Friction

When a body moves or tends to move over another body, a force opposing the motion develops at contact surfaces. This force which opposes the movement or the tendency of movement is called frictional force or simply friction.

However there is a limit beyond which the magnitude of this force can not increase. If the applied force is more than this limit, there will be the movement of one body over the other. This value of maximum frictional force when the motion is impending is known as 'Limiting friction.' The state of body is called limiting equilibrium.

When the applied force is less than the limiting friction, the body remains at rest and such frictional force is called 'static friction.'

If the value of applied force exceeds the limiting friction the body starts moving is known as 'Dynamic Friction.'

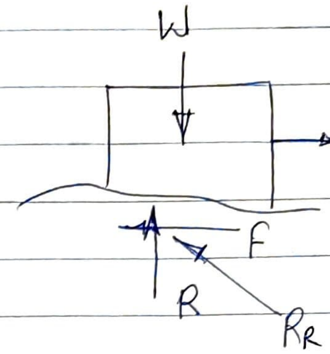
Dynamic friction is found to be less than the limiting friction Dynamic friction may be classified into two types.

(a) Sliding Friction
(b) Rolling Friction

Sliding friction is the friction experienced by a body when it slides over the body.

Rolling friction is the friction experienced by a body when it rolls over a surface.

* ## A block on Rough Surface :-



If the block is placed on rough surface, the reaction is not acting, normal to the surface.
The reaction which is actually inclined to the rough surface can be resolved into two components.
(a) along the surface (b) Normal to the surface
The component acting along the surface is frictional force and the component normal to the surface is called normal reaction. (N) or R.

* ## Coefficient of Friction

It is experimentally found that the magnitude of limiting friction bears a constant ratio to the normal reaction between the two surfaces & this ratio is called 'Coefficient of Friction.'

$$\mu = \frac{F}{N}$$

The ratio of static frictional force to the normal reaction is called 'Coefficient of static friction.'

$$\mu_s = \frac{F_s}{N} \quad \text{------ for impending motion.}$$

The ratio of kinetic frictional force to the normal reaction is called 'Coefficient of Dynamic friction.'

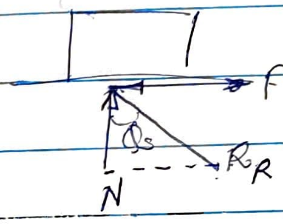
$$\mu_K = \frac{F_K}{N} \quad \text{------ for actual motion.}$$

* Angle Of friction:-

① Angle of static friction:

For impending motion, the angle between the normal reaction & resultant reaction is called as angle of static ~~m~~ friction.

$$\tan \phi_s = \frac{f_s}{R}$$



$$\text{But} \quad \frac{f_s}{R} = \mu_s$$

$$\therefore \tan \phi_s = \mu_s$$

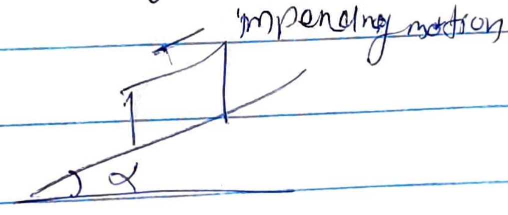
$$\therefore \phi_s = \tan^{-1} \mu_s$$

for actual motion, where $P = F_k$ the angle ~~betwn~~ between the normal reaction ~~to~~ and the resultant ~~re~~ reaction is called angle of Kinetic friction

$$\therefore \phi_k = \tan^{-1} \mu_k$$

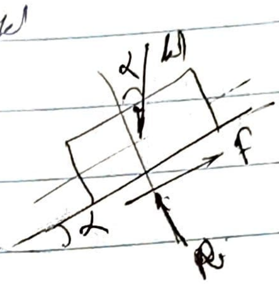
Angle of Repose:-

It is defined as the angle of inclined plane whith horizontal at which body is just on verge of sliding ~~(impen~~ (impending motion) & so $f_s = \mu_s . R$. Angle of repose is denoted by α.



* Relation between Angle of friction & Angle of Repose:

Draw FBD of block of weight W



$\Sigma F_x = 0$, $\mu R - W \sin\alpha = 0$

$\therefore \mu_s R = W \sin\alpha$

$\Sigma F_y = 0$

$R - W\cos\alpha = 0$

$R = W\cos\alpha$

$\therefore \mu_s . W\cos\alpha = W\sin\alpha$

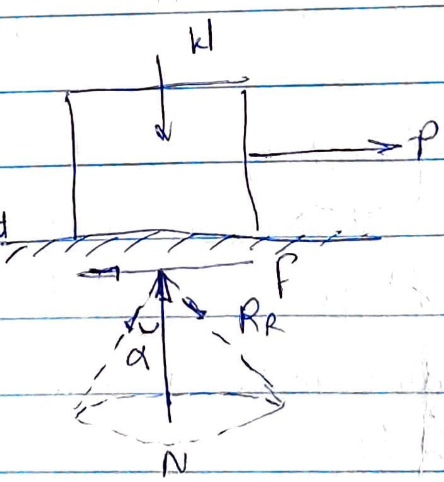
$\therefore \mu_s = \tan\alpha$

$\mu_s = \tan\phi_s$

$\therefore \phi_s = \alpha$

* Cone of Friction:-

It is an imaginary cone generated by revolving resultant reaction (R_R) about the normal reaction R.



* Laws Of Friction

Coulomb's laws of friction are as follows

① The force of friction is always acts in a direction opposite to that in which body tends to move.

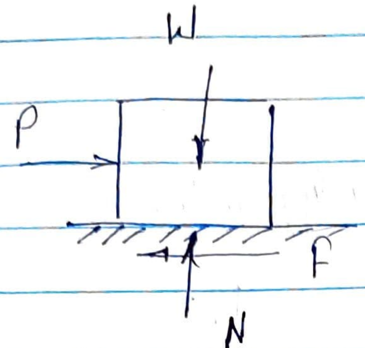
② Till the limiting value is reached, the magnitude of friction is exactly equal to the force which tends to move body.

③ The value of limiting friction bears a constant ratio to the normal reaction between the two surfaces of contact & this ratio is called coefficient of friction.

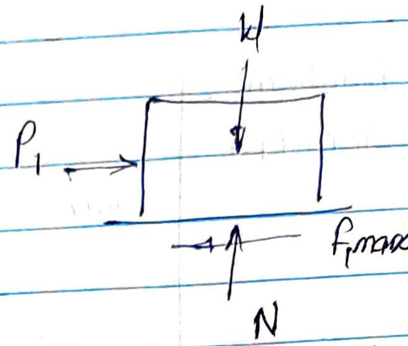
④ The force of friction depends upon the roughness of the surface

⑤ The force of friction is independent of the area of contact between the two surfaces.

