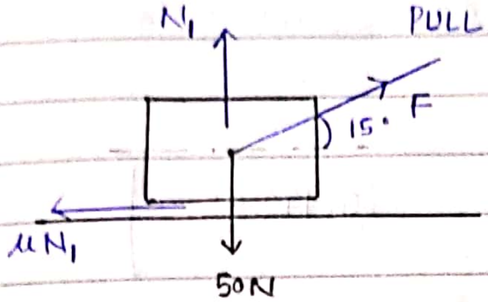
U19CS012 (D-12)

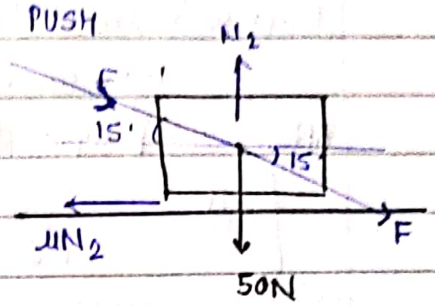
Date

FRICTION LECTURE ASSIGNMENT

1.)



$[\mu = 0.4]$



$\Sigma F_x = 0 \quad F\cos(15°) - \mu N_1 = 0 \quad -①$

$\Sigma F_y = 0 \quad N_1 + F\sin(15°) - 50 = 0 \quad -②$

$N_1 = 50 - F\sin(15°) \quad -②$

$F\cos(15°) - (0.4)(50 - F\sin(15°)) = 0$

$F = \dfrac{(50\times0.4)}{\cos(15°) + 0.4\sin(15°)}$

$\Sigma F_x = 0 \quad F\cos 15° - \mu N_2 = 0 \quad -①$

$\Sigma F_y = 0 \quad N_2 - 50 - F\sin(15°) = 0$

$N_2 = 50 + F\sin(15) \quad -②$

$F\cos 15 - 0.4(50 + F\sin 15°) = 0$

$F = \dfrac{50\times0.4}{(\cos 15° - 0.4\sin(15°))}$

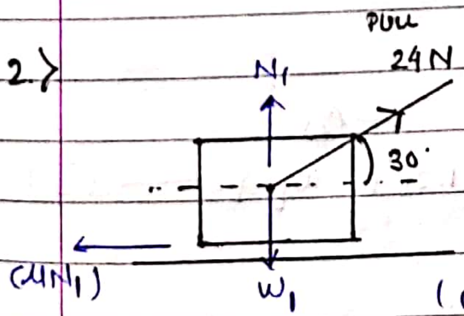
$F_{pull} = 18.7\ N$

$F_{push} = 23.19\ N$

Comment : $\because$ $F_{push} > F_{pull}$

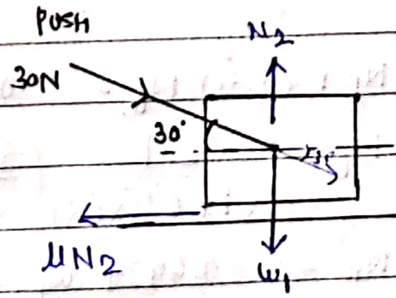
$\therefore$ It is easier to pull the block then to push it.

2.)



$(w_1 = ?)$

$(\mu = ?)$



$\Sigma F_x = 0 \quad 24\cos(30°) = \mu N_1$

$\Sigma F_y = 0 \quad N_1 = w_1 - 24\sin(30°)$

$24\cos(30°) = \mu(w_1 - 24\sin 30°) \quad -\ Eq\ 1$

$\Sigma F_x = 0 \quad 30\cos 30° = \mu N_2$

$\Sigma F_y = 0 \quad N_2 = w_1 + 30\sin 30°$

$30\cos 30° = \mu(w_1 + 30\sin 30°) \quad Eq\ 2$

$\dfrac{24\cancel{\cos(30°)}}{w_1 - 24\sin 30} = \dfrac{30\cancel{\cos(30°)}}{w_1 + 30\sin 30}$

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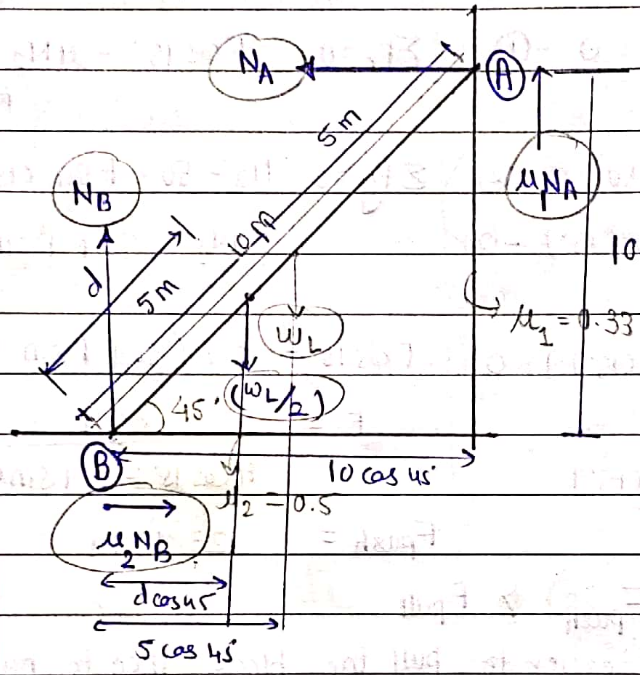
$(\cancel{24}^{4} \times 30\ (\sin 30^\circ)) \times 2 = \cancel{8}\, w_1$

