A BRIEF OVERVIEW FRICTION

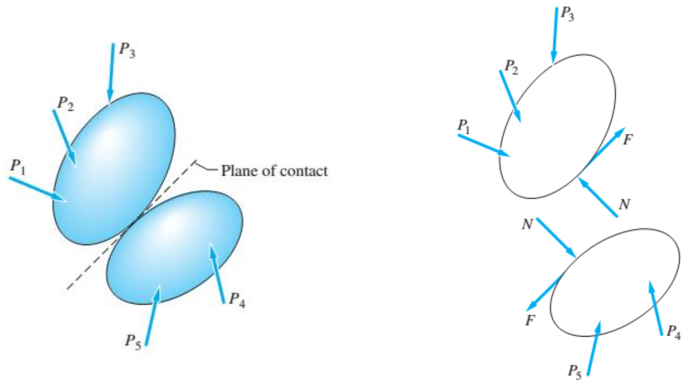
FRICTION

- Friction resists relative sliding motion between two surfaces that are in contact.
- Friction may be helpful; as seen during walking, applications to clutches, belts etc.
- It may also be detrimental; wear in machinery, reduction of efficiency in transmission of power by converting mechanical energy into heat.
- It plays a very important role in a lot of engineering applications.

- Friction may be dry or wet.
- *Dry* or *Coloumb* Friction occurs when there is no layer of fluid separating the contacting surfaces.

FRICTION
Coloumb's Theory of Dry Friction

- Has been found to give satisfactory results in practical problems.
- Explanation:
  - Two bodies in contact, will each experience a normal reaction, N and Friction force, F which will act in a direction opposite to that the body wants to move in.



FRICTION
Coloumb's Theory of Dry Friction

- The relation between the Normal and the Friction force can be one of three cases:
  - Static Case: where there is no sliding movement between the two bodies, *N* and *F* are related by

$$F \leq F_{\max} = \mu_s N$$

and there will be no movement so long as

$$F \leq F_{\max}$$

  - Impending Sliding Case:

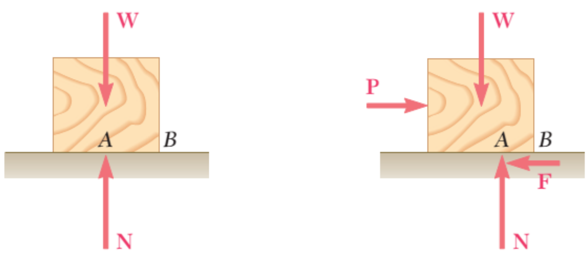
$$F = F_{\max} = \mu_s N$$

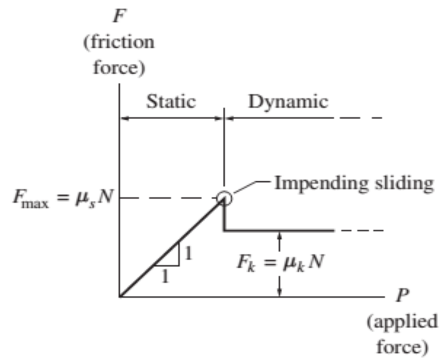
  - Dynamic Case: when the two bodies are already sliding relative to each other,

$$F_k = \mu_k N$$

FRICTION
Coloumb's Theory of Dry Friction

- When a force P is applied to a body in the direction shown, the body experiences friction in the direction shown. The body will move when P exceeds F.
- Once the body is moving, the force P required to keep it moving is less than what was required to make it start moving. Hence, Static Friction Force > Dynamic Friction force

