To do ...

- HW 25 due Today

- WA10 due Sunday April 10

- Quiz 5 this week - Tues April 5 to Sat April 9

- Last TAM 210 class - Friday April 8

- TAM 210 FINAL
  - Tues April 19 – Sat April 23
  - CBTF
  - 1 hr 50 min
Dry friction: Static

1.) $P=0$, no motion, equilibrium
2.) $P<F_s$, no motion, $P=F_s$ (E.U)
3.) $P=F_s$, no motion, impending motion (E.U)
4.) $P>F_s$ sliding

$F = P$

Q: How do we experimentally measure $\mu_s$?

$\Sigma F_x: 0$

$\Sigma F_y: \text{mg} = W$

$F_s = \mu_s \text{mg}$

$\Sigma F_x: F - \text{mg} \sin \theta = 0$

$\Sigma F_y: N - \text{mg} \cos \theta = 0$

$\theta = \theta_c$

$F_c = \text{mg} \sin \theta$

$\sin \theta \cdot \tan \theta = \mu_c$
we now have an important relation

\[ F_s = \mu_s N \]

\( \text{Q: What happens to } \Theta_{cr} \text{ with:} \)

mass, material, area...

\[ \Theta_{cr} \]

\[ \Theta_{cr} \]

\[ \Theta_{cr} \]

[\( \text{A) None} \)]
**Dry friction:** Kinetic

If \( P > F_s \): friction force is no longer a function of \( \mu_s \) but instead of \( \mu_k \)

\[
F_k = \mu_k N
\]

\[
\mu_k = \mu_s (25\%)
\]

![Diagram showing force relationships and friction](image)

For friction:

\[
P - F = 0
\]

\[
P - F_k = m\ddot{a}
\]

\[
P - \mu_k N = m\ddot{a}
\]

\[
P - F_{\text{max}} = 0
\]
Rapid Refresh ...

- i
- <3
- c
- l
- i
- c
- k
- e
- r
A 10 lb block is in equilibrium. What is the magnitude of the friction force between this block and the surface?

A) 0 lb  B) 1 lb  C) 2 lb  D) 3 lb

μ_s = 0.3
If a block is stationary, then the friction force acting on it is 

\[ \text{A) } \leq \mu_s N \quad \text{B) } = \mu_s N \]
\[ \text{C) } \geq \mu_s N \quad \text{D) } = \mu_k N \]
iQ>clicker

A ladder is positioned as shown. Please indicate the direction of the friction force on the ladder at B.

A) ↑
B) ↓
C) →
D) ↘
Dry friction

- Friction acts \textit{tangent} to contacting \textit{surfaces} and in a \textit{direction opposed} to motion of one surface relative to another.
- Maximum static frictional force occurs when motion is impending.
- Kinetic friction is the \textit{tangent} force between two bodies after motion begins. Less than static friction by about 25%.
- Coefficient of \textit{static} friction is the ratio \( \mu_s = \frac{F_{\text{max}}}{N} \)
- Coefficient of \textit{kinetic} friction is the ratio \( \mu_k = \frac{F_k}{N} \)
- Coefficient of friction is independent of normal force and area of contact.

\[ \mu_s = \frac{F_s}{N} \]

\[ \nabla \]

\[ F_x : \quad P - F = 0 \]  
\[ F_y : \quad N - mg = 0 \]

\[ F_x \propto N \]  
\[ \text{i.e. } N \uparrow \text{ so does } F \uparrow \]

\[ \text{but } \mu_s = \frac{F_s}{N} = \text{Const.} \]
As long as bodies are rigid, $\mu$ does not change!

Think about F1 racing tires!
Think about ice skating!
$\mu = 0.6$! Ice/metal

But because of skate shape, pressure, friction melting

Triple phase / decrease $\mu$
Change in material property at surface.
Given:  Crate weight = 250 lb and 
\( \mu_s = 0.4 \)

Find:  The maximum force \( P \) that can be 
applied without causing movement of 
the crate.

