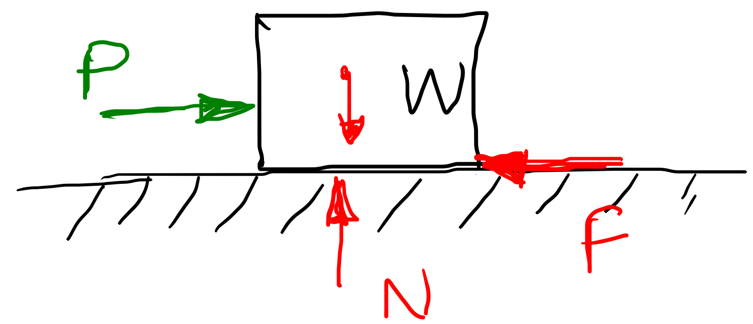
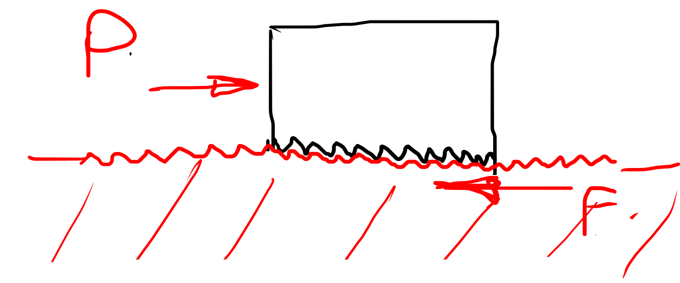
Friction:

- (1.) Static friction
  - (i) Dry/coulamb friction
  - (ii) wet/ Fluid friction
- (2.) Dynamic friction
  - (i) Dry friction
    - (a) sliding
    - (b) Rolling
  - (ii) wet/fluid
    - (a) sliding
    - (b) Rolling

