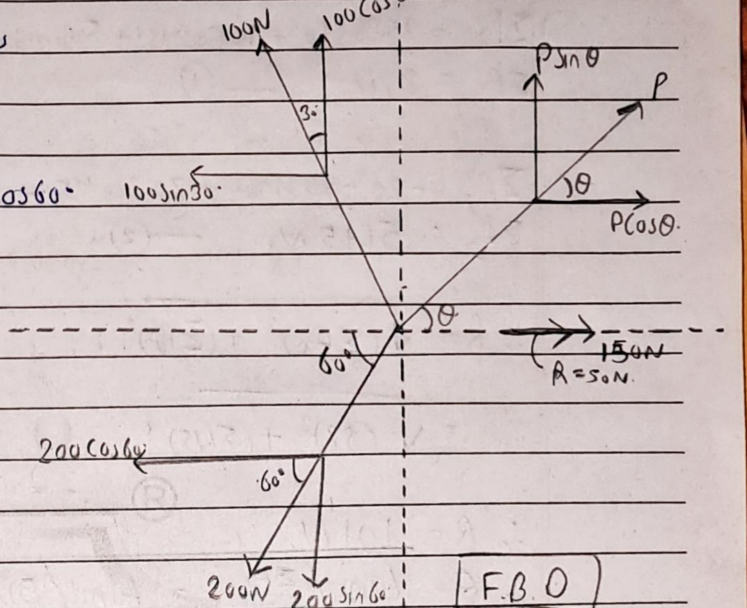
∵ Resultant, R = 50N is along +ve axis

∴ $R_x = 50N$ & $R_y = 0N$

∴ $\Sigma f_x = R_x$

∴ $50 = 150 - 100\sin 30° + P\cos\theta - 200\cos 60°$

∴ $50 = P\cos\theta$ —— (I)



∴ $\Sigma f_y = R_y$

$0 = P\sin\theta + 100\cos 30° - 200\sin 60°$

$0 = P\sin\theta - 86.6$

$86.6 = P\sin\theta$ —— (II)

From (I) & (II)

$\frac{P\sin\theta}{P\cos\theta} = \frac{86.6}{50} \Rightarrow \therefore \tan\theta = \frac{86.6}{50}$ ie $\theta = \tan^{-1}\left(\frac{86.6}{50}\right)$

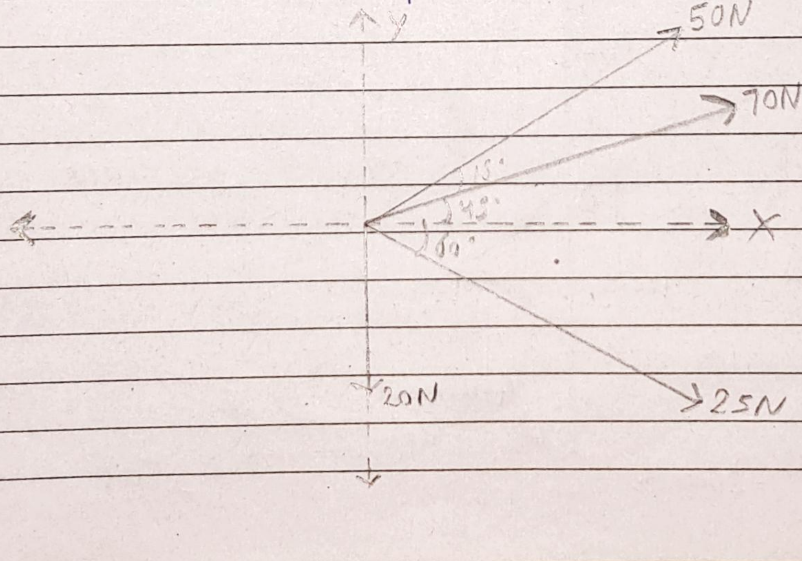
∴ $\theta = 59.9°$

Now, Substituting $\theta = 59.9°$ in eqn (I).

∴ $P = \frac{50}{\cos 59.9} = 99.7N$

∴ Magnitude of force P is 99.7N & Direction is 59.9°.

Q4 Determine the resultant of forces as given in fig. find the angle which resultant makes with positive X-axis.



