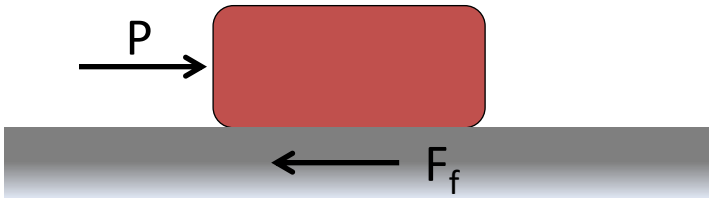
FRICTION:

- The force that against motion

CHAPTER

8

FRICTION



P = Motion force

F_f = Friction force

Friction → Dry Friction

Friction → Fluid Friction

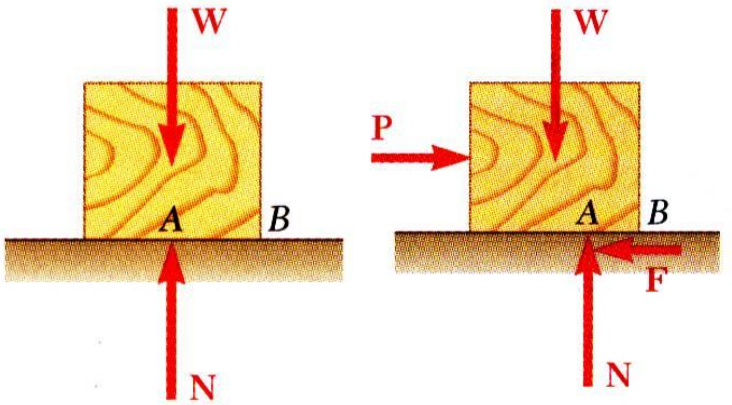
There are two types of friction: *dry* or *Coulomb friction* and *fluid friction*. Fluid friction applies to lubricated mechanisms. The present discussion is limited to dry friction between non-lubricated surfaces.

- In preceding chapters, it was assumed that surfaces in contact were either *frictionless* (surfaces could move freely with respect to each other).

- Actually, no perfectly frictionless surface exists. For two surfaces in contact, tangential forces, called *friction forces*, will develop if one attempts to move one relative to the other.

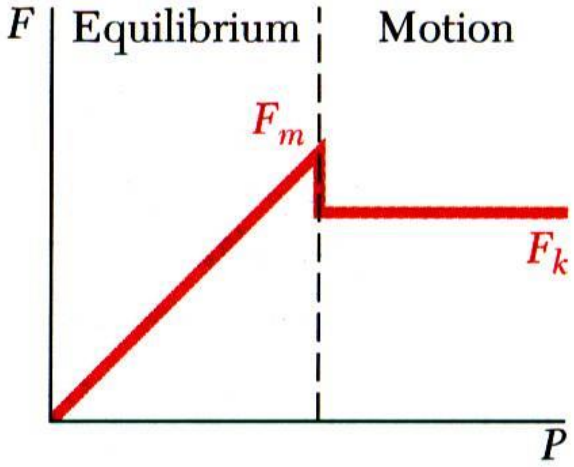
- However, the friction forces are limited in magnitude and will not prevent motion if sufficiently large forces are applied.

- The distinction between frictionless and rough is, therefore, a matter of degree.



- Block of weight *W* is placed on a horizontal surface. Forces acting on the block are its weight and reaction of surface *N*.

- Small horizontal force *P* is applied. For the block to remain stationary, in equilibrium, a horizontal component F_f of the surface reaction is required. F_f is a *static-friction force*.



- As *P* increases, the static-friction force *F* increases as well until it reaches a maximum value F_m.

$$F_m = \mu_s N$$

- Further increase in P causes the block to begin to move as *F* drops to a smaller *kinetic-friction force* F_k.

$$F_k = \mu_k N$$

Table 8.1. Approximate Values of Coefficient of Static Friction for Dry Surfaces

Metal on metal	0.15–0.60
Metal on wood	0.20–0.60
Metal on stone	0.30–0.70
Metal on leather	0.30–0.60
Wood on wood	0.25–0.50
Wood on leather	0.25–0.50
Stone on stone	0.40–0.70
Earth on earth	0.20–1.00
Rubber on concrete	0.60–0.90

- Maximum static-friction force:

$$F_m = \mu_s N$$

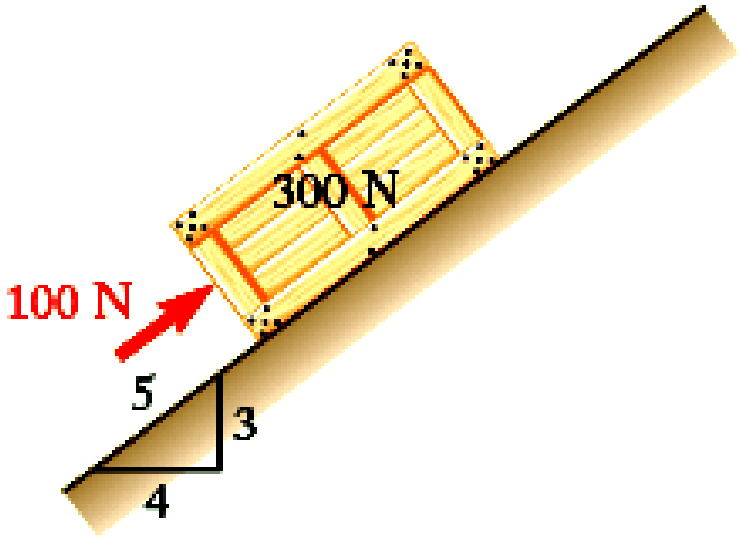
- Kinetic-friction force:

$$F_k = \mu_k N$$

$$\mu_k \cong 0.75\mu_s$$

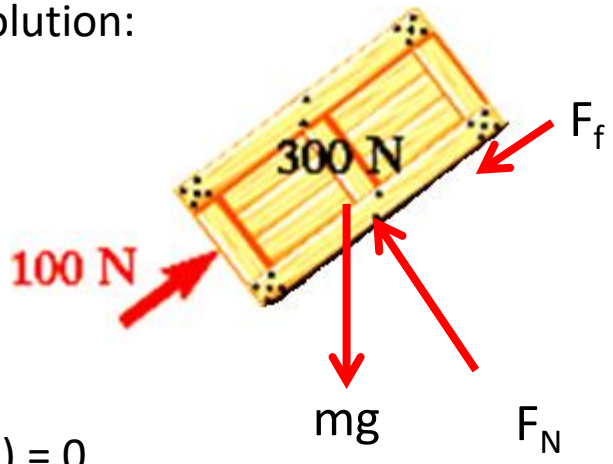
- Maximum static-friction force, F_m and kinetic-friction force, F_k are:
  - proportional to normal force
  - dependent on type and condition of contact surfaces
  - independent of contact area

CATEGORY 1 – Determine whether the body is equilibrium or in motion



Ex. 1: A 100 N force acts as shown on a 300 N block placed on an inclined plane. The coefficients of friction between the block and plane are U_s = 0.25 and U_k = 0.20. Determine whether the block is in equilibrium and find the value of the friction force.

Solution:



Assume the block is about to move incline the plane.

$\sum F_x = 0$; (↗)

$100N - F_f - 300(\sin 36.86) = 0$

$F_f = -80N$

$F_f = 80N$ (↗) → -ve means that the block is opposite motion. It is moving down the plane. 80N needed to oppose the block from moving down the plane.

$\sum F_y = 0$; (↖)

$F_N - 300N(\cos 36.86) = 0$

$F_N = 240N$

$F_m = \mu_s F_N$

$= 0.25\ (240N)$

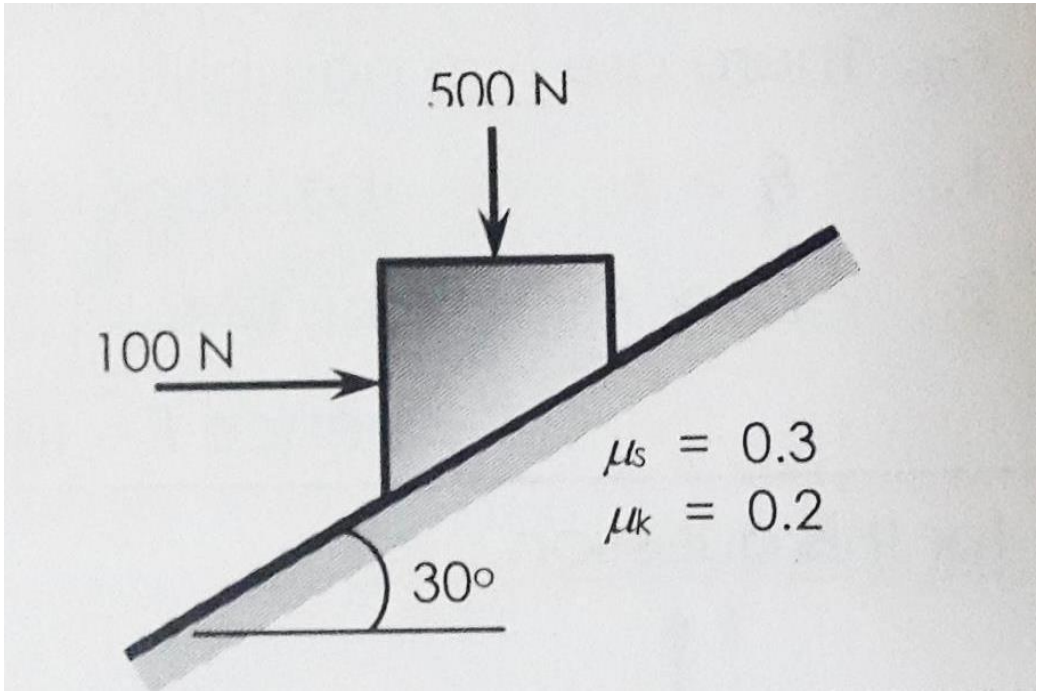
$= 60N$ → Max static friction owned by the block and contacting surface is 60N. Not enough because the total friction force needed to oppose the block from moving or maintain in equilibrium is 80N. Thus, the block is <u>moving down</u>, not equilibrium. $F_m < F_f$

$F_{factual} = \mu_k F_N$

$= (0.2)\ (240N)$

$= 48N$ (↗)

