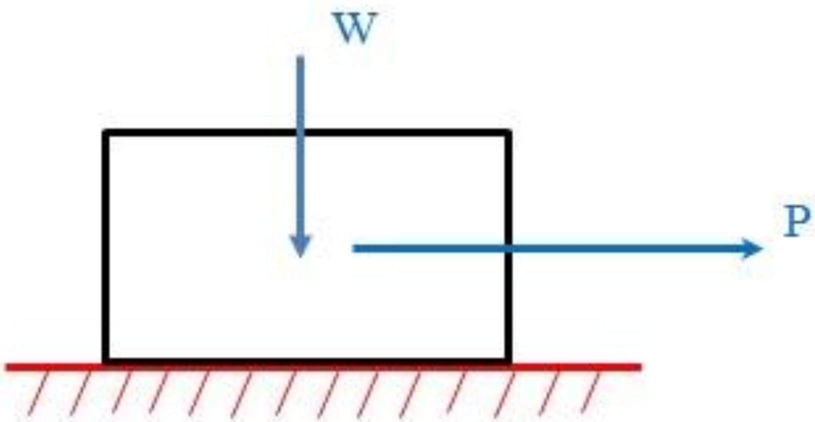
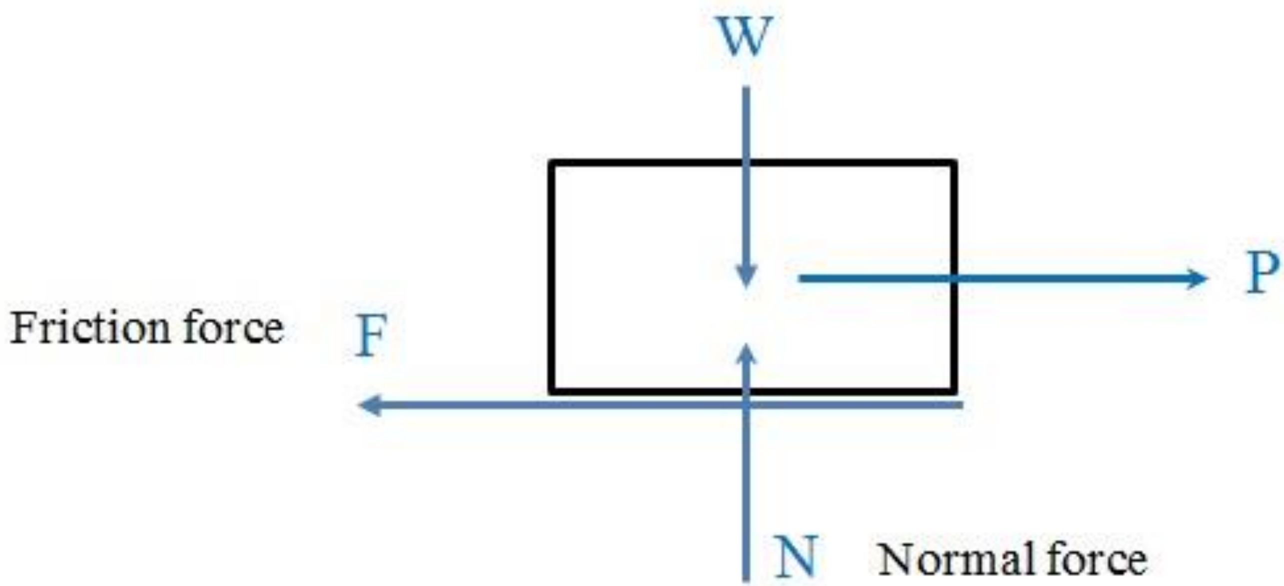
FRICTION

Dry Friction

1) The friction is always opposite to the direction of motion.
2) $F = M_s N$ only when motion is impending, where: M_s is static coefficient of friction.
3) When motion exists $F = M_k N$ = constant independent velocity, where: M_k is kinetic coefficient of friction. $M_k < M_s$ ($M_k \approx ¾ M_s$)
4) When there are no motion or impending motion $F \neq M_s N \neq M_k N$, F is computed from equilibrium.