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$\Sigma f_x = 25\cos 60^\circ + 70\cos 45^\circ + 50\sin 30^\circ$

$\Sigma f_x = 87N$ — (1)

$\Sigma f_y = -20 - 25\sin 60 + 70\sin 45^\circ + 50\cos 30^\circ$

$\Sigma f_y = 51.15N.$ — (2)

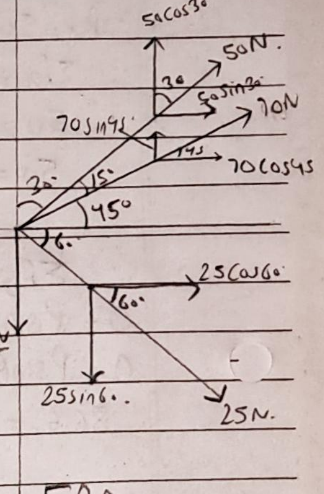
$\therefore R = \sqrt{(\Sigma f_x)^2 + (\Sigma f_y)^2}$

$= \sqrt{(87)^2 + (51.15)^2}$

$\therefore R = 101N.$

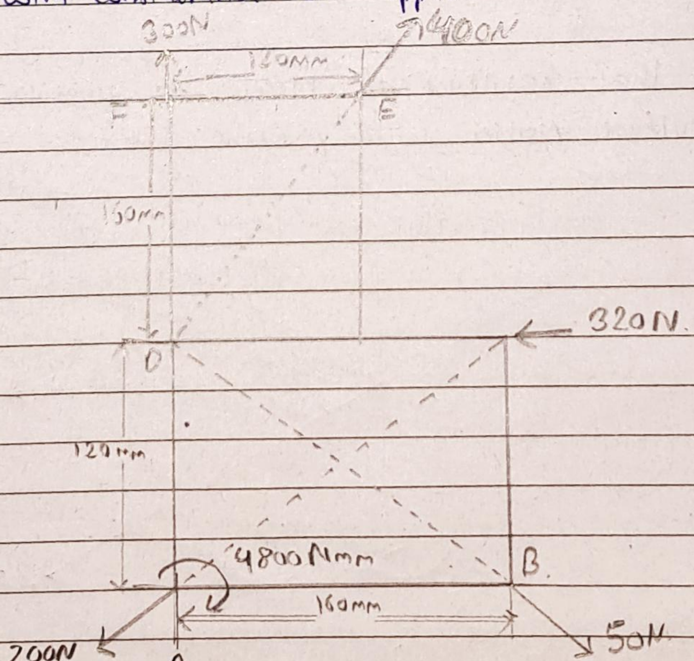
$\therefore \theta = \tan^{-1}\left(\frac{\Sigma f_y}{\Sigma f_x}\right) = \tan^{-1}\left(\frac{51.5}{87}\right) = 30.45^\circ$

$\therefore \theta = 30.45^\circ$



FBD.

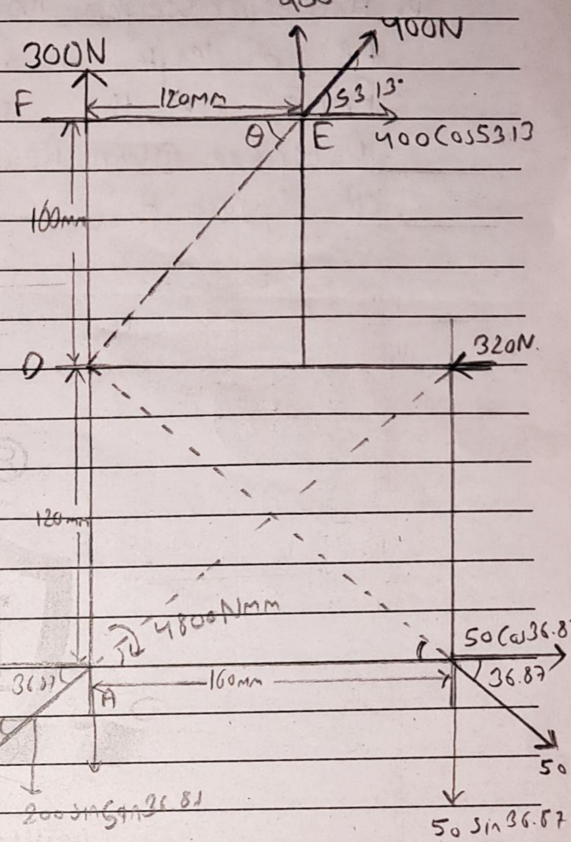
Q5 Find the Resultant of co-planar forces system given below & Locate the same on AB with consideration of applied moment of 4800 Nm