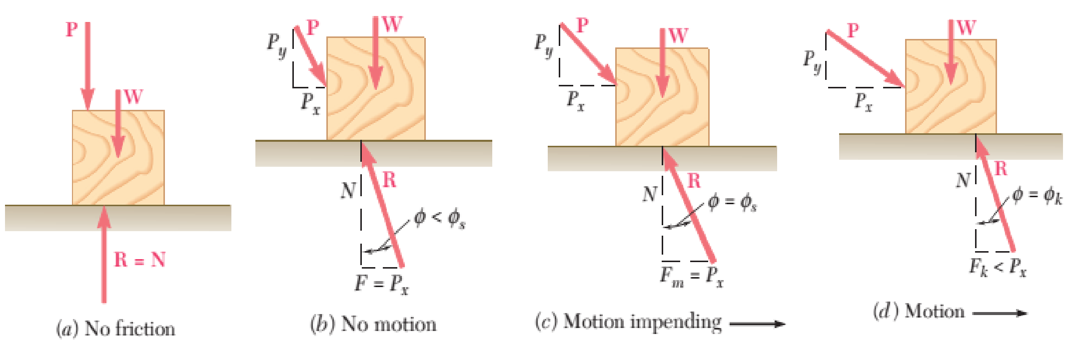




Variation of Friction Force with Applied Force
Source: Engineering Mechanics – Statics by Pytel

FRICTION
Angles of Dry Friction

- The Friction force and Normal Reaction acting on a body can be resolved into a resultant.
- The angle this resultant makes with the normal reaction is referred to as the angle of friction.
- There can be the angle of static friction and the angle of kinetic friction.



$$\tan\phi_s = \frac{F_m}{N} = \frac{\mu_s N}{N}$$

$$\tan\phi_s = \mu_s$$

$$\tan\phi_k = \frac{F_k}{N} = \frac{\mu_k N}{N}$$

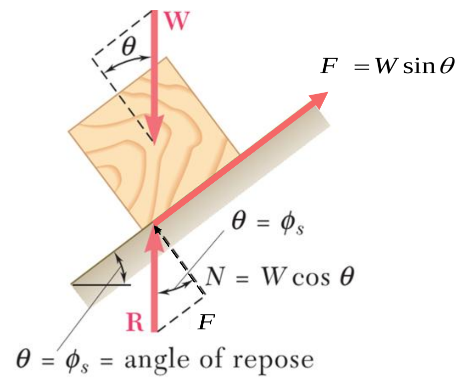
$$\tan\phi_k = \mu_k$$

FRICTION
Angles of Dry Friction

- The co-efficient of static friction between two surfaces is determined experimentally.
- A block of one material is placed on a plane of variable inclination of the second material.
- Inclination is increased until sliding is imminent, in which case $F_s = F_{\max} = \mu_s N$

$$\phi_s = \theta = \frac{F}{N} = \frac{\mu_s N}{N} = \mu_s$$

- θ is known as the *angle of repose*
- $\mu_s = \tan\theta$



Motion impending

FRICTION
Laws of Dry Friction

- Coloumb and other subsequent works, give the following laws of friction:
  - The maximum frictional resistance that can be developed is independent of the size of the areas in contact.
  - The maximum static Friction Force, F_{max} and the dynamic friction force F_k are each proportional to the normal reaction between the surfaces.

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

$$F_k = \mu_k N$$

where μ_s and μ_k are the static and kinetic co-efficients of friction respectively.

  - The limiting value of Static friction force is greater than the kinetic friction force
  - For low velocities, the kinetic frictional resistance is practically independent of velocity.

FRICTION
Some Limitations

- Some limitations of Coloumb's Theory and other related works include:
  - The co-efficients of friction are all determined experimentally and are at best approximations. They may vary with environmental conditions, the condition of the surfaces among other factors.
  - The theory of dry friction is applicable only to surfaces that are dry or that contain only a small amount of lubricant. If there is relative motion between the surfaces of contact, the theory is valid for low speeds only.
  - There are situations where the amount of friction between surfaces depends on the area of contact. For example, the traction (friction force) between an automobile tire and the pavement can be increased under certain conditions by letting a small amount of air out of the tire, thus increasing the contact area.

