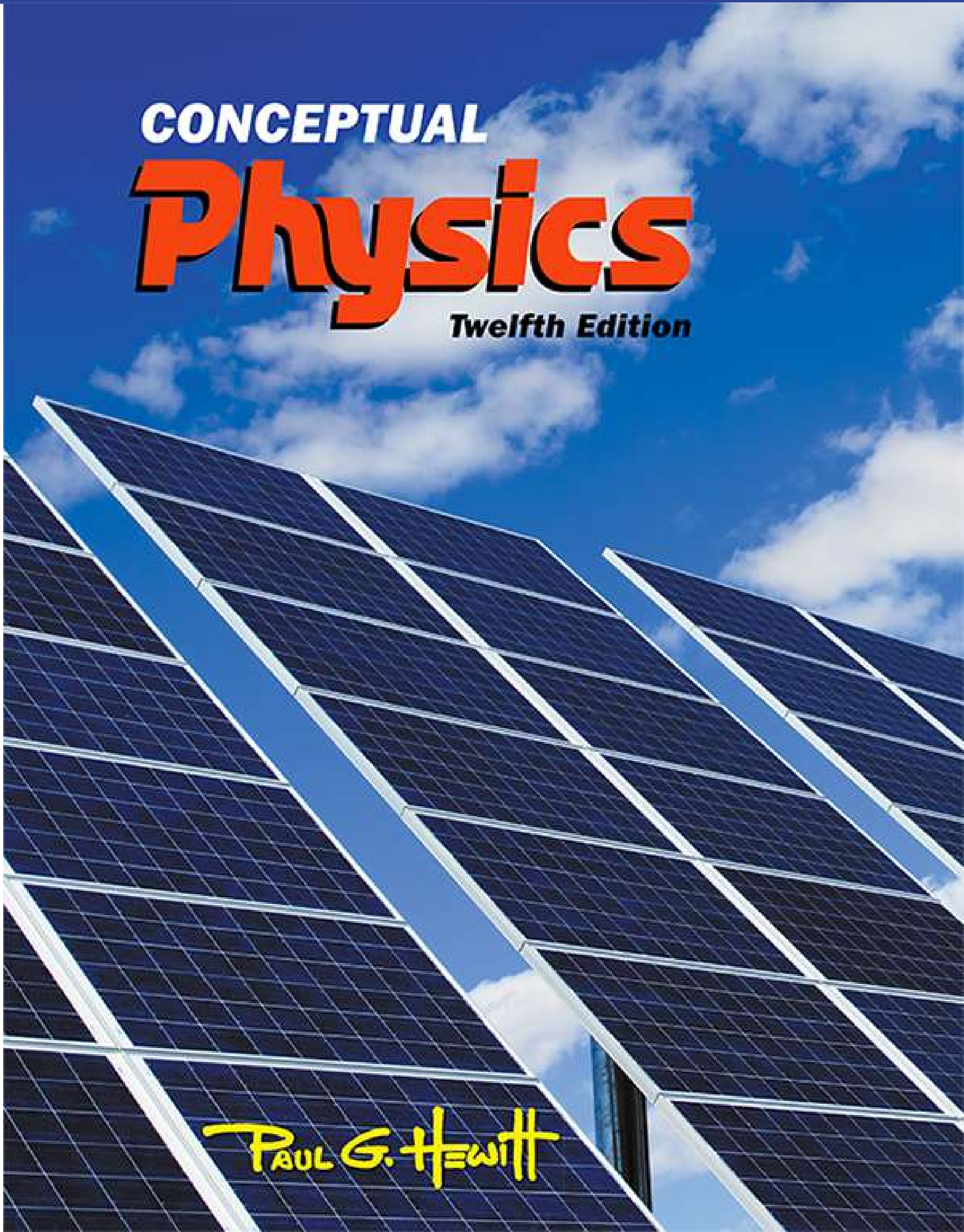
# Chapter 5: Newton's Third Law of Motion