For θ at point E,

$\tan\theta = \frac{160}{120} \quad \therefore \theta = \tan^{-1}\left(\frac{16}{12}\right) =$

$\therefore \theta = 53.13$



For θ at point A,

$\tan\theta = \frac{120}{160} \quad \therefore \theta = \tan^{-1}\left(\frac{12}{16}\right)$

$\theta = 36.87°$

$\Sigma fx = -200\cos 36.87° + 50\cos 36.87°$
$-320 + 400\cos 53.13$
$= -200N$ ie $200N (\leftarrow)$

$\Sigma fy = -200\sin 36.87° - 50\sin 36.87°$
$+ 400\sin 53.13 + 300$
$= 469.9N \approx 470N (\uparrow)$

$R = \sqrt{(\Sigma fx)^2 + (\Sigma fy)^2} = \sqrt{(200)^2 + (470)^2} = 510.7N.$

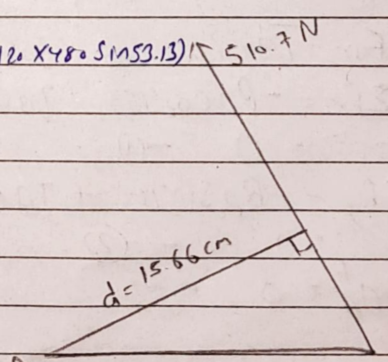
$\therefore \theta = \tan^{-1}\left(\frac{\Sigma fy}{\Sigma fx}\right) = \tan^{-1}\left(\frac{470}{200}\right) = 66.94°$

Using Varignon's Theorem,

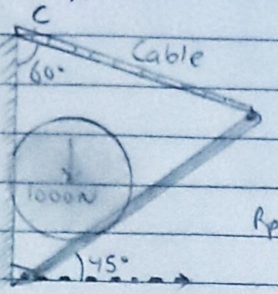
$\Sigma M_A^F = \Sigma M_R^F = R \times d$

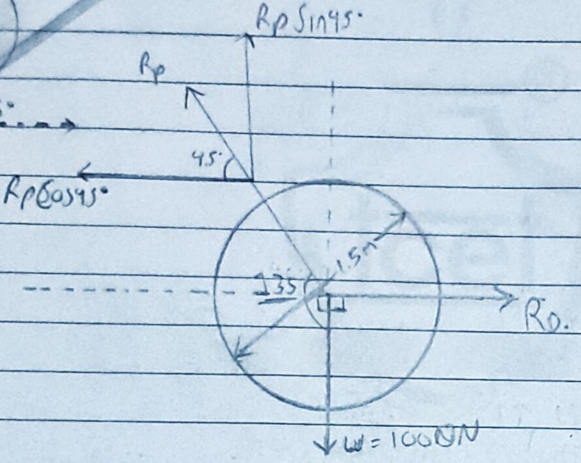
$\therefore -(160 \times -50\sin 36.87°) + (320 \times 120) - 4800 + (120 \times 480\sin 53.13)$
$-(280 \times 400\cos 53.13) = 510.7 \, d$

$\therefore d = 15.66mm$ (↺)

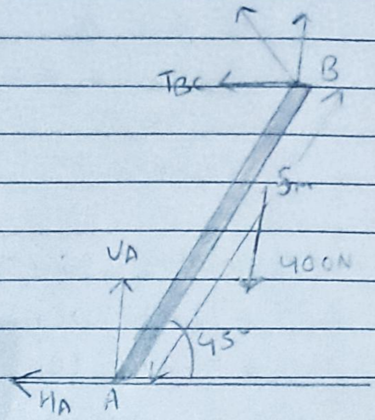


Q) A cylinder weighing 1000N & 1.5m diameter is supported by a beam AB of length 6m & weight 400N as shown in fig. Neglecting friction at the surface of contact of the cylinder, Determine, (i) Wall Reaction at D, (ii) Tension on cable BC & (iii) Hinged Reaction at Support A.





