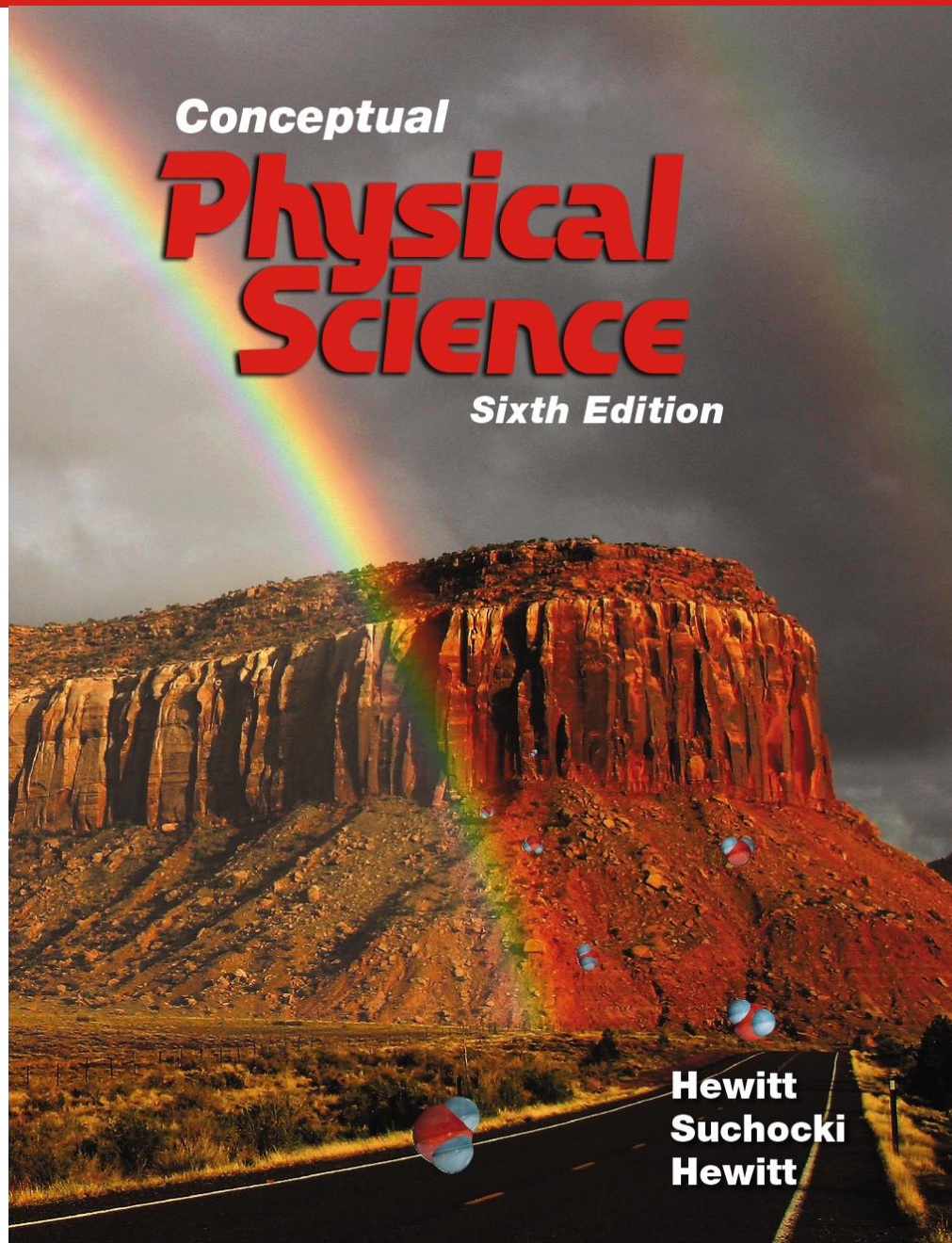
Chapter 3: Newton's Laws of Motion



This lecture will help you understand:

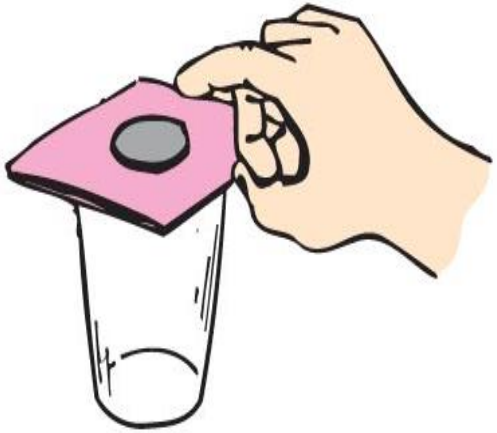
- Newton's First Law of Motion
- Newton's Second Law of Motion
- Forces and Interactions
- Newton's Third Law of Motion

Newton's First Law of Motion

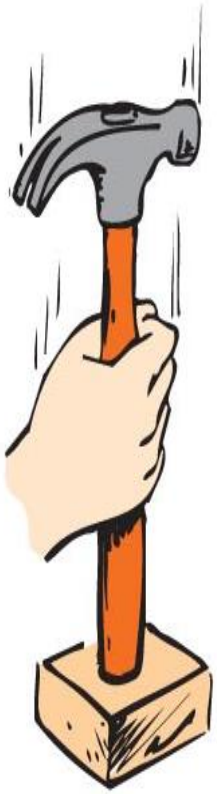
- The law of inertia: (originating with Galileo)

Every object continues in a state of rest or of uniform speed in a straight line unless acted on by a nonzero force.

Examples of Inertia



Why will the coin drop into the glass when a force accelerates the card?



Why do the downward motion and sudden stop of the hammer handle tighten the hammerhead?

Inertia in Action

- Rapid deceleration is sensed by the driver who lurches forward.
- It is also an example of Newton's Second Law because no force stops the driver while the brakes stop the vehicle.

Newton's Second Law of Motion

- The law of acceleration:

The acceleration produced by a net force on an object is directly proportional to the net force, is in the same direction as the net force, and is inversely proportional to the mass of the object.

Force of hand accelerates the brick

Twice as much force produces twice as much acceleration

Twice the force on twice the mass gives the same acceleration

Newton's Second Law of Motion

- Newton's second law in equation form:

$$\text{Acceleration} = \frac{\text{net force}}{\text{mass}}$$

$$a = \frac{F}{m}$$

- small net force, large mass $\Rightarrow$ small acceleration
- large net force, small mass $\Rightarrow$ large acceleration

Newton's Second Law of Motion

- When acceleration is *g*—free fall.
  - When the only force acting on a falling object is gravity, with negligible air resistance, the object is in **free fall**.
  - An object in free fall accelerates toward Earth at 10 m/s per second.

Newton's Second Law of Motion
CHECK YOUR NEIGHBOR

At one instant an object in free fall has a speed of 40 m/s. Its speed one second later is

A. also 40 m/s.

B. 45 m/s.

C. 50 m/s.

D. none of the above.

Newton's Second Law of Motion
CHECK YOUR ANSWER

At one instant an object in free fall has a speed of 40 m/s. Its speed one second later is

