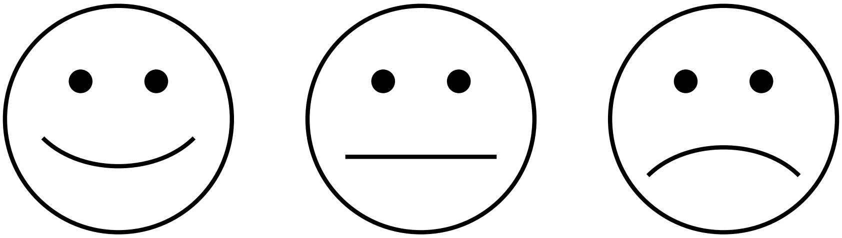
Studio 4: Gravity and Friction

<u>Warm-Up Activity</u>
How do you feel about the quizzes?

(A) (B) (C) (D) (E)



(Newton's) Laws of Motion

(1) An object in motion (or at rest) stays in motion (or at rest) unless a net external force acts on it.

(2) The net force on an object is equal to the object's mass times its acceleration:

$$\vec{F}^{net} = m\vec{a}.$$

(3) If A exerts a force on B, then B exerts a force of the same magnitude on A in the opposite direction:

$$\vec{F}_{AB} = -\vec{F}_{BA}.$$

Types of Forces

- Gravity $\vec{F}^g_{AB} = m_A \vec{g}_B$
  - Newtonian $\vec{g}_B = G\frac{M_B}{r^2}(-\hat{r})$, $G = 6.67408 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$
  - Near-Earth $\vec{g}_E = g(-\hat{y}),\ g = 9.81\frac{\mathrm{m}}{\mathrm{s}^2} \approx 10\frac{\mathrm{m}}{\mathrm{s}^2}$
- Normal $\vec{F}^N$ always $\perp$; varies in magnitude
- Tension $\vec{F}^T$ uniform (massless, inextensible rope)
- Spring
- Friction
  - Static Friction $F^{sf} \leq \mu_s |\vec{F}^N|$
  - Kinetic Friction $F^{kf} = \mu_k |\vec{F}^N|$

S4-1: The Elevator

- You attach a volleyball with mass 275 grams to a string and suspend it from the ceiling of an elevator.
- The elevator is moving upward at constant speed 1.5 m/s.
- Our goal is to determine the tension in the string.
  - Choose a system and identify any assumptions you are making.
  - Sketch and label a free body diagram.
  - Determine the tension.
  - Make sense of your answer.

S4-2: The Accelerating Elevator

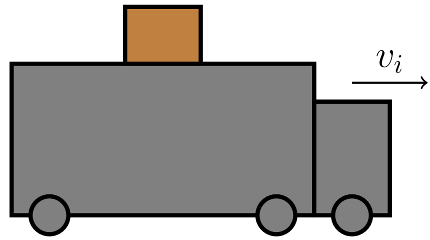
- You attach a volleyball with mass 275 grams to a string and suspend it from the ceiling of an elevator.
- The elevator is moving upward at initial speed 1.5 m/s and accelerating upward at a constant rate of 2.5 m/s^2.
  - Do you want to change your system or assumptions?
  - How (if at all) does your free body diagram change?
  - How (if at all) does the tension change?

S4-3: The Space Elevator

- You attach a volleyball with mass 275 grams to a string and suspend it from the ceiling of an elevator.
- The elevator is located 400 km above the surface of the Earth and moving upward at constant speed.
  - Do you want to change your system or assumptions?
  - How (if at all) does your free body diagram change?
  - How (if at all) does the tension change?

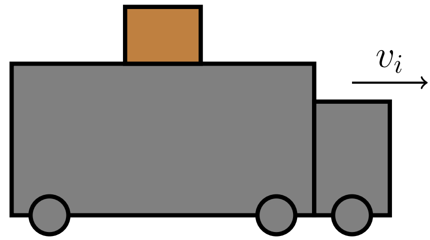
S4-4: The Crate on Top of the Truck I (Gaining Speed)

- A truck is initially moving to the right with speed v_i.
- The driver left a crate on top of the truck. We know the mass of the crate (m_c) and the coefficients of friction (μ_s and μ_k).
- The truck begins *speeding up*, but the driver wants to prevent the crate from sliding.
  - Draw a free-body diagram for the crate.
    - What kind of friction acts on it?
    - What direction is the friction?
  - What do we know about the truck's velocity? What about its acceleration?



S4-5: The Crate on Top of the Truck II (Slamming on the Brakes)

- A truck is initially moving to the right with speed v_i.
- We know the mass of the crate (m_c) and the coefficients of friction (μ_s and μ_k).
- The driver suddenly has to slam on the brakes, causing the crate to begin sliding.
  - Draw a free-body diagram for the crate.
    - How is it different from before?
  - Determine the acceleration of the crate relative to the ground.



Solving Problems Using Forces

- Identify a system.
- Identify the (external) forces acting on the system.
  - Draw a free-body diagram.
- Identify the acceleration (**not a force**).
  - Static/dynamic equilibrium (acceleration = 0)
  - Dynamics (acceleration not 0)
- Use the laws of motion.

Main Ideas

- Forces arise from interactions between objects.
- There are many different *kinds* of forces that we can analyze differently.
- Objects can only change their motion when acted upon by an external force.
- The net force on an object is equal to its mass times its acceleration.
- Forces are vectors.
- When more than one force acts on an object, we can add all the forces together.
- We can model forces quantitatively.