F.B.D (Cylinder)



F.B.D (Beam).

Applying Lami's Theorem

$$\frac{R_D}{\sin 135°} = \frac{1000}{\sin 135°} = \frac{R_P}{\sin 90°}$$

$\therefore R_D = 1000N$ & $R_P = 1414N$.

For Tension on Cable BC (T_{BC})

$\Sigma F_x = -R_P \cos 45° - T_B \sin 45° - H_A = 0$ — (1)

$\Sigma F_y = -R_P \sin 45° + T_B \cos 45° - 400 + V_A = 0$ — (2)

$\Sigma M_A^F = 0$ (+ve)

$\Sigma M_A^f = 0$ (+ve)

$= 1414(1.8) + 400(3\cos 45^\circ) - T_{BC}(6) = 0$

$\therefore T_{BC} = 568.04N$

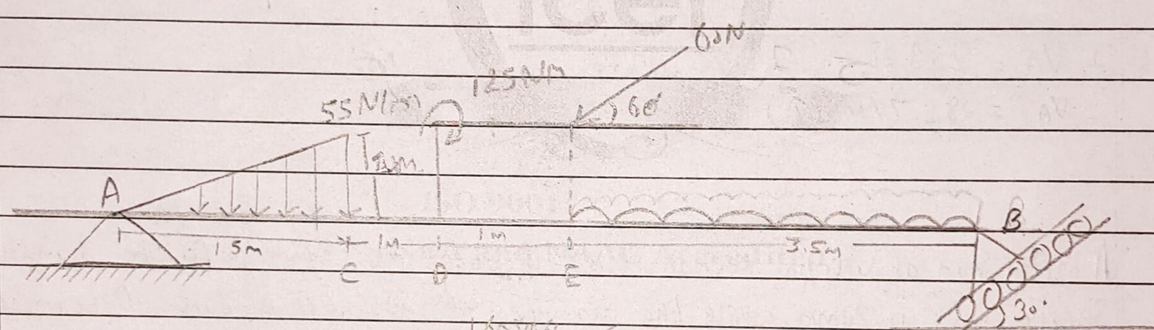
Putting T_{BC} in eqn ① & ②.

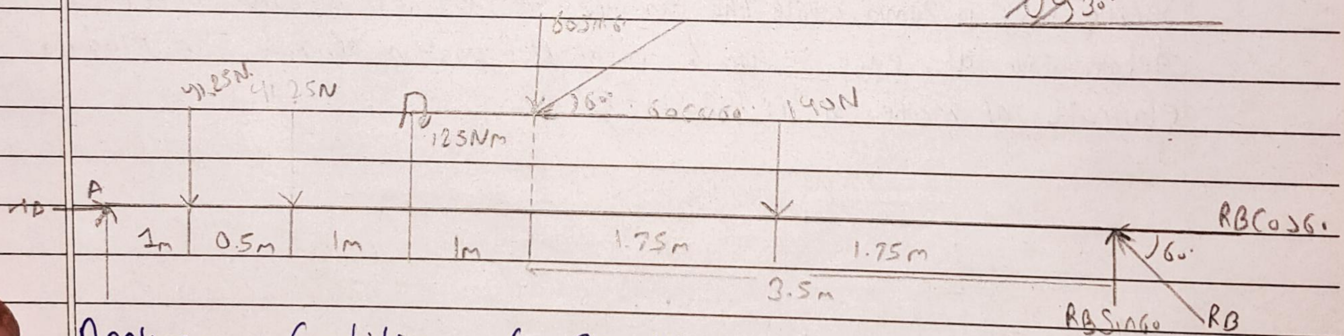
$H_A = 598.33N$ & $V_A = 998.33N$.

$\therefore R_A = 1163.9N$.

$\therefore$ Reaction at D is 1000N, Tension on BC is 568.04N & Hinge Reaction at A is 1163.9N.