Theory of Dry Friction

Experimetally,

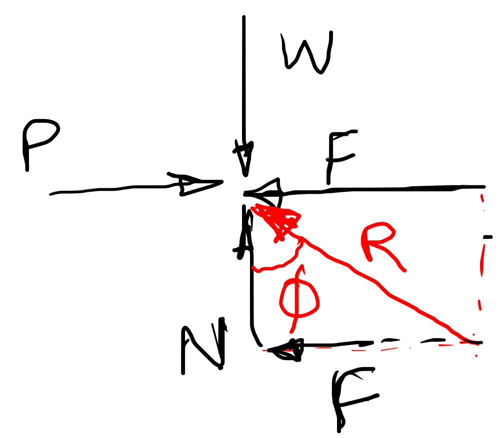




$$F \propto N$$

$$F = \mu N \quad \text{— (1)}$$

μ - coefficient of friction



$$\tan\phi = \frac{F}{N} \quad \text{— (2)}$$

$$\tan\phi = \frac{\mu N}{N} = \mu$$

$$\mu = \tan\phi$$

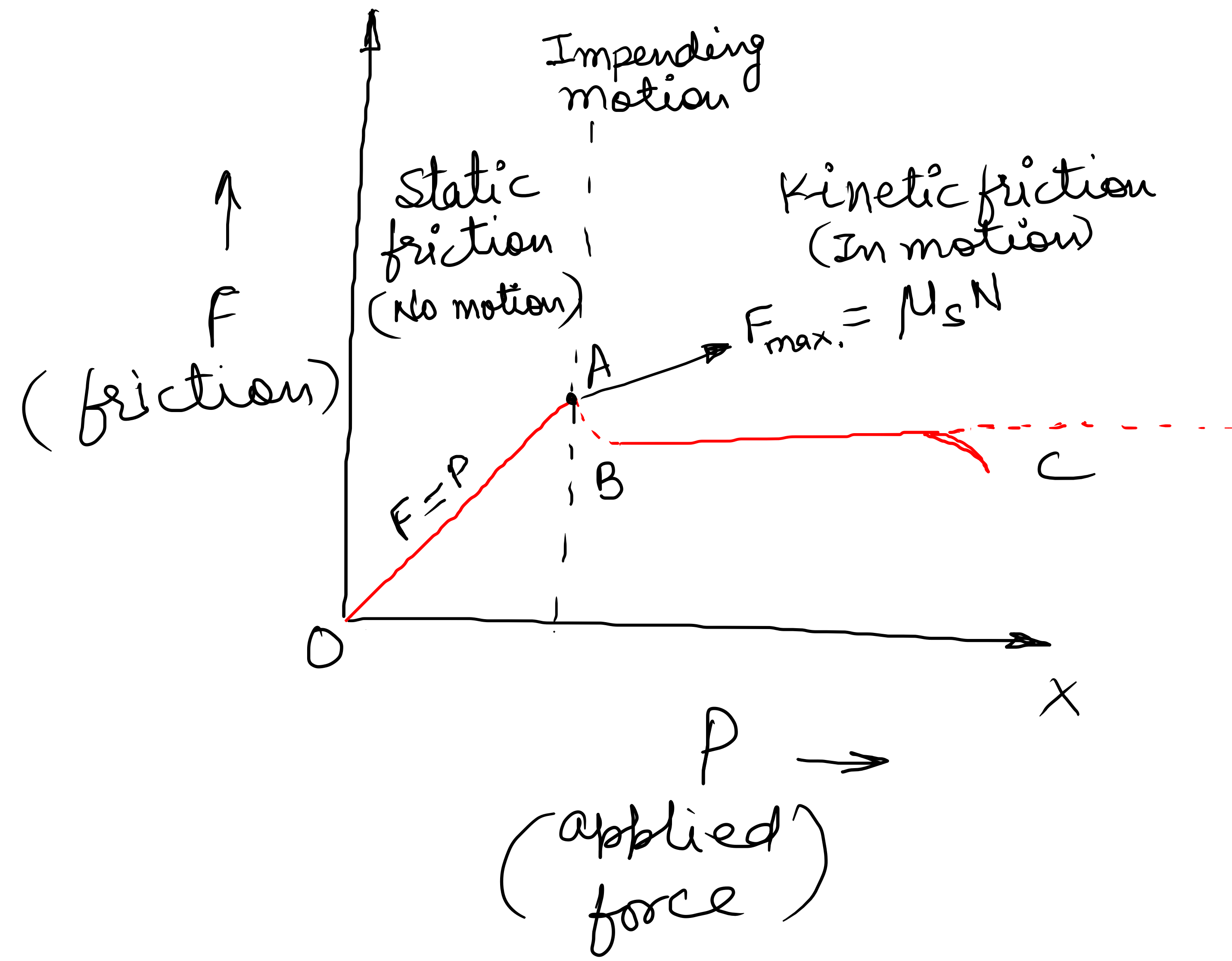
$$\phi = \tan^{-1}\mu$$

, ϕ = angle of friction

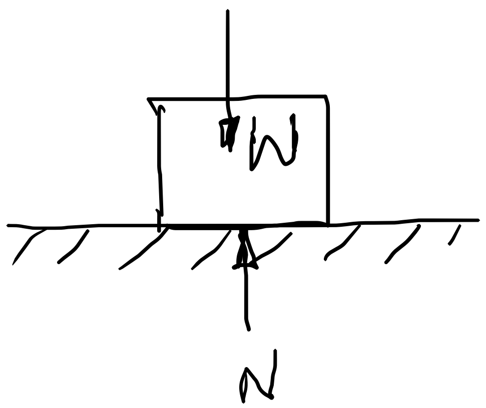
N = normal reaction

F = Friction

$$F_{max} = F_s = \mu_s N_s$$

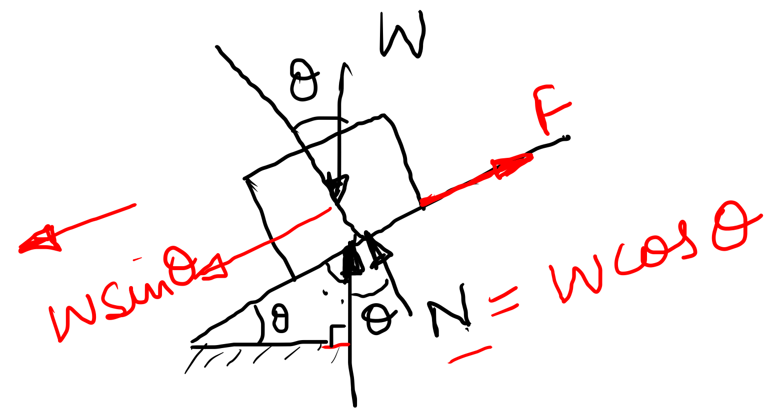


Angle of Repose (θ)