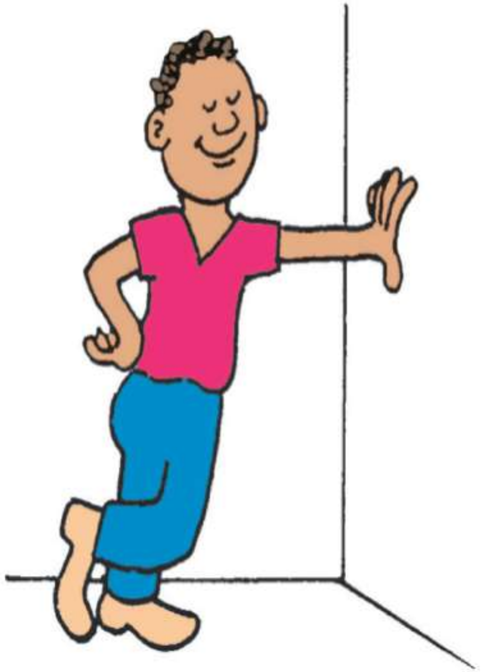


# This lecture will help you understand:

- Forces and Interactions
- Newton's Third Law of Motion
- Vectors and the Third Law
- Summary of Newton's Three Laws of Motion

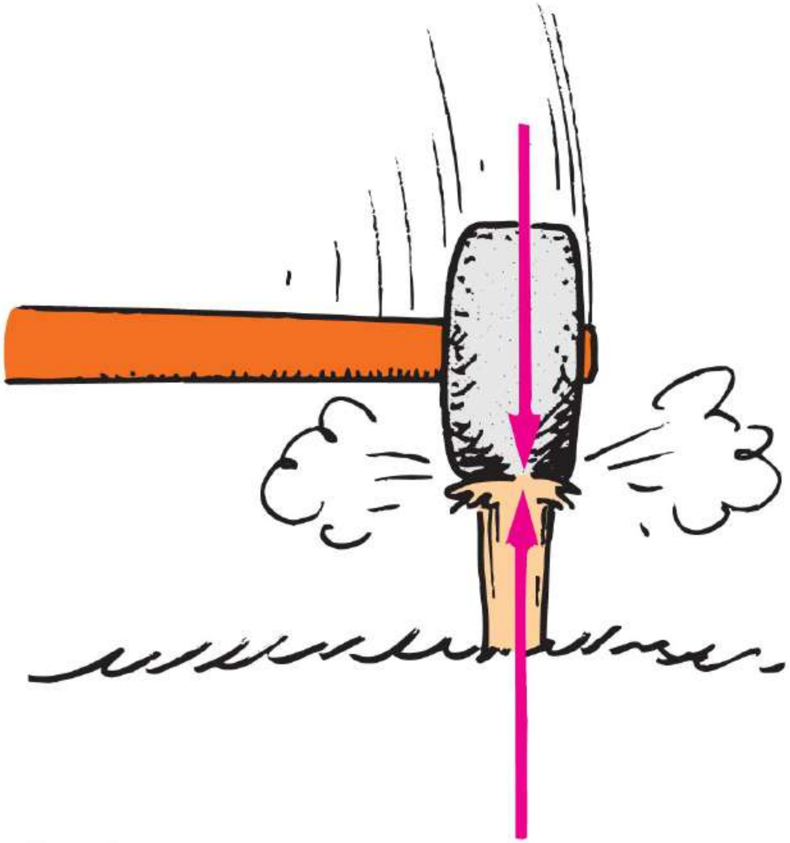
# Forces and Interactions

- Interaction
  - is between one thing and another.
  - requires a pair of forces acting on two objects.
- Example: interaction of hand and wall pushing on each other Force pair—you push on wall; wall pushes on you.