⑥ After the body starts moving, the dynamic friction comes into play, the magnitude of which is less than that of limiting friction & it bears a constant ratio with normal force. This ratio is called coefficient of dynamic friction.



Equilibrium is maintained. No motion

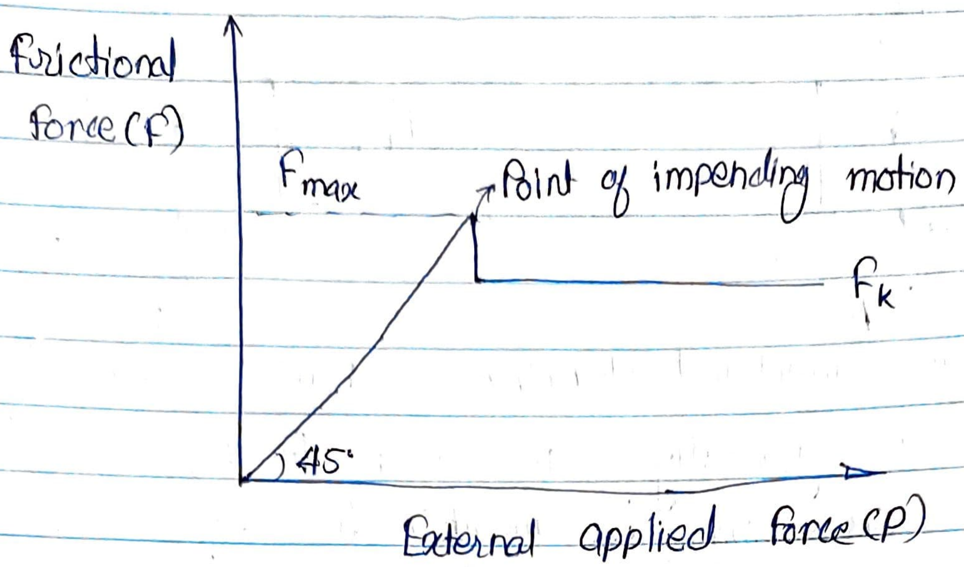


Point of impending motion.

If P is gradually increased to P_1, then F also increases correspondingly to maintain the equilibrium. However there is a limit up to which the frictional force can increase. The maximum or limiting value of friction is termed as "limiting static friction" & denoted by F_{max} when motion is impending. At this point, the block is on the verge of sliding / moving & this instant is known as "point of impending motion."

It should be noted that frictional force equal to $\mu_s N$ is applicable only at the point of impending motion. If body does not move under the action of external forces then the frictional force developed is less than the max^m value of static friction.

If P is increased further, the frictional force cannot balance it & motion occurs. Once motion has started, the frictional force acting between the surfaces usually decreases so that a smaller force is necessary to maintain uniform motion. The frictional force acting between surfaces in relative motion is termed as Force of Kinetic Friction.

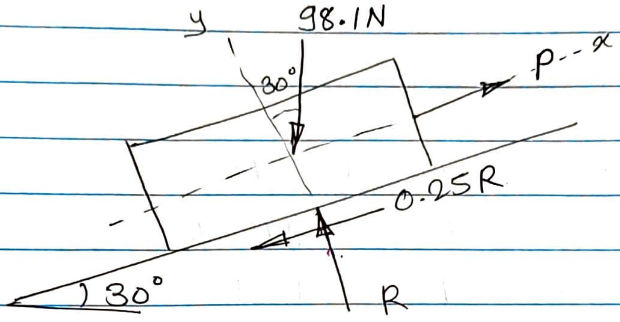


The results of this experiment can be depicted in a graph as shown in fig. Plotting magnitude of frictional force (F) against the applied force P.
Upto the point of impending motion, the frictional force F increases linearly with the applied force P. The slope of line being 45° as F is equal to P until the limiting value is reached. Beyond the point of impending motion the frictional force F ~~increases~~ drops to force of kinetic friction. (F_k) & it almost remains constant.

The sudden drop in frictional force from F_{max} to F_k can be observed when we try to push or pull a chair on the floor, there will be a jerk just before motion begins.

when	$F < F_{max}$	------	No motion occurs
when	$F = F_{max}$	------	motion impends
when	$F > F_{max}$	------	body is under motion.

① * ③ A block of mass 10 kg rests on an inclined plane as shown in fig. If the coefficient of static friction between the block and plane is $\mu_s = 0.25$. Determine the maximum force P to maintain the equilibrium.



Consider the equilibrium of the block.

$$\Sigma F_y = 0$$

$$R - 98.1\cos 30 = 0$$

$$R = 84.957N$$

$$\Sigma F_x = 0$$

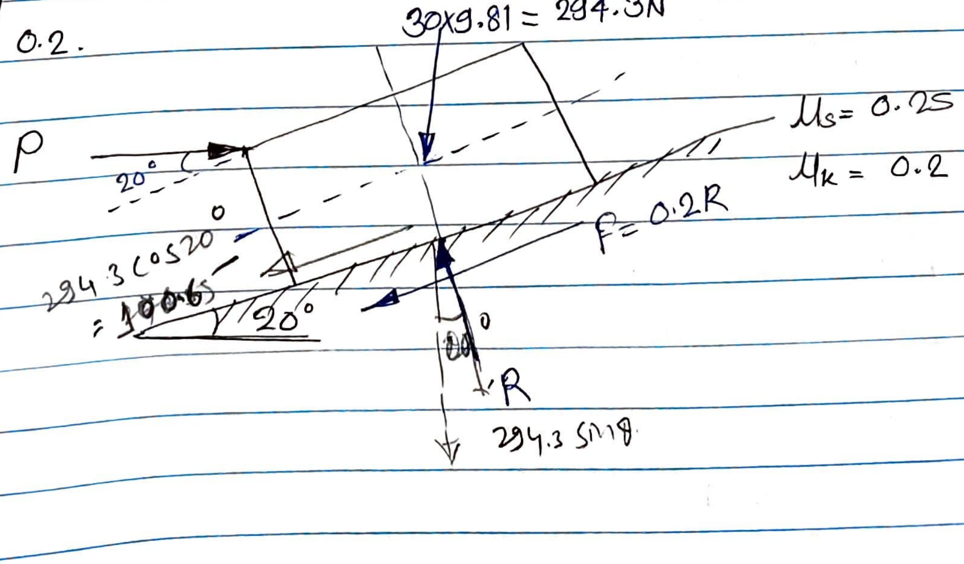
$$P - 0.25R - 98.1\sin 30 = 0$$

$$P = 0.25 \times 84.957 + 98.1\sin 30$$

$$P = 70.289N$$

May 2017

② * Determine the horizontal force P needed to just start moving the 30kg block up the plane as shown in fig. Take $\mu_s = 0.25$ and $\mu_k = 0.2$.