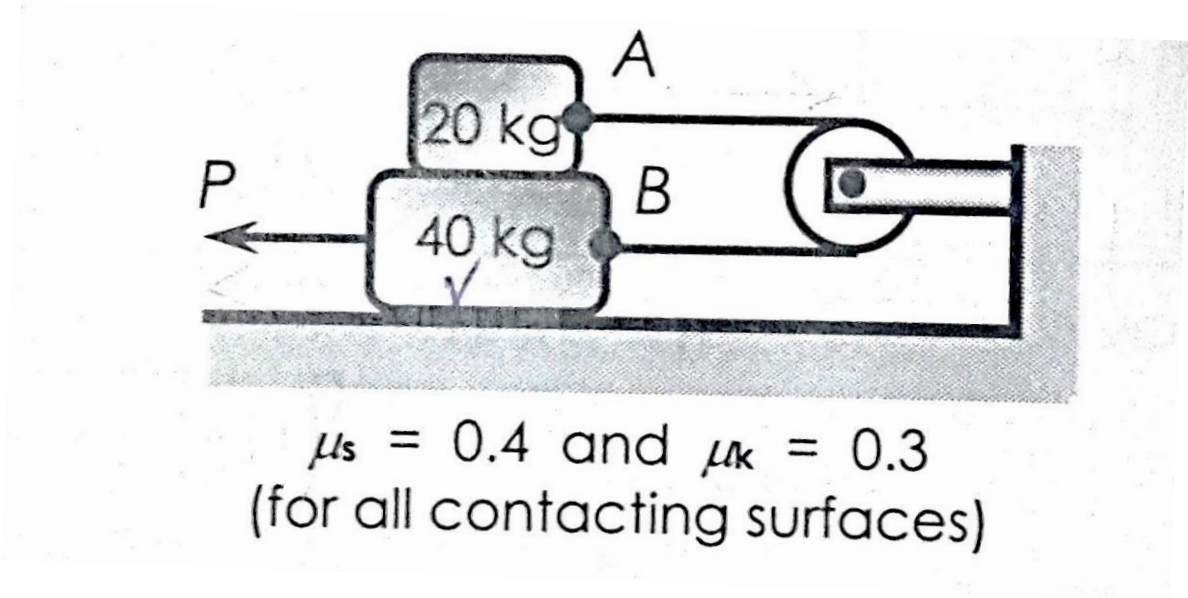
Ex. 2: Determine whether the block is in equilibrium or in motion. Hence, find the magnitude and direction of the friction force.



Ans: Block is moving down.

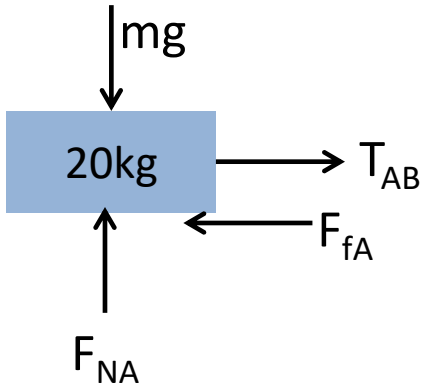
$F_{factual}$ = 96.6N (↗)

CATEGORY 2 – Friction involving two or more bodies



Ex. 3: Determine the value of P to start moving the 40kg mass.

Solution:



Better to solve separately because solve together block might not be solved.

$\sum F_y = 0$; (↑)

$F_{NA} - mg = 0$

$F_{NA} = (20kg)\ (9.81\ m/s^2)$

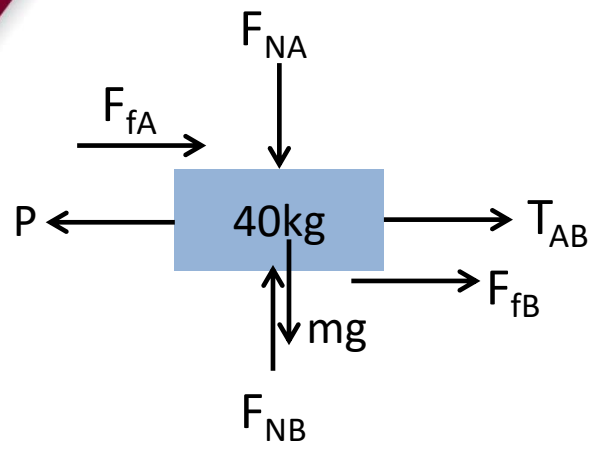
$= 196.2N$

$\sum F_x = 0$; (→)