Rough surface



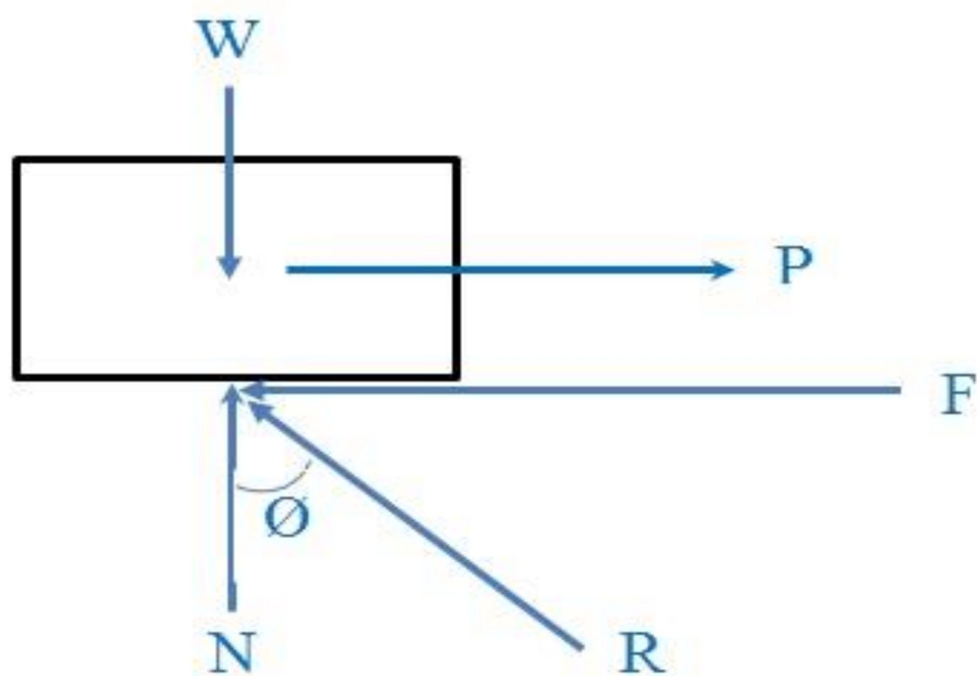
Angle of Friction Ø

Angle of friction is the angle between N & R, in the case of impending motion

$$\tan \emptyset_s = \frac{M_s \ N}{N} = M_s$$

In case of motion

$$\emptyset_k = tan^{-1} M_k$$



Types of Problems Involving Friction

1- Case of impending motion

Put $F = M_s N$ and solve for the unknown using equilibrium equations.

2- Case of steady motion

Put $F = M_k N$ and apply equilibrium equations to solve for the unknowns.

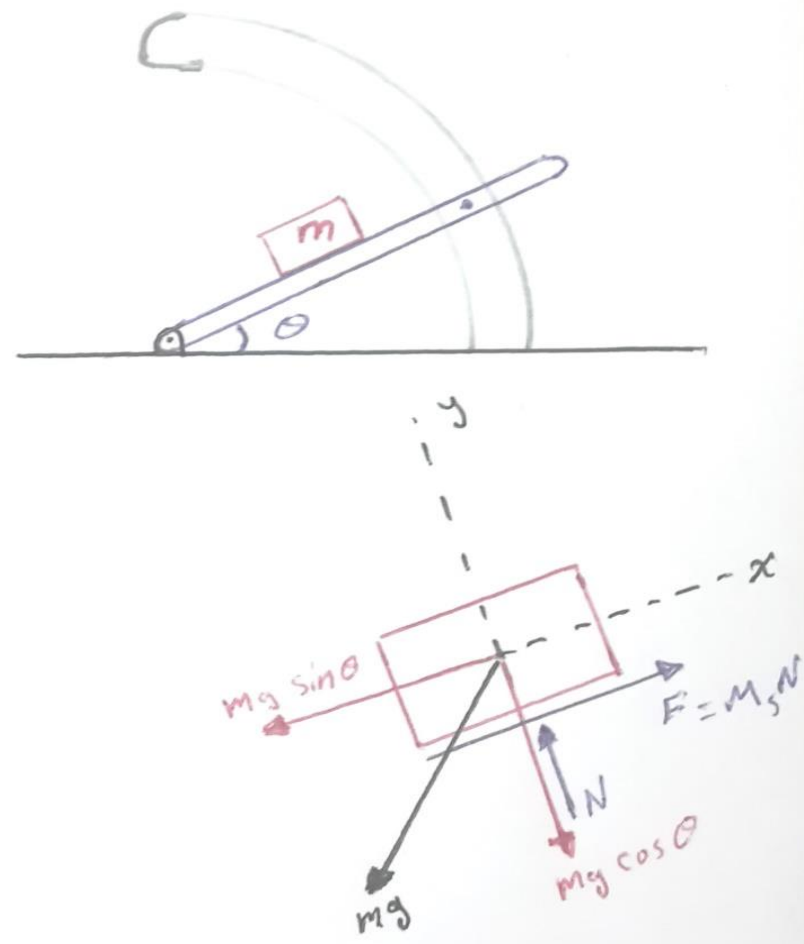
3- Unknown case (not clear the body is in equilibrium or in motion)

