Announcements

- Got i-Clicker?
- Practice PrairieLearn Homework and Quiz now live
- MATLAB clinic starts tonight, check Piazza post for details
- Remember to go through the course website
  - Office hours are posted (Schedule)
- Recommended reading: Hibbeler chapters 1-2

- Upcoming deadlines:
  - Tuesday (1/22)
    - PrairieLearn HW1
  - Friday (1/25)
    - Written Assignment 1
Lecture Objectives

- What is “statics”?  
- Newton’s laws of motion  
- Newton’s law of gravitational attraction  
- Force vectors and vector operations
Chapter 1: General Principles
What is “statics”?

- Science
  - Life
  - Physical
  - Social
  - More!

- Astronomy
- Physics
- Chemistry
- More!

- Relativity
- Mechanics
- Thermo
- More!

L2 - Gen Principles & Force Vectors
Mechanics

Mechanics is a branch of the physical sciences that is concerned with the state of rest or motion of bodies that are subjected to the action of forces.
Newton’s laws of motion

First law: Particle *at rest* (or moving in a straight line with constant velocity) stays that way unless another force comes in.

Second law: a particle acted upon by an unbalanced force $F$ experiences an acceleration $\mathbf{a}$ that is proportional to the particle mass $m$:

$$F = ma$$

Third law: The mutual forces of action and reaction between two particles are _______ equal, _______ opposite and _______ collinear.
state of rest or motion of bodies that are subjected to the action of forces

Which forces?

* gravity
* electromag
* strong (nucleus)
* normal
* friction

TAM 210/211:
gavity & contact forces only

L2 - Gen Principles & Force Vectors
Newton’s law of gravitational attraction

The mutual force $F$ of gravitation between two particles of mass $m_1$ and $m_2$ is given by:

$$F = G \frac{m_1 m_2}{r^2}$$

$G$ is the universal constant of gravitation (small number)
$r$ is the distance between the two particles

**Weight** is the force exerted by the earth on a particle at the earth’s surface:

$$F = mg, \quad g = G \frac{M_e}{r_e^2}$$

$M_e$ is the mass of the earth
$r_e$ is the distance between the earth’s center and the particle near the surface
$g$ is the acceleration due to the gravity
### Units

**Table 1-1: Systems of Units**

<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Time</th>
<th>Mass</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>International System of Units (SI)</td>
<td>m</td>
<td>s</td>
<td>kg</td>
<td>newton* (N)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(kg·m/s²)</td>
</tr>
<tr>
<td>U.S. Customary (FPS)</td>
<td>ft</td>
<td>s</td>
<td>slug*</td>
<td>pound</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(lb·s²/ft)</td>
<td></td>
</tr>
</tbody>
</table>

*Derived unit.

\[ W = mg \]

\[ G = 66.73 \times 10^{-12} \frac{m^3}{kg \cdot s^2} \]

\[ g = 9.81 \frac{m}{s^2} \]

\[ g = 32.2 \frac{ft}{s^2} \]
Why so picky? Units matter...

- A national power company mixed up prices quoted in kilo-Watt-hour (kWh) and therms.
  - Actual price: $50,000
  - Paid while trading on the market: $800,000

- In Canada, a plane ran out of fuel because the pilot mistook liters for gallons! He landed the plane safely without power on an emergency airstrip.
Numerical Calculations

**Significant figures**

The number of significant figures contained in any number determines the accuracy of the number. Use 3 or > significant figures for final answers. For intermediate steps, use symbolic notation, store numbers in calculators or use more significant figures, in order to maintain precision.

\[ 1.0 \% \text{ error} \]

**Answer:** 1354.76585 N

\[ \rightarrow 1350 \text{ N} \]

\[ \times 1400 \text{ N} \]
Force vectors

A force—the action of one body on another—can be treated as a vector, since forces obey all the rules that vectors do.
Scalars and vectors

<table>
<thead>
<tr>
<th></th>
<th>Scalar</th>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examples</strong></td>
<td>Mass, Volume, Time</td>
<td>Force, Velocity</td>
</tr>
<tr>
<td><strong>Characteristics</strong></td>
<td>It has a magnitude</td>
<td>It has a magnitude and direction</td>
</tr>
<tr>
<td><strong>Special notation</strong></td>
<td>None</td>
<td>Bold font or symbols (“→”)</td>
</tr>
<tr>
<td>used in TAM 210/211</td>
<td></td>
<td>Ex: $\vec{A}$, $\vec{A}$</td>
</tr>
</tbody>
</table>

**Multiplication or division of a vector by a scalar**

$$B = \alpha A$$

$\alpha = 2$

- magnitude 2x
- direction stays the same
**Vector addition**

All vector quantities obey the parallelogram law of addition \( R = A + B \)

![Parallelogram law](image)

Commutative law: \( R = A + B = B + A \)

![Triangle rule](image)

Associative law: \( A + (B + C) = (A + B) + C \)
**Vector subtraction:**

$$R = A - B = A + (-B)$$

$(-B)$ has the same magnitude as $B$ but is in opposite direction.

**Scalar/Vector multiplication:**

$$\alpha(A + B) = \alpha A + \alpha B$$

$$(\alpha + \beta)A = \alpha A + \beta A$$

$\alpha = -1$  
$\alpha \overrightarrow{B}$

equal in magnitude, opposite in direction
Cartesian vectors

Rectangular coordinate system: formed by 3 mutually perpendicular axes, the x, y, z axes, with unit vectors \( \hat{i}, \hat{j}, \hat{k} \) in these directions.

Note that we use the special notation "\( \wedge \)" to identify basis vectors (instead of the "\( \rightarrow \)" notation)

\( (\hat{i}, \hat{j}, \hat{k}) \) or \( (i, j, k) \)

Right-handed coordinate system

Rectangular components of a vector

\[ A = A_x + A_y + A_z \]

Cartesian vector representation

\[ A = A_x \hat{i} + A_y \hat{j} + A_z \hat{k} \]
Right-hand Rule

Sort the following coordinate systems into Cartesian and non-Cartesian.

Label the missing coordinate axes in Cartesian coordinate system.
Magnitude of Cartesian vectors

\[ A = |\mathbf{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2} \]

x-, y-component form variables: \( A_x, A_y \)
magnitude and angular direction variables: \( A, \theta \)

\[ A_x = A \cos \theta \]
\[ A_y = A \sin \theta \]

\[ A = \sqrt{A_x^2 + A_y^2} \]

\[ \theta = \tan^{-1}\left(\frac{A_y}{A_x}\right) \]
**Direction of Cartesian vectors**

Expressing the direction using a unit vector:

\[
u_A = \frac{A}{A} = \frac{A_x}{A} \mathbf{i} + \frac{A_y}{A} \mathbf{j} + \frac{A_z}{A} \mathbf{k}
\]

Direction cosines are the components of the unit vector:

\[
\cos(\alpha) = \frac{A_x}{A} \\
\cos(\beta) = \frac{A_y}{A} \\
\cos(\gamma) = \frac{A_z}{A}
\]
Addition of Cartesian vectors

\[ \overrightarrow{R} = \overrightarrow{A} + \overrightarrow{B} = (A_x + B_x) \hat{i} + (A_y + B_y) \hat{j} + (A_z + B_z) \hat{k} \]