$$\Sigma F_y = 0$$

$$N - 294.3\cos 20 - P\sin 20 = 0$$

$$N = P\sin 20 + 276.551 \quad \text{--- (1)}$$

$$\Sigma F_x = 0$$

$$-0.25N + P\cos 20 = 100.656 \quad \text{--- (2)}$$

$$-F_f + P\cos 20 - 276.55 = 0$$

$$-0.25N + P\cos 20 = 100.656$$

$$-0.25(P\sin 20 + 276.551) + P\cos 20 = 100.656$$

$$-0.085P - 69.137 + 0.939P = 100.656$$

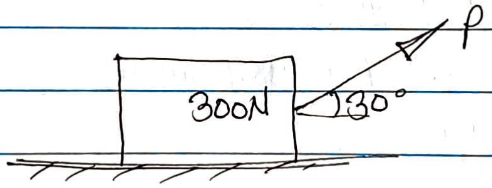
$$0.854P = 169.793$$

$$P = 198.820\,N$$

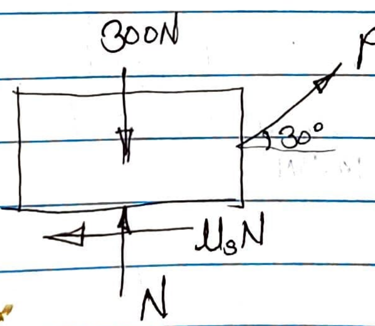
$$N = 344.551\,N$$

Dec. 2012

(3) * (A) A body of weight 300N is kept on a rough horizontal plane and a force P is applied to just move the body horizontally as shown in fig. Find the magnitude of force P required if coefficient of static friction is $\mu_s = 0.4$



:-



$$\Sigma F_y = 0$$

$$P\sin 30 - 300 + N = 0$$

$$\therefore N = -P\sin 30 + 300 \quad \text{--- (1)}$$

$$\Sigma F_x = 0$$

$$P\cos 30 - \mu_s N = 0$$

$P\cos 30 = \mu_s N$

$P\cos 30 = 0.4N$ —— (2)

From (1)

$P\cos 30 = 0.4(300 - P\sin 30)$

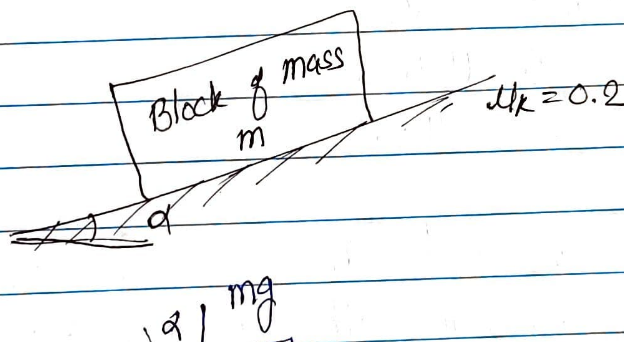
$0.866P = 120 - 0.2P$

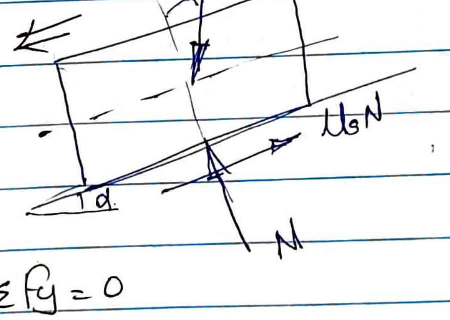
$1.066P = 120$

$\boxed{\therefore P = 112.57N}$

Dec. 2014

(4)* A block of mass m rest on a frictional plane which makes an (5) angle α with the horizontal as shown in fig. If the coefficient of friction between the block and the frictional plane is 0.2. Determine the angle α for limiting condition.





$\Sigma F_y = 0$

$N - mg\cos\alpha = 0$

$\therefore N = mg\cos\alpha$ —— (1)

$\Sigma F_x = 0$

$-mg\sin\alpha + \mu_s N = 0$

$\therefore \mu_s N = mg\sin\alpha$

$0.2N = mg\sin\alpha$ —— (2)

From (1)

$$0.2\,(mg.\cos\alpha) = mg.\sin\alpha$$

$$0.2\cos\alpha = \sin\alpha$$

$$\tan\alpha = 0.2$$

$$\alpha = 11.31^\circ$$

* Alternate Method:-

For limiting condition, angle of inclination of plane is the angle of Repose,

$$\alpha = \theta \qquad \tan\alpha = \tan\phi$$

$$\tan\theta = \mu_s \qquad \tan\alpha = \mu$$

$$\tan\theta = 0.2 \qquad \alpha = \tan^{-1}\mu$$

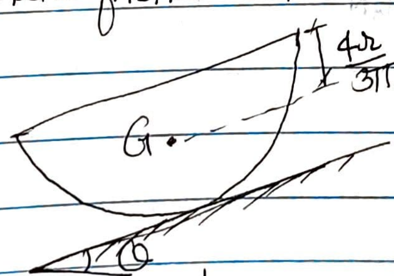
$$\therefore \theta = 11.31^\circ$$

$$\therefore \alpha = 11.31^\circ$$

May 2016

(5) * The homogeneous semi-cylinder has a mass m and mass centre at

(6) G as shown in fig. Determine the largest angle θ of the inclined plane upon which it rest, so that it does not slip down the plane. The coefficient of static friction between the plane and the cylinder is 0.3



When the semicylinder is about to slide down the plane, under its own weight the angle made by the plane w.r.to horizontal i.e θ is known as the angle of repose.

