الكورس الاول
السعـر/

محاضرة / -6-
التاريخ /

Engineering Mechanics

الميكانيك الهندسي

لطلبة الدراسات الاولية

المرحلة الاولى
قسم الهندسة الموارد المائية

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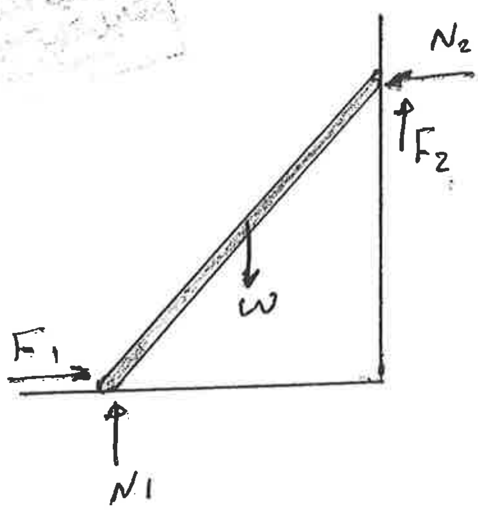
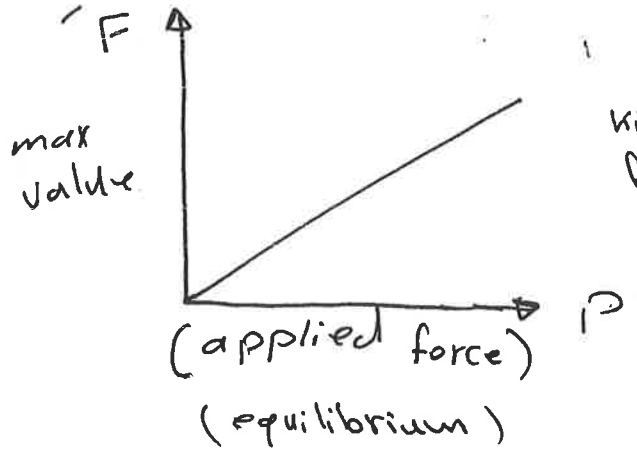
FRICTION

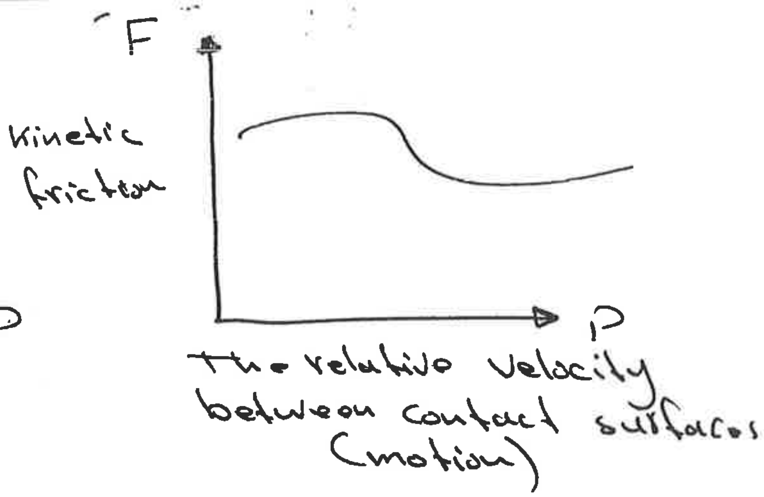
- is the force tangent to the contact surface which resists the motion, or the tendency toward motion of one body relative to the other.

- In actual practice, if the contact surface is not smooth, so, the reaction of one body on the other is not normal to the contact surface. This reaction is resolved into two components, one perpendicular and the other tangent to the contact surface (frictional force).

Note: free-body diagrams for problems involving friction must include a frictional force tangent to the contact surface







frictional force between two bodies will increase as the force tending to cause sliding

The max static frictional force $\bar{F}$ is $>$ the kinetic frictional force

Law of Friction

1- The max frictional force $\bar{F}$ is proportional to the normal force (N)

2. The max frictional force is independent of the size of the contact area.

3. The kinetic frictional force is independent of the velocity of the bodies in contact.

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Coefficient of Friction:.