# Newton's Third Law of Motion

- *Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.*



# 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

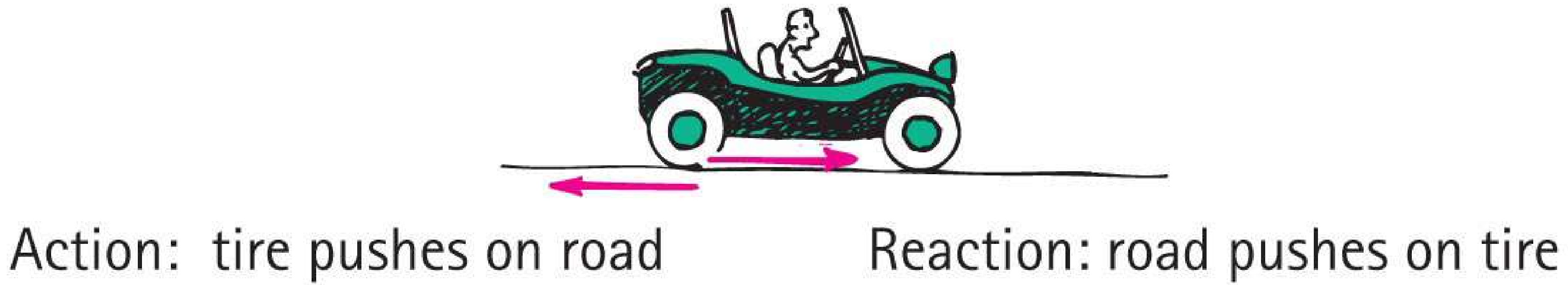
B. **1500 N.**

# Newton's Third Law of Motion, Continued

- 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.

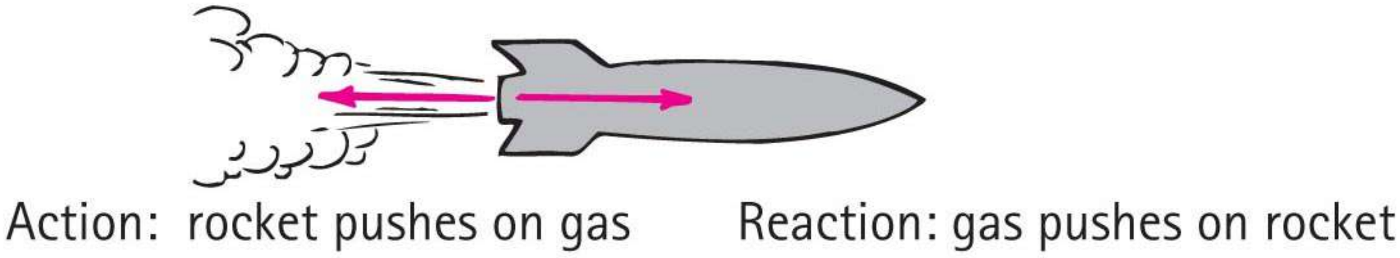
# Newton's Third Law of Motion, Continued-1

- Re-expression of Newton's third law:
- **To every action there is always an opposed equal reaction.**
- Example: Tires of car push back against the road while the road pushes the tires forward.



# Newton's Third Law of Motion, Continued-2

- Simple rule to identify action and reaction
  - Identify the interaction—one thing interacts with another
    - Action: Object A exerts a force on object B.
    - Reaction: Object B exerts a force on object A.
    - Example: Action—rocket (object A) exerts force on gas (object B).
      Reaction—gas (object B) exerts force on rocket (object A).



# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued

When you step off a curb, Earth pulls you downward. The reaction to this force is

A. a slight air resistance.
B. nonexistent in this case.
C. you pulling Earth upward.
D. None of the above.

# Newton's Third Law of Motion CHECK YOUR ANSWER, Continued

When you step off a curb, Earth pulls you downward. The reaction to this force is

C. **you pulling Earth upward.**

**Comment:**

Due to the enormous mass of Earth, don't look for evidence of the upward pull on Earth!

# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-1

When you step off a curb, Earth pulls you downward and you pull Earth upward. Why do you not sense Earth moving upward toward you?

A. Earth is fixed, so it cannot move.
B. Earth can move, but other objects on it prevent it from moving.
C. It moves, but by an imperceptible amount.
D. None of the above.

# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-1

When you step off a curb, Earth pulls you downward and you pull Earth upward. Why do you not sense Earth moving upward toward you?

C. **It moves, but by an imperceptible amount.**

**Explanation:**

The force you exert on Earth is just as much as the force Earth exerts on you. You move more than Earth does because Earth's mass is enormously greater than your mass. Earth's tiny motion is less than you can perceive. (Can you accept what you can't see?)

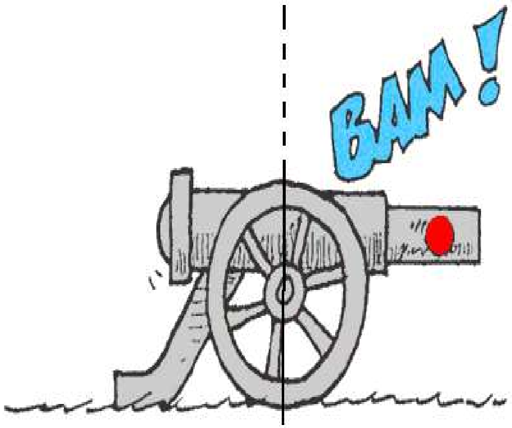
# Newton's Third Law of Motion, Continued-3

- Action and Reaction on Different Masses
  - Cannonball: $\frac{F}{m} = \mathbf{a}$
  - Cannon: $\frac{F}{\mathbf{m}} = a$
- The same force exerted on a small mass produces a large acceleration.
- The same force exerted on a large mass produces a small acceleration.

# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-2

When a cannon is fired, the accelerations of the cannon and cannonball are different because the

A. forces don't occur at the same time.
B. forces, although theoretically the same, in practice are not.
C. masses are different.
D. ratios of force to mass are the same.



# Newton's Third Law of Motion CHECK YOUR ANSWER, Continued-2

When a cannon is fired, the accelerations of the cannon and cannonball are different because the

C. **masses are different.**

# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-3

Consider a high-speed bus colliding head-on with a flying bug. The force of impact splatters the unfortunate bug over the windshield. Which is greater, the force on the bug or the force on the bus?

A. Bug
B. Bus
C. Both the same amount.
D. Cannot say

# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-3

Consider a high-speed bus colliding head-on with a flying bug. The force of impact splatters the unfortunate bug over the windshield. Which is greater, the force on the bug or the force on the bus?

C. **Both the same amount.**

**Comment:**

Although the forces are equal in magnitude, the effects are very different. Do you know why?

# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-4

Two people of equal mass on slippery ice push off from each other. Will both move at the same speed in opposite directions?

A. Yes
B. Yes, but only if both push equally.
C. No
D. No, unless acceleration occurs.

# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-4

Two people of equal mass on slippery ice push off from each other. Will both move at the same speed in opposite directions?

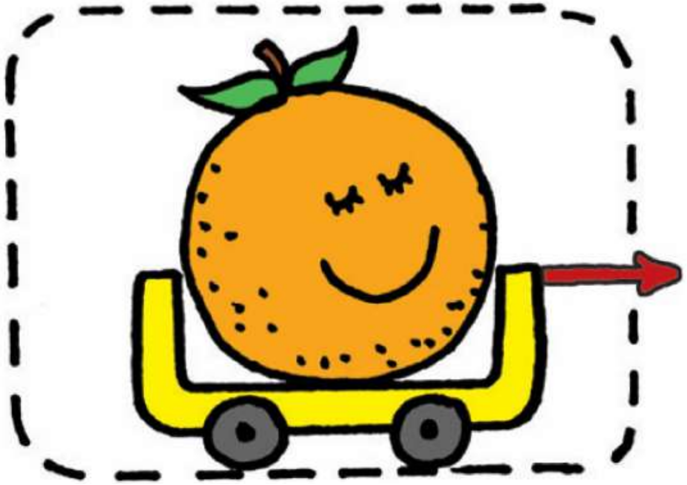
A. **Yes**

**Explanation:**

In whatever way they push, equal-magnitude forces acting on equal masses produce equal accelerations; therefore, both undergo equal changes in speed.

