Statics - TAM 211

Lecture 25

November 22, 2018

Chap 8.2

Announcements

- Upcoming deadlines:
  - Friday (11/23)
    - Written Assignment 9
  - Tuesday (11/27)
    - Prairie Learn HW 10
  - **Friday (11/30) all in Teaching Building A418-420**
    - 8:00 am: Quiz 5, On paper. Chapter 7+8 (Internal forces, Friction)
    - 9:00 am: Lecture 28 (Center of Gravity/Composite Areas)
    - 10:00 am: Discussion section for ALL students

- **Reminder: Discussion Section**
  - **12% of final grade**
  - **Attendance + Participation**
  - **No grade given for discussion section if > 5 minutes late**

Chapter 8: Friction

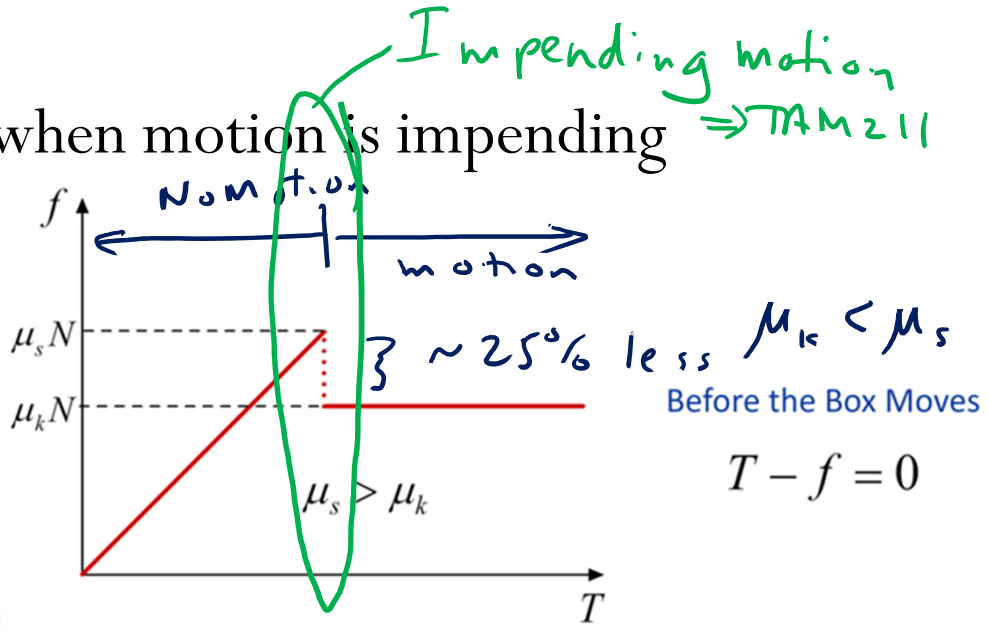
Goals and Objectives

- Sections 8.1-8.2
- Introduce the concept of dry friction
- Analyze the equilibrium of rigid bodies subjected to this force

Recap: Dry friction

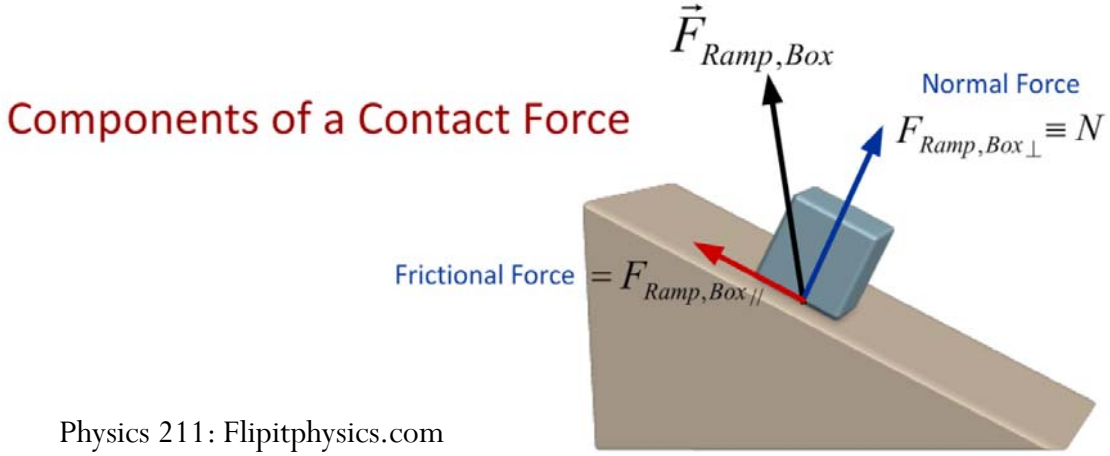
- Friction acts tangent to contacting surfaces and in a direction <u>opposed</u> to motion of one surface relative to another
- Friction force F is related to the coefficient of friction and normal force N
  - Static friction (no motion): $F_s \leq \mu_s N$
  - Kinetic friction (moving): $F_k = \mu_k N$
- <u>Maximum</u> static frictional force occurs when motion is impending