The coefficient of static friction, μ, is define as the ratio of the magnitude of the max. stat. frictional force, $\acute{F}$, to the magnitude of the normal force, N, between the two surfaces.

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

Surfaces in Contact	μ
steel on steel	0.4 - 0.8
metal on stone	0.3 - 0.7
wood on wood	0.2 - 0.5
Rubber on concrete	0.6 - 0.8

* The coefficient of kinetic friction is less than the coefficient of static friction.

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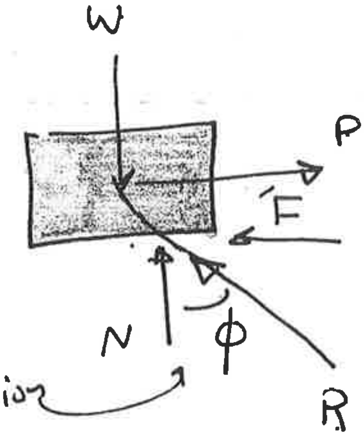
Angle of Friction

from the fig



$N = R\cos\phi$, $R\sin\phi = \acute{F}$

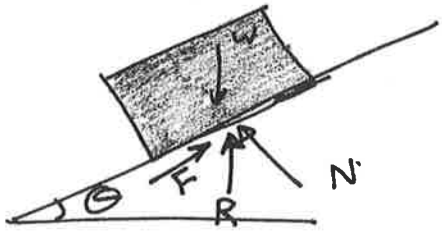
$\tan\phi = \frac{\acute{F}}{N} = \mu$

angle of friction

(The block has impending motion)

If the angle (θ) increased to same limiting value. The block will move down the plane. The angle at which motion of the block impends is called the angle of repose

(the block is in equil if the angle θ is small angle)



From the equation of equilibrium.

$N = W\cos\theta$. $F = \acute{F} = W\sin\theta$, $\tan\theta = \frac{\acute{F}}{N} = \mu$

Note: The angle of friction is equal to the angle of repose.

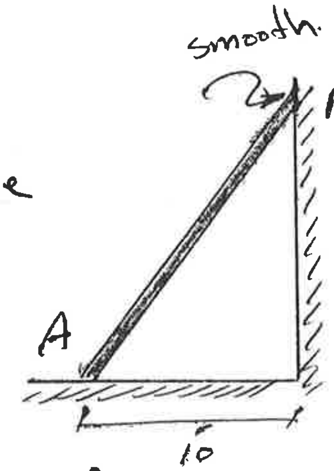
Types of problems Involving frictional forces:

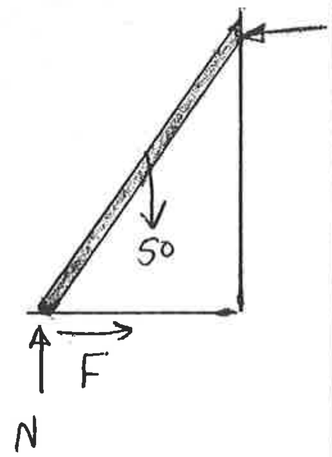
1. Impending motion is not assured
2. Impending motion is specified at all contact surfaces
3. Impending motion is known to exist, but either the type of impending movement (slipping or tipping) is not specified.

Ex:- Determine the frictional force at A acting on the ladder.

ladder weighs 50 N

$\mu = .3$ between the ladder and floor.





Solution:

$\uparrow \sum F_y = 0$

$N - 50 = 0 \Longrightarrow N = 50\,N \uparrow$

$\sum M_B = 0$ (+)

$24\,F + 5(50) - 10(50) = 0$

$F = 10.42\,N \longrightarrow$

$\bar{F} = \mu N = 0.3(50) = 15 N$

since $F < \bar{F}$

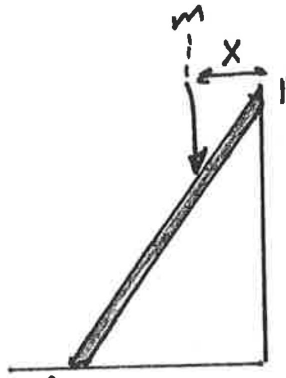
$\therefore$ the ladder is in equilibrium.