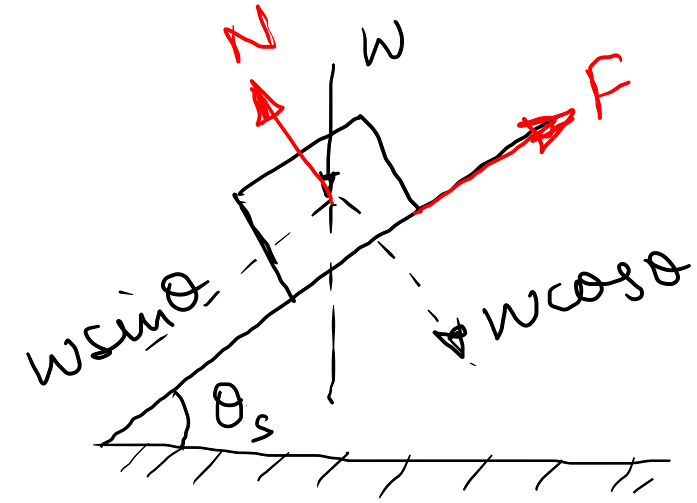
(i) No friction

$$\theta = 0^\circ$$



(ii) No motion

$$\theta < \theta_s$$



(iii) Impending motion

$$\theta = \theta_s$$

$$N = W\cos\theta_s$$

$$F = W\sin\theta_s$$

$$F = \mu_s N$$

$$W\sin\theta_s = \mu_s W\cos\theta_s$$

$$\tan\theta_s = \mu_s$$

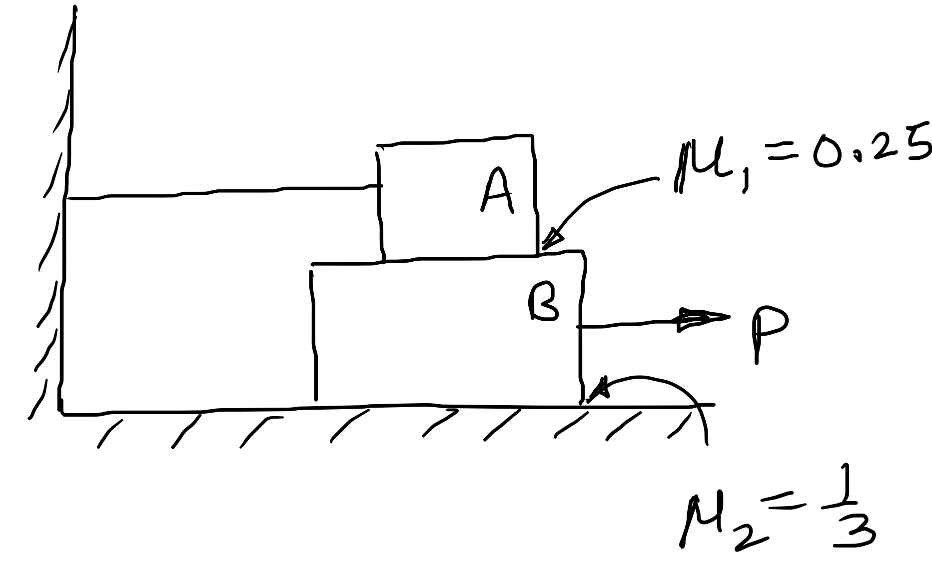
Also $\tan\phi_s = \mu_s$

$$\therefore \boxed{\phi_s = \theta_s}$$

Q:1 What should be value of force 'P' to move the block 'B', If –

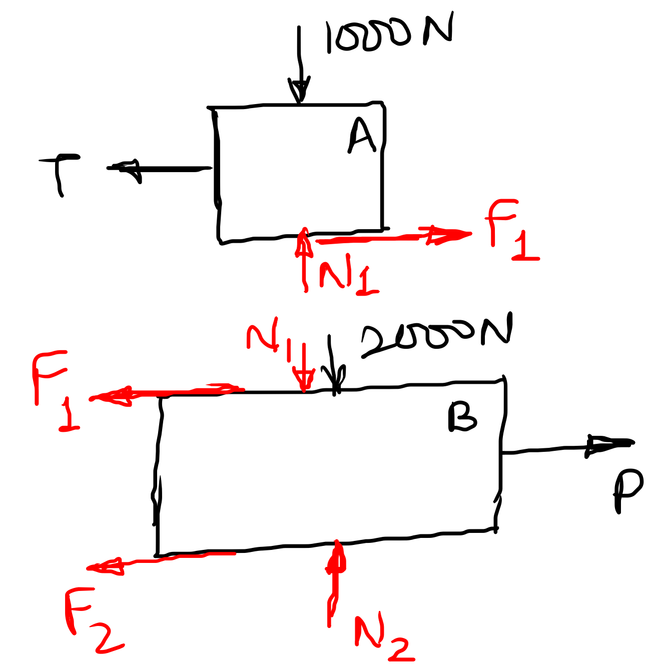
(i) P is horizontal

(ii) P acts at 30° upwards to horizontal



Sol^n: (i) When P is horizontal

Considering block 'A'



$\Sigma F_x = 0, \quad T = F_1$

$\Sigma F_y = 0, \quad N_1 = 1000 N$

$T = F_1 = \mu_1 N_1 = 0.25 \times 1000 = 250 N$

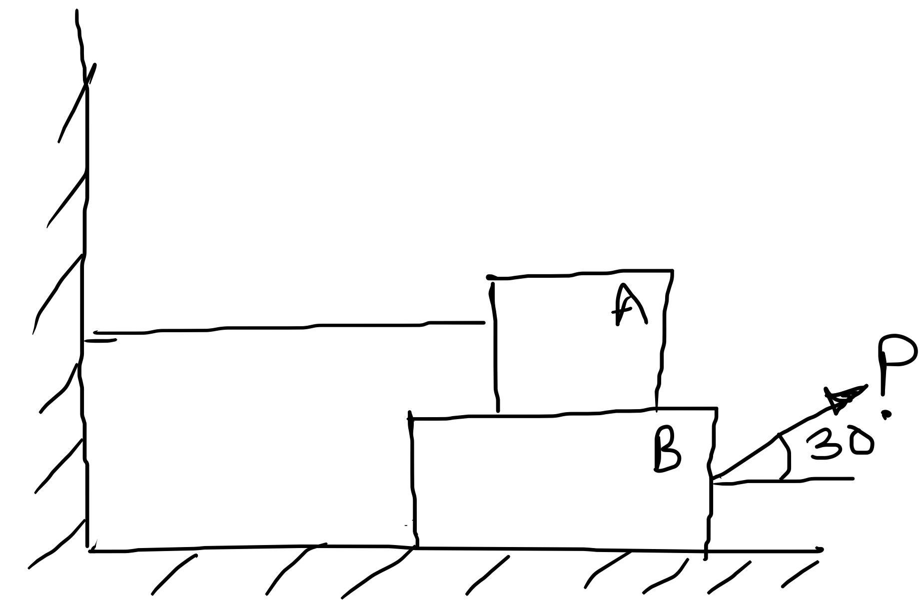
Considering block 'B'

$\Sigma F_x = 0, \quad P - F_1 - F_2 = 0 \Rightarrow \boxed{P = 1250 N}$

$\Sigma F_y = 0, \quad N_2 - N_1 - 2000 = 0 \Rightarrow N_2 = 3000 N, \quad F_2 = \mu_2 N_2 = \frac{1}{3} \times 3000$

$= 1000 N$

(ii) When P is inclined

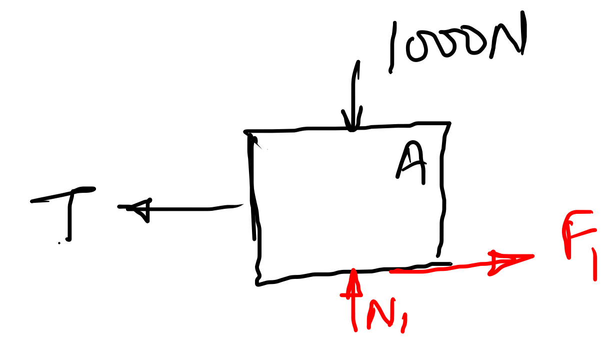


Considering Block 'A'

