Announcements

- Upcoming deadlines:
  - Friday (11/23)
    - Written Assignment 9
  - Tuesday (11/27)
    - Prairie Learn HW 10
  - Quiz 5
    - Week of Nov 26

- Prof. H-W office hours
  - Monday 3-5pm (Room C315 ZJUI Building)
  - Wednesday 7-8pm (Residential College Lobby)
Recap: Relations Among Distributed Load (w), Shear Force (F) and Bending Moments (M)

Relationship between distributed load and shear:

\[
\frac{dV}{dx} = w
\]

Slope of shear force = distributed load intensity

\[
\Delta V = V_2 - V_1 = \int w \, dx
\]

Change in shear force = area under loading curve

Relationship between shear and bending moment:

\[
\frac{dM}{dx} = V
\]

Slope of bending moment = shear force

\[
\Delta M = M_2 - M_1 = \int V \, dx
\]

Change in moment = area under shear curve
Recap: Relationships Among Concentrated Force (F) or Moment (M₀), Shear Force (V) and Bending Moments (M)

Wherever there is an external concentrated force or a concentrated moment, there will be a change (jump) in shear or moment, respectively.

\[
\Sigma F_y:
V + F - (V + \Delta V) = 0
\]
\[
\Delta V = F
\]

Jump in shear force due to concentrated point force F

\[
\Sigma M_O:
(M + \Delta M) - M - M_O - V(\Delta x) = 0
\]
\[
\Delta M = M_O + V(\Delta x)
\]
\[
\Delta M = M_O, \text{ when } \Delta x \to 0
\]

Jump in bending moment due to concentrated couple moment M₀

Note: the text, these notes, and convention assume that an applied concentrated moment M₀ in clockwise direction results in a positive change in M(x)

Note that for a concentrated force or moment, w = 0. Therefore, \( \frac{dV}{dx} = w = 0 \), so V(x) must be constant.
Draw the shear force and moment diagrams for the beam.

Exercise: derive \( V(x) \) and \( M(x) \) as shown.
Draw the shear force and moment diagrams for the beam.

Exercise: derive $V(x)$ and $M(x)$ as shown.
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
Friction

Friction is a force that resists the movement of two contacting surfaces that slide relative to one another. This force acts tangent to the surface at the points of contact and is directed so as to oppose the possible or existing motion between the surfaces.

Dry Friction (or Coulomb friction) occurs between the contacting surfaces of bodies when there is no lubricating fluid.
Friction

In designing a brake system for a bicycle, car, or any other vehicle, it is important to understand the frictional forces involved.

This is a good link to explain different types of forces:
http://www.yourarticlelibrary.com/science/4-important-types-of-force-explained-with-diagram/31675
Dry friction

- Consider the effects of pulling horizontally a block of weight $W$ which is resting on a rough surface.

- The floor exerts an uneven distribution of normal forces $\Delta N_n$ and frictional forces $\Delta F_n$ along the contacting surface.

- These distributed loads can be represented by their equivalent resultant normal forces $N$ and frictional forces $F$.
Dry friction

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

\[ \sum M_0 = -P h + W x = 0 \rightarrow x = \frac{P}{W} \]

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

\[ F_s = \mu_s \ N \]

where \( \mu_s \) is called the coefficient of static friction
1.  $P = 0 \rightarrow$ no motion; no friction
2.  $P < F_s \Rightarrow P < \mu_s W \rightarrow$ no motion; friction force $|F| = |P|$
3.  $P = F_s = \mu_s W \rightarrow$ no motion, but on the point of sliding
4.  $P > F_s \rightarrow$ box begins to slide, since $\sum F_x > 0$

When $P > F_s$, the frictional force is no longer a function of the coefficient of static friction, but instead it will drop to a smaller value $F_k$, i.e.,

$$F_k = \mu_k N$$

where $\mu_k$ is called the coefficient of kinetic friction, or dynamic friction. Typical values for $\mu_k$ are approximately 25% smaller than the ones for $\mu_s$.

### Table 8–1 Typical Values for $\mu_s$

<table>
<thead>
<tr>
<th>Contact Materials</th>
<th>Coefficient of Static Friction ($\mu_s$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal on ice</td>
<td>0.03–0.05</td>
</tr>
<tr>
<td>Wood on wood</td>
<td>0.30–0.70</td>
</tr>
<tr>
<td>Leather on wood</td>
<td>0.20–0.50</td>
</tr>
<tr>
<td>Leather on metal</td>
<td>0.30–0.60</td>
</tr>
<tr>
<td>Aluminum on aluminum</td>
<td>1.10–1.70</td>
</tr>
</tbody>
</table>
Before the Box Moves

\[ T - f = 0 \]
Before the Box Moves

\[ T - f = 0 \]

Maximum Static Friction

\[ f_{\text{max}} = \mu_s N \]

Coefficient of Static Friction

Physics 211: Flipitphysics.com
Before the Box Moves

\[ T - f = 0 \]
Summary: Dry friction

- Friction acts tangent to contacting surfaces and in a direction opposed to motion of one surface relative to another.

- Friction force \( F \) is related to the coefficient of friction and normal force \( N \):
  - Static friction: \( F_s \leq \mu_s N \)
  - Kinetic friction: \( F_k = \mu_k N \)

- Magnitude of coefficient of friction depends on the two contacting materials.

- Maximum static frictional force occurs when motion is impending.

- Kinetic friction is the tangent force between two bodies after motion begins. Less than static friction by \( \sim 25\% \).

Components of a Contact Force

| Table 8–1 Typical Values for \( \mu_s \) |
|-----------------|-----------------|
| Contact Materials | Coefficient of Static Friction (\( \mu_s \)) |
| Metal on ice     | 0.03–0.05       |
| Wood on wood     | 0.30–0.70       |
| Leather on wood  | 0.20–0.50       |
| Leather on metal | 0.30–0.60       |
| Aluminum on aluminum | 1.10–1.70       |
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.
Find the maximum force $P$ that can be applied without causing movement of the crate.