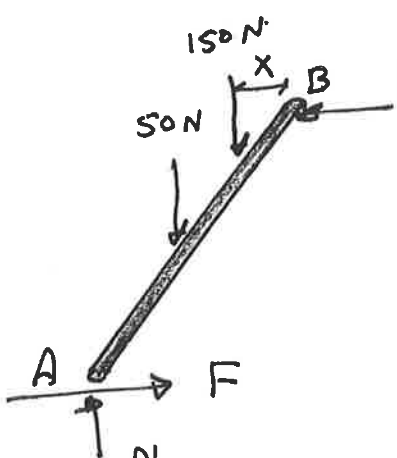
Procedure for type (1)

1- Assume the system to be in equilibrium
2. Determine F & N
3. Compar F with $\bar{F} = \mu N$

If $F < \bar{F}$ assumption is correct
If $F > \bar{F}$ equilibrium does not exist.

Ex:- A 150 N man starts to climb the ladder
Determine the distance X when the ladder starts
to slip.





since motion impends

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

$\therefore F = \bar{F} = 0.3 * 200 = 60\ N.$

$\sum F_y = 0 \uparrow +$

$N - 50 - 150 = 0$

$\therefore N = 200\ N \uparrow$

$\sum M_B = 0 \circlearrowleft +$

$X(150) + 5(50) - 10(200) + 24(60) = 0$

$\therefore X = 2.07$ (distance from wall)

Procedure for Type 2

1. write the equation $F = \bar{F} = \mu N$ for all surfaces when motion impends. make sure that the sense of friction force is correct.

2. Determine the unknown quantities by using equations of equilibrium & friction equations.

Ex:- Determine the distance x when motion of the ladder impends.

$\mu_2 = 0.2$ between B and the vertical wall

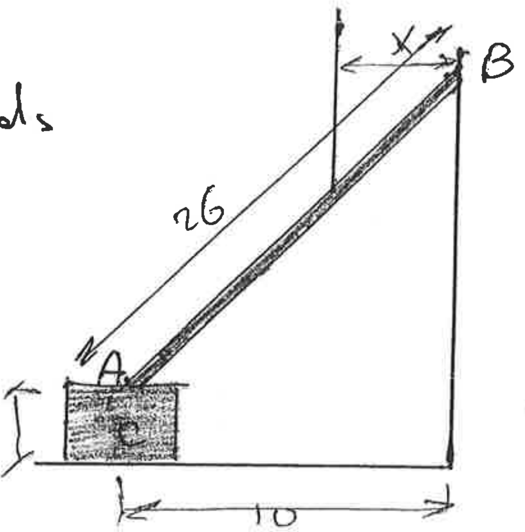
$\mu_2 = 0.35$ between A and the box c.

$\mu_3 = 0.25$ between C and the floor.

Box C weighs 100 N

<u>Solution</u>

let assum that motion impends at A and B (1)



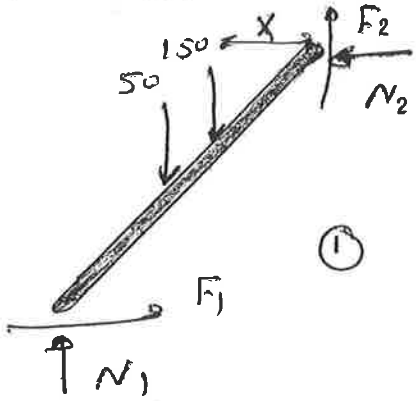
$\therefore F_1 = F_1 = \mu_1 N_1 = 0.35 N_1$

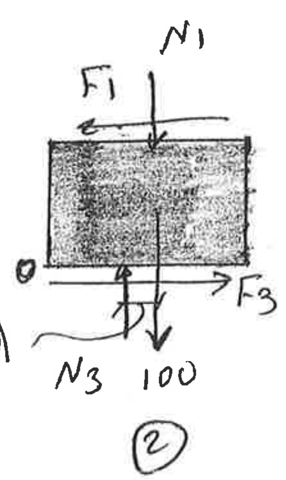
$F_2 = F_2 = \mu_2 N_2 = 0.2 N_2$

$\sum F_x \xrightarrow{+} = 0$

$F_1 - N_1 = 0$

$\therefore N_2 = F_1 = 0.35 N_1$





$\sum F_y = 0 \uparrow$

$N_1 + F_2 - 50 - 150 = 0$

$N_1 + 0.2 N_2 = 200$

$N_1 + 0.2(0.35 N_1) = 200$

$\therefore N_1 = 186.9 N$

$\therefore \bar{F}_1 = 0.35(186.9) = 65.4\ N$

To check the assumption that (motion does not impend between C and the floor) (2)