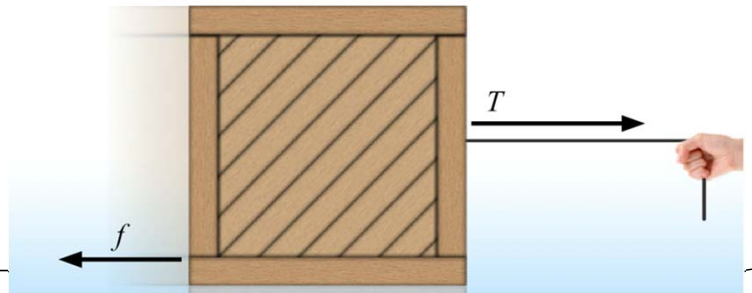
("Impending" = about to happen)



Before the Box Moves

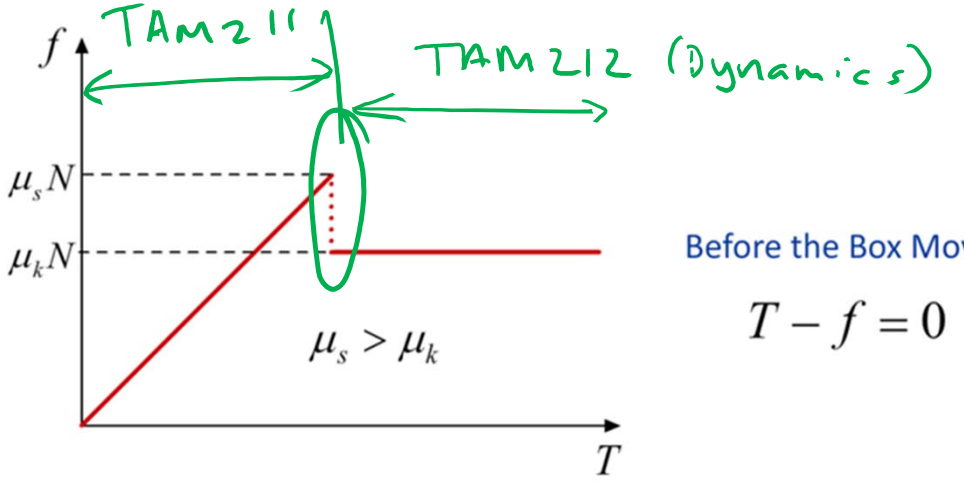
$$T - f = 0$$





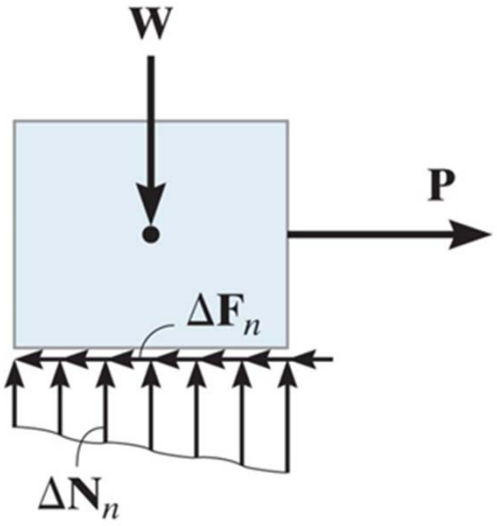
Dry Friction Problems

("Impending" = about to happen)