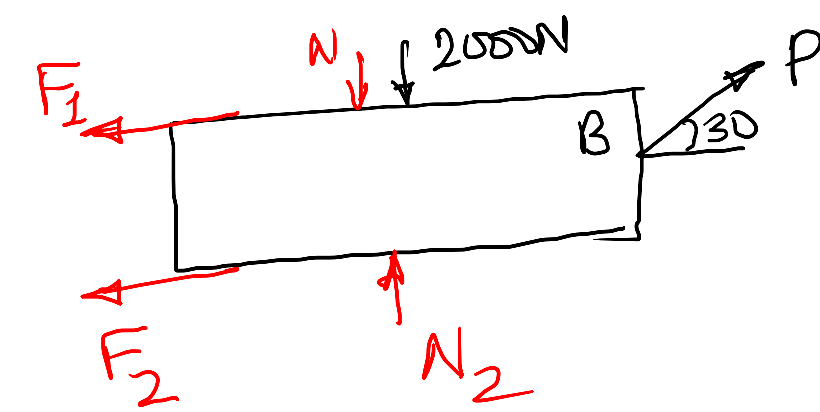
$\Sigma F_x = 0, \quad T = F_1 = \mu N_1 = 0.25 \times 1000$

$= 250\ N$

$\Sigma F_y = 0, \quad N_1 = 1000\ N$



Considering Block 'B'



$\Sigma F_x = 0, \quad P\cos 30 - F_1 - F_2 = 0$

$\Sigma F_y = 0, \quad \underline{N_2} + P\sin 30^\circ - N_1 - 2000 = 0$

$F_2 = \mu_2 \underline{N_2}$

$\boxed{P = 1210.54\ N}$

$\boxed{F_2 = 798.24\ N}$

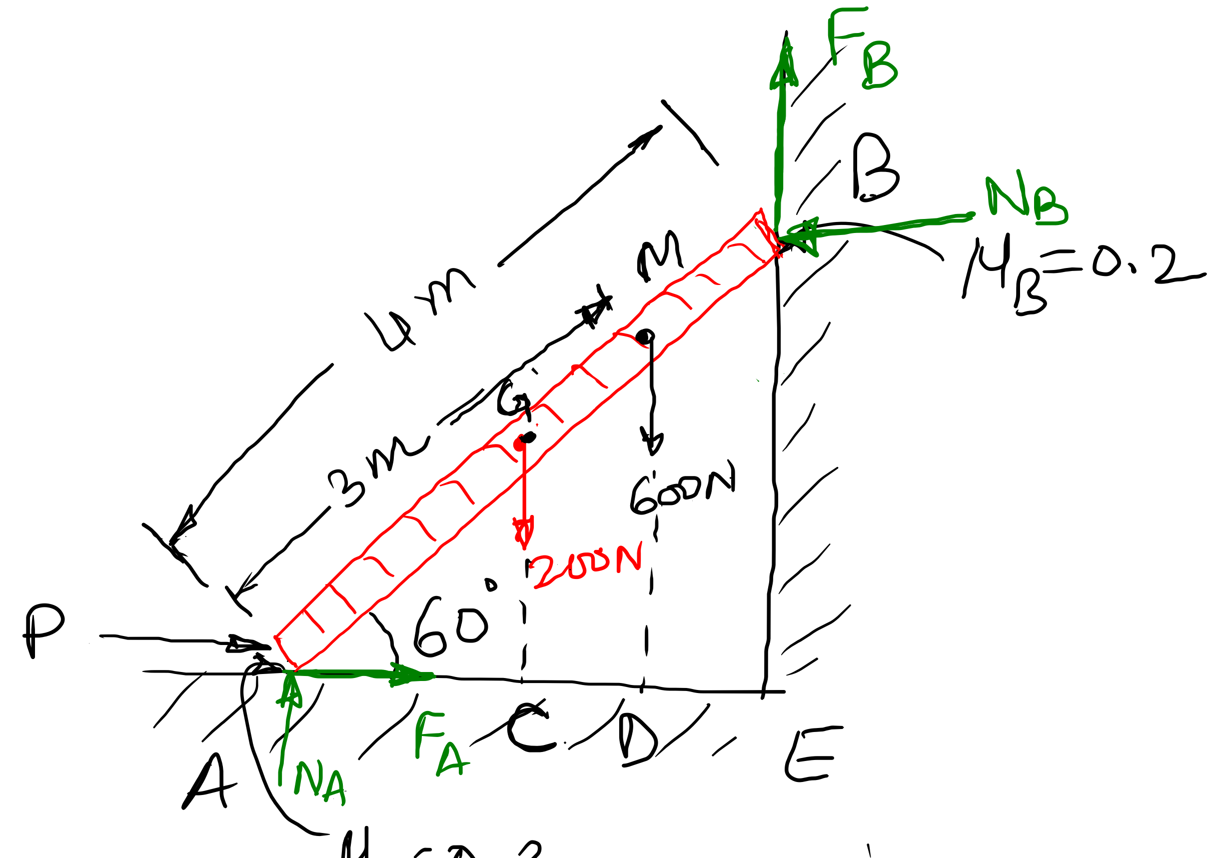
Ladder friction

Q: 2

$L = 4m$

$W_{ladder} = 200N$

$W_{man} = 600N$



For equilibrium of ladder

$\Sigma M_A = 0$, $\quad F_B \times AE + N_B \times BE - 200 \times AC - 600 \times AD = 0$ — (1)