$+\uparrow \Sigma F_y = N_3 - 186.9 - 100 = 0$

$\therefore N_3 = 286.9\ N \uparrow$

$\xrightarrow{+} \Sigma F_x = 0$

$F_3 - 65.4 = 0 \implies F_3 = 65.4\ N \longrightarrow$

$\bar{F}_3 = \mu_3 N_3 = 0.25(286.9) = 71.7\ N$

since $F_3 < \bar{F}_3$ $\therefore$ the assumption is correct and the box will not slip

- To check the assumption that block C does not tip over.

$\Sigma M_o = 0$ $\circlearrowright +$

$N_1(2) + 100(2) - F_1(2) - N_3(2-d) = 0$

$d = 0.4559$ cm

or $N_3(d) - \bar{f}_1(2) = 0$

$286.9(d) - 65.4(2) = 0$

$\therefore d = 0.4559$ cm

since $d < 2$ $\therefore$ the box C will not tip over.

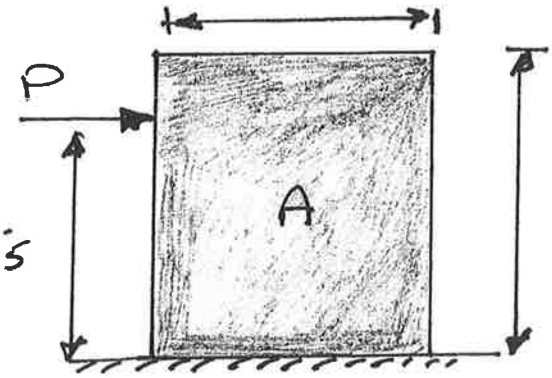
The distance X can be determined as follows:-

$\Sigma M_B = 0$ ↻+

$$X(150) + 5(50) + 24(65.4) - 10(186.9) = 0$$

$$\therefore X = 0.329 \text{ cm}.$$

EX:- The solid 400-lb block A is shown in the fig. $\mu = 0.34$ between the block and the horizontal plane. Determin the force (P) which will cause motion of A to impend.

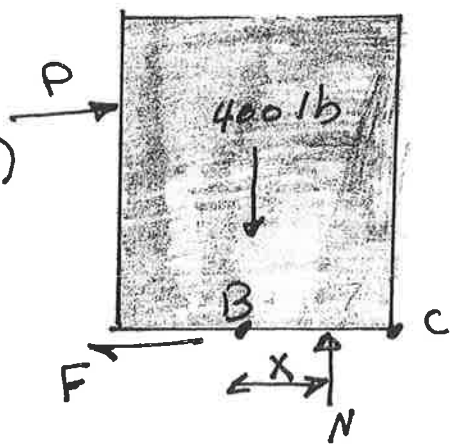


Solution

- if tipping is assumed, N will act C and P can be determined as following:-

$$\overset{+}{\curvearrowright}\Sigma M_C = 25P - 10(400) = 0$$

$\therefore P = 160$ lb (To tip body A)



If slipping is assumed, P can be determin as following:-

$\sum F_y = 0 \uparrow +$

$N - 400 = 0 \Longrightarrow N = 400 \text{ lb} \uparrow$

$F = \bar{F} = \mu N = 0.3(400) = 136 \text{ lb}$

$\sum F_x = 0 \xrightarrow{+}$

$P - 136 = 0 \quad \therefore \quad P = 136 \text{ lb}$ (To make body A slip)

$\therefore$ The force to cause impending motion is

$136 \text{ lb} \rightarrow$

Procedure for Type (3)

1. Set $F = \bar{F} = \mu N$ at the surfaces where sliding is assumed or place N at the corner about which the body is assumed to tip. At all other surfaces motion is assumed not to impend.