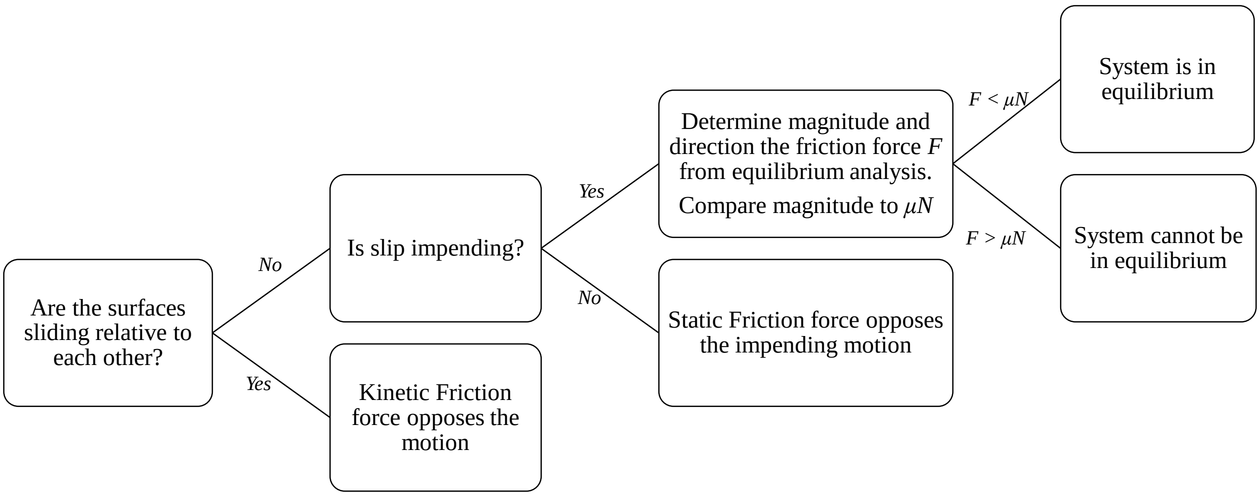
FRICTION

- Problems involving dry friction are solved in pretty much the same way as equilibrium problems.

- Free body diagrams on which forces and dimensions must be correctly indicated.

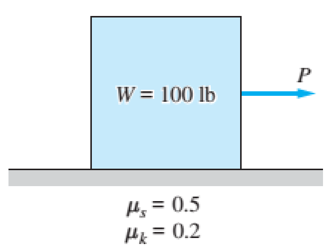
- Friction forces must always oppose the direction of motion.

FRICTION
Approach to solving problems



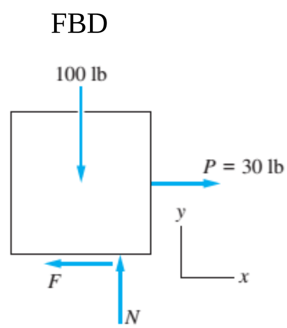
FRICTION

- Example
- A force of P of 30 lb is applied as shown to a 100 lb block that was initially at rest. Determine if the block will slide or not.



FRICTION

Solution



Assuming equilibrium,

$+\rightarrow \sum F_x = 0; P - F = 0$

$+\uparrow \sum F_y = 0; \text{-}100\ \text{lb} + N = 0$

$F = 30\ \text{lb}$

$N = 100\ \text{lb}$

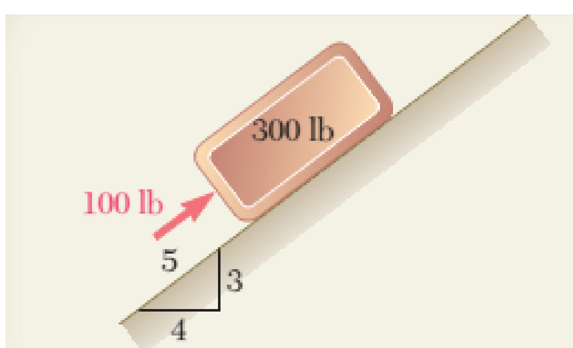
$F_{\max} = \mu_s N = 0.5(100\ \text{lb}) = 50\ \text{lb}$

Since $F < F_{\max}$, the body is in static equilibrium and will remain at rest.

FRICTION

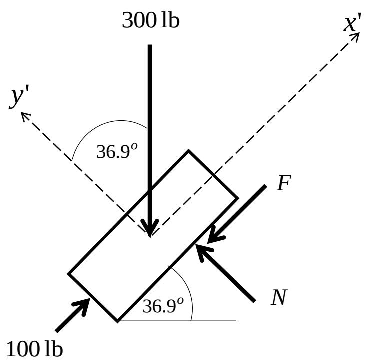
Example

- A 100-lb force acts as shown on a 300-lb block placed on an inclined plane. The coefficients of friction between the block and the plane are μ_s = 0.25 and μ_k = 0.20. Determine if the block will slide down the plane and also determine value of the friction force.