A. Denote the friction force by F
B. Assume equilibrium, find F
C. Compute $F^* = M_s N$

When $F < F^*$ the body is in equilibrium

But when $F > F^*$ the body is in motion, and the actual friction force is $F = M_k N$

Ex: Determine the maximum angle Ɵ before the block of mass m begins to slip, (M_s = 0.3).



Max Ɵ when motion impends

F = 0.3 * N

$$\sum F_x = 0 \; ; \qquad 0.3 * N - m * g * \sin\theta = 0$$

$$0.3 * N = m * g * \sin\theta \quad -------(1)$$

$$\sum F_y = 0 \; ; \qquad N - m * g * \cos\theta = 0$$

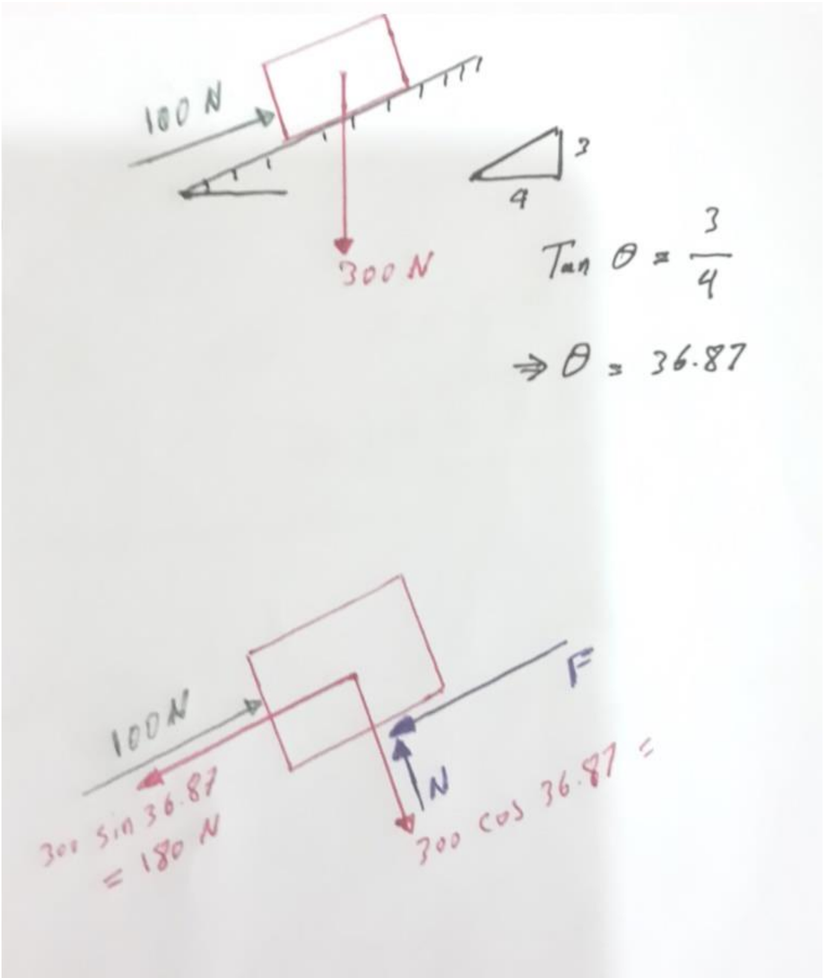
$$N = m * g * \cos\theta \quad -------(2)$$

$$\frac{0.3\, N}{N} = \frac{mg\sin\theta}{mg\cos\theta}$$

Tan Ɵ = 0.3

Then Ɵ = 16.7

Ex: Given M_s = 0.25 and M_k = 0.2 , determine whether the block is in equilibrium or not, also find the value of the friction force.