$AE = 4\cos 60°$

$BE = 4\sin 60°$

$AC = 2\cos 60°$

$AD = 3\cos 60°$

$F_B = \mu_B N_B$

$\Rightarrow N_B = 284.68N$

$F_B = 56.94 N$

$$\Sigma F_x = 0, \quad P + F_A - N_B = 0$$

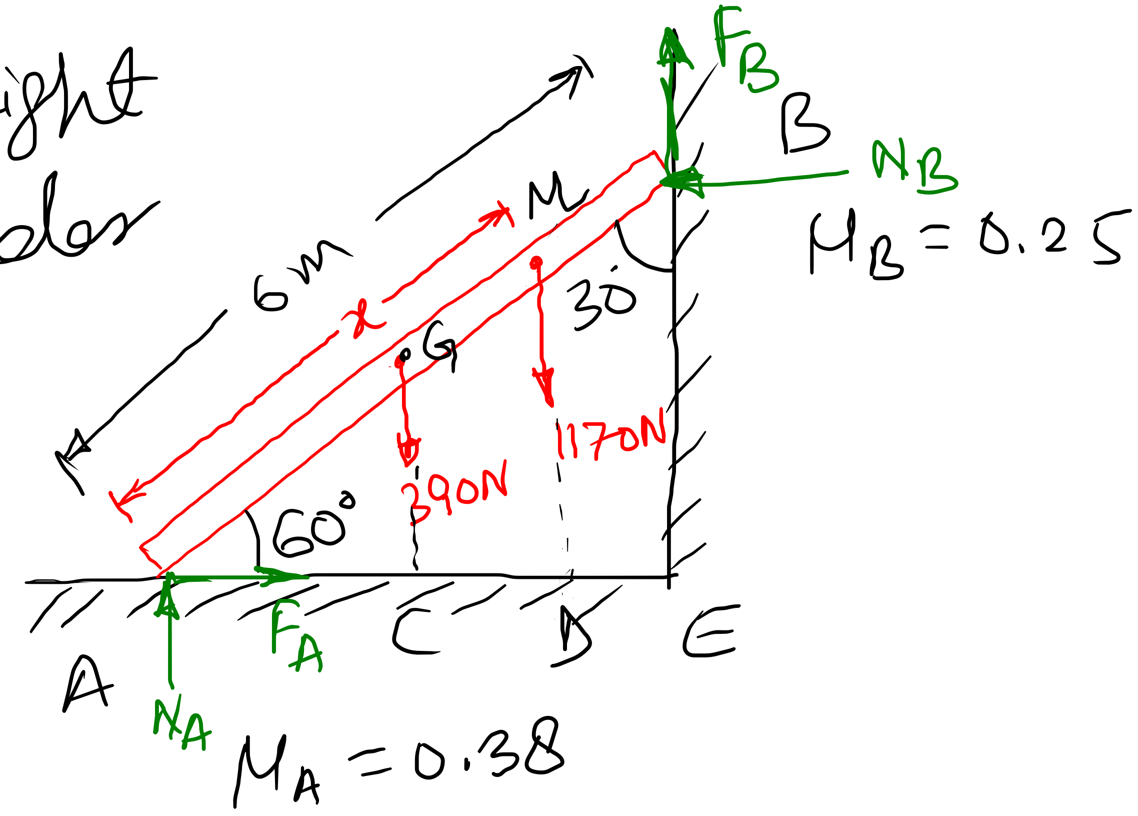
$$\Sigma F_y = 0, \quad N_A + F_B - 200 - 600 = 0$$

$$N_A = 743.06\,N$$

$$\therefore F_A = \mu_A N_A = 222.92\,N$$

$$P = 61.76\,N$$

Q:3 Find how far a man of weight 1170N can climb before the ladder begins to slip?



Sol^n: For equilibrium

$$\Sigma F_x = 0, \quad F_A - N_B = 0 \quad \text{--- (1)}$$

$$F_A = \mu_A N_A \quad \text{--- (2)}$$

$$\Sigma F_y = 0, \quad N_A + F_B - 390 - 1170 = 0 \quad \text{(3)}$$

$$F_B = \mu_B N_B \quad \text{--- (4)}$$

$AE = 6\cos 60°$

$AD = x \cos 60°$

$AC = 3\cos 60°$

$BE = 6 \sin 60°$

$$\begin{bmatrix} N_A = 1424.66\ N \\ F_A = 541.37\ N \end{bmatrix} \quad \begin{bmatrix} N_B = 541.37\ N \\ F_B = 135.34\ N \end{bmatrix}$$