$T_{AB} - F_{fA} = 0$

$T_{AB} - 0.4F_N = 0$

$T_{AB} = 78.48N$



$\sum F_y = 0; (\uparrow)$

$- F_{NA} - mg + F_{NB} = 0$

$196.2N - (40kg)(9.81m/s2) + F_{NB} = 0$

$F_{NB} = 588.6N$

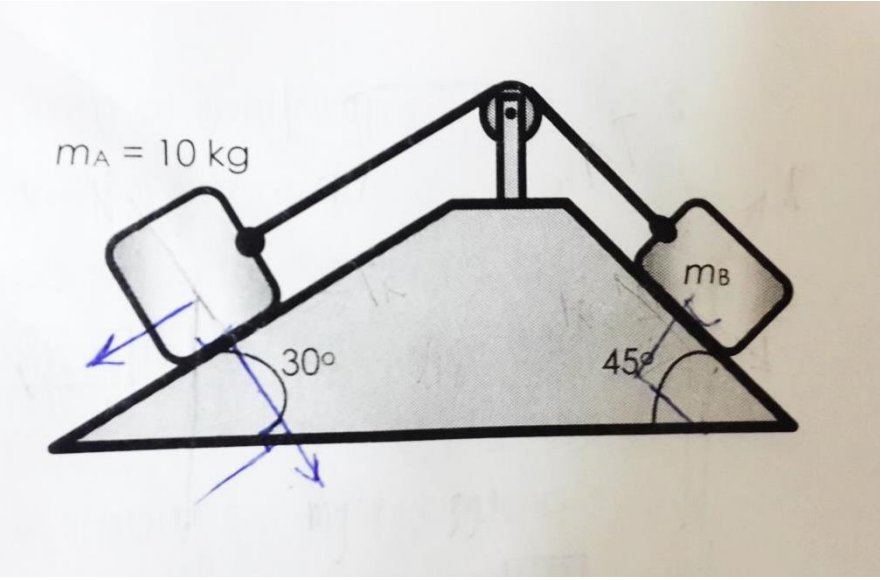
$\sum F_x = 0; (\rightarrow)$

$F_{fA} + TAB + F_{fB} - P = 0$

$\mu_s F_{NA} + 78.48N + \mu_s F_{NB} - P = 0$

$0.4 (196.2N) + 78.48N + 0.4 (588.6N) - P = 0$

$P = 392.4N$

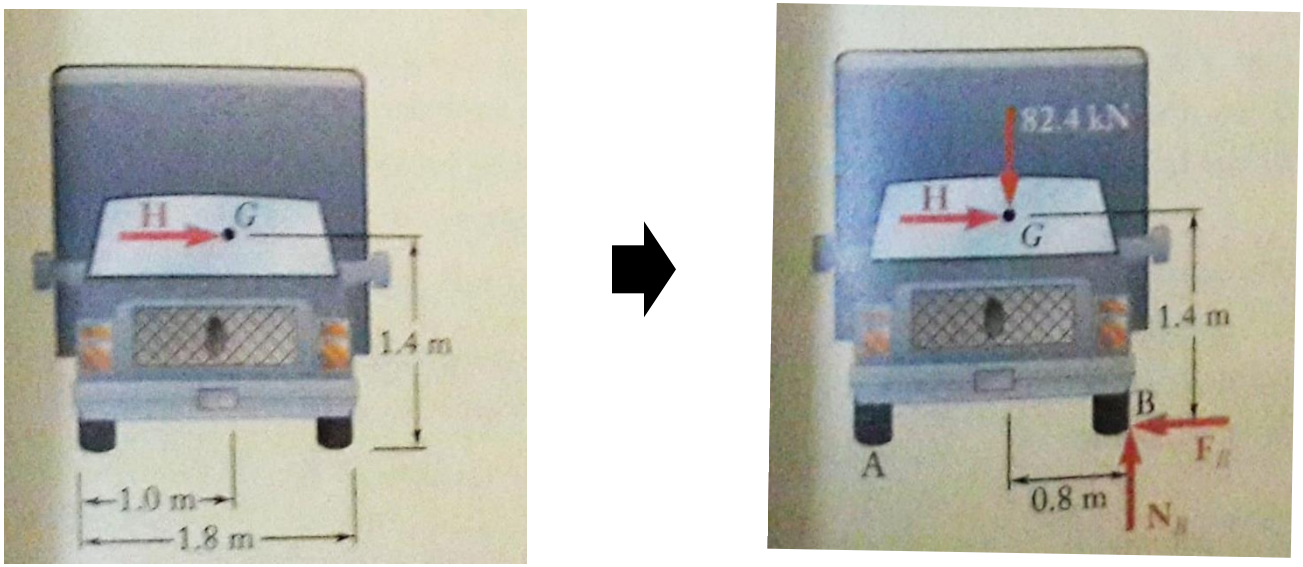


Ex. 4: Two blocks, a 10 kg mass, m_A and m_B are connected by cable on the incline planes as shown. If the coefficient of statics friction between all contacting surfaces, $\mu_s = 0.3$, determine the mass m_B such that :

(a) Mass m_A on the verge moving up the 30^o incline.
(b) Mass m_A is on the verge of moving down the 30^o incline.

(a) $m_B = 15.35kg$
(b) $m_B = 2.62kg$

CATEGORY 3 – Tipping or impending motion: The block is tilt or slide

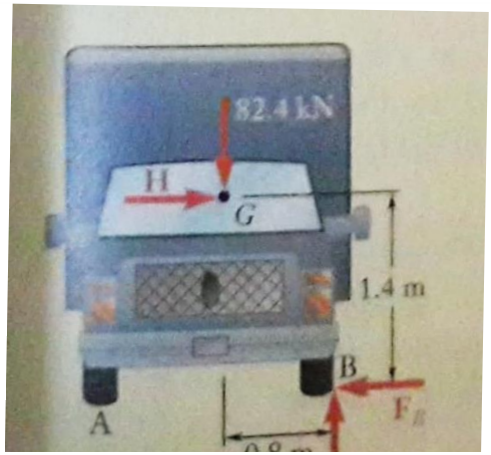


Ex. 5: A 8400kg truck is travelling on a level horizontal curve, resulting in an effective lateral force H (applied at the center of gravity, G of the truck). Treating the truck as a rigid system with the center of the gravity shown, determine:

(a) The maximum force, H before tipping of the truck can occur

(b) The minimum μs between tires and road-way such the slipping does not occur before tipping

Solution:



Assume the body is tilt at B due to force H, no normal force and friction at A.