Q7. Find support Reaction of beam as shown in figure





Applying Conditions of equilibrium,

$\Sigma f_x = 0$.

$\therefore H_A - 60\cos 60^\circ - R_B\cos 60^\circ = 0$.

$\therefore H_A - 30 - R_B\cos 60^\circ = 0$.

$\therefore H_A - R_B\cos 60^\circ = 30$. —①

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$\Sigma F_y = 0.$

$\therefore V_A + R_B \sin 60 - 41.25 - 60 \sin 60° - 140 = 0.$

$\therefore V_A + R_B \sin 60° = 233.1 N$ — (2)

$\Sigma M_A^F = 0$

$\therefore -(4.5 \times 60 \sin 60°) - 6.25 \times 140) - 125 + (8 \times R_B \sin 60°) = 0.$

$R_B = \frac{154.2}{\sin 60°}$

$R_B = 173.72 N.$

Substituting R_B in eqn (1) & (2),

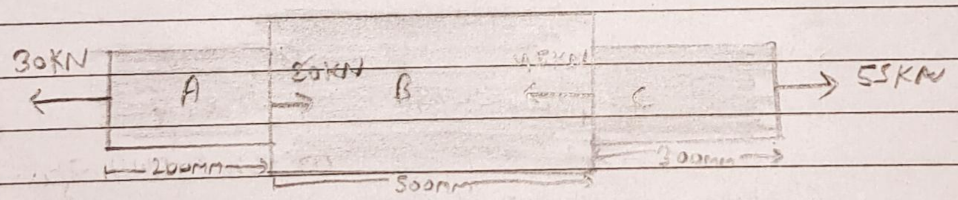
$\therefore H_A = 30 + 173.72 \cos 60°$

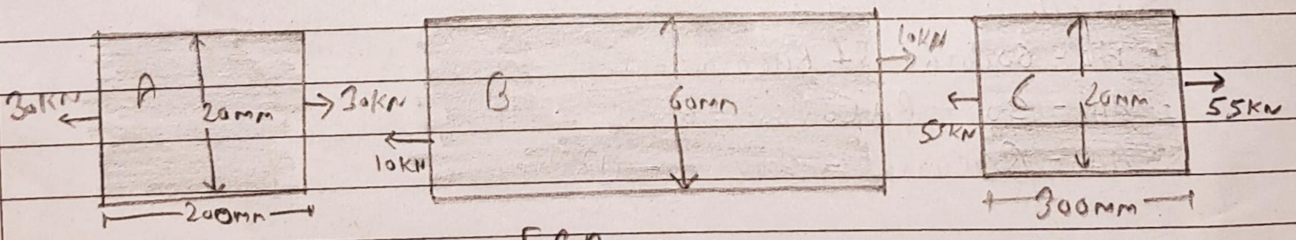
$\therefore H_A = 116.86 N \ (\longrightarrow)$

$\therefore V_A = 233.21 - 173.72 \sin 60°$

$\therefore V_A = 82.77 N \ (\uparrow)$

Q8 A metal rod of varying section (A, B, C) is loaded as shown in fig. The diameter of Section A & C is 20mm, while the diameter of Section B is 60mm. Determine deformation at each section & total Deformation of rod. The modulus of elasticity of material is $5 \times 10^3 N/mm^2$





Area of section A, $A_1 = \frac{\pi}{4} \times (20)^2 = 314 mm^2$

Area of section B, $A_2 = \frac{\pi}{4} \times (60)^2 = 2826 mm^2$

Area of section C, $A_3 = \frac{\pi}{4} \times (20)^2 = 314 mm^2$.

Deformation at each section,

$\therefore \Delta_1 = \frac{P_1 l_1}{A_1 E} = \frac{30 \times 1000 \times 200}{314 \times 5 \times 1000} = 3.821 N/mm^2$

$\therefore \Delta_2 = \frac{P_2 l_2}{A_2 E} = \frac{10 \times 1000 \times 500}{2826 \times 5 \times 1000} = 0.3538 \; N/mm^2$

