Recall:

Relative motion:
\[ \vec{V} \text{ B wrt R} = \vec{V}_B \text{ wrt } \vec{A} + \vec{V}_A \text{ wrt R} \]

E.g. \[ \vec{V}_{\text{rain wrt ground}} = \vec{V}_{\text{rain wrt car}} + \vec{V}_{\text{car wrt ground}} \]

\[ \vec{V}_{\text{boat wrt ground}} = \vec{V}_{\text{boat wrt water}} + \vec{V}_{\text{water wrt ground}} \]

Uniform circular motion:
\[ l \vec{\nu} l = \text{const} = \text{speed} \]
\[ \vec{\nu} \text{ tangent to path} \]
\[ l\vec{a}l = \frac{V^2}{r} \text{, points toward center} \]
How does the magnitude of the force that Darling the daughter exerts on Kitty the cat compare with the force that Kitty exerts on Darling?

*A. F_{Darling on Kitty} > F_{Kitty on Darling}*

*B. F_{Darling on Kitty} = F_{Kitty on Darling}*

*C. F_{Darling on Kitty} < F_{Kitty on Darling}*

---

"Do stop pulling the cat's tail, Darling."

"I'm not pulling Mummy, Kitty's pulling!"
Today:

- Forces
  - Newton’s laws of motion
  - Gravitational force
  - Normal force
  - Friction
  - Tension
  - Spring force
have $\vec{a} \cdot \vec{F}$, what else matters? => max: $1 \vec{a} \cdot \frac{1}{m}$

III: Newton's second law of motion

\[ \vec{a}_{\text{of object}} = \frac{\Sigma \vec{F}_{\text{on object}}}{m_{\text{obj}}} = \frac{\vec{F}_{\text{net on obj}}}{m_{\text{obj}}} \]

in component form:

\[ a_x = \frac{\Sigma F_{x, \text{on obj}}}{m_{\text{obj}}} \quad a_y = \frac{\Sigma F_{y, \text{on obj}}}{m_{\text{obj}}} \]

\[ \Rightarrow 2\text{-D problem} = 2 \text{ 1-D problems} \]

Note: External forces only? Internal forces don't affect the motion!
Newton's first law of motion (special case of VII)

If \( \Sigma \vec{F}_{\text{on object}} = 0 \), then \( \vec{a} = 0 \)

\( \Rightarrow \) if object is initially at rest, then \( \vec{v}(t) = 0 \) for all \( t > 0 \).

\( \Rightarrow \) initially moving, then \( \vec{v} = \text{const} \) for all \( t \).

Units of force:

\[ [F] = [m][a] = \text{kg} \cdot \frac{\text{m}}{\text{s}^2} = \text{N} \) (Newtons)
Overhead views of a block that lies on a frictionless floor are shown below.

\[ \text{want } \vec{v} = \text{const} \Rightarrow \vec{a} = 0 \Rightarrow \Sigma \vec{F} = 0 \]

If the force magnitudes are chosen properly, in which situations is it possible that the block is either stationary or moving with constant velocity?

A. (2) and (3)
B. (2) and (4)
C. (2), (3), and (4)
D. All four
Newton's 3rd law of motion

\[ \vec{F}_{A \text{ on } B} \leftrightarrow \vec{F}_{B \text{ on } A} \]

\[ \vec{F}_{A \text{ on } B} = - \vec{F}_{B \text{ on } A} \]

"interaction pair" = forces involved in the interaction of two objects

= action-reaction pair
Nth: Forces in an interaction pair act on different objects (never on the same)!

\[ \vec{F} \text{ apple on earth and } \vec{F} \text{ earth on apple} \]

- Nth true even if object are moving or accelerating!
Newton's Third Law:

\[ \vec{F}_{\text{earth on apple}} = -\vec{F}_{\text{apple on earth}} \]

"Proof": Break earth up into N apple-sized chunks:

Forces on apple:

\[ F_{\text{chunk 1 on apple}} + F_{\text{chunk 2 on apple}} + \ldots + F_{\text{chunk N on apple}} = \vec{F}_{\text{earth on apple}} \]

Forces on chunks of earth:

\[ F_{\text{apple on chunk 1}} + F_{\text{apple on chunk 2}} + \ldots + F_{\text{apple on chunk N}} = \vec{F}_{\text{apple on earth}} \]

It only seems reasonable that each term \( F_{\text{chunk i on apple}} \) and \( F_{\text{apple on chunk i}} \) on either side should be equal, so the sums must be equal.
Which of the following forces are 3rd-law interaction pairs?

A. Weight $W$ of mass $m$ and tension $T$ of rope
B. $W$ and gravitational force of mass $m$ on earth
C. Tension $T$ and force of mass $m$ on rope
D. Two of the above
E. Three of the above
Some Forces:

- **Weight**: $\vec{W} = \text{gravitational force} = F_g$, acting on an object
  - force on object due to Earth's gravity
  - $\vec{W} = m \vec{g}$
  - pointing to center of Earth
  - $[g = 10 \text{ m/s}^2 \text{ at Earth's surface}]$

- **Normal Force**: $\vec{N} = F_n$ to surface by surface on object
  - $\vec{N}$ prevent motion perpendicular to a surface (into surface)
  - **Self-adjusting force**, to prevent motion into surface $\Rightarrow a_n = 0$
  - $\vec{N}$ always perpendicular to surface (90° wrt surface)
  - $\vec{N}$ is the $\perp$ component of the force by a surface on an object
- Friction:
  - perpendicular to surface
  - opposes motion relative to surface
  - component of the force by a surface on an object

\[ \vec{F}_{\text{friction}} \]

\[ \vec{N} \]

\[ \vec{w} \]

\[ \vec{v} \]

- Tension \( \vec{T}_1 \) on rope

\[ \vec{T}_2 \]

\[ \overrightarrow{+x} \]

\[ m \]

\[ \overrightarrow{a} \]

- e.g. rope, wire, rod, bone, muscle, ...

\[ \sum F_x = m \cdot \overrightarrow{a} = \vec{T}_1 - \vec{T}_2 \]

\[ \Rightarrow \text{if } \overrightarrow{a} = 0, \text{ then } \boxed{\vec{T}_1 = \vec{T}_2} \]
also: if \( m_{\text{rope}} \approx 0 \)  \( \Rightarrow \)  \( T_1 - T_2 = \max a_x = 0 \) \( a_x = 0 \)

\[ \Rightarrow \begin{cases} T_1 = T_2 \end{cases} \quad \text{even if } a_x \neq 0 \]

\[ \Rightarrow \text{use this in P2207 unless otherwise stated} \]

\( T_1 \): equal in magnitude at either end of the rope (if \( m_{\text{rope}} \approx 0 \), or \( a^2 = 0 \))

- force each piece of rope exerts on the adjacent piece/section/object

\[ \text{Spring Force: } - \vec{F}_{\text{spring}} \]

For ideal spring:

\[ \vec{F}_{\text{by spring on block}} = -k \vec{x} \]

\( k \): “Spring Constant”