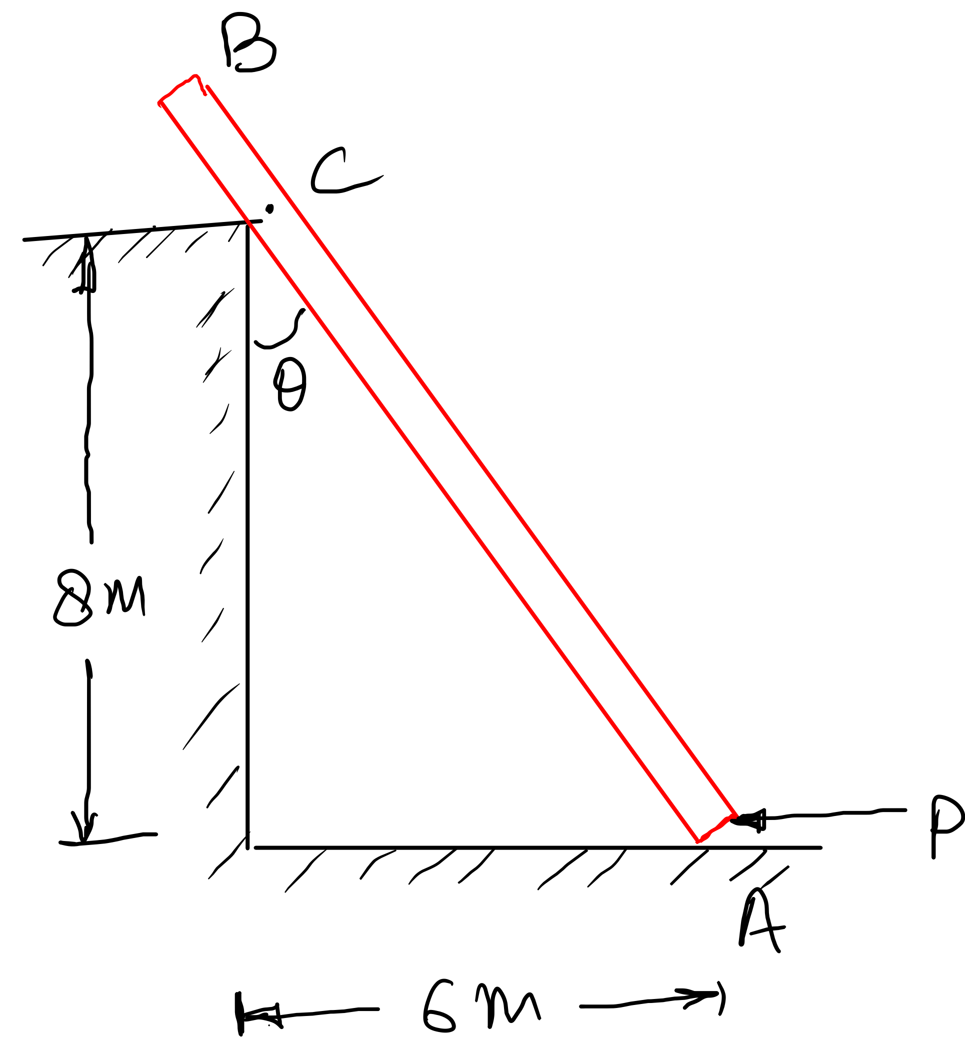
$\Sigma M_A = 0, \quad F_B \times AE + N_B \times BE - 390 \times AC - 1170 \times AD = 0$

$135.34 \times 6\cos 60^\circ + 541.37 \times 6\sin 60^\circ - 390 \times 3\cos 60^\circ - 1170 \times x\cos 60^\circ = 0$

$\Rightarrow \quad x = 4.50\ m$ [Along the ladder from A]

Height ascended by man, $h = MD = x\sin 60^\circ = 3.897\ m$

Q.4 A uniform ladder of 14m long and 150N weighing is supported as shown in figure. Determine the force 'P' required to move the ladder if the coeff. of friction for all contact surfaces is 0.4.



Solⁿ:

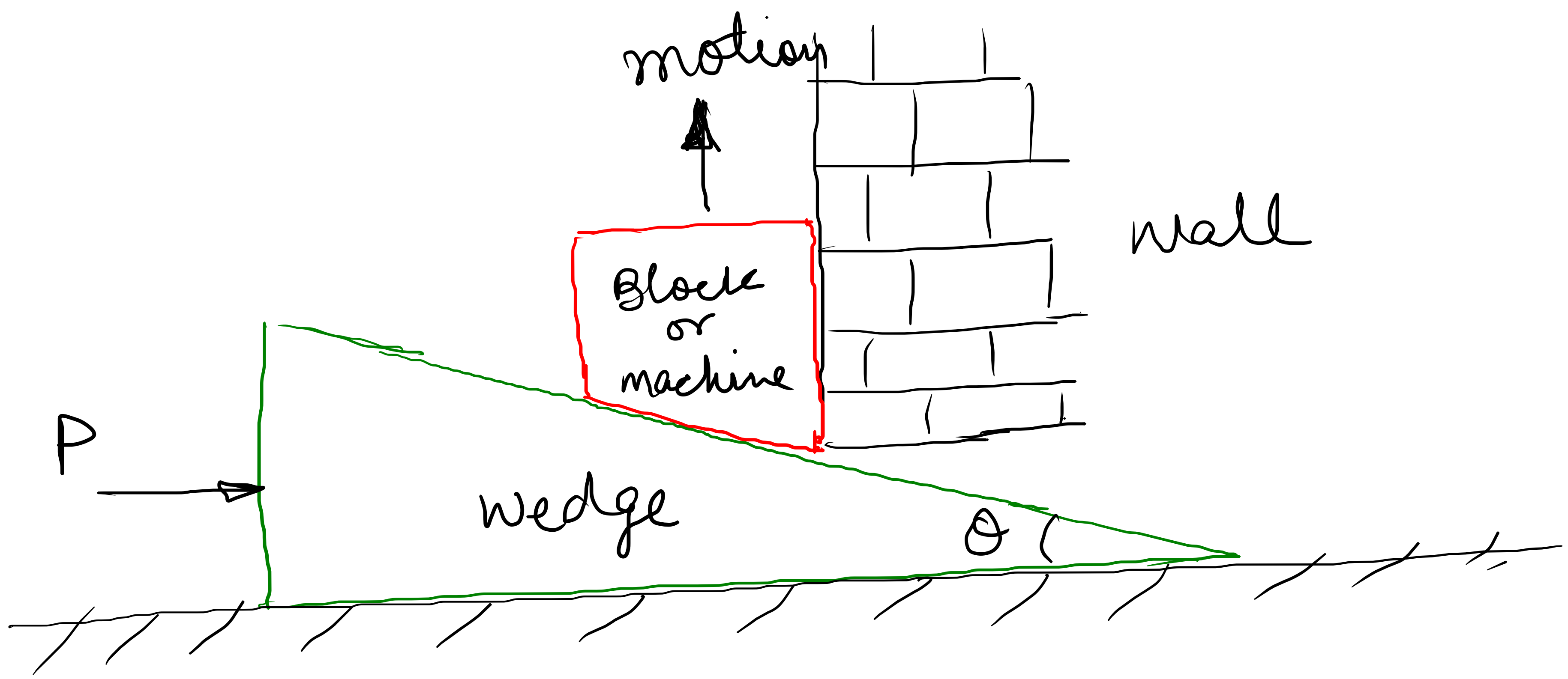
$\theta = 36.87^\circ$

$N_A = 132.36\,N$

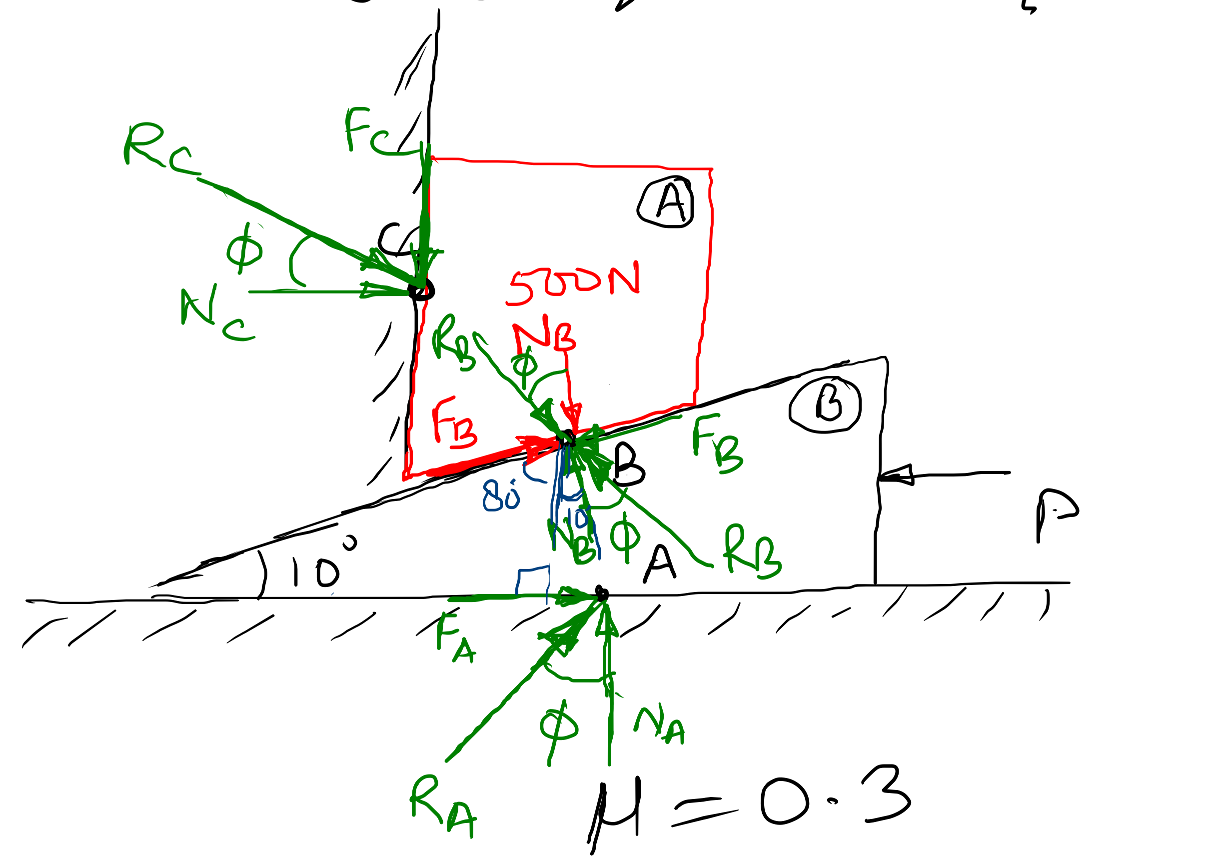
$N_C = 63N$

$P = 118.5\,N$

Wedge Friction



Q: 5 Determine the minimum horizontal force required to raise the block 'A'.