+ve

$\sum M_B = 0;$

$82.4kN\ (0.8m) - H\ (1.4m) = 0$

$H = 47.09kN\ (\rightarrow)$

$\sum F_x = 0;$

$H - F_{fB} = 0$

$F_{fB} = 47.09kN\ (\leftarrow)$

$\sum F_y = 0;$

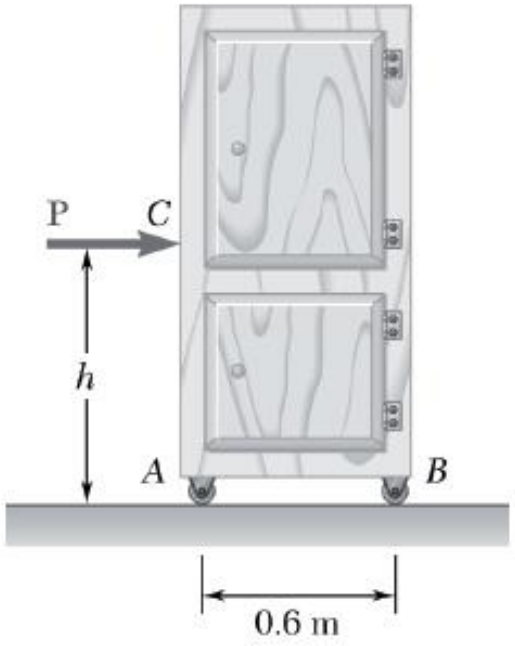
$-82.4kN + F_{NB} = 0$

$F_{NB} = 82.4kN\ (\uparrow)$

$Fm = \mu_s F_{NB}$

$47.09kN = \mu_s\ (82.4kN)$

$\mu_s = 0.571$



Ex. 6: A 480-N cabinet is mounted on casters that can be locked to prevent their rotation. The coefficient of static friction between the floor and each caster is 0.30. Assuming that the casters at both *A* and *B* are locked, determine:

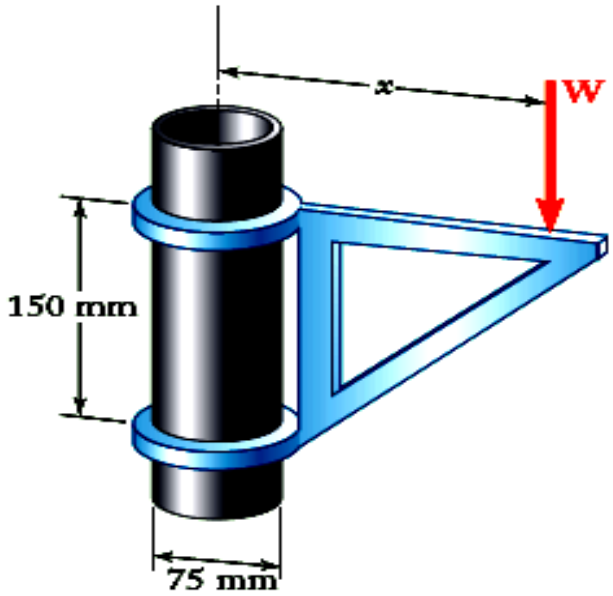
(a) The force **P** required to move the cabinet to the right

(b) The largest allowable value of *h* if the cabinet is <u>not</u> to tip over.

(a) P = 144N

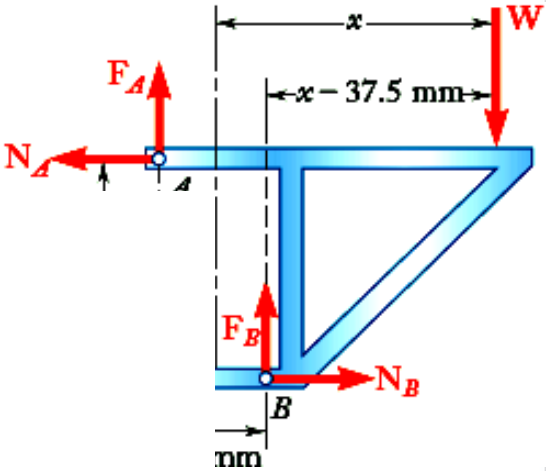
(b) h = 1m

CATEGORY 4 – Determine required quantity



Ex 7.: The moveable bracket shown may be placed at any height on the 75mm. diameter pipe. If the coefficient of friction between the pipe and bracket is 0.25, determine the minimum distance *x* at which the load can be supported. Neglect the weight of the bracket.

Solution:



+ve

$\sum M_B = 0;$

$-W(x - 0.0375m) + F_{NA}(0.15m) - F_{fA}(0.075m) = 0$

$-Wx + 0.0375W + 0.15FNA - 0.15\ F_{NA}(0.075m) = 0$

$-Wx + 0.0375W + 0.1313\ F_{NA} = 0$ ---------- 1st Equ.

$\sum F_x = 0;$ (→)

$F_{NA} + F_{NB} = 0$

$F_{NA} = F_{NB}$

$\sum F_y = 0;$ (↑)

$F_{fA} + F_{fB} - W = 0$ (since $F_{NA} = F_{NB}$),

$0.25F_{NA} + 0.25\ F_NA - W = 0$

$0.5\ F_{NA} = W$ or $F_{NA} = 2W$ ---------- 2nd Equ.