$240 \sin 30^\circ = w_1$

ANS: $[\, w_1 = \boxed{120\ N}\,]$

$$\left[\mu = \frac{24 \cos(30^\circ)}{120 - 24 \sin(30^\circ)} = \boxed{0.19245}\right]$$

3.>



FBD of Ladder

W_L = weight of ladder

$[\, W_{man} = W_L/2 \,]$ - given

$\Sigma F_x = 0$

$\mu_2 N_B - N_A = 0$

$[\, N_A = 0.5\, N_B \,]$ - (1)

$\Sigma F_y = 0$

$N_B + (0.33)(N_A) = W_L + ((W_L)/2)$ — (2)

$$\left[N_B = \frac{1}{(1 + 0.33 \times 0.5)} \left(\frac{3\, W_L}{2}\right) = [1.2875\ W_L] \right] \text{ — (I)}$$

$[\, N_A = 0.6437\ W_L \,]$ — (II)

$\Sigma M_B = 0$

$(-)(W_L) \times 5 \cos(45^\circ) + (-) \times \left(\frac{W_L}{2}\right) \times d \cos 45^\circ + (\mu_1 N_A)\, 10 \cos 45 + N_A\, 10 \sin 45 = 0$

$(\cancel{W_L})((0.33)\, 10 \cancel{\cos 45} + 10 \cancel{\sin 45^\circ})(0.6437) = \cancel{W_L}\left(5 \cancel{\cos(45^\circ)} + \frac{d}{2} \cancel{\cos 45}\right)$

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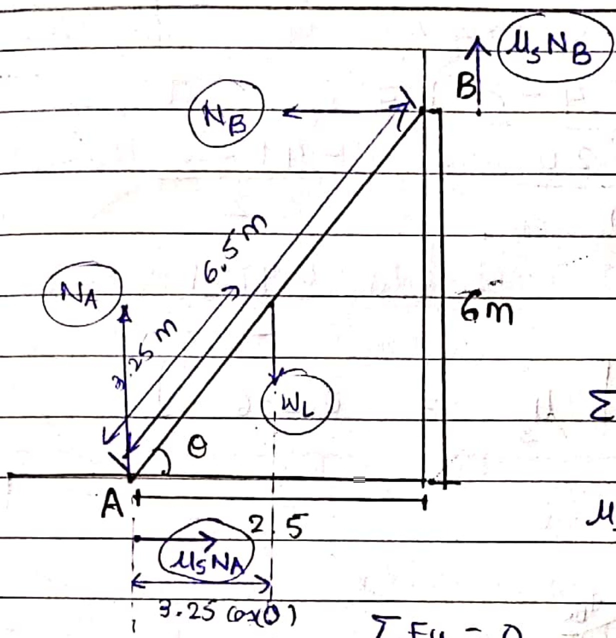
$$10(1+0.33)(0.6437) = \left(5 + \frac{d}{2}\right)$$

$$(3.5612)\,2 = d$$

$$\left[d = 7.1224\ m\right]$$

4.)



$\theta = \tan^{-1}(6/2.5)$

$(\mu_s) = (?)$

$\Sigma F_x = 0$

$\mu_s N_A = N_B$ — (1)

$\Sigma F_y = 0$

$$N_A - W_L + \mu_s N_B = 0$$

$$N_A + (\mu_s)^2 N_A = W_L$$

$$\left[N_A = \frac{W_L}{1+(\mu_s)^2}\right] \quad -(\mathrm{I})$$

$$\left[N_B = \frac{(\mu_s)(W_L)}{(1+(\mu_s)^2)}\right] \quad -(\mathrm{II})$$

$$\Sigma M_A = 0 \quad (-)(W_L)\left(\frac{3.25}{2}\left(\frac{2.5}{6.5}\right)\right) + N_B(6) + \mu_s N_B(2.5) = 0$$

$$N_B(6 + \mu_s(2.5)) = W_L(1.25)$$

$$\frac{(\mu_s)\cancel{(W_L)}}{(1+(\mu_s)^2)}(6 + \mu_s(2.5)) = \cancel{(W_L)}(1.25)$$