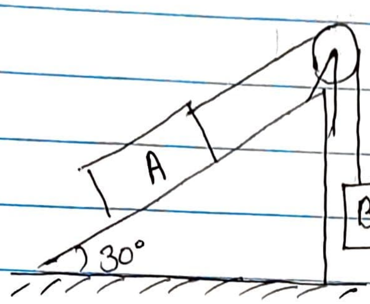
we know that $\tan\theta = \mu_s$

$$\tan\theta = 0.3$$

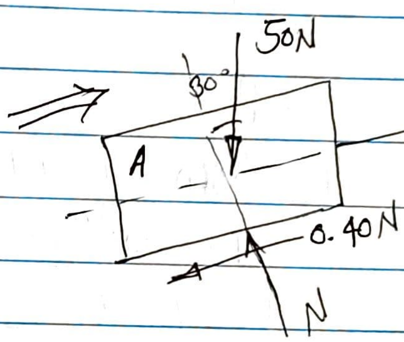
$$\theta = 16.7^\circ$$

Dec. 2004

06 Two blocks A and B are connected by a string passing over a
1 Smooth pulley as shown in fig. The block A weighs 50N. If the coefficient of friction between the plane and the block is 0.40. Find the maximum and minimum values of mass of block B for equillibrium of the system.



(a) For maximum value of m_B



For Block A :

$$\Sigma F_y = 0$$

$$N = 50 \cos 30$$

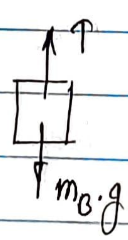
$$\Sigma F_x = 0$$

$$-50 \sin 30 - 0.40 N + T = 0$$

$$\therefore T = 50 \sin 30 + 0.4 (50 \cos 30)$$

$$\therefore T = 42.32 N$$

For Block B :

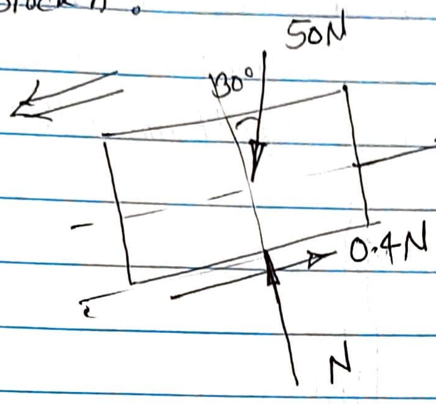


$$T - m_B g = 0$$

$$m_B = \frac{T}{g} = \frac{42.32}{9.81} = 4.31 \text{ kg}$$

(b) for minimum value of 'm_B'

For Block A:



$$\Sigma F_y = 0$$

$$N = 50\cos 30$$

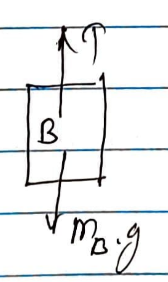
$$\Sigma F_x = 0$$

$$T - 50\sin 30 + 0.4N = 0$$

$$\therefore T = 50\,\cancel{\cos}\sin 30 - 0.4(50\cos 30)$$

$$T = 7.68\,N$$

For Block B:



$$\therefore T - m_B g = 0$$

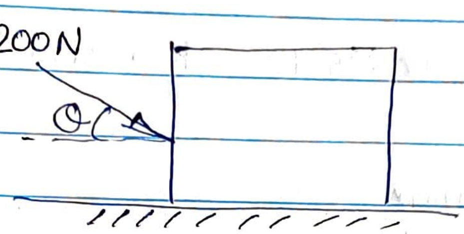
$$m_B = \frac{T}{g} = \frac{7.68}{9.81}$$

$$m_B = 0.783\,kg$$

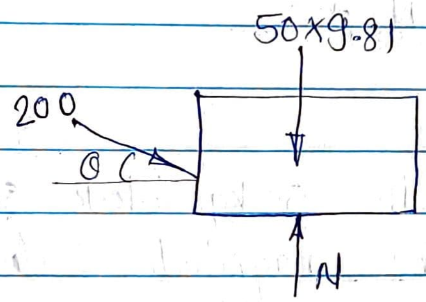
$\therefore$ The mass of block varies between $4.31\,kg > m_B > 0.783\,kg$

*

(1) Determine whether the 50 kg block shown in fig. is in equilibrium & find the magnitude of & direction of the frictional force when (a) $\theta = 10^\circ$ & (b) $\theta = 40^\circ$ Take $\mu_s = 0.3$ & $\mu_k = 0.2$



→ The F.B.D. of block shown in fig. without frictional force



$$\Sigma F_y = 0$$

$$N - 50 \times 9.81 - 200 \sin\theta = 0$$

$$\therefore N = 490.5 + 200 \sin\theta$$

$$F_{r\,max} = \mu_s N$$

$$= 0.3 (490.5 + 200 \sin\theta)$$

$$\Sigma F_x = 200 \cos\theta \rightarrow$$

a] for $\theta = 10^\circ$

$$\therefore F_{r\,max} = 0.3 (490.5 + 200 \sin 10)$$

$$= 157.57 N$$

$$\Sigma F_x = 200 \cos 10 = 196.96 N \rightarrow$$

$$\Sigma F_x > F_{r\,max}$$

$\therefore$ Object moves towards right &

$$F_r = \mu_k N = 0.2 (490.5 + 200 \sin 10)$$

$$F_r = 105.05 N$$

b) For $\theta = 40°$

$f_{r\,max} = 0.3\,(490.5 + 200 \sin 40)$

$= 185.72\ N$

$\Sigma F_x = 200 \cos 40 = 153.21\ N \rightarrow$

$\Sigma F_x < f_{r\,max}$

∴ Object doesn't move.

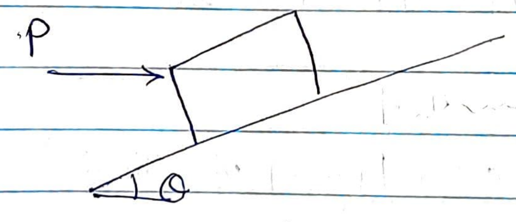
∴ $f_r = \Sigma F_x$

∴ $f_r = 153.21\ N \leftarrow$

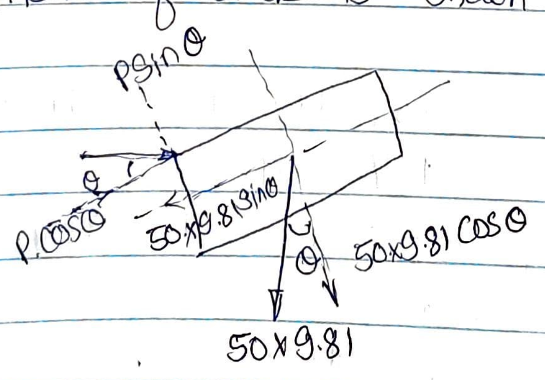
② Determine whether the 50 kg block shown in fig is in equilibrium & find the magnitude & direction of the frictional force when a) $P = 200N$, $\theta = 20°$