1) The friction force F
2) Assume equilibrium

$$\sum F_x = 0$$

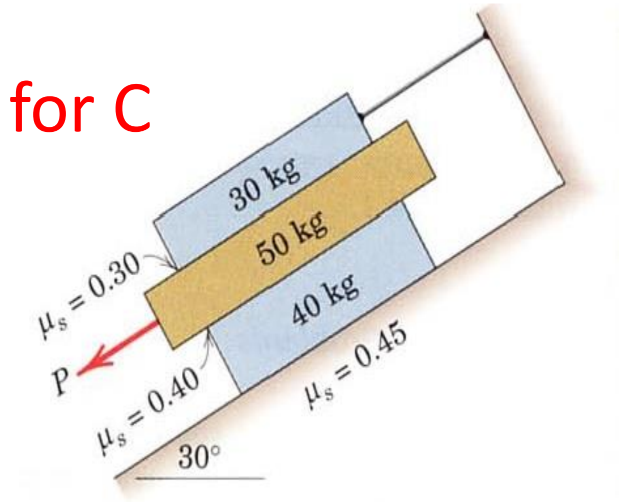
-F + 100 – 180 = 0
Then F = - 80 (N)
Tendency of motion is down
$F^* = M_s$ N

$$\sum F_y = 0$$

N = 300 cos 36.87
Then N = 240 (N)
$F^* = M_s$ N = 0.25 * 240 = 60 (N)
Since F > F^* the body is moving downwards,
then the friction force is F = M_k N
F=0.2 * 240 = 48 (N)

EX: Determine the max value of P before any slipping teak place.

m = 0.3 for A, m = 0.4 for B , m = 0.45 for C



<u>Solution</u>

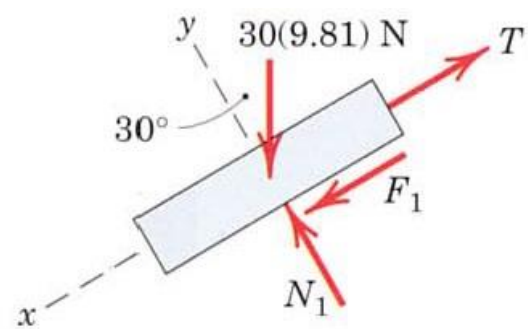
Impending motion $f = m_s N$

<u>Case (1)</u>

Block C fixed, block B impends motion

For block A

$\sum F_y = 0$; $N_1 = 30\ g \cos 30$ then $N_1 = 255$ (N)



For block B

$\sum F_y = 0$; $N_2 = N_1 + 50\ g \cos 30$

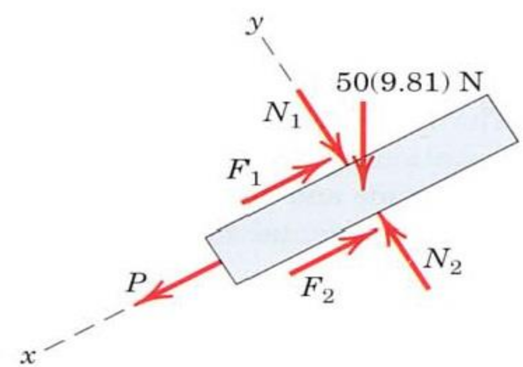
$= 255 + 50 * 9.81 * 0.866$

$N_2 = 680$ (N)