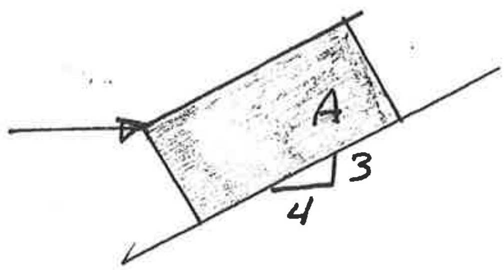
2. Determine the frictional and normal forces at all surfaces where motion is assumed not to impend.

3. check the initial assumption by comparing F and $\bar{F}$ all surfaces when slipping was assumed not to impend. or check the Position of N when tipping was assumed not to impend.

5.1 Body A weighs 200 N, $\mu = .4$ between A and the plane. Determin the frictional force on the block.

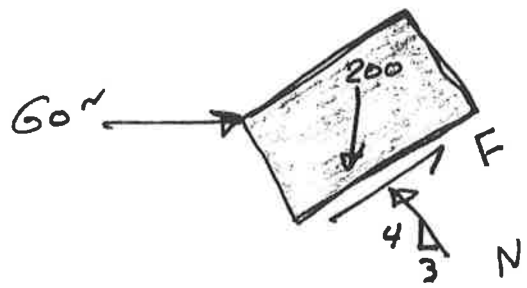
Soln::

Assume A is in equilibrium



$\Sigma F_y = 0 \uparrow +$

$-200 + F \cdot \frac{3}{5} + N \cdot \frac{4}{5} = 0$



$0.8 N = 200 - 0.6 F$

$N = 250 - 0.75 F$

$\Sigma F_x = 0 \xrightarrow{+}$

$60 + 0.8 F - N\, 0.6 = 0$

$60 + 0.8 F - 0.6 (250 - 0.75 F) = 0$

$1.25 F = 90$

$\therefore F = 72 \text{ N}$

$N = 250 - 0.75 (72) = 196 \text{ N}$

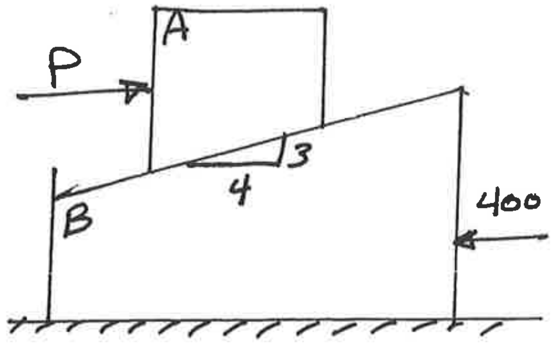
The max. value of frictional force $\bar{F} = \mu N$

$= 0.4 (196)$

$= 78.4 \text{ N}$

$\because F < \bar{F}$ $\therefore$ The assumption is correct, or A is in equilibrium and the frictional force is 72 N

5.5 A weighs 1000 N, B weighs 2000 N, $\mu = 0.2$ between A and B, $\mu = 0.1$ between B and the surface. Determin the max. Value of the force (P) for which body A will be in equilibrium.



* A impends motion on body B. downword

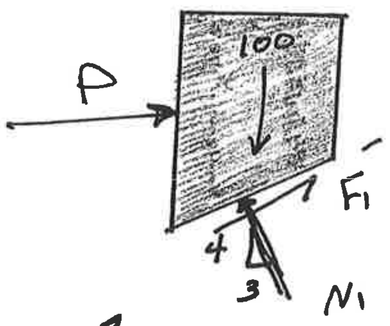
$\bar{F}_1 = \mu N_1$
$= 0.2 N_1$

$\sum F_y = 0 \uparrow +$

$N_1 * \frac{4}{5} + \bar{f}_1 \frac{3}{5} - 1000 = 0$

$0.8 N_1 + 0.6(0.2 N_1) = 1000$

$N_1 = 1086.95$



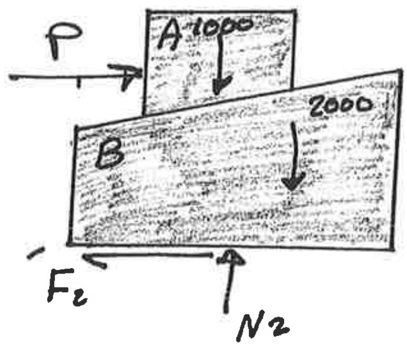
$\bar{F}_1 = 0.2(1086.95) = 217.39$

$\sum F_x = 0 \xrightarrow{+}$

$P + \bar{F} \frac{4}{5} - N_1 \frac{3}{5} = 0$

$\therefore P = 478.25 \, N.$

$\therefore$ A and B impend motion on the horizontal surface.