b) $P = 200N$ $\theta = 45°$

c) $P = 100N$ $\theta = 20°$ where $\mu_s = 0.3$ & $\mu_k = 0.2$



:→ The F.B.D. of block is shown in fig: without frictional force



$\Sigma F_y = 0$

$N - P\sin\theta - 50 \times 9.81 \cos\theta = 0$

$N = P\sin\theta + 490.5\cos\theta$

$F_{r\,max} = \mu_s N$

$= 0.3\left[P\sin\theta + 490.5\cos\theta\right]$ —— ①

$\Sigma F_x = P\cos\theta - 50 \times 9.81 \sin\theta$

a] for $P = 200N$ $\theta = 20°$

$F_{r\,max} = 0.3\left[200\sin 20 + 490.5\cos 20\right]$

$= 158.8N$

$\Sigma F_x = 200\cos 20 - 50 \times 9.81 \sin 20$

$= 20.18N$

$\Sigma F_x < F_{r\,max}$

$\therefore$ object does not move

$\therefore F_r = \Sigma F_x$

$\underline{F_r = 20.18N \quad \theta = 20°}$

b] for $P = 200N$, $\theta = 45°$

$F_{r\,max} = 146.48N$

$\Sigma F_x = -205.41N$ 45°

$\Sigma F_x > F_{r\,max}$

$\therefore$ object moves down the incline.

$\therefore F_r = \mu_k N$

$= 0.2(200\sin 45 + 490.5\cos 45)$

$\underline{F_r = 97.65N, \ 45°}$

c] for $P = 100N$ $\theta = 20°$

$F_{n\,max} = 148.54\,N$

$F_x = -73.8$

$\Sigma F_x < F_{n\,max}$

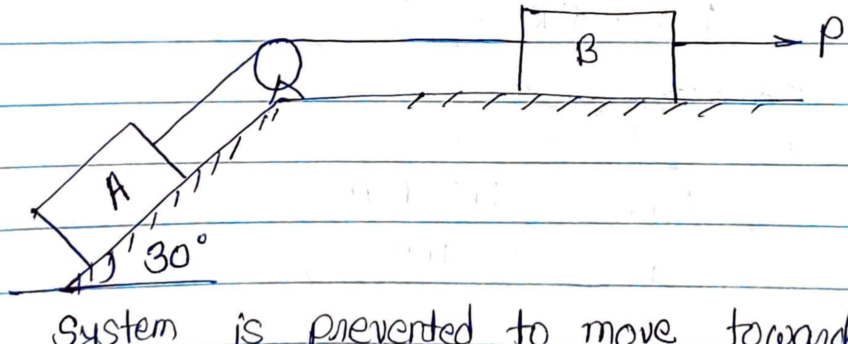
$\therefore$ Object does not move

$F_n = F_x = 73.8, 20 \rightarrow$

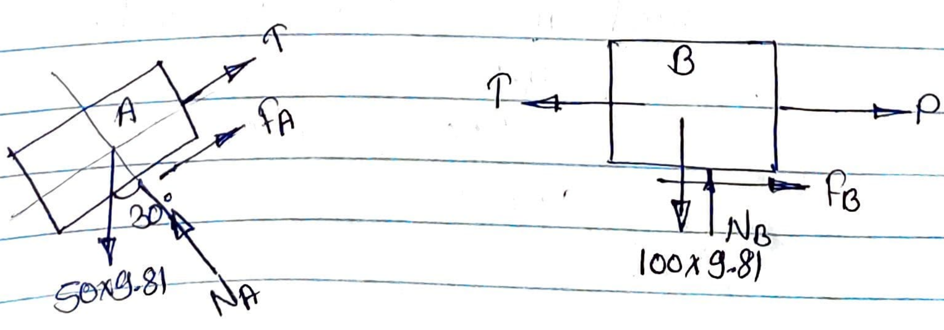
(3) Two blocks A & B having masses 50kg & 10kg respectively are connected by a string which passes over frictionless pulley as shown in fig. Coefficient of friction between block & surface is 0.2 for both A&B. Determine force P if

a] The system is prevented to move towards left.

b] The system is just on the point of moving towards right.



a] System is prevented to move towards left.



For Block A,

$\Sigma F_y = 0.$

$N_A - 50 \times 9.81 \cos 30 = 0$

$N_A = 424.785 N \Rightarrow F_A = 0.2 \times 424.785$

$= 84.957 N$

$\Sigma F_x = 0.$

$T + F_A - 50 \times 9.81 \sin 30 = 0$

$T = 50 \times 9.81 \sin 30 - 84.957$

$T = 160.293 N$

For Block B, $\Sigma F_y = 0$

$N_B - 100 \times 9.81 = 0$

$N_B = 981 N$

$F_B = 0.2 \times 981 = 196.2 N$

$\Sigma F_x = 0$

$P + F_B - T = 0.$

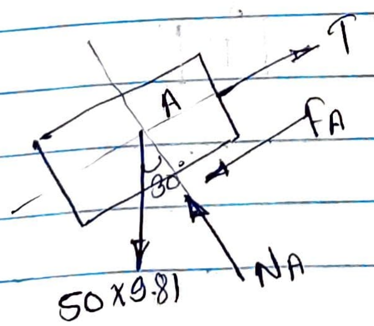
$P = 160.293 - 196.2$

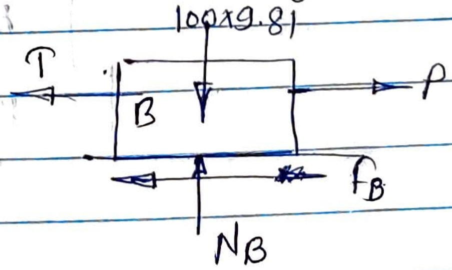
$P = -35.27 N$

-ve value of P indicates that the system will not be able to move towards left even if left to itself making P equal to zero.

$\therefore P = 0$

b] System is just on the point of moving towards right.