$$(6\mu_s + 2.5(\mu_s)^2) = (1.25) + (1.25)(\mu_s)^2$$

$$\left[1.25(\mu_s)^2 + 6\mu_s - 1.25 = 0\right]$$

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$a > 0$

$1 > 0$

$16 + 4 > 0$

$D > 0$

$$1.25x^2 + 6x - 1.25 = 0$$

$$x^2 + 4x - 1 = 0$$

$$x_{min} \Rightarrow \cancel{\text{at } x = \frac{-(4)}{2(1)}}$$

$$\cancel{= (-2)}$$

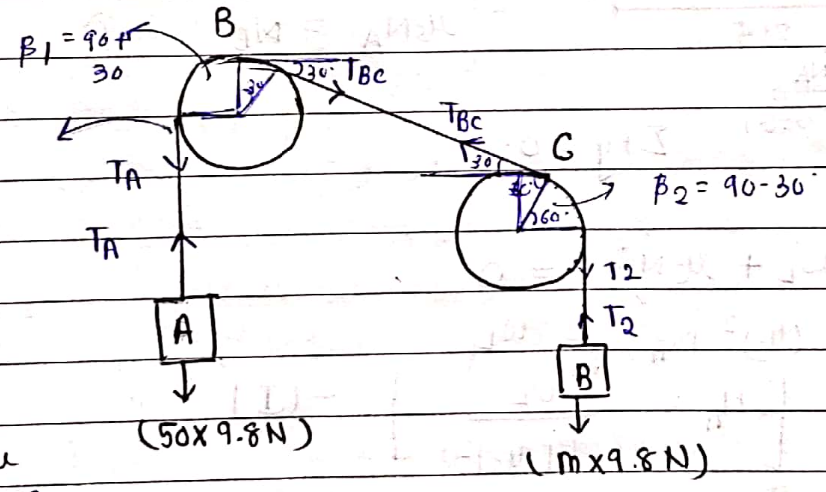
$$\cancel{f(-2) = 4 - 8 - 1 =}$$

$$x = \frac{-4 \pm \sqrt{20}}{2(1)} = \frac{-4 + \sqrt{20}}{2}$$ (μ can't be negative)

$$= \frac{0.4721}{2}$$

ANS : $\boxed{\mu_s = 0.236}$

5.)



$50 \times 9.8 = T_A$ — ①

$m \times 9.8 = T_2$ — ②

right side

$$\frac{T_2}{T_1} = e^{\mu\beta}$$

$\beta_1 = 120° = 2\pi/3$

$$T_A = (T_{BC})(e)^{\mu(\beta_1)}$$

$$T_{BC} = ((50 \times 9.8))((e)^{(-1)(0.25)(\frac{2\pi}{3})}) \quad \text{— ①}$$

$$T_{BC} = (T_2)(e)^{\mu(\beta_2)}$$

$$(T_2) = (T_{BC})((e)^{(-(0.25)(\pi/3))}) \quad \text{— ②}$$

$$m \times 9.\cancel{8} = 50 \times 9.\cancel{8} \times e^{-0.25(\frac{2\pi}{3} + \pi/3)}$$

$$= 50 \; e^{(\frac{1}{4}\pi)}$$

$$m = 50 \; e^{-\pi/4} = m \Rightarrow \frac{50}{(e^{\pi/4})} = 22.796 \text{ kg}$$

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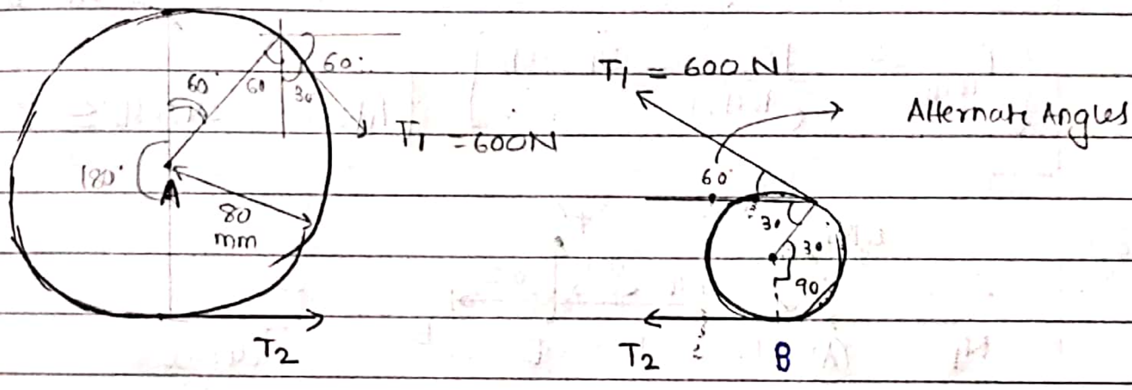
ANS : (1) $\left[m = 22.8 \text{ kg} \right]$

$$T_{BC} = (m \times 9.8)(e)^{(\pi/12)} \qquad Eq^n \; (2)$$

$$= 22.8 \times 9.8 \times (e)^{(\pi/12)}$$

ANS : (2) $= \boxed{290.308 \text{ N}}$

6.)