$\Sigma F_y = 0 \quad \uparrow +$

$N_2 = 1000 + 2000 \Longrightarrow N_2 = 3000 \uparrow$

$\bar{F}_2 = 0.1(3000) = 300\ N \leftarrow$

$\Sigma F_x = 0 \quad \xrightarrow{+}$

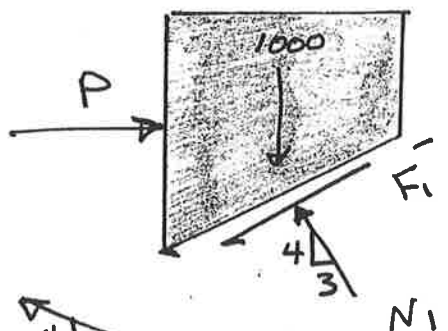
$P - 300 - 400 = 0 \Longrightarrow P = 700\ N \rightarrow$

$\therefore$ $P = 700\ N$ is the max. Value for which A will be in equilibrium.

motion A impends on body B upward.

$\bar{F}_1 = .2 N_1$

$\Sigma F_y = 0 \quad \uparrow +$



$0.8 N_1 - 1000 - 0.6 \bar{F}_1 = 0$

$0.8 N_1 - 0.6(.2 N_1) = 1000$

$N_1 = \dfrac{1000}{.68} = 1470.588\ N$ (4, 3)

$\bar{F}_1 = 294.11\ N$ (3, 4)