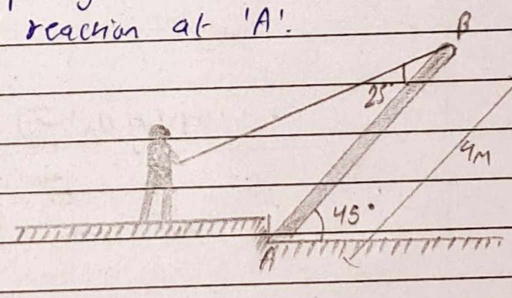
$\therefore \Delta_3 = \frac{P_3 l_3}{A_3 E} = \frac{55 \times 1000 \times 300}{314 \times 5 \times 1000} = 10.5 N/mm^2$

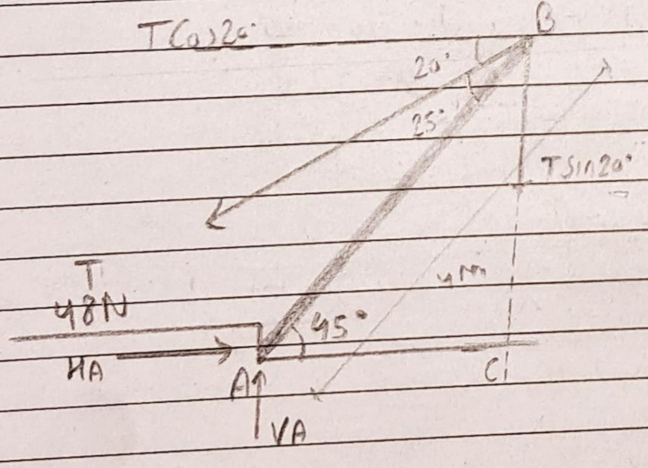
Total Deformation of Rod,

$\Delta_T = 3.821 + 0.3528 + 10.5$

$\therefore \Delta_T = 14.67$ mm

Q3. A man raises a 10kg Joist of length 4m by pulling on a rope as shown in fig. Find the tension 'T' in the rope & reaction at 'A'.





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Applying Conditions of Equilibrium,

$\Sigma f_x = 0.$

$\therefore HA - T\cos 20° = 0$ — ①

$\Sigma f_y = 0$

$\therefore VA - T\sin 20° - 98 = 0$ — ②

$\Sigma M_A^f = 0.$

$[(T\cos 20°) \times 2.83] - [T\sin 20° \times 2.83] - (98 \times 1.41) = 0.$

$\therefore T(2.66 - 0.968) = 138.18$

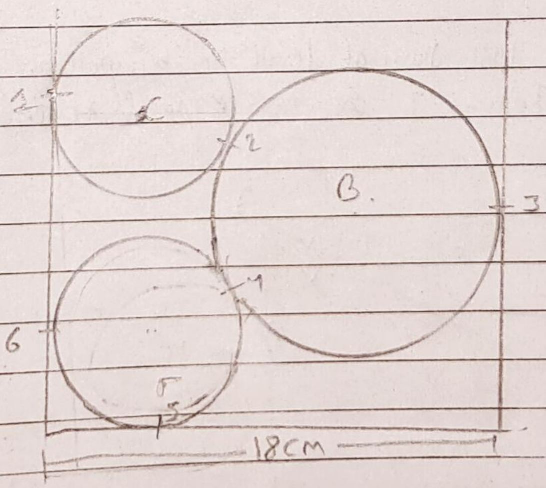
$\therefore T = 81.67\ N.$

Substituting 'T' value in eqn ① & ②.

$\therefore HA = 76.14\ N.$

$\therefore VA = 126\ N.$

Q10. 3 Cylinders are piled up as shown in fig. Determine the reaction at all the contact surfaces. (Cylinder A: radius = 4cm, M = 15kg ; Cylinder B: radius = 6cm, M = 40kg ; & Cylinder C: radius = 5cm., M = 20kg.)