The Tension in the Belt will be due to B $\quad \alpha = 90° + 30°$

$= 120° = \left(\frac{2\pi}{3}\right)$

tight $\leftarrow \dfrac{T_1}{T_2} = e^{\mu_s(\alpha)}$

$$\frac{600}{T_2} = (e)^{(0.25 \times (2\pi/3))}$$

$$\left[T_2 = 355.43 \text{ N} \right]$$

Torque on A $= \dfrac{600 \times 80}{(1000)} - \dfrac{(355.43) \times 80}{(1000)}$

ANS : $\left[= 19.57 \text{ Nm} \right]$

7.) $\mu_h = 0.25 \qquad \mu_s = 0.2$

$\alpha =$ angle made by rope with horizontal $= 90° + 90° = 180° = \pi$

$\beta =$ angle made by rope with vertical $= 180° = \pi$

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$$\therefore \mu_h(\alpha) + \mu_v \beta = \pi(0.25 + 0.2)$$
$$= 1.4137$$

For P_{min} — For P_{max}

tight $T_1 = 100$ lb $\quad T_2 = P_{min}$

$$\frac{(100)}{T_2} = e^{\mu_h \alpha + \mu_v \beta}$$

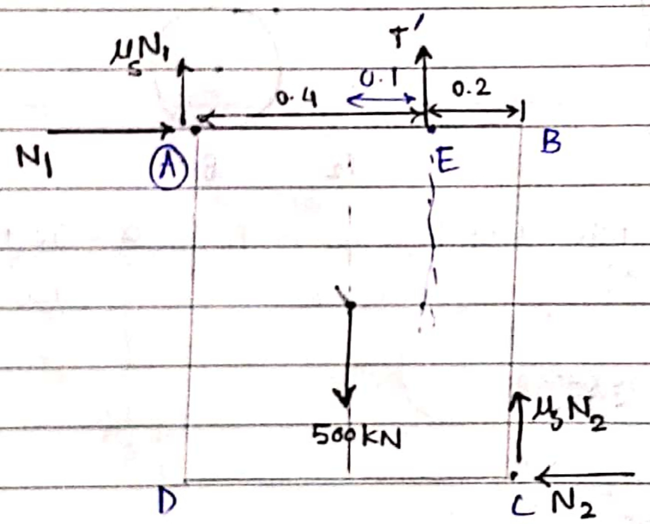
$$\left[P_{min} = \frac{100}{e^{1.4137}} = 24.3 \text{ lb} \right]$$

tight $T_1 = P_{max} \quad T_2 = 100$ lb

$$P_{max} = (100)\, e^{1.4137}$$
$$= 411 \text{ lb}$$

$$\left[\text{ANS: } 24.3 \text{ lb} \le P \le 411 \text{ lb} \right]$$

8.)



$\mu_s = 0.6$

due to T

the N_1 & N_2 will act as shown.

$\Sigma F_x = 0$

$N_1 = N_2$ —①

$\hookrightarrow = N$

$\Sigma F_y = 0 \qquad 500 = \mu_s N_1 + \mu_s N_2 + T'$

$[\, 500 = 1.2(N) + T' \,]$ ——— (I)

$\Sigma M_E = 0$

$$-(\mu_s N_1)(0.4) + \mu_s N_2 (0.2) - N_2 \times 0.8 + (500\text{ kN}) \times (0.1) = 0$$

$$N(0.4\mu_s - \mu_s(0.2) + 0.8) = 500 \text{ kN} \times 0.1$$

$$N((0.6) \times 0.2 + 0.8) = (50)$$

$$\left[N = \frac{50}{0.92} = 54.347 \text{ N} \right]$$

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Using (I)

$$T' = 500 - 1.2N = 434.78 \text{ N}$$

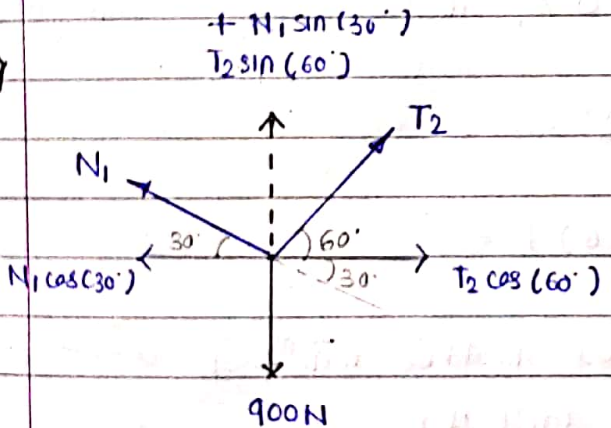
$$[T' = 434.78 \text{ N}]$$

As crate is moving downwards $T' > T$

$$\therefore \frac{T'}{T} = e^{\mu\beta} \qquad \beta = 2(2\pi) = 4\pi$$

ANS: $\left[T = \frac{T_1' \, (434.78)}{(e)^{0.3 \times 4\pi}} = 10.02 \text{ kN} \right]$

9.)