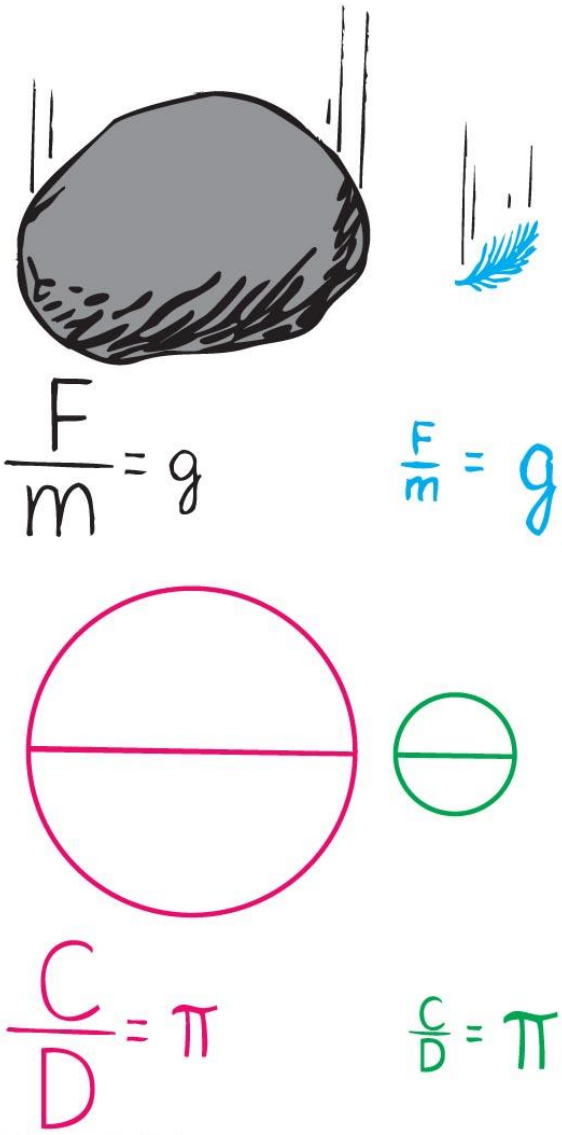
A. also 40 m/s.
B. 45 m/s.
C. 50 m/s.
D. none of the above.

Explanation:

We assume the object is falling downward.

Newton's Second Law of Motion

When acceleration is g—free fall.



The ratio of weight to mass is the same for all falling objects in the same locality; hence, their accelerations are the same in the absence of air resistance.

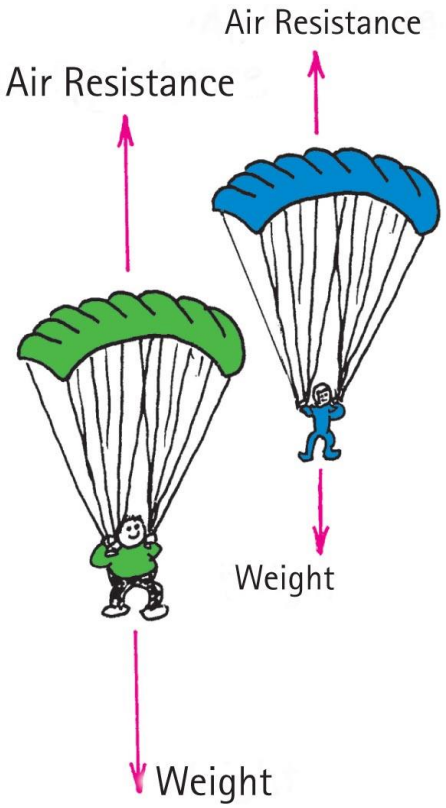
Newton's Second Law of Motion

- When acceleration is *g*—free fall.
  - Demonstration of a feather and a coin in a vacuum.
  - In a vacuum, a feather and a coin fall together at *g*—the acceleration due to gravity.

Newton's Second Law of Motion

- When acceleration is **less than *g***—non-free fall.

Non-free fall occurs when two forces act on a falling object a force due to gravity acting downward air resistance acting upward



Newton's Second Law of Motion

- When acceleration is less than *g*—non-free fall
  - as falling object gains speed, force exerted by surrounding air increases
  - force of air resistance may continue to increase until it equals the weight
  - at this point, net force is zero and no further acceleration
  - object has reached terminal velocity—continues falling at constant velocity with no acceleration