1. Draw a FBD

2. There are four unknowns: 
   \( P, N, F, \theta \)

3. First, assume slipping, we have 3 EoE and friction

4. Sum forces in \( x \) and \( y \)
   \[ \Sigma F_x: P - F = 0 \]
   \[ P = F = \mu_s N = \mu_s W \]
   \[ \Sigma F_y: N - W = 0 \]
   \[ N = W \]
   \[ P = 100 \text{ lb} \]

5. Sum moments to find \( \theta \)

\[ \Sigma M_o: xN - yP = 0 \]
\[ \theta = \frac{yP}{N} = \frac{(4.5 \text{ ft})(100 \text{ lb})}{250 \text{ lb}} = 1.8 \text{ ft}. \]

\[ \theta = 1.8 \text{ ft} > 1.5 \text{ ft} \quad \text{no slipping, the box will tip first!} \]
Draw the FBD.

Sum the forces and moments:

\[ \Sigma F_x: \quad P - F = 0 \quad P = F = ? \]

\[ \Sigma F_y: \quad N - w = 0 \quad N = w = 250\, \text{lb} \]

\[ \Sigma M_y: \quad (1.5)N - yP = 0 \]

\[ P = \frac{xw}{y} = \frac{(1.5 \times 250)}{4.5} = 83.3\, \text{lb} \]

\[ P = 83.3\, \text{lb} < 100\, \text{lb} \quad \text{will tip before slip!} \]
It is observed that when the bed of the dump truck is raised to an angle of $\theta = 25^\circ$ the vending machines will begin to slide off the bed. Determine the static coefficient of friction between a vending machine and the surface of the truck bed.

**Sum Forces:**

$\sum F_x: \quad W \sin \theta - F = \phi$

$\sum F_y: \quad N - W \cos \theta = \phi$

$F_x = \frac{W \sin \theta}{\cos \theta}$

$\tan \theta = \frac{F}{N}$

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

$N_x = F_y (2.5) = 0$

$\chi = \frac{F_y (2.5)}{N} = \mu_s N (2.5)$

$\chi = (2.5) \mu_s = (2.5) (0.4666) = 1.165 \text{ ft}$

$\chi = 1.165 \text{ ft} < 1.5 \text{ ft} \quad \therefore \text{ will slip before tip!}$
tip not slip.
Two uniform boxes, each with weight 200 lb, are simply stacked as shown. If the coefficient of static friction between the boxes is \( \mu_s = 0.8 \) and between the box and the floor is \( \mu_s = 0.5 \), determine the minimum force \( P \) to cause motion.

Q: How many possible scenarios?

A) 1  
B) 2  
C) 3  
D) 4  
E) none

Q: Is the \( P \) same for all?

If I: DRAW FBD

**Sum forces in \( x \) :**

\[ \sum F_x : \quad P - F = 0 \quad P = F = \mu_s N = \mu_s W \]

**Sum forces in \( y \):**

\[ \sum F_y : \quad N - W = 0 \quad N = W \]

\[ P = (0.8)(200) = 160 \text{ lb} \]

If II: sun moments about 0
Sum moments about U:

\[ \sum M_U : \quad w(\frac{3}{2}) - P(1) = 0 \]

\[ P = \left( \frac{3}{2} \right)(200) = 300 \text{ lb} \]

Sum forces in x ? y:

\[ \sum F_x : \quad P - F_x = 0 \quad P = \mu_S F_x = \mu_S N \]

\[ \sum F_y : \quad N - 2w = 0 \quad N = 2w \]

\[ P = \mu_S 2w = \left( \frac{1}{2} \right)(2)(200) = 200 \text{ lb} \]

Sum the moments:

\[ \sum M_A : \quad \left( \frac{3}{2} \right)(2w) - 5P = 0 \]

\[ P = \frac{3w}{5} = \frac{3(200)}{5} \]

\[ P = 120 \text{ lb} \]
\( F_v < F_i < F_{\text{thr}} < F_{\text{III}} \)

1 slide
1+2 tip
1+2 slide
1+ tip