For Block A $\Sigma F_y = 0$

$N_A - 50 \times 9.81 \cos 30 = 0$

$N_A = 424.785 N$

$F_A = 84.957 N$

$\Sigma F_x = 0$

$T - F_A - 50 \times 9.81 \sin 30 = 0$

$\therefore T = 330.21 N.$

For B,

$\Sigma F_y = 0$

$N_B - 100 \times 9.81 = 0.$

$N_B = 981 N$

$F_B = 196.2 N$

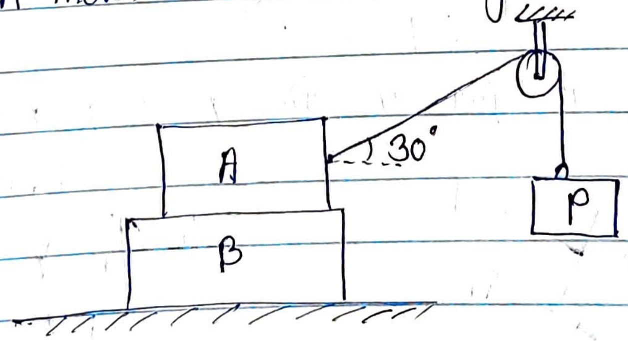
$\Sigma F_x = 0.$

$P - T - F_B = 0$

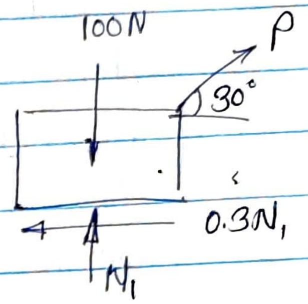
$P = 330.21 + 196.2$

$P = \cancel{526.41 N}$ $\underline{\underline{349.82 N}}$

(4) Two blocks A = 100N & B = 150 N are resting on ground as shown fig. Coefficient of friction between ground & block B is 0.10. & that between block B & A is 0.30. Find the minimum value of weight P in the pan so that motion starts. Find whether B is stationary w.r.t ground & A moves or B is stationary w.r.t. A.



Case I :- B is stationary w.r.t. ground & A moves.
Consider given A is in limiting equilibrium which means block A moves over the surface of B.



Consider F.B.D. of Block A.

$\Sigma F_y = 0$

$N_1 + P\sin 30 - 100 = 0$

$N_1 = 100 - P\sin 30.$

$\Sigma F_x = 0$

$P\cos 30 - 0.3N_1 = 0.$

$P\cos 30 - 0.3[100 - P\sin 30] = 0$

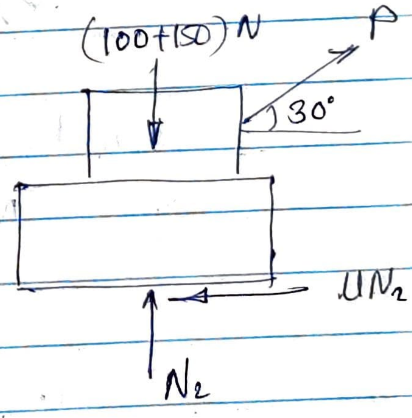
$P\cos 30 - (0.3\times 100) + 0.3P\sin 30 = 0$

$P(\cos 30 + 0.3\sin 30) = 0.3\times 100$

$\therefore P = \dfrac{0.3\times 100}{\cos 30 + 0.3\sin 30}$

$P = 29.53N.$

Case II : B is stationary w.r.t. to A.
Consider both blocks A & B moving together.



$\Sigma F_y = 0$

$N_2 - 250 + P\sin 30 = 0$

$N_2 = 250 - P\sin 30$

$\Sigma F_x = 0$

$P\cos 30 - \mu N_2 = 0$

$P\cos 30 - 0.1(250 - P\sin 30) = 0$

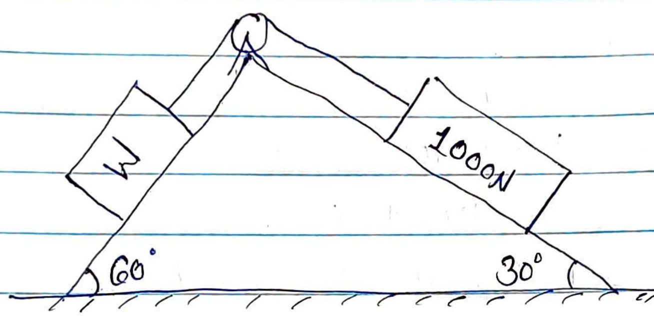
$P\cos 30 - 0.1\times 250 + 0.1P\sin 30 = 0$

$P(\cos 30 + 0.1\sin 30) = 0.1\times 250$

$P = \dfrac{0.1\times 250}{\cos 30 + 0.1\sin 30} = 27.29N$

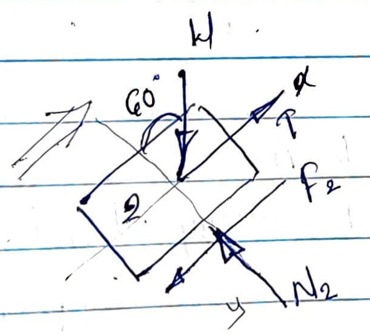
From both cases. we can declare Case II is initiated first & ∴ min value of $P = 27.29N$

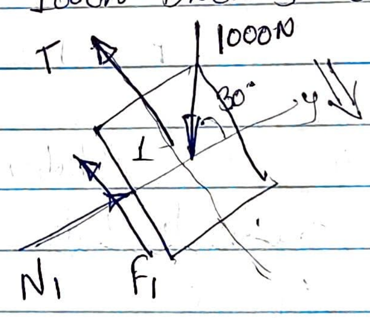
(5) Two planes AC & BC inclined at 60° & 30° to the horizontal meet at C shown in fig. A block of wt. 1000N rests on the inclined plane BC & is tied by a rope passing over a pulley to a block weighing W newtons & resting on the plane AC. If the coefficient of friction between the blocks plane BC is 0.28 & that between the block & the plane AC is 0.20. Find the least & greatest value of W for the equilibrium of the system.



a] For the least value of W

In this case motion of 1000N block is downward.





Consider block 1 (1000N)

$\Sigma y = 0$ $\quad N_1 - 1000 \cos 30 = 0.$

$\therefore N_1 = 866.03\ N$

$f_1 = 0.28 \times 866.03 = 242.49\ N$

$\Sigma F_x = 0$ — $\quad T + f_1 - 1000 \sin 30 = 0.$

$T = -242.49 + 500 = 257.51\ N$

Consider block 2.