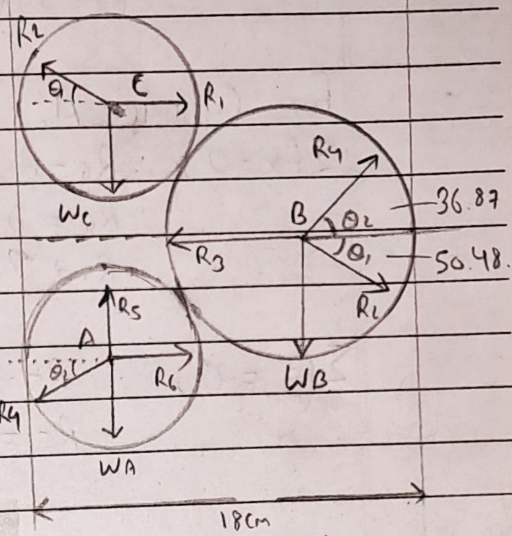
Reaction R_1, R_3, R_5 & R_6 are perpendicular to ~~each other~~ their respective surfaces

We have,

$R_A = 4cm$ & $M_A = 15kg$

$R_C = 5cm$ & $M_C = 20kg$

$R_B = 6cm$ & $M_B = 40kg$



$AB = 10cm$, $BC = 11cm$

$BP = 18 - R_C - R_B$

$BP = 18 - 5 - 6 = 7cm$

$AQ = 18 - 4 - 6 = 8cm$

In ΔBCP, $\cos\theta_1 = \frac{BP}{BC} = \frac{7}{11}$

$\therefore \theta_1 = 50.48°$

In ΔABQ, $\cos\theta_2 = \frac{AQ}{AB} = \frac{8}{10}$

$\therefore \theta_2 = 36.87°$

For Cylinder C:

Applying Lami's Theorem

$$\frac{R_1}{\sin(90+50.48)} = \frac{R_2}{\sin 90} = \frac{196.2}{\sin(180-50.48)}$$

$\therefore R_1 = 161.84$ & $R_2 = 254.34N$.

For Cylinder B,

Applying COE

$\Sigma F_x = 0$, $\therefore -R_3 + R_2\cos\theta_1 + R_4\cos\theta_2 = 0$.

$\therefore -R_3 + 254.34\cos 50.48 + R_4\cos 36.87 = 0$.

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$\Sigma f_y = 0, \therefore R_4 \sin\theta_2 - R_3 \sin\theta_1 - (40 \times 9.8) = 0.$

$\therefore R_4 \sin 36.87 - 254.34 \sin 50.98 - (40 \times 9.8) = 0.$

$\therefore R_3 = 946.99 N \quad \& \quad R_4 = 981.22 N.$

For Cylinder A,

$\Sigma f_x = 0, \therefore R_6 - R_4 \cos\theta_2 = 0.$

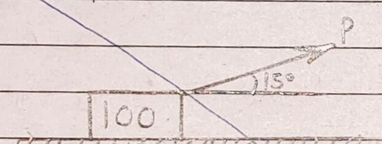
$\therefore R_6 = 981.22 \cos 36.87$

$\therefore R_6 = 785 N.$

$\Sigma f_y = 0, \therefore R_5 - R_4 \sin\theta_2 = 0.$

$\therefore R_5 = 737.74 N.$

Q11 Determine minimum value & the Direction of a force P required to cause motion of a 100 kg Block to impend up 30° plane. The coefficient of friction is 0.20.



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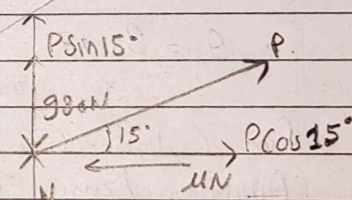