- 3 types of static problems with dry friction

1. No apparent impending motion
2. Impending motion at all points of contact
3. Impending motion at some points of contact



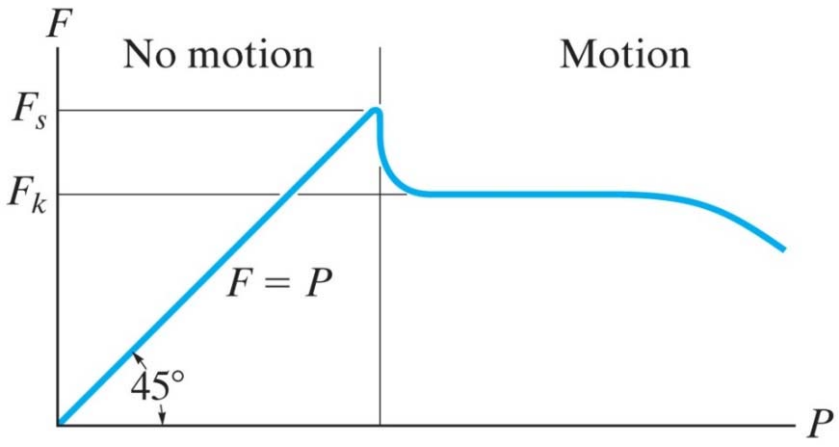
Note that all of these cases are for IMPENDING motion (since static case). Therefore, in tipping problems, the entire bottom surface is still in contact with ground.

Slipping and Tipping

- **Impending slipping motion**: the maximum force F_s before slipping begins is given by

$$F_s = \mu_s N$$

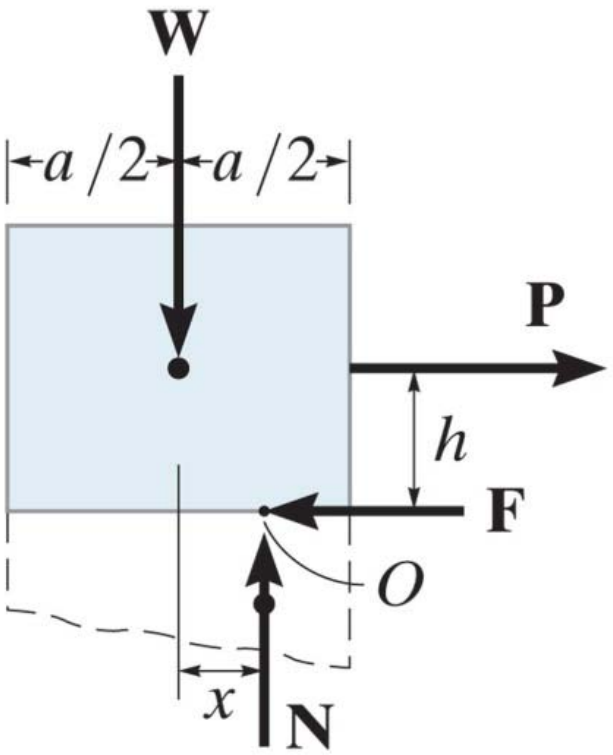
Slipping starts when P just exceeds $\mu_s N$



- **Tipping condition**: to avoid tipping of the block, the following equilibrium should be satisfied:

$$\sum M_O = -Ph + Wx = 0 \rightarrow x = \frac{P\,h}{W}$$

Compute value for x based on the applied loads:
If $x > a/2$, then these loads would cause tipping.
Otherwise $x < a/2$, will only slip