1st and 2nd equ. have been solved simultaneously;

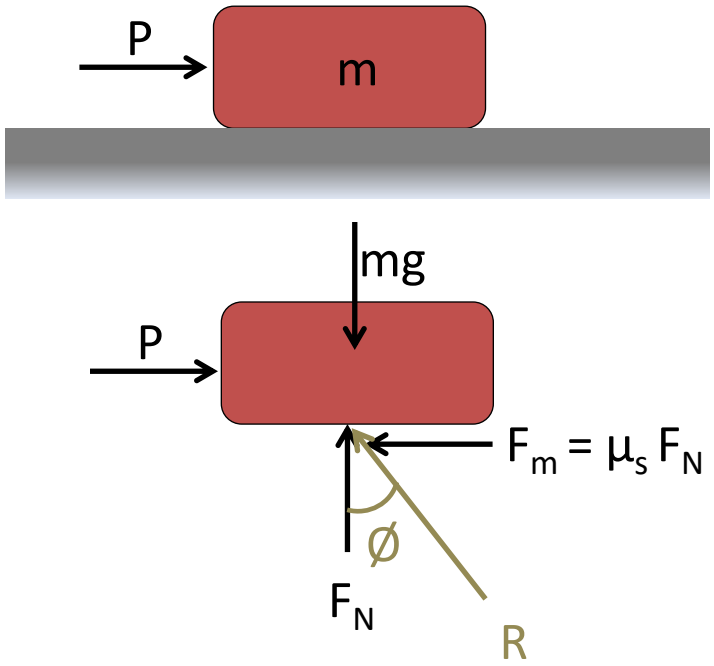
$-Wx + 0.0375W + 0.1313(2W) = 0$

$-Wx + 0.0375W + 0.2626W = 0$

$-Wx + 0.3 = 0$

$W(-x + 0.3) = 0$

$x = 0.3m$



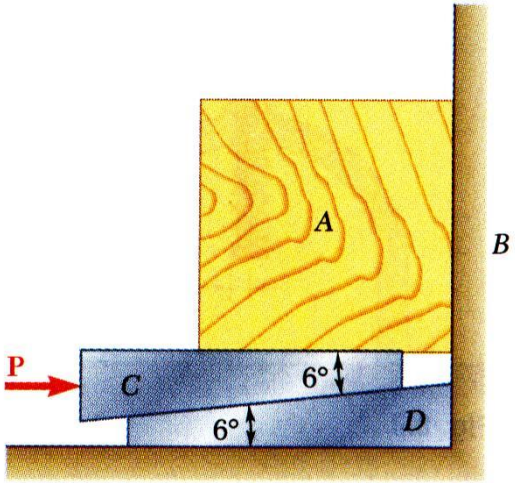
Friction angle, Ø is the angle between F_N and resultant, R (F_N and F_f):

$$\text{Tan } Ø = \mu_s$$ Angle of static friction

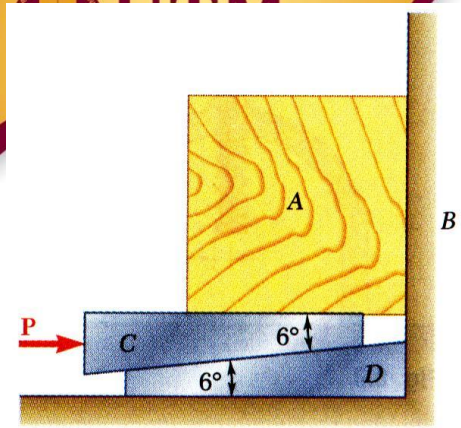
If motion takes place. The magnitude of the friction force drop to F_k:

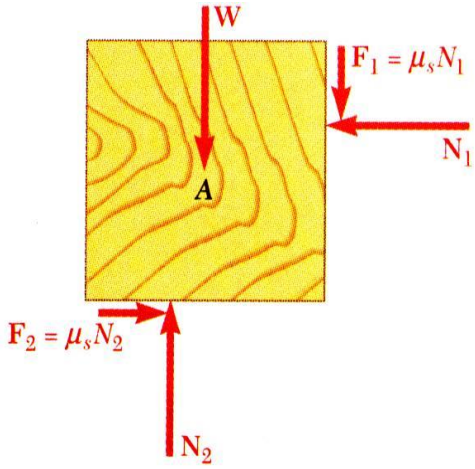
$$\text{Tan } Ø = \mu_k$$ Angle of kinetic friction

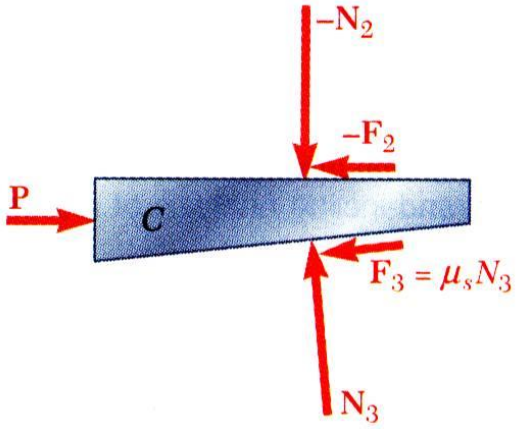
CATEGORY 6 – Wedges



- *Wedges* - Simple machines used to raise/lower or maintain heavy loads.
- Force required to lift block is significantly less than block weight.
- Friction prevents wedge from sliding out
- Want to find minimum force *P* to raise block.
- Problem solving is similar to category 2, both bodies (block and wedge) are solved separately.







