Studio 4: Gravity and Friction

Warm-Up Activity

(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 $F^{kf} = \mu_k |\vec{F}^N|$

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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

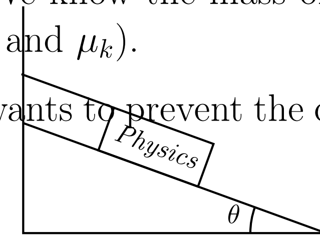
- You attach a volleyball with mass 275 grams to a string and suspend it from the ceiling of an elevator.
- The elevator is moving upward at constant speed 1.5 m/s and accelerating upward at a constant rate of 2.5 m/s^2.
  - Do you want to change your system or assumptions?
  - How (if at all) does your 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 the crate?
    * What direction is the force of friction?
  - What do we know about the truck's
    * velocity?
    * 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.