Dry Friction Problem Procedure

A. Draw FBD for each body

- Friction force vector points in opposite direction of impending motion

B. Determine # unknowns

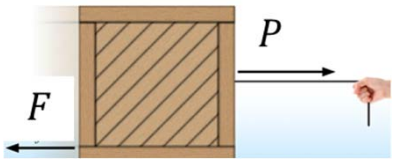
C. Apply equations of equilibrium

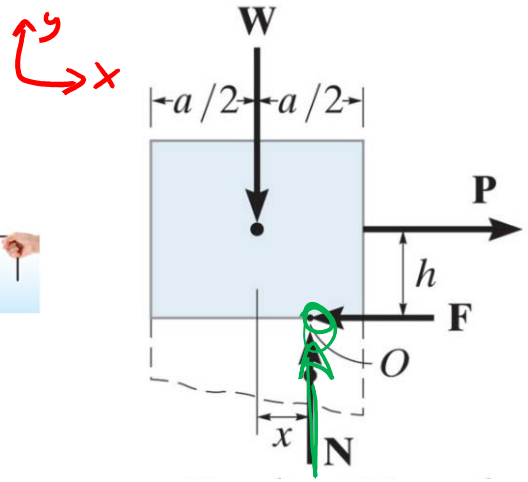
i. If checking for slipping:

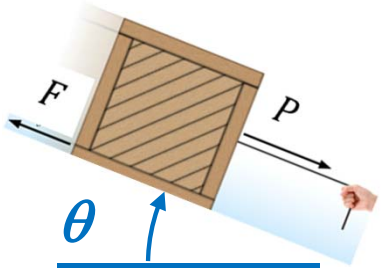
- Examine $\sum F_x = 0, \sum F_y = 0$, and case when slipping starts $F_s = \mu_s N$

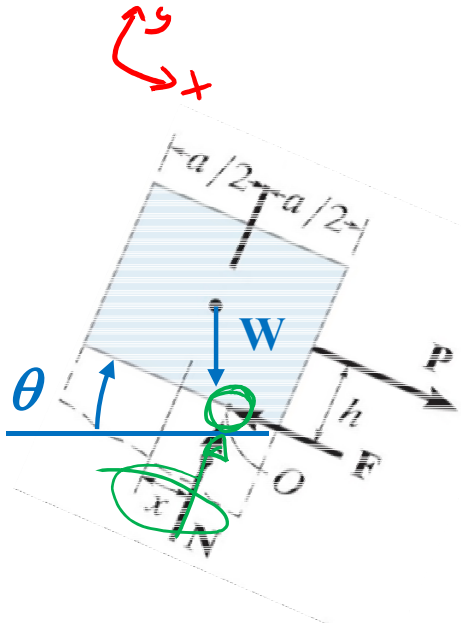
ii. If checking for tipping:

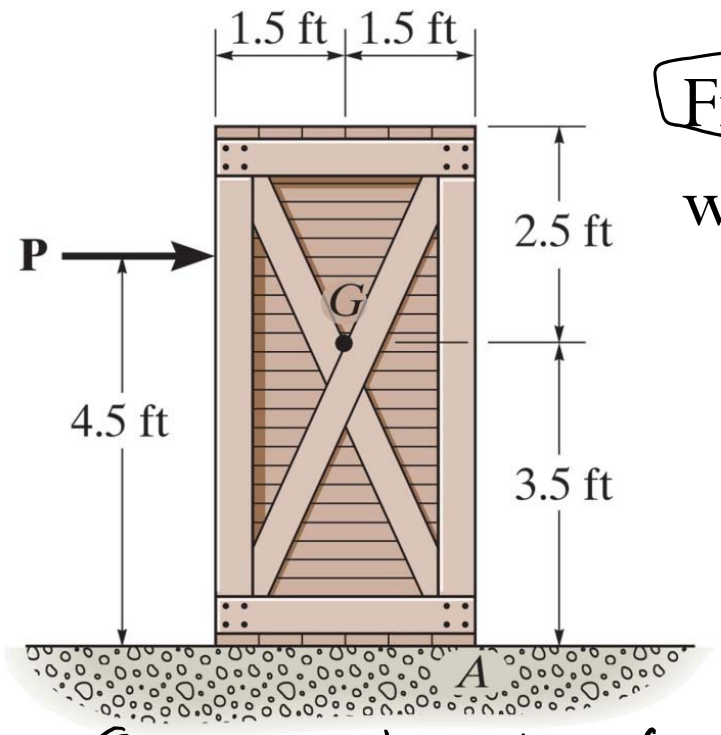
- Examine $\sum M_O = 0 = -Ph + Wx$, solve for $x = \frac{P\,h}{W}$
- If $x > a/2$, then tip. If $x < a/2$, then slip.