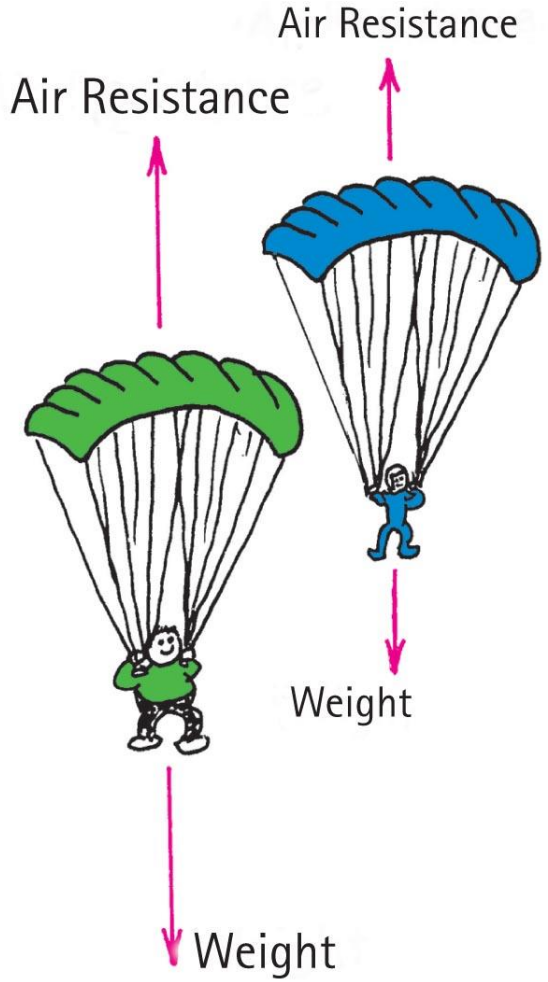
Newton's Second Law of Motion
A situation to ponder…

- Consider a heavy and light person with same-size parachutes jumping together from the same altitude.

A situation to ponder…
CHECK YOUR NEIGHBOR

Who will reach the ground first?

A. The light person.
B. The heavy person.
C. Both at the same time.
D. Not enough information.



A situation to ponder…
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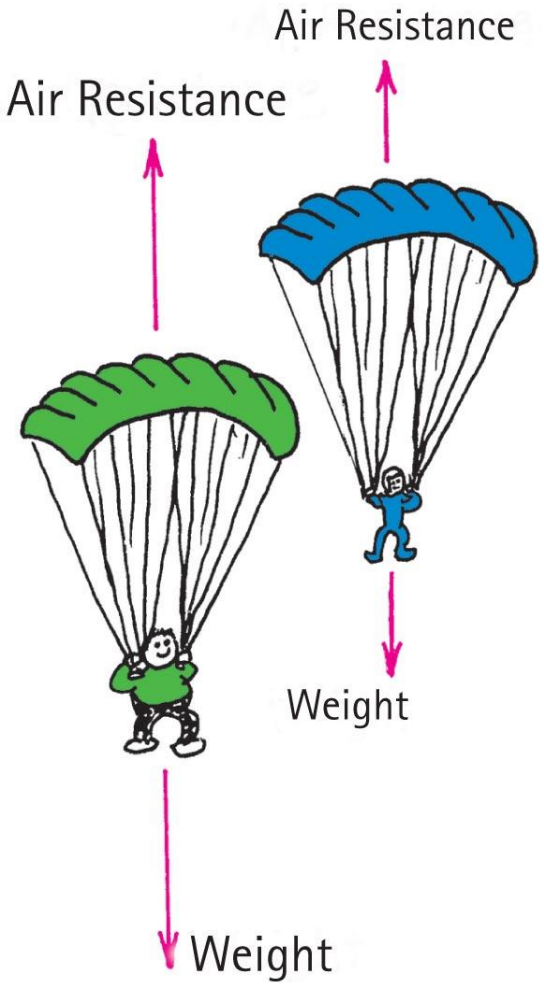


Explanation:

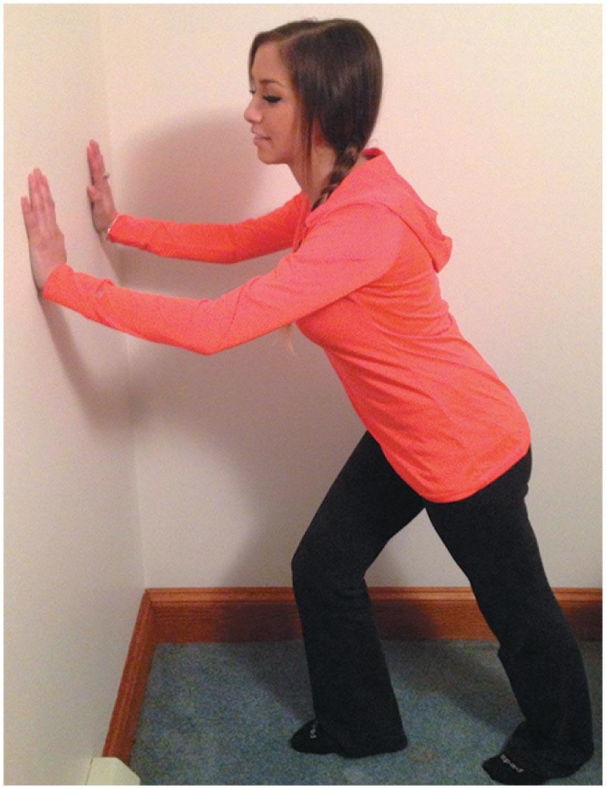
The heavier person has a greater terminal velocity.

Forces and Interactions

- **Force** is simply a push or a pull.
- **Interaction** occurs between one thing and another.

Example:

When you push against a wall, you're interacting with the wall.



Newton's Third Law of Motion

- Law of action and reaction:
  - **Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.**

Example:

When your hand presses on the wall, the wall simultaneously presses on your hand. Hand and wall press on each other with equal and opposite forces.

Newton's Third Law of Motion

- Action and reaction forces
  - one force is called the action force; the other force is called the reaction force
  - are co-pairs of a single interaction
  - neither force exists without the other
  - are equal in strength and opposite in direction
  - always act on *different* objects

Newton's Third Law of Motion
CHECK YOUR NEIGHBOR

A soccer player kicks a ball with 1500 N of force. The ball exerts a reaction force against the player's foot of

A. Somewhat less than 1500 N.

B. 1500 N.

C. somewhat more than 1500 N.

D. None of the above.

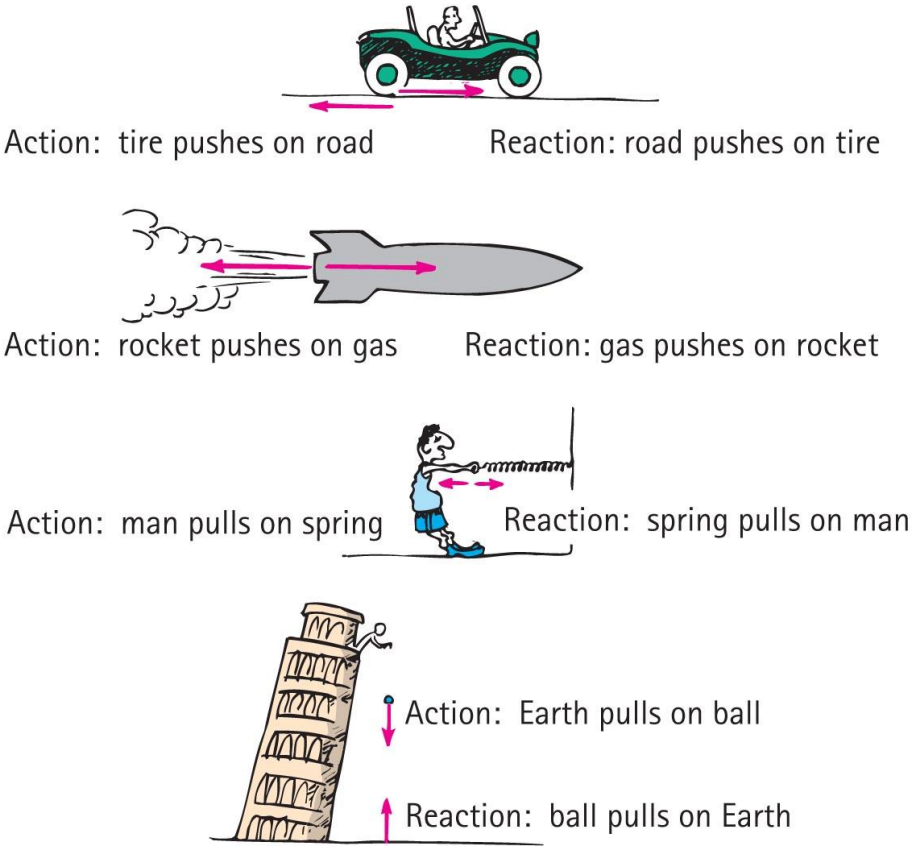
Newton's Third Law of Motion
CHECK YOUR ANSWER