$\Sigma F_x = 0$

$N_1 \cos(30^\circ) = T_2 \cos(60^\circ)$

$[\sqrt{3} N_1 = T_2]$

$\Sigma F_y = 0$

$900 = T_2 \sin(60^\circ) + N_1 \sin(30^\circ)$

$900 = N_1 (\sqrt{3} \sin(60^\circ) + \sin(30^\circ))$

$[N_1 = 450]$ —— (I)

$[T_2 = \sqrt{3}(450) = 779.42 \text{ N}]$ —— (II)

$\beta = 60^\circ = \pi/3$ $\qquad [T = 375 \text{ N}]$

$[T_2 = 779.42 \text{ N}]$

$$\frac{779.42}{375} = (e)^{\mu(\pi/3)}$$

$$\ln\left(\frac{779.42}{375}\right) \frac{3}{\pi} = \mu$$

$$[\mu = 6.986]$$

ANS: $[\mu = 6.99]$

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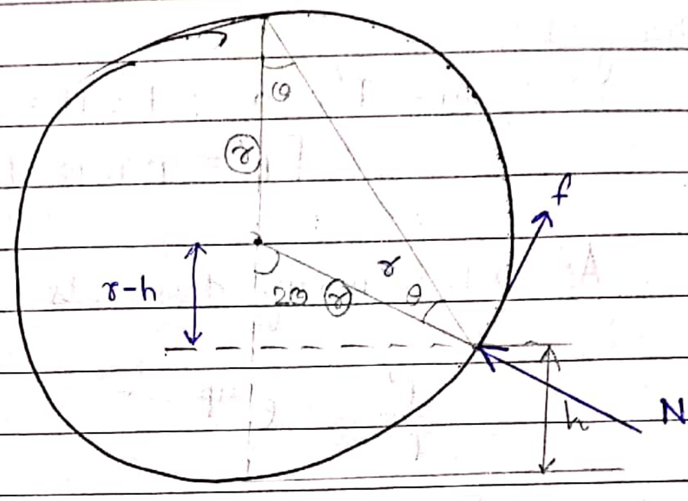
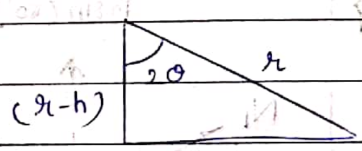
10.)



when the cylinder is pulled over, it loses contact with ground.

$$\cos(2\theta) = \frac{(r-h)}{h}$$



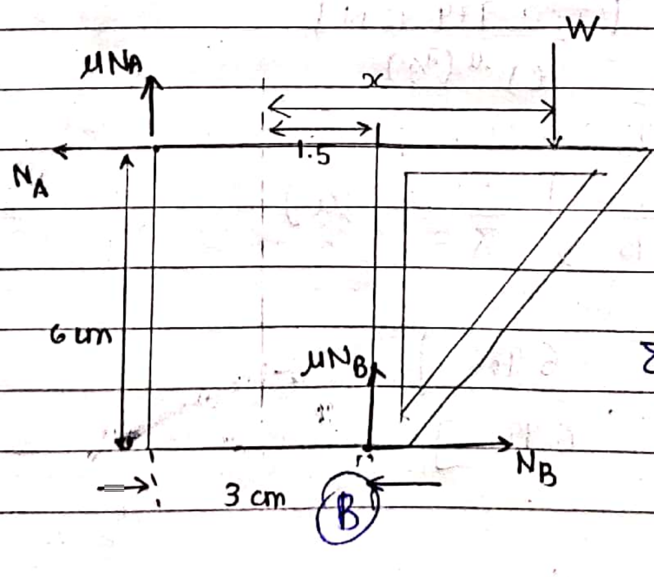
$$h = r(1-\cos(2\theta))$$

for h_{max} $\cos(2\theta)$ should be $min^m \Rightarrow \theta \rightarrow max^m$

$$\phi_{max} = \tan^{-1}(\mu_s)$$
$$= \tan^{-1}(0.3)$$
$$= 16.699°$$

ANS: $\left[h_{max} = r(1-\cos(2(16.699))) = 0.248 \text{ m} \right]$

11.)