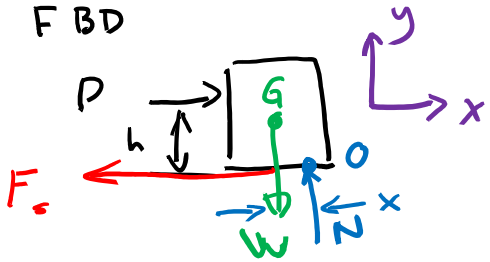
Find the maximum force P that can be applied without causing movement of the crate.

Given:
$\mu_s = 0.4$
$W = 250\,lb$

Find P

2 cases of impending motion (Slip or Tip)

① FBD



② # UNKNOWNS ?

P, F, N, x

③ Need to solve for slipping & tipping.

1st assume slipping:

$\Sigma F_x = 0 \quad P - F_s = 0 \Rightarrow P = F_s = \mu_s N = (0.4)(250\,lb) \Rightarrow P = 100\,lb$

$\Sigma F_y = 0 \quad N - W = 0 \Rightarrow \boxed{N = W = 250\,lb}$

Will the crate tip?

$+\circlearrowleft \Sigma M_O = 0 \quad Wx - Ph = 0 \quad x = \frac{Ph}{W} = \frac{(100\,lb)(4.5\,ft)}{250\,lb} \Rightarrow \boxed{x = 1.8\,ft}$

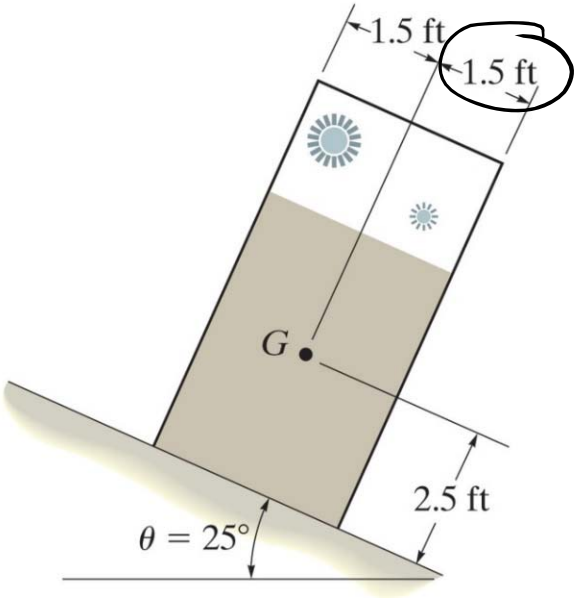
$\frac{a}{2} = 1.5\,ft \quad \therefore x > a/2 \quad \boxed{\therefore \text{Tip}}$

Must solve for P that causes initial tipping

$\Sigma M_O = 0 \rightarrow Wx - Ph = 0 \Rightarrow P = \frac{xW}{h} = \frac{(1.5\,ft)(250\,lb)}{4.5\,ft}$

$\therefore \boxed{P = 83.3\,lb}$ FINAL SOLN

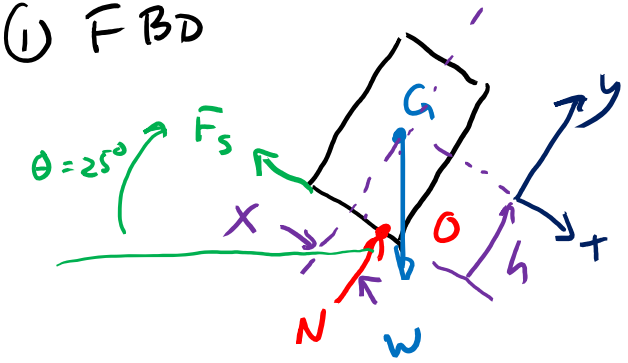
It is observed that when the bed of the dump truck is raised to an angle of $\theta = 25^o$ the vending machines will begin to slide off the bed. Determine the static coefficient of friction between a vending machine and the surface of the truck bed.



Find unknown μ_s.