- Block as free body:

$$\sum F_x = 0:$$

$$-N_1 + \mu_s N_2 = 0$$

$$\sum F_y = 0:$$

$$-W - \mu_s N_1 + N_2 = 0$$

or

$$\vec{R}_1 + \vec{R}_2 + \vec{W} = 0$$

- Wedge as free body:

$$\sum F_x = 0:$$

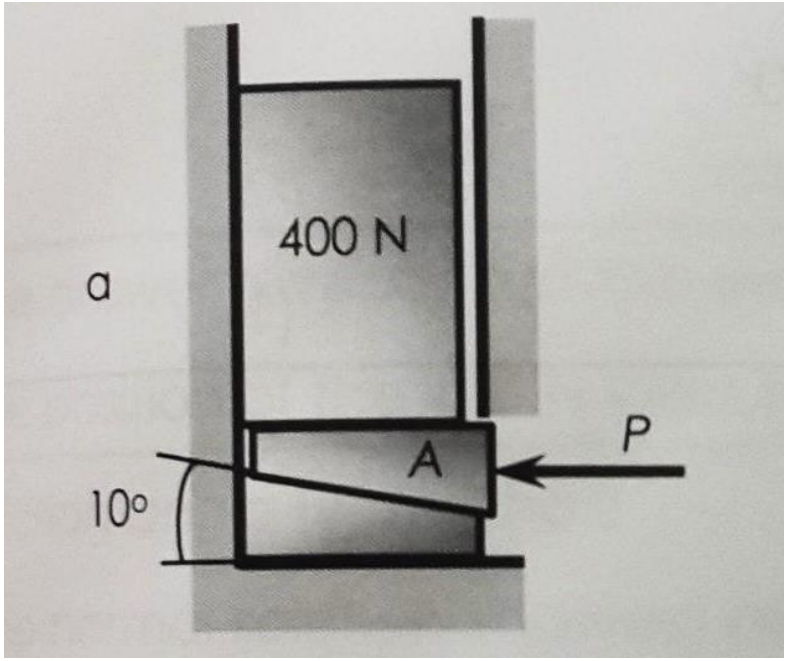
$$-\mu_s N_2 - N_3(\mu_s \cos 6° + \sin 6°) + P = 0$$

$$\sum F_y = 0:$$

$$-N_2 + N_3(\cos 6° - \mu_s \sin 6°) = 0$$

or

$$\vec{P} - \vec{R}_2 + \vec{R}_3 = 0$$

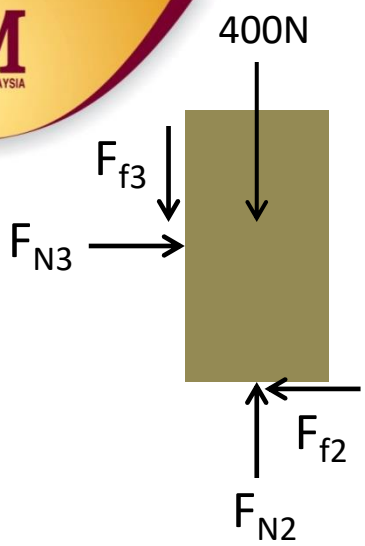


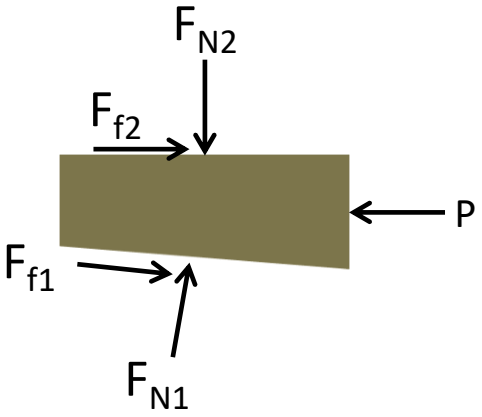
Ex. 9: Determine the minimum force so that 400N load is on the verge of moving up. The coefficient of static friction is $\mu_s = 0.25$

Component Method

Friction Angle Method

Component Method





Block:

$\sum F_x = 0$; ($\longrightarrow$)

$F_{N3} - F_{f2} = 0$

$F_{N3} - \mu_s F_{N2} = 0$

$F_{N3} = 0.25\ F_{N2}$

$\sum F_y = 0$; ($\uparrow$)

$F_{N2} - F_{f3} - 400N = 0$

$F_{N2} - 0.25\ F_{N3} - 400N = 0$

$F_{N2} - 0.25\ (0.25\ F_{N2}) - 400 = 0$

$F_{N2} = 426.67N$

So, $F_{f2} = 0.25\ (426.67N) = 106.67N$

$F_{N3} = 0.25\ (426.67N) = 106.67N$

$F_{f3} = 0.25\ (106.67N) = 26.67N$

Wedge:

$\sum F_y = 0$; ($\uparrow$)

$- F_{N2} - F_{f1} \sin 10^o + F_{N1} \cos 10^o = 0$

$- 426.67N - 0.25\ F_{N1} \sin 10^o + F_{N1} \cos 10^o = 0$

$- 426.67N - 0.0434\ F_{N1} + 0.9848\ F_{N1} = 0$

$F_{N1} = 453.23N$

So, $F_{f1} = 0.25\ (453.23N) = 113.31N$

$\sum F_x = 0$; ($\longrightarrow$)