$\Sigma F_x = 0$

$[N_A = N_B]$

$\Sigma F_y = 0$ $\quad \mu N_A + \mu N_B = W$

$[2 \times 0.25 \times N_A = W]$

$[0.5 N_A = W]$

$(N_A = 2W)$

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$\Sigma M_B = 0$

$(-1)(\mu N_B)(3) + (N_B)(6) - (W)(x - 1.5) = 0$

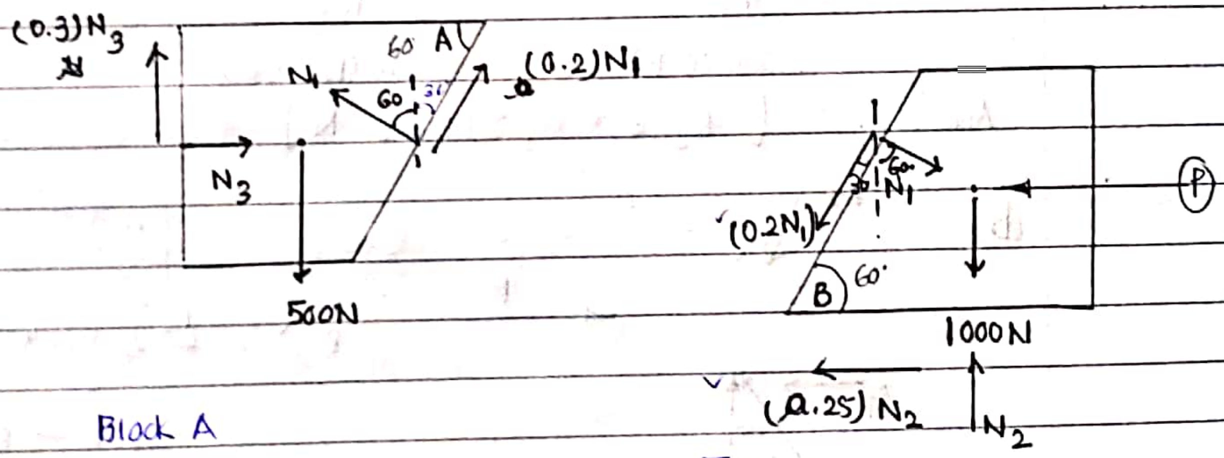
$(2W)(6 - 3(\mu)) = W(x - 1.5)$

$2(6 - 3(0.25)) = x - 1.5$

$6(1.75) + 1.5 = x$

$[x = 12 \text{ cm}]$

12.)



Block A

$\Sigma F_x = 0$

$N_3 + (0.2 N_1)\sin 30 = N_1 \sin 60$ —(1)

$N_3 = N_1(\sin 60 - 0.2 \sin 30°)$ —(1)

$\Sigma F_y = 0$

$(0.3 N_3) - 500 + N_1 \cos 60 + (0.2 N_1)\cos 30° = 0$

$$N_1 = \frac{500}{(0.3(\sin 60 - 0.2\sin 30°) + \cos 60° + 0.2\cos 30°)}$$

$N_1 = [553.7 \text{ N}]$

$\Sigma F_x = 0$

$N_1 \sin 60° = P + 0.25 N_2 + 0.2 N_1 \sin 30°$

$\Sigma F_y = 0$

$N_2 - 1000 - N_1 \cos 60° - (0.2 N_1 \cos(30°)) = 0$

$[N_2 = 1000 + N_1(\cos 60° + 0.2\cos 30°) = 1372.75 \text{ N}]$

$P = N_1 \sin 60° - 0.2 N_1 \sin 30 - 0.25 N_2$

$= 424.195 - \left(\frac{1372.75}{4}\right)$

$P = [80.9625 \text{ N}]$

[ANS: $P = 81$ N]

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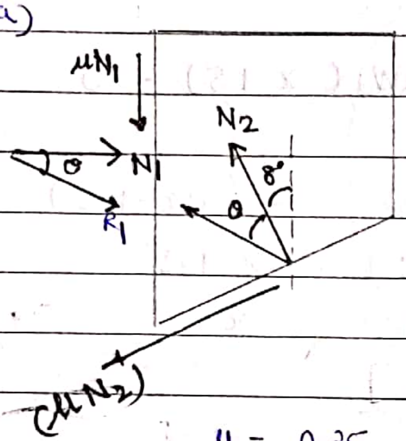
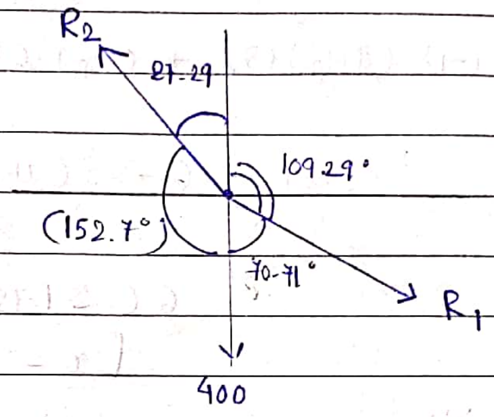
13) (a) To raise Block B