$\Sigma f_x = 0.$

$\mu N = P \cos 15°$

$P \cos 15° - 0.20 N = 0. \quad -(i)$

$\Sigma f_y = 0.$

$\cancel{P \sin 15° + 980 +}$

$P \sin 15° + N = 980. \quad -(ii)$

Solving eqn (i) & (ii) Simultaneously

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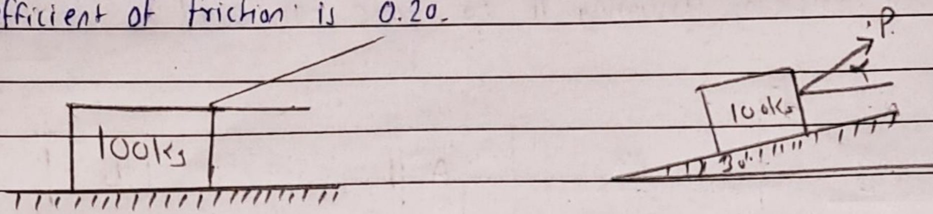
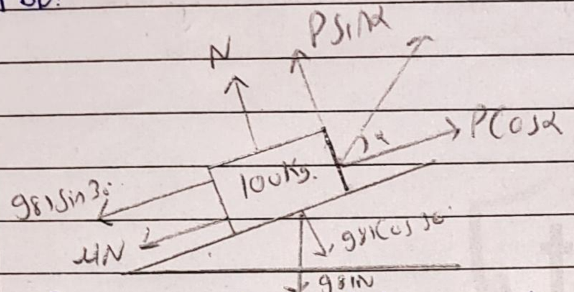
Q10 Determine minimum value & Direction of a force P required to cause Motion of an 100 kg block to impend upon 30° inclined plane. The Coefficient of friction is 0.20.



Soln FBD:



Here $\tan\alpha = \mu$

$\alpha = \tan^{-1}(\mu)$

$= \tan^{-1}(0.2)$

$\alpha = 11.31°$

∵ Because condition of Just impending condition of Equilibrium are applicable

$\Sigma f_x = 0.$ $P\cos 11.31 - 0.2N - 490.5$ — (i)

$0.98P - 0.2N = 490.5$ — (i).

$\Sigma f_y = 0$ $N - P\sin 11.31 - 981\cos 30° = 0$

$0.19P - N = -849.57$ — (ii)

From (i) & (ii)

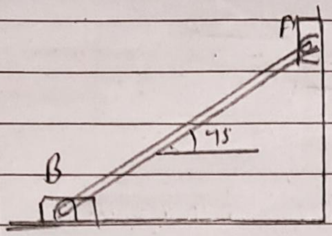
$0.98P = 0.2(0.19P + 849.57) + 490.5$

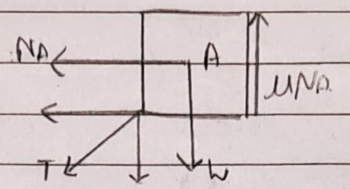
$0.942p = 169.914 + 490.5.$

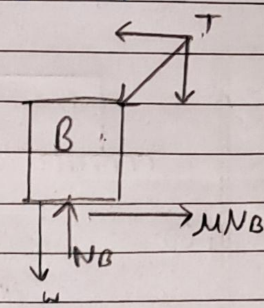
$P = 701.07N$

∴ P's minimum value is ~~660N~~ 701.7N & Direction is 11.31°

Q12 Two Blocks A & B are identical 'w', each are supported by rod inclined at 45° to horizontal. If block are in limiting equilibrium. Find coefficient of friction, assuming it to same for wall & floor.







For Block A,

$\Sigma fx = 0$

$NA = T\cos 45° = \frac{T}{\sqrt{2}}$ — ①

$\Sigma fy = 0$: $T\sin 45° + \mu NA = w$

$\frac{T}{\sqrt{2}} + \frac{\mu T}{\sqrt{2}} = w. \quad \therefore \frac{T}{\sqrt{2}}(\mu + 1) = w.$ — ②.

For Block B;

$\Sigma fx = 0$, $T\cos 45° = \mu NB$; $\mu NB = \frac{T}{\sqrt{2}}$ — ③

$\Sigma fy = 0$, $NB = w + \frac{T}{\sqrt{2}}$ ∴ from ① we get, $\mu \cdot \left(w + \frac{T}{\sqrt{2}}\right) = \frac{T}{\sqrt{2}}$

$\therefore \mu\left(w + \frac{T}{\sqrt{2}}\right) = \frac{T}{\sqrt{2}}$: By Simplifying, $\mu^2 + 2\mu - 1 =$

$w = \frac{T}{\sqrt{2}}\left(\frac{1-\mu}{\mu}\right)$ — ④ : $\mu = \frac{-2 \pm \sqrt{8}}{2}$

from ② & ④. : $\boxed{\mu = 0.414}$

$\frac{T}{\sqrt{2}}(\mu + 1) = \frac{T}{\sqrt{2}}\left(\frac{1-\mu}{\mu}\right)$

frictional Coefficient is 0.414.