Soln:

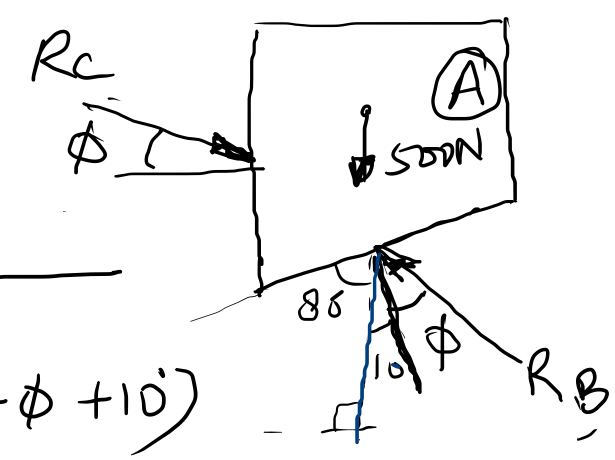
$\mu = 0.3$

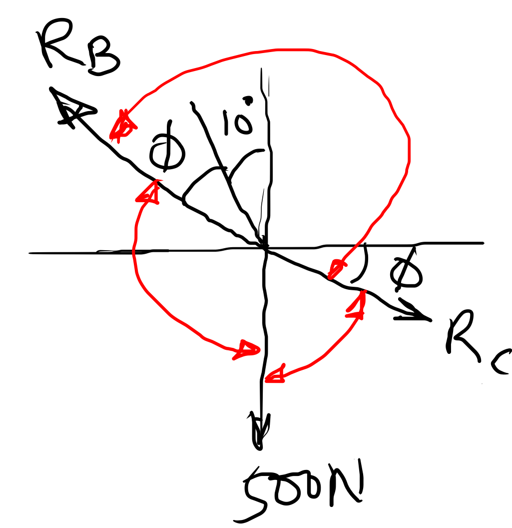
$\tan\phi = \mu$

$\phi = \tan^{-1}\mu = 16.7^\circ$

Now, consider equilibrium of block 'A'

Apply Lami's theorem



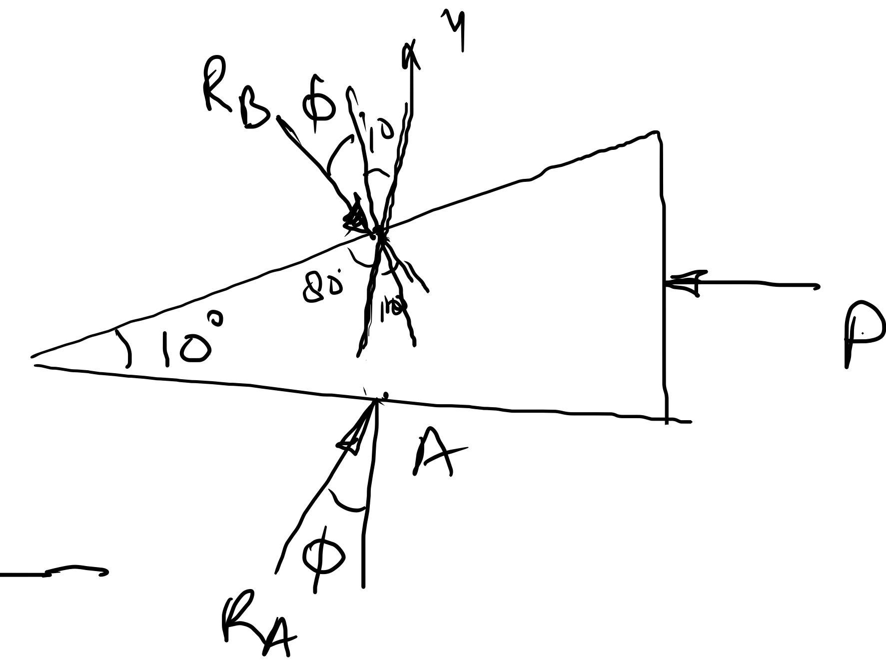


$$\frac{R_B}{\sin(90^\circ-\phi)} = \frac{R_C}{\sin(180^\circ-\phi-10^\circ)} = \frac{500}{\sin(90^\circ+\phi+\phi+10^\circ)}$$

$R_B = 659.14\,N$, $R_C = 309.20\,N$

Consider equilibrium of wedge 'B'

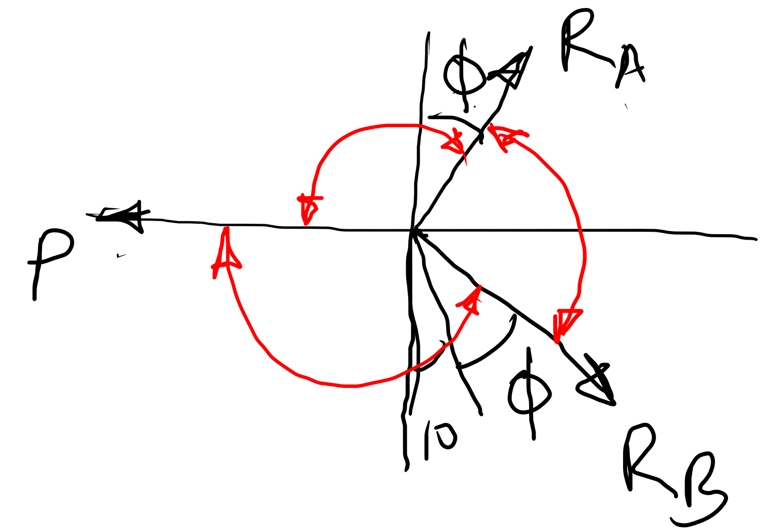
Apply Lami's theorem



$$\frac{R_A}{\sin(90^\circ+10^\circ+\phi)} = \frac{R_B}{\sin(90^\circ+\phi)} = \frac{P}{\sin(180^\circ-\phi-\phi-10^\circ)}$$

$\Rightarrow$ $R_A = 614.79\ N$

$P = 472.83\ N$



Q:6 Determine the value of 'P' to raise the block 'A' take $\mu = 0.2$ for all the contact surfaces.

<u>Sol^n:</u>

$P = 245.96\,N$