FRICTION

Solution



Assuming equilibrium,

$$+\nearrow\sum F_{x'} = 0; 100\text{ lb} - (300 \sin 36.9)\text{ lb} - F = 0$$

$$+\nwarrow\sum F_{y'} = 0; -(300 \cos 36.9)\text{ lb} + N = 0$$

$$F = -80\text{ lb}$$

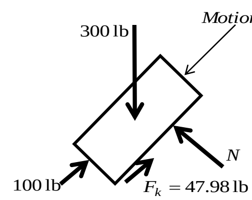
$$N = 239.9\text{ lb}$$

$$F_{\max} = \mu_s N = 0.25(239.9\text{ lb}) = 59.98\text{ lb}$$

Since $F > F_{\max}$, the body will not be at rest. It will slide down the plane.

Therefore, Force due to friction is dynamic. It will be given by

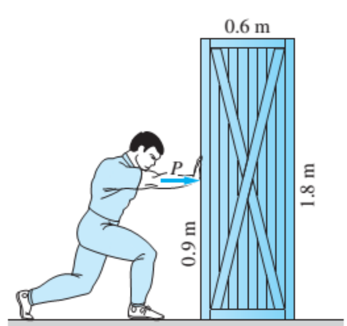
$$F_k = \mu_k N = 0.20(239.9\text{ lb}) = 47.98\text{ lb}$$



FRICTION

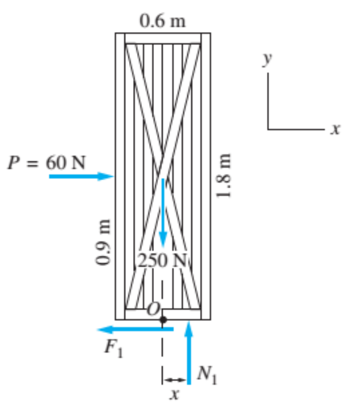
Example

- A force of 60 N is being applied to a 250 N crate by a man as shown below. Determine if the crate will remain in static equilibrium. The weight of the crate acts through its geometric center, and the coefficient of static friction between the crate and the floor is 0.3



FRICTION

➢Solution



Assuming equilibrium,

$$\xrightarrow{+} \sum F_x = 0; -F_1 + 60\text{ N} = 0$$

$$+\uparrow \sum F_y = 0; N_1 - 250\text{ N} = 0$$

$$\circlearrowleft + \sum M_O = 0; -N_1 x + (P)0.9\text{ m} = 0$$

$x = 0.216\text{ m} < 0.3\text{ m}$

The crate will not tip over

$F_{1\max} = \mu_s N_1 = 0.3(250) = 75\text{ N}$

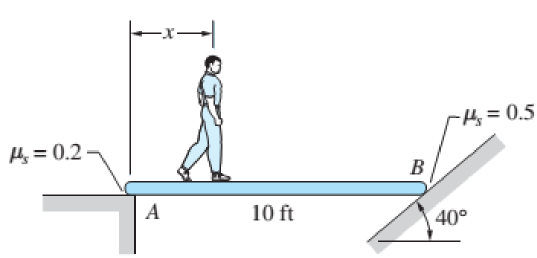
$P < F_{1\max}$

$\therefore$ Crate will not slide

FRICTION

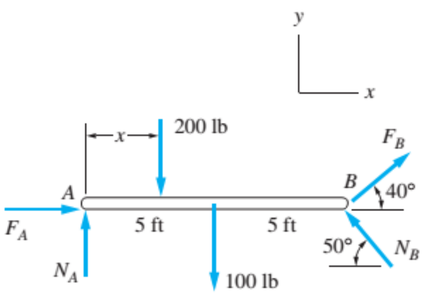
Example

➢The uniform 100-lb plank is resting on friction surfaces at A and B. The coefficients of static friction are shown in the figure. If a 200-lb man starts walking from A toward B, determine the distance x when there will be impending sliding of the plank.