$\Sigma F_y = 0$ $\quad N_2 - W \cos 60 = 0.$

$\therefore N_2 = 0.5W$ $\quad F_2 = 0.2 \times 0.5W = 0.1W$

$\Sigma f_x = 0.$

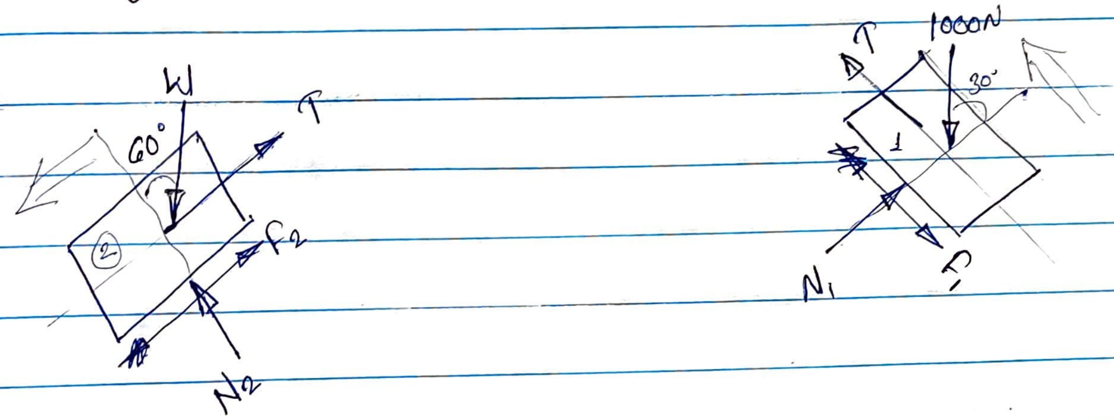
$$T - f_2 - W\sin 60 = 0$$

$$257.51 - 0.1W - W\sin 60 = 0$$

$$W = \frac{257.51}{(0.1 + \sin 60)} = 266.57\ N.$$

b] For greatest value of W:

In this case 1000N block will be on the verge moving up the plane.



Consider block 1.

$\Sigma F_y = 0$

$$N_1 - 1000\cos 30 = 0$$

$$N_1 = 866.03\ N$$

$$F_1 = 242.49N$$

$\Sigma f_x = 0$

$$T - F_1 - 1000\sin 30 = 0$$

$$\therefore T = 242.49 + 500 = 742.49\ N$$

Consider Block 2.

$\Sigma F_y = 0 \quad N_2 - W\cos 60 = 0$

$$\therefore N_2 = 0.5W$$

$$f_2 = 0.1W$$

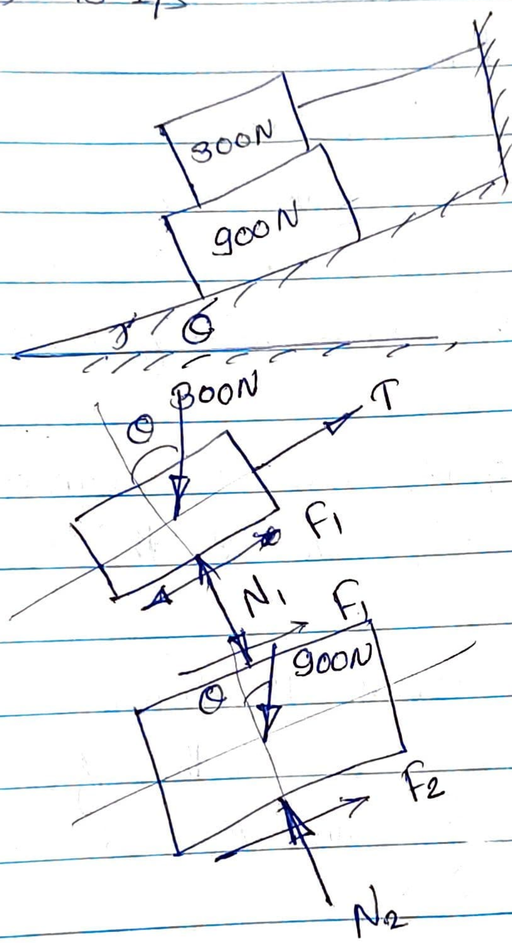
$$\Sigma F_x = 0$$

$$T + f_2 - W \sin 60 = 0.$$

$$742.49 + 0.1W - W \sin 60 = 0$$

$$\therefore W = \frac{742.49}{0.1 + \sin 60} = 969.28\,N.$$

(1) What should be the value of θ in fig that will make the motion of 900N block down the plane to impend? The coefficient of friction for all contact surfaces is 1/3