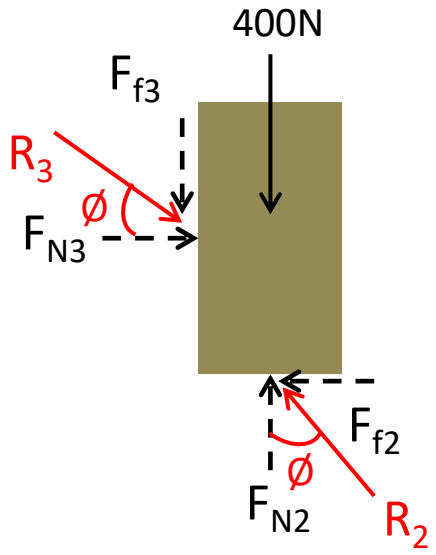
$F_{f2} + F_{f1} \cos 10o + F_{N1} \sin 10^o - P = 0$

$106.67N + 113.31N \cos 10^o + 453.23N \sin 10^o - P = 0$

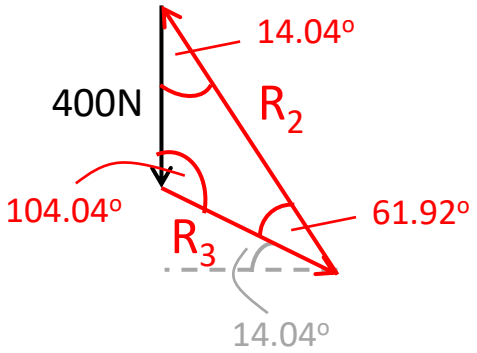
$P = 296.96N \sim 297N$

Friction Angle Method

Block:



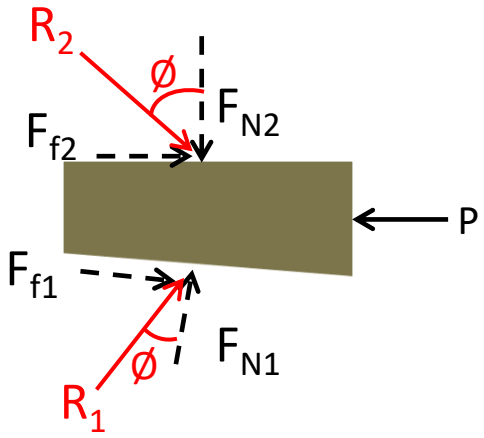
Tan Ø = μ_s
Tan Ø = 0.25
Ø = 14.04°



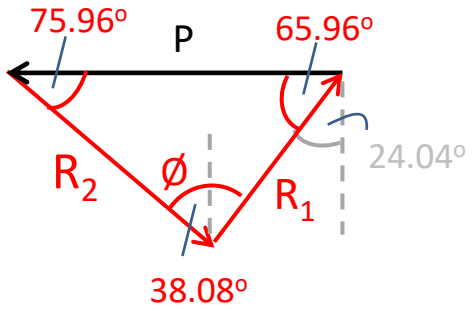
$$\frac{400N}{Sin\ 61.92^o} = \frac{R_2}{Sin\ 104.04^o} = \frac{R_3}{Sin\ 14.04^o}$$

R_2 = 440N
R_3 = 110N

Wedge:

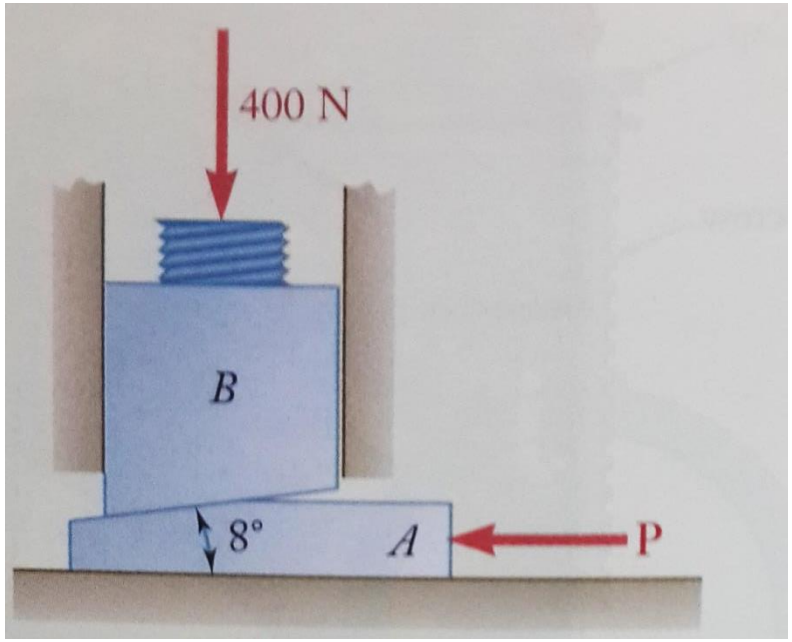


Tan Ø = μ_s
Tan Ø = 0.25
Ø = 14.04°



$$\frac{440N}{Sin\ 65.96^o} = \frac{R_1}{Sin\ 75.96^o} = \frac{P}{Sin\ 38.08^o}$$

R_1 = 467.4N
P = 297N



Ex. 10: The position of the machine block B is adjusted by moving the wedge A. Knowing that the coefficient is statics friction is 0.35 between all surface contact, determine the force P required to;

(a) Raise block B

(b) Lower block B