FRICTION

Solution



Assuming equilibrium,

$$+\rightarrow \sum F_x = 0;\ F_A - (N_B \cos 50)\,\text{lb} + (F_B \cos 40)\,\text{lb} = 0$$

$$+\uparrow \sum F_y = 0;\ N_A - 200\,\text{lb} - 100\,\text{lb} + (N_B \sin 50)\,\text{lb} + (F_B \sin 40)\,\text{lb} = 0F = -80\,\text{lb}$$

$$\circlearrowleft + \sum M_A = 0;\ (200\,\text{lb})x + (200\,\text{lb})5\,\text{ft} - (F_B \sin 40\,\text{lb})10\,\text{ft} - (N_B \sin 50\,\text{lb})10\,\text{ft} = 0$$

Subtituting $F_A = 0.2N_A$ and $F_B = 0.5N_B$ and solving,

$N_A = 163.3\,\text{lb}$

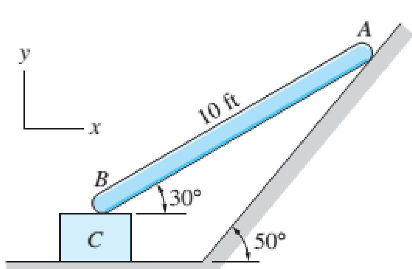
$N_B = 125.7\,\text{lb}$

$x = 4.34\,\text{ft}$

FRICTION

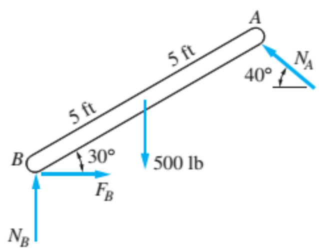
Example

- Determine if the system below will be in static equilibrium. The uniform bar AB weighs 500 lb, and the weight of block C is 300 lb. Friction at A is negligible, and the coefficient of static friction is 0.4 at the other two contact surfaces.

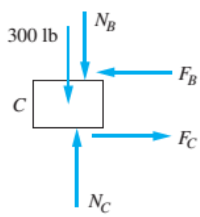


FRICTION

Solution



(b)

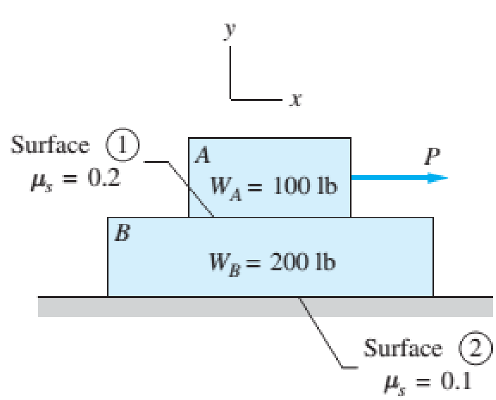


Ans:
The system will not be in equilibrium because $F_c > F_{c}max$ for the block, C.

FRICTION

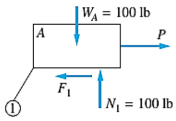
Example

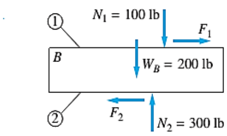
- Determine the maximum force P that can be applied to block A without causing either block to move.

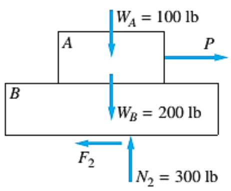


FRICTION

Solution







(b)

For surface 1,

$$F_1 = F_{1\max} = \mu_{s1} N_1 = 0.2(100) = 20\text{ lb}$$

The block A FBD then gives

$$+\rightarrow \sum F_x = 0;\ P\text{-}F_1 = 0$$

$$P = 20\text{ lb}$$

For surface 2,

$$F_2 = F_{2\max} = \mu_{s2} N_2 = 0.1(300) = 30\text{ lb}$$

The FBD of the entire system (b) then gives

$$+\rightarrow \sum F_x = 0;\ P\text{-}F_2 = 0$$

$$P = 30\text{ lb}$$

So the largest force that can be applied without causing motion is 20 lb