Consider equilibrium of 300N block,

$\Sigma F_y = 0$

$N_1 - 300 \cos\theta = 0$

$N_1 = 300 \cos\theta$

$F_1 = \mu N_1 = \theta . \frac{1}{3} \times 300 \cos\theta = 100 \cos\theta$

consider equilibrium of 900 N block

$\Sigma F_y = 0$

$N_2 - N_1 - 900 \cos\theta = 0$

$N_2 = \cancel{N_1}\, 300\cos\theta + 900\cos\theta$

$= 1200 \cos\theta$

$F_2 = \frac{1}{3} N_2 = \frac{1}{3} 1200 \cos\theta$

$= 400 \cos\theta$

$\Sigma F_x = 0$

$F_1 + F_2 - 900 \sin\theta = 0$

$100 \cos\theta + 400 \cos\theta = 900 \sin\theta$

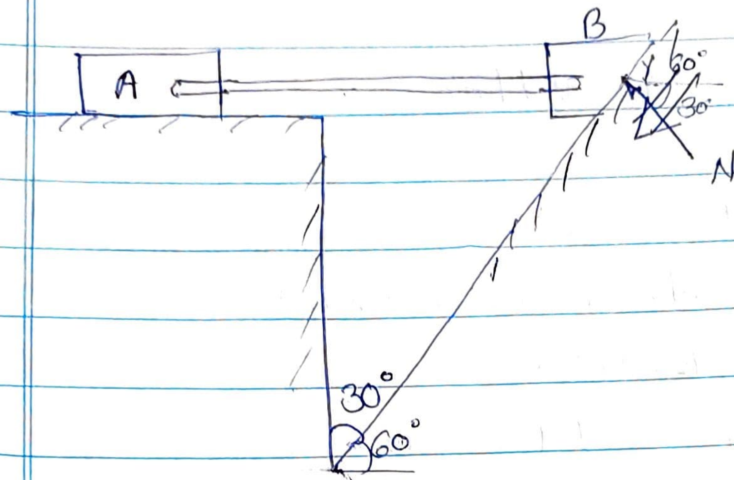
$500 \cos\theta = 900 \sin\theta$

$\frac{\sin\theta}{\cos\theta} = \tan\theta = \frac{500}{900}$

$\theta = 29.05°$

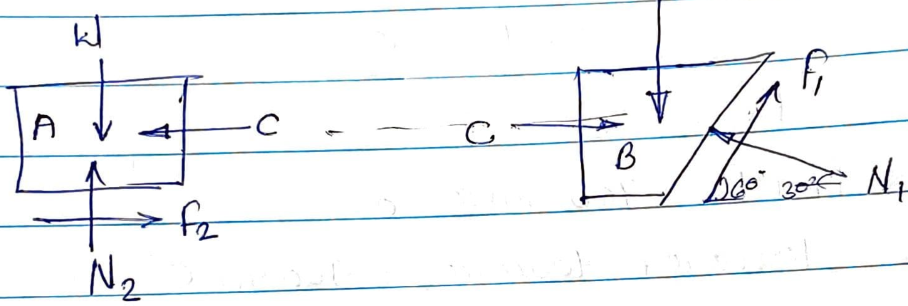
(2) Two blocks connected by a horizontal link AB are supported on two rough planes as shown in fig. The coefficient of friction between the block A & horizontal surface is 0.4. The limiting angle of friction between block B & inclined plane is 20°. What is the smallest wt. W of the block A for which equilibrium of the system can exists, If the wt. of block B is 5KN.?

(A)



(9)

$\mu = \tan 20 = 0.36$.



Consider the equilibrium of block B.

$\Sigma F_y = 0$.

$N_1 \sin 30 + f_1 \sin 60 - 5 = 0$

$0.5N_1 + N_1 \tan 20 \cdot \sin 60 = 5$

$\mu = \tan 20 = 0.36$.

$f_1 = 0.36 N_1 \sin 60 = 0.311 N_1$

$0.5N_1 + 0.311 N_1 = 5$

$N_1 = 6.133$ kN.

$f_1 = 2.232$ kN.

$\Sigma F_x = 0$.

$C + f_1 \cos 60 - N_1 \cos 30 = 0$

$C = 6.133 \cos 30 - 2.232 \cos 60$

$= 4.196$ kN.

Now consider the equilibrium of block A.

$\Sigma H = 0.$

$F_2 - C = 0.$

$F_2 = C = 4.196\,kN.$

$F_2 = \mu N_2 = 0.4 N_2$

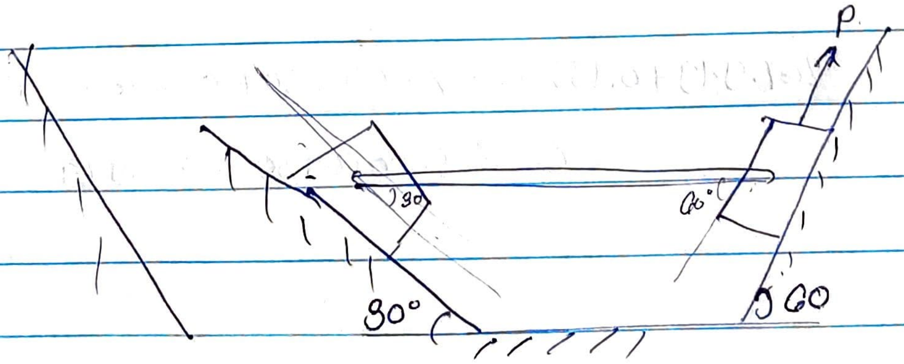
$N_2 = \dfrac{F_2}{0.4} = \dfrac{4.196}{0.4} = 10.49\,kN.$

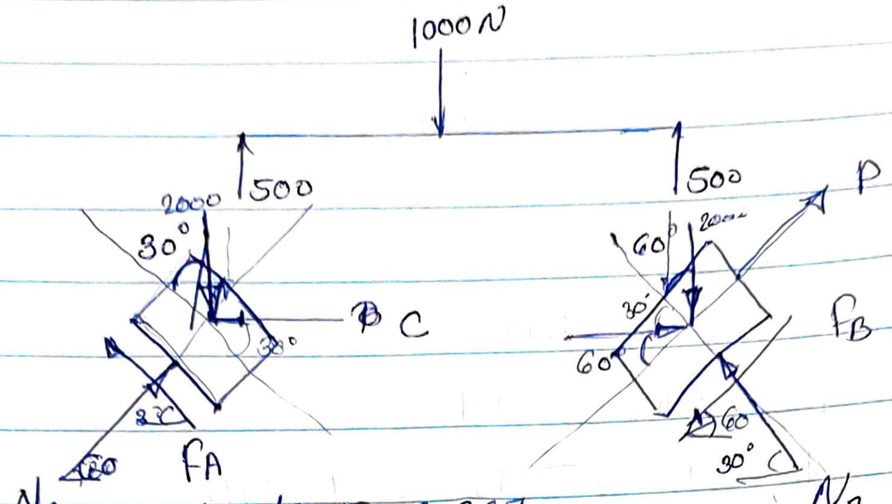
$\Sigma F_y = 0$

$W - N_2 = 0.$

$W = N_2 = 10.49\,kN.$

(3) Two block A & B each weighing 1500N are connected by a uniform horizontal bar weighing 1000N. If the angle of limiting friction for all contact surfaces is 15°, find the force P directed parallel to the 60° inclined plane that will cause motion impending to the right.





$\mu = \tan 15 = 0.267$

Consider equilibrium of block A,

$\Sigma F_y = 0$

$N_A - C \sin 30 - 2000 \sin 30 = 0$

$N_A = 1000 + C \sin 30.$

$f_A = 0.267 (1000 + C \sin 30) = 267.949 + 0.1335C$

$\Sigma F_x = 0.$

$f_A - 2000 \cos 30 + C \cos 30 = 0.$

$267.949 + 0.1335C - 2000 \cos 30 + 0.866C = 0.$

$C = 2000 \cos 30 - 267.949$

Block A

$\Sigma V = 0$

$N_A \cos 30 + f_A . \sin 30 - 2000 = 0$.

$f_A = 0.267 \, N_A$.

$N_A \cos 30 + 0.267 N_A . \sin 30 = 2000$

$\therefore N_A = 2000 N$.

$f_A = 535.90 N$

$\Sigma F_x = 0$

$-C + N_A \sin 30 - f_A . \cos 30 = 0$

$\therefore C = 2000 \sin 30 - 535.90 \cos 30$

$= 535.90 N$.

Consider block B

$\Sigma f_y = 0$

$N_B - 2000 \cos 60 - C \cos 30 = 0$

$N_B = 2000 \cos 60 + 535.90 \cos 30$

$= 1464.1 N$.

$f_B = 392.30 N$

$\Sigma f_x = 0$

$P - f_B - 2000 \sin 60 + C \sin 30 = 0$

$P = 392.30 + 2000 \sin 60 + 535.90 \sin 30$

$= 1856.40 N$.