(a)





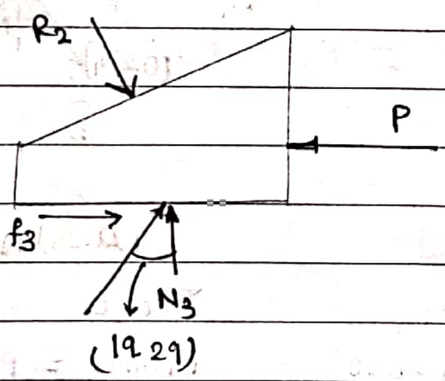
$\mu = 0.35$

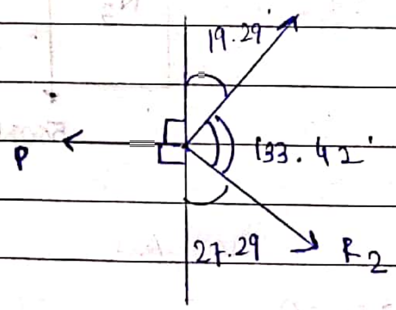
$\therefore \theta = \tan^{-1}(\mu) = \tan^{-1}(0.35) = 19.29$

$$\frac{R_2}{\sin(70.71)} = \frac{400}{\sin(186.58)}$$

ANS : $[R_2 = 549.28 \text{ N}]$

(b)



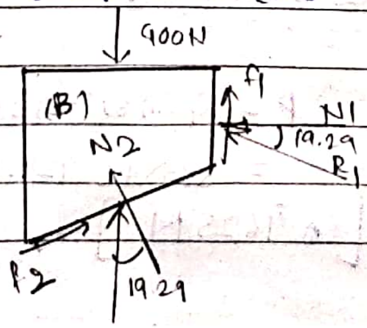


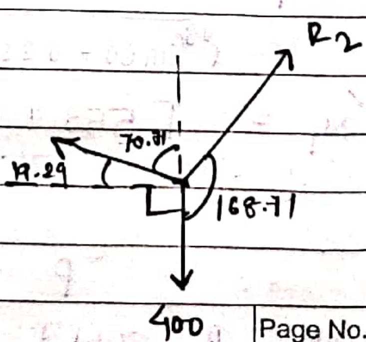
$$\frac{R_2}{\sin(109.29)} = \frac{P}{\sin(133.42)}$$

$$P = \frac{(549.28)\sin(133.42)}{\sin(109.29)}$$

ANS : $[P = 422.69 \text{N}]$ $(\leftarrow)$

(b) To lower block (B)





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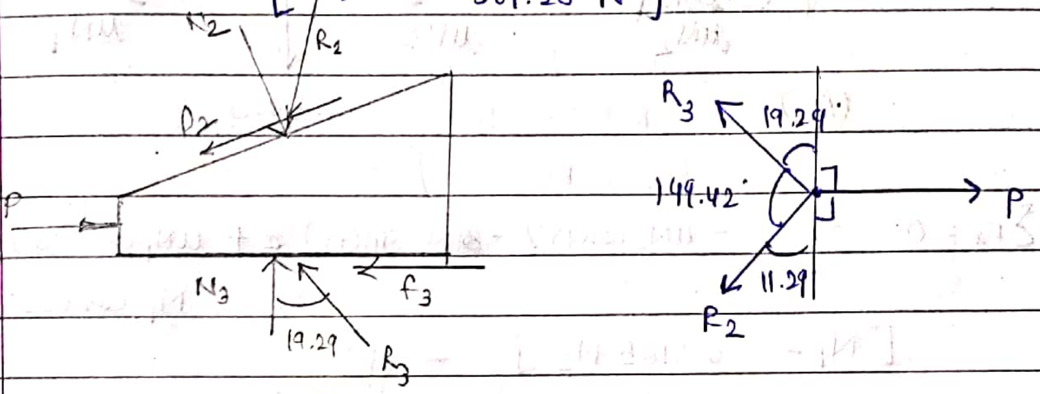
$$\frac{400}{\sin(70.71+11.29)} = \frac{R_2}{\sin(19.29+90)}$$