$\sum F_x = 0$; $P = 0.3\ N_1 + 0.4\ N_2 - 50\ g \sin 30$

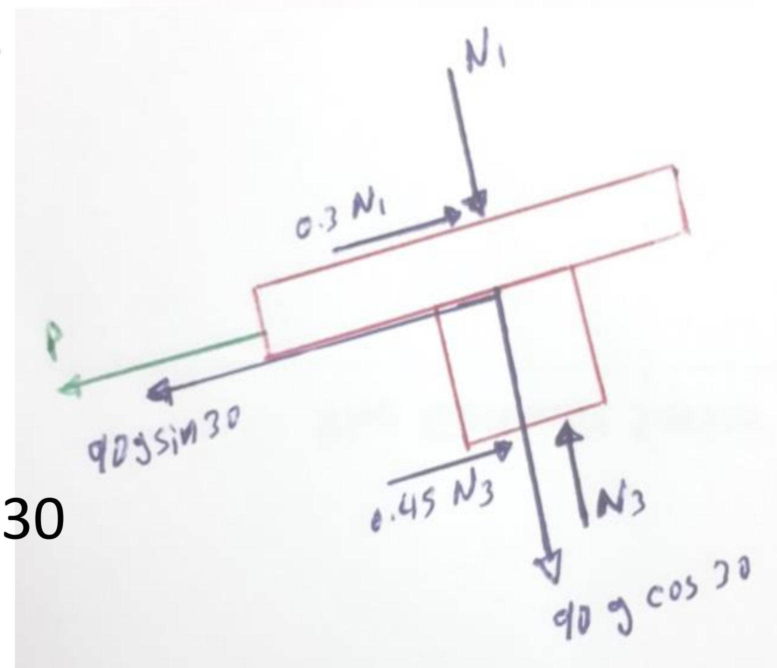
$= 0.3 * 255 + 0.4 * 680 - 50 * 9.81 * 0.5$

$P = 103.1$ (N)



Case (2)

Block B and C impend motion together



$\sum F_y = 0$; $N_3 = N_1 + 90\text{ g} \cos 30$

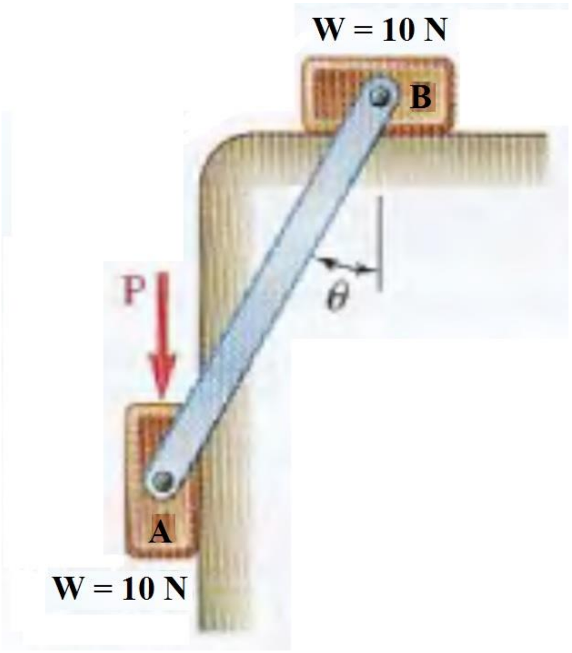
$= 1019.6$ (N)

$\sum F_x = 0$; $P = 0.3\ N_1 + 0.45\ N_3 - 90\text{ g} \sin 30$

$P = 93.8$ (N)

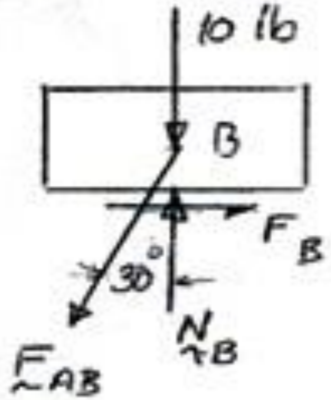
$P_{max} = 93.8$ (N)

Determine the smallest force **P** that made block **A** impending motion. The two blocks have a weight of W= 10 N , if the coefficients of static friction for all surfaces are μ_s = 0.3. Neglecting the rod weight, the rod angle is Ө =30º.

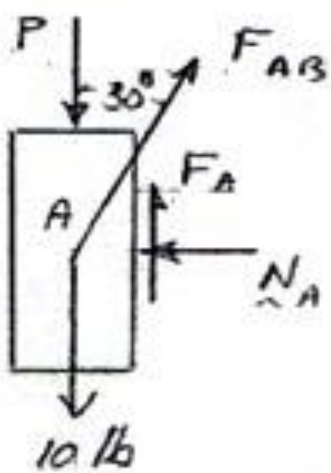


SOLUTION

FBD block B:



FBD block A:



(*b*) For P_{max}, motion impends at both surfaces

B: $\uparrow \Sigma F_y = 0$: $N_B - 10 \text{ lb} - F_{AB}\cos 30° = 0$

$$N_B = 10 \text{ lb} + \frac{\sqrt{3}}{2}F_{AB} \quad (1)$$

Impending motion: $F_B = \mu_s N_B = 0.3N_B$

$\rightarrow \Sigma F_x = 0$: $F_B - F_{AB}\sin 30° = 0$

$$F_{AB} = 2F_B = 0.6N_B \quad (2)$$

Solving (1) and (2) $N_B = 10 \text{ lb} + \frac{\sqrt{3}}{2}(0.6N_B)$

$$= 20.8166 \text{ lb}$$

Then $F_{AB} = 0.6N_B = 12.4900 \text{ lb}$

A: $\rightarrow \Sigma F_x = 0$: $F_{AB}\sin 30° - N_A = 0$

$$N_A = \frac{1}{2}F_{AB} = \frac{1}{2}(12.4900 \text{ lb}) = 6.2450 \text{ lb}$$

Impending motion: $F_A = \mu_s N_A = 0.3(6.2450 \text{ lb}) = 1.8735 \text{ lb}$

$\uparrow \Sigma F_y = 0$: $F_A + F_{AB}\cos 30° - P - 10 \text{ lb} = 0$

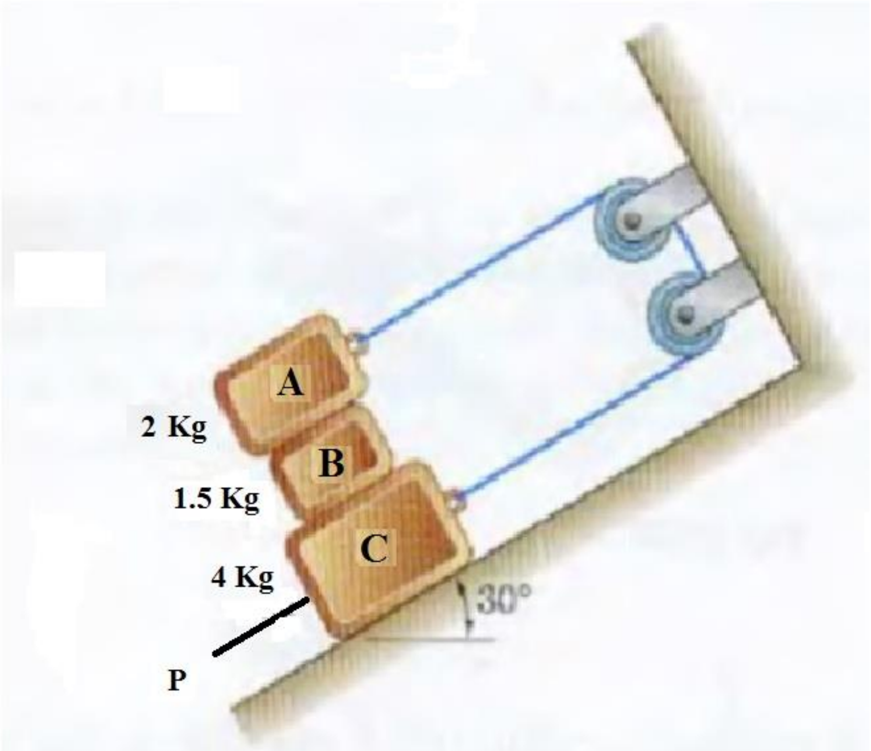
$$P = F_A + \frac{\sqrt{3}}{2}F_{AB} - 10 \text{ lb}$$

$$= 1.8735 \text{ lb} + \frac{\sqrt{3}}{2}(12.4900 \text{ lb}) - 10 \text{ lb} = 2.69 \text{ lb}$$

$P = 2.69$ lb ◀

Since $P = 2.69$ lb to initiate motion,

For the figure below, determine the minimum value of P that makes block C sliding down. The coefficient of friction between all surfaces is 0.4 .



Case (1) A&B moves up and C move down

N1 = 29.74 N
F1= 11.9 N
T=29.1 N
N2=63.72 N
P=45.88 N

Case (2) A moves up and C&B move down

N1 = 17 N
F1= 6.8 N
T=16.6 N
N2=63.73 N
P=21.9 N

H.W :

Chapter 6:

3, 5, 7, 8,22, 24