Compare 2 possible cases of "impending motion" (slip or Tip)

(1) FBD



(2) # UNKNOWNS : x, N, W, F_s, μ_s

(3) Look at slipping & Tipping

Assume slipping $F_s = \mu_s N$

$\Sigma F_x = 0 \quad -F_s + W\sin\theta = 0 \Rightarrow F_s = W\sin\theta$

$\Sigma F_y = 0 \quad N - W\cos\theta = 0 \Rightarrow N = W\cos\theta$

$$\mu_s = \frac{F_s}{N} = \frac{W\sin\theta}{W\cos\theta} = \tan\theta$$

$$\mu_s = \tan\theta = \tan(25^\circ) \Rightarrow \boxed{\mu_s = 0.466}$$

Will it tip or slip first?

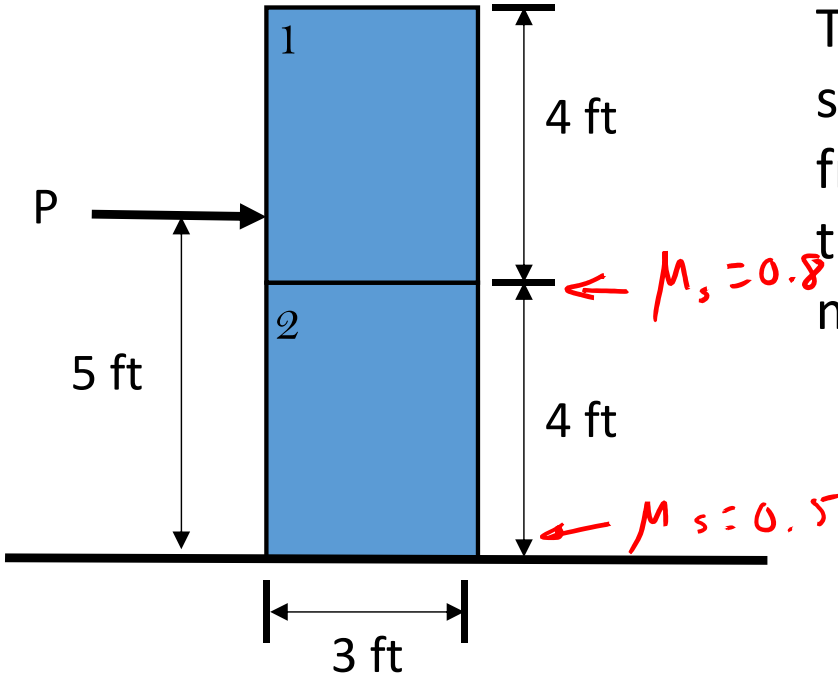
ΣM_o: $\quad x\, W\cos\theta - h\, W\sin\theta = 0$

$$x = \frac{h\, W\sin\theta}{W\cos\theta} = h\tan\theta = (2.5\text{ ft})\tan(25^\circ)$$

$$\boxed{x = 1.17\text{ ft}}$$

$$\frac{a}{2} = 1.5\text{ ft}$$

$$x < \frac{a}{2} \Rightarrow \boxed{\text{SLIP}}$$



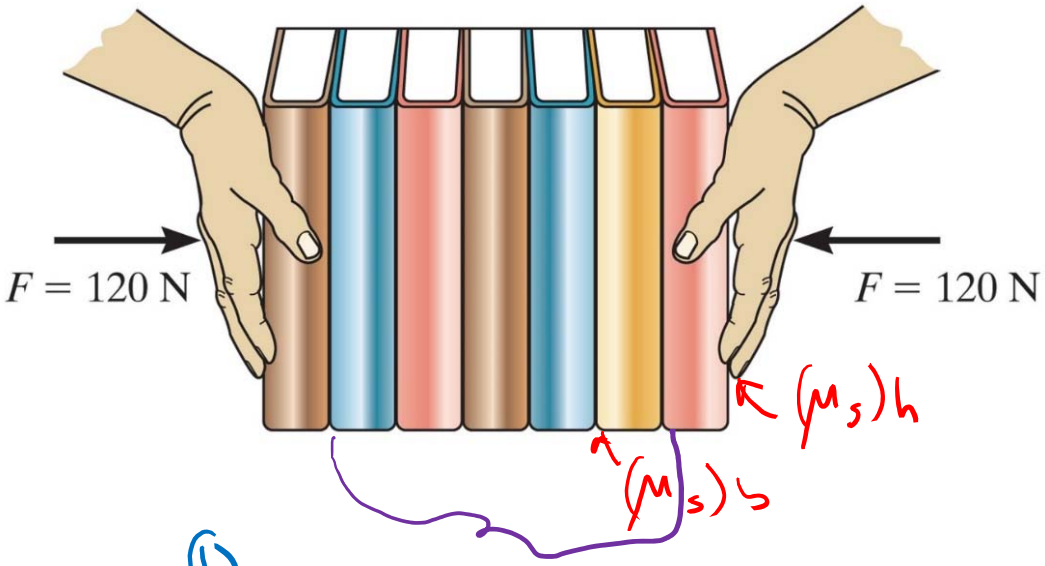
Two uniform boxes, each with weight 200 lb, are simply stacked as shown. If the coefficient of static friction between the boxes is $\mu_s = 0.8$ and between the box and the floor is $\mu_s = 0.5$, determine the minimum force P to cause motion.