$$[R_2 = 381.25\ N]$$



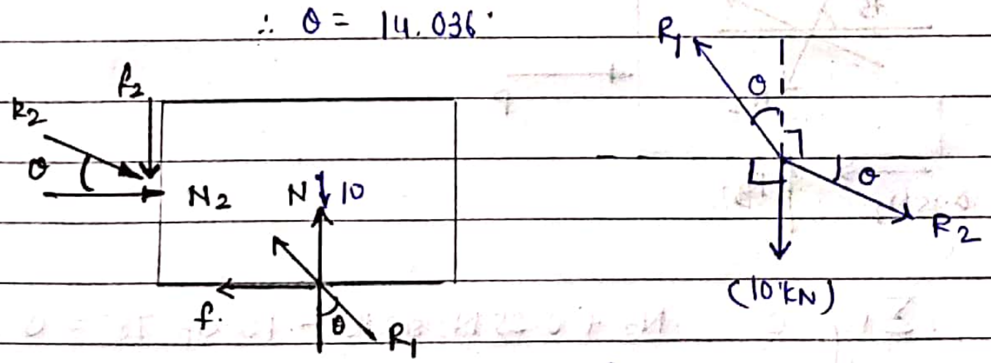
$$\frac{P}{\sin(149.42')} = \frac{R_2}{\sin(109.29)}$$

ANS: $[P = 206.52\ N]$ ($\longrightarrow$)

14.7

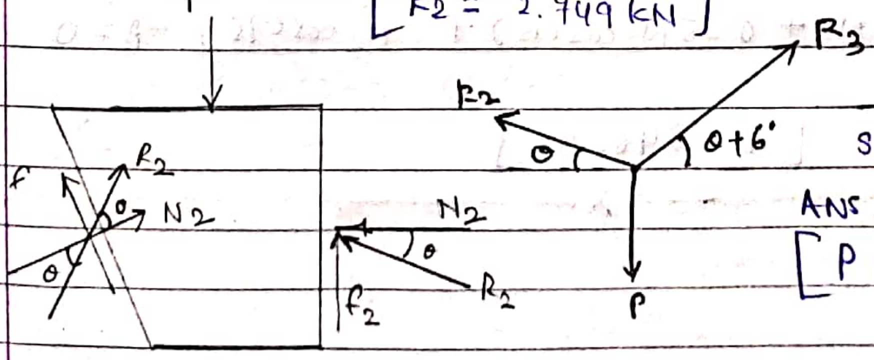
$\mu = 0.25$ $\therefore \tan^{-1}(\mu) = \tan^{-1}(0.25) = 14.036'$

$\therefore \theta = 14.036'$



$$\frac{10}{\sin(90+20)} = \frac{R_2}{\sin(180-\theta)} \qquad \theta = 14.036'$$

$$[R_2 = 2.749\ kN]$$

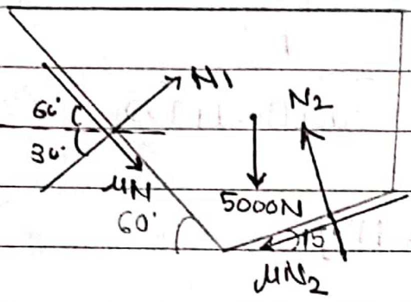


$$\frac{P}{\sin(174-20)} = \frac{2.749}{\sin(96+\theta)}$$

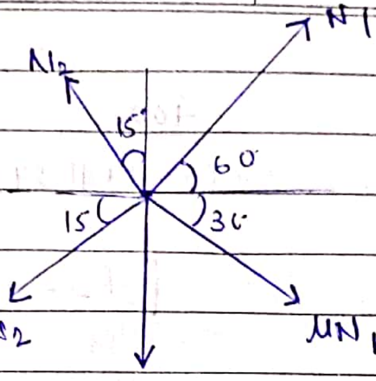
ANS,

$[P = 1.639\ kN]$

15.7



(A)



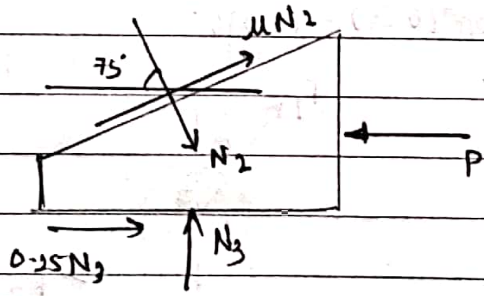
$\Sigma F_x = 0 \Rightarrow -\mu N_2 \cos(15°) - \mu N_2 \sin(15) + \mu N_1 \cos(30°) + N_1 \cos(60°) = 0$

$[N_1 = 0.5165 N_2]$ — (1)

$\Sigma F_y = 0$

$N_2 \sin(75) + N_1 \sin(30°) = 5000 + 0.25 N_1 \sin 60 + 0.25 N_2 \sin(15)$

$[N_2 = 4772.3585 N]$



$\Sigma F_y = 0 \quad N_3 + 0.25 N_2 \sin 15 - N_2 \sin 75° = 0$

$[N_3 = 4300.95 N]$

$\Sigma F_x = 0$

$0.25 N_3 + 0.25 N_2 \cos(15) + N_2 \cos(75°) - P = 0$

ANS: $[P = 3462 N]$

X