A soccer player kicks a ball with 1500 N of force. The ball exerts a reaction force against the player's foot of

A. somewhat less than 1500 N.
B. 1500 N.
C. somewhat more than 1500 N.
D. None of the above.

Newton's Third Law of Motion

- Simple rule to identify action and reaction:
  - Action—object A exerts a force on object B.
  - Reaction—object B exerts a force on object A.



Newton's Third Law
CHECK YOUR NEIGHBOR

A bird flies by

A. flapping its wings.
B. pushing air down so that the air pushes it upward.
C. hovering in midair. remain in one place in the air.
D. inhaling and exhaling air.

Newton's Third Law
CHECK YOUR ANSWER

A bird flies by

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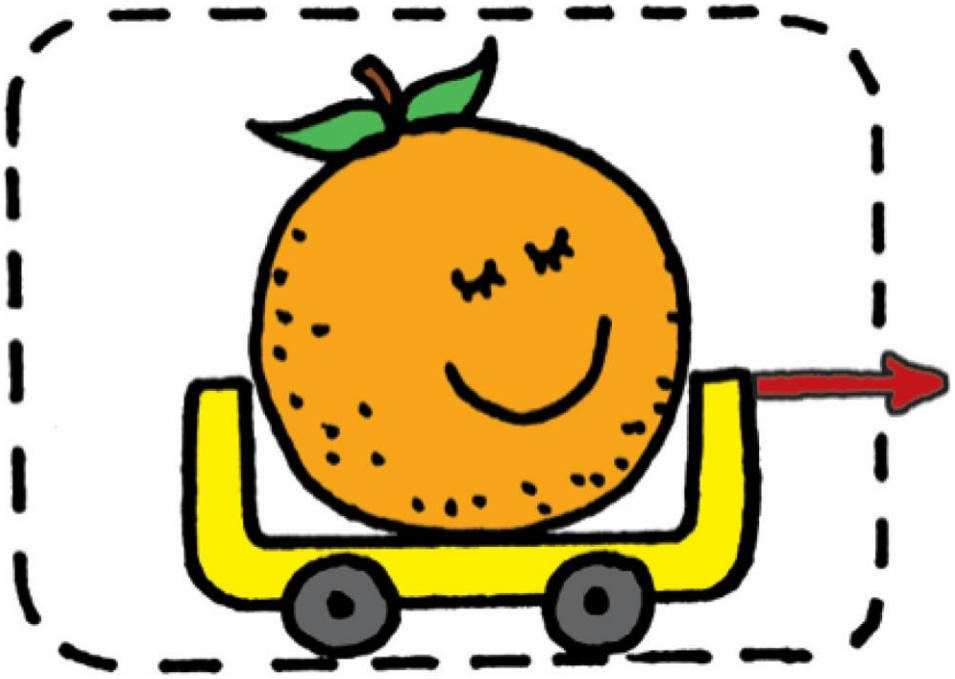
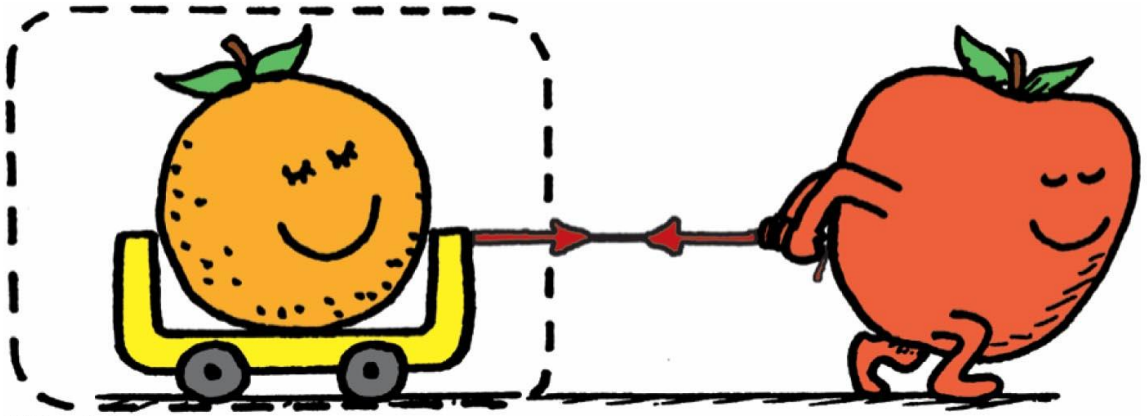
Newton's Third Law of Motion