$\Sigma F_x = 0 \quad \xrightarrow{+}$

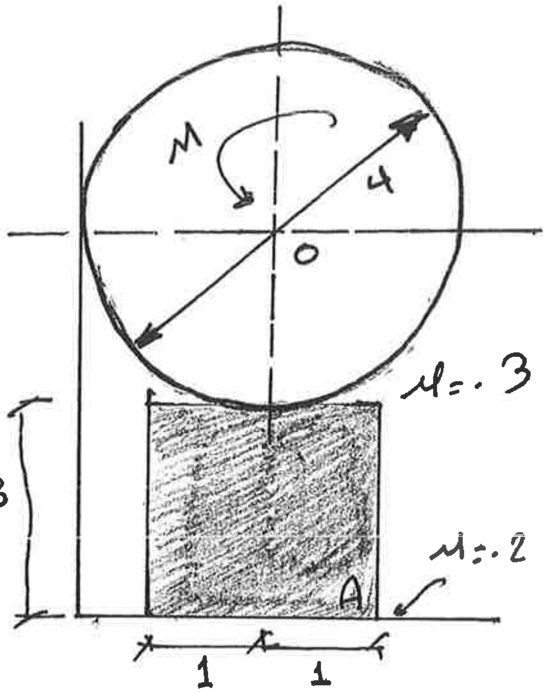
$P - N_1(.6) - (.8)\bar{F}_1 = 0$

$P - 1470.588(0.6) - (0.8)(294.11) = 0$

$P = 1117.64\ N \longrightarrow$

5.34 Determin the min. moment (M) necessary to rotate the cylinder counter clockwise.

1. The cylinder has impending rotation counterclockwise.



$\Sigma F_x = 0 \Longrightarrow N_1 = .3 N_2$

$\Sigma F_y = 0 \Longrightarrow .3N_1 + N_2 = 600$

$.3(.3N_2) + N_2 = 600$

$N_2 = 550.45$

$\therefore N_1 = 165.135$

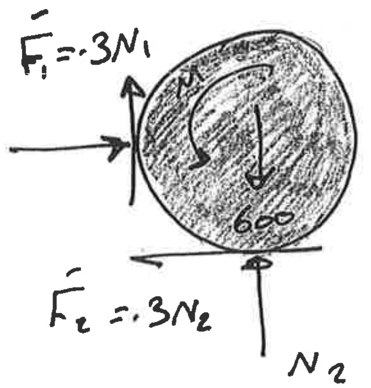
$\bar{F}_2 = .3N_2 = 165.135$

$\Sigma M_o = 0$

$m = \bar{F}_1(2) + \bar{F}_2(2)$

$= 2(.3)(165.135) +$

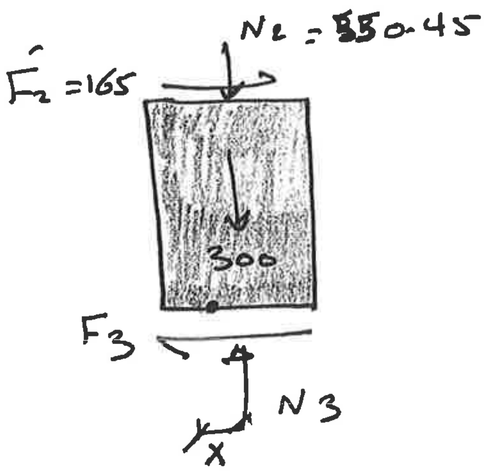
$2(.3)(550.45) = 429.35$



-check slipping of A

$\Sigma F_y = 0$

$N_3 = 300 + 550.45 = 850.45$



$\Sigma F_y = 0$

$F_3 = \bar{F}_2 = 165.135$

$\bar{F}_3 = .2(N_3) = .2(850.45)$
$= 170.09$

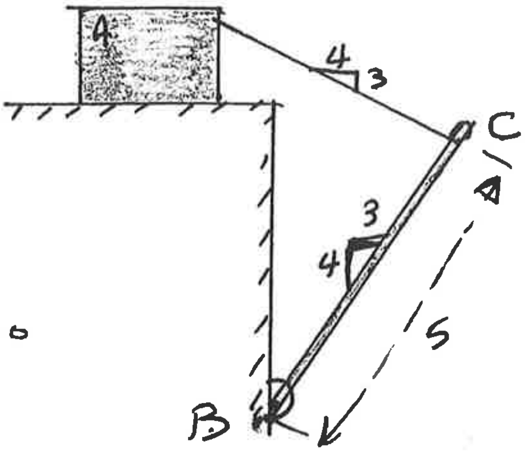
$\therefore F_3 < \bar{F}_3 \quad \therefore$ ok

(148)

5.6 A weighs 50 N. $\mu = .5$ between A and the plane, BC weighs 100 N. Determin the forces acting on body A.

Solution

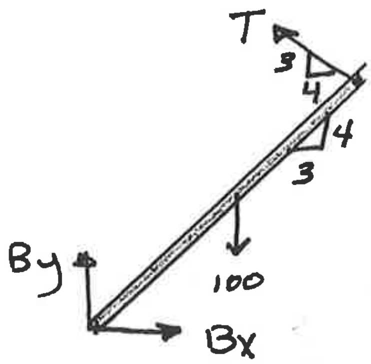
Assume A is in equilibrium



$\Sigma M_B = 0$ +

$T_c(5) - [100(2.5)(0.6)] = 0$

$T_c = 30$



$\Sigma F_y = 0$ $\uparrow +$

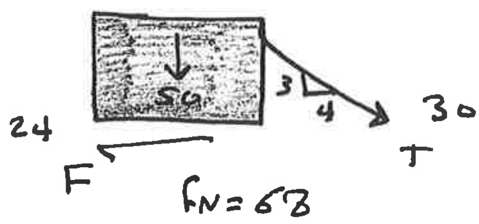
$N - 50 - 30(0.6) = 0$

$N = 68N \uparrow$

$\Sigma F_x = 0$ $\xrightarrow{+}$

$-F + 30(.8) = 0$

$F = 24$



The max frictional force is

$\bar{F} = \mu N = 0.5(68) = 34\ N$

$\because$ $F < \bar{F}$ $\therefore$ The assumptio is correct

or A is in equilibrium