FORCES AND FREE-BODY DIAGRAMS

Newton’s Laws Yo!
Recall: Net Forces

- **Force**: any influence that tends to accelerate an object; a push or a pull; measured in NEWTONS (N)

- **Net Force**: combination of all the forces acting on an object

**FORCE is a VECTOR QUANTITY**
- **Support Force/Normal Force** - the force pushing back on an object at rest.
  - A book sits on the table: What forces act on it?
    - Force of book on table (due to **gravity**)
    - Force of table on book (support force, aka normal force)
  - Bathroom scale: What forces act on it?
    - Force of you on scale (due to gravity)
    - Force of scale on you (support force, aka normal force)
  - Gymnast on Rings
    - Rope undergoes “stretching” force when hanging by it
      - Two vertical ropes share the load (think trapeze, pull ups)
Recall: Friction

- Friction results from relative motion between objects.
- Frictional forces are forces that resist or oppose motion.
  - Depends on....
    - 2 surfaces in contact (silk, sand paper...)
    - Normal Force (more weight on top of book ↑ Friction)
Types of Friction

- Static friction
- Sliding (Kinetic) friction
- Rolling friction
Free-body diagrams

Free-body diagrams are used to show the relative magnitude and direction of all forces acting on an object.
This diagram shows four forces acting upon an object. There aren’t always four forces.
Problem 1

- A book is at rest on a table top. Diagram the forces acting on the book.

- In this diagram, there are normal and gravitational forces on the book.
An egg is free-falling from a nest in a tree. Neglect air resistance. Draw a free-body diagram showing the forces involved.
Gravity is the only force acting on the egg as it falls.
A flying squirrel is gliding (no wing flaps) from a tree to the ground at constant velocity. Consider air resistance. A free body diagram for this situation looks like...
Gravity pulls down on the squirrel while air resistance keeps the squirrel in the air for a while.
Problem 4

A rightward force is applied to a book in order to move it across a desk. Consider frictional forces. Neglect air resistance. Construct a free-body diagram. Let’s see what this one looks like.
Note the larger applied force arrow pointing to the right since the book is accelerating to the right. Friction force opposes the direction of motion. The force due to gravity and normal forces are balanced.
Problem 5

A skydiver is descending with a constant velocity. Consider air resistance. Draw a free-body diagram.
Gravity pulls down on the skydiver, while air resistance pushes up as she falls.
Problem 6

A man drags a sled across loosely packed snow with a rightward acceleration. Draw a free-body diagram.
The applied force arrow points to the right and is larger than the frictional force since the object is accelerating. Since the sled is on the ground, the normal and gravitational force are balanced.
Problem 7

A football is moving upwards toward its peak after having been booted by the punter. Draw a free-body diagram. (Neglect air friction)
The force of gravity is the only force described. (no air resistance).
Problem 8

A car runs out of gas and is coasting down a hill.
The car is coasting down the hill, there is dragging friction of the road (left pointing arrow) as well as gravity and normal forces, but no applied force.
Done.
What is Friction again?

■ Force that acts oppose the relative motion of two surfaces

■ High for dry and rough surfaces

■ Low for smooth and wet surfaces
Free Body Diagram

\[ F_g = mg \]
\[ F_N = F_g \]
\[ f_f = F \]
Static Friction

The Force of Static Friction keeps a stationary object at rest!

\[ f_s = F_N \times \mu_s \]

\[ \mu_s = \text{coefficient of static friction} \]
Kinetic Friction

Once the Force of Static Friction is overcome, the Force of Kinetic Friction is what slows down a moving object!

\[ f_k = F_N \times \mu_k \]

\[ \mu_k = \text{coefficient of kinetic friction} \]
Types of Friction

To initiate motion of the box, the man must overcome the Force of Static Friction.

Upon sliding, the baseball player will come to a complete stop due to the Force of Kinetic Friction.
Representative values for the coefficient of friction

<table>
<thead>
<tr>
<th>Surfaces</th>
<th>$\mu_{\text{static}}$</th>
<th>$\mu_{\text{sliding}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>rubber on concrete</td>
<td>0.80</td>
<td>0.65</td>
</tr>
<tr>
<td>wood on wood</td>
<td>0.50</td>
<td>0.20</td>
</tr>
<tr>
<td>ice on ice</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>glass on glass</td>
<td>0.94</td>
<td>0.40</td>
</tr>
<tr>
<td>steel on steel</td>
<td>0.74</td>
<td>0.57</td>
</tr>
</tbody>
</table>

**Friction**
(dry sliding friction)

\[ F_f = \mu F_n \]

- **Friction force (N)**
- **Coefficient of friction**
- **Normal force (N)**
Problem 1: How much force is needed to keep a 78Kg block moving at a constant speed across the floor if the coefficient of friction b/n the block and the floor is 0.21?

Friction
(dry sliding friction)

Friction force (N) \( F_f = \mu F_n \)

Coefficient of friction

Normal force (N)
First, find the weight (measure of $F_g$ on an object.) and then find $F_f$.

- $F_w = mg$
  - $F_w = (78 \text{ kg})(9.8 \text{ m/s/s})$
  - $F_w = 764.4 \text{ N}$

- $F_f = \mu F_n$
  - $F_f = (0.21)(764.4)$
  - $F_f = 160.5 \text{ N}$
Problem 2: What is the coefficient of friction between a box with a weight of 637N and the floor if it is pulled at a constant speed with a force of 75N?
Simply solve for $\mu$.

\[ F_f = \mu F_n \]

- To solve for $\mu$ you need only the friction force and the normal force.
- Since the box is pulled at a constant velocity, meaning a net force of 0N, the $F_{\text{app}}$ will equal the $F_r$.
- Thus:
  - $F_f = \mu F_n$
  - $75N = \mu(637N)$
  - $\mu = 0.117$ or $0.12$