- Defining your system
  - consider a single enclosed orange
    - applied external force causes the orange to accelerate in accord with Newton's second law
    - action and reaction pair of forces is not shown



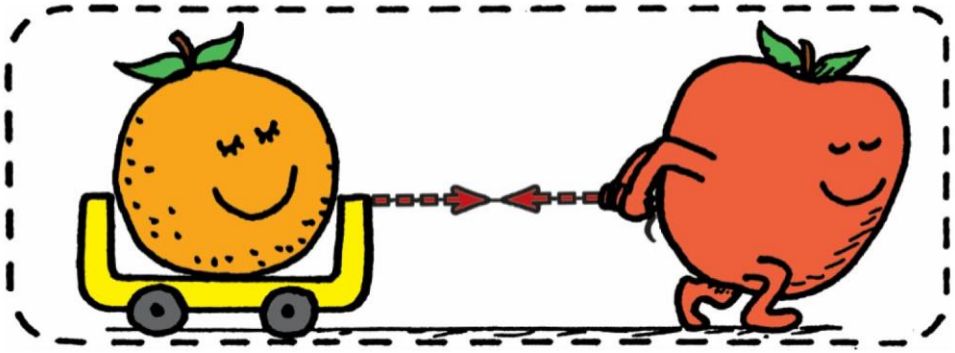
Newton's Third Law of Motion

- Consider the orange and the apple pulling on it
  - action and reaction do not cancel (because they act on different things)
  - external force by apple accelerates the orange



Newton's Third Law of Motion

- Consider a system comprising both the orange and the apple
  - the apple is no longer external to the system
  - force pair is internal to system, which doesn't cause acceleration
  - action and reaction within the system cancel
  - with no external forces, there is no acceleration of system



Newton's Third Law of Motion

- Consider the same system, but with external force of friction on it
  - same internal action and reaction forces (between the orange and apple) cancel
  - a second pair of action-reaction forces (between the apple's feet and the floor) exists

Newton's Third Law of Motion

- one of these acts by the system (apple on the floor) and the other acts on the system (floor on the apple)
- external frictional force of floor pushes on the system, which accelerates
- second pair of action and reaction forces do not cancel