How many possible motions? 4

A) 1 tip
B) 1 slip
C) 1 + 2 tip
D) 1 + 2 slip

$\Rightarrow$ Solve for P for each case; compare P values and pick the smallest P

$\Rightarrow$ case D is solution ($P = 120$ lb)



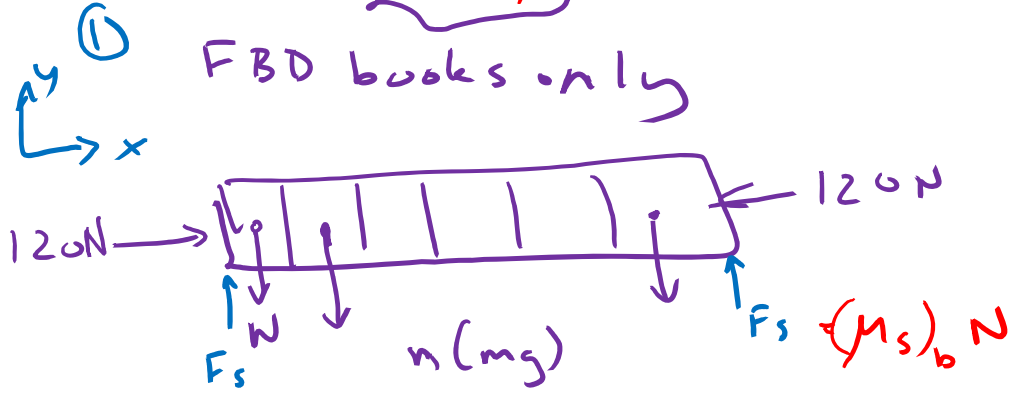
Determine the greatest number of books that can be supported in the stack.

Mass of each book: 0.95 kg

Coefficient friction hand-book: $(\mu_s)_h = 0.8$

Coefficient friction book-book: $(\mu_s)_b = 0.4$

① FBD books only

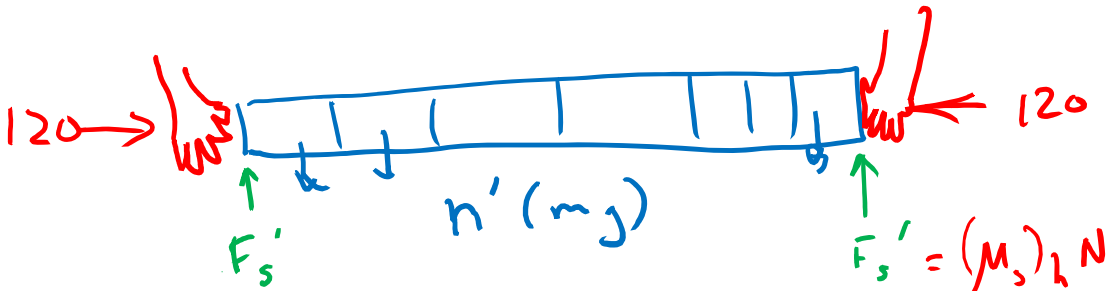


$\Sigma F_x = 0$

$\Sigma F_y = 0$

$n \simeq 10$

② FBD of books + hands



$N = 120\ N$

compare n vs. n'

$n' \simeq 20$

$n < n'$

$N = n + 2 =$ 12 books

↑ outer books