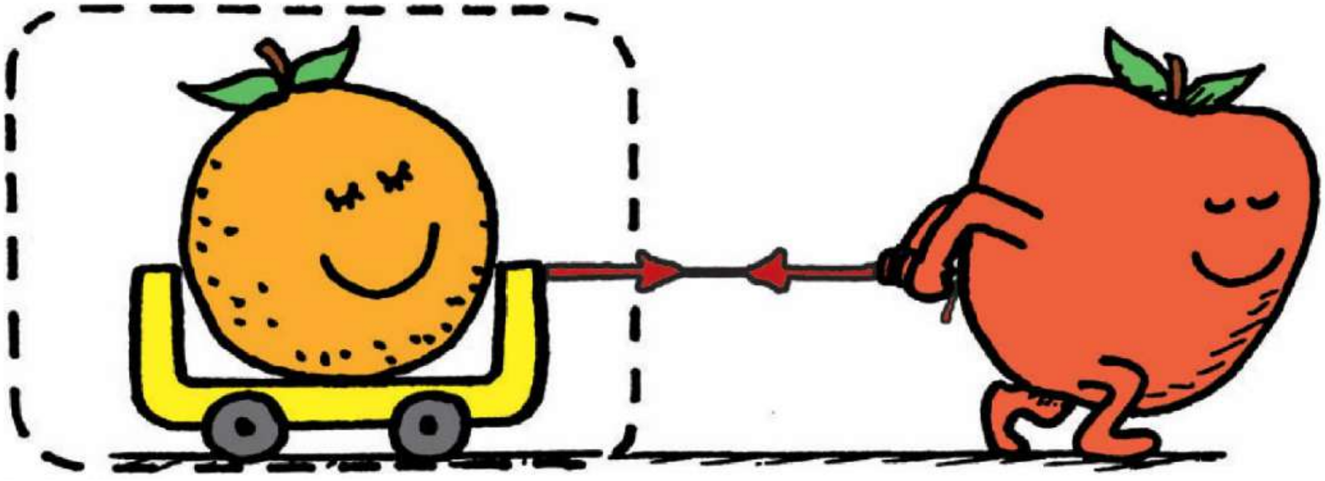
# Newton's Third Law of Motion, Continued-4

- Defining Your System
  - Consider a single enclosed orange.
    - Applied external force causes the orange to accelerate in accord with Newton's second law.
    - We see here only the action force (red vector).



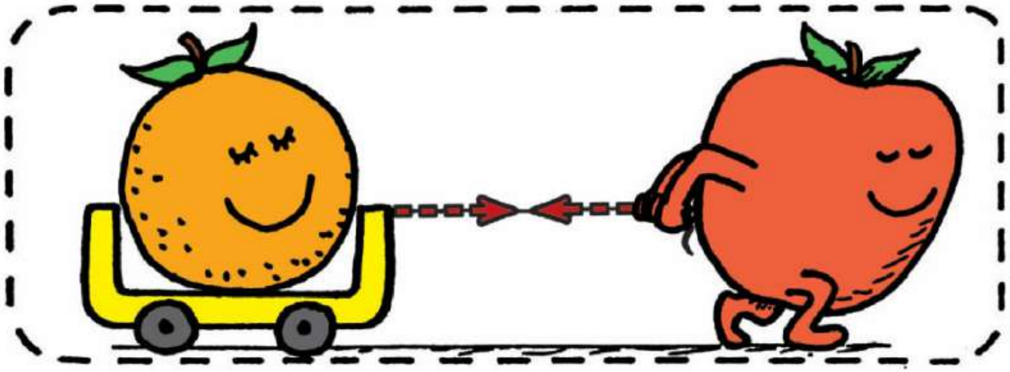
# Newton's Third Law of Motion, Continued-5

- Consider the orange and the apple pulling on it.
  - Action and reaction do not cancel (because they act on different objects).
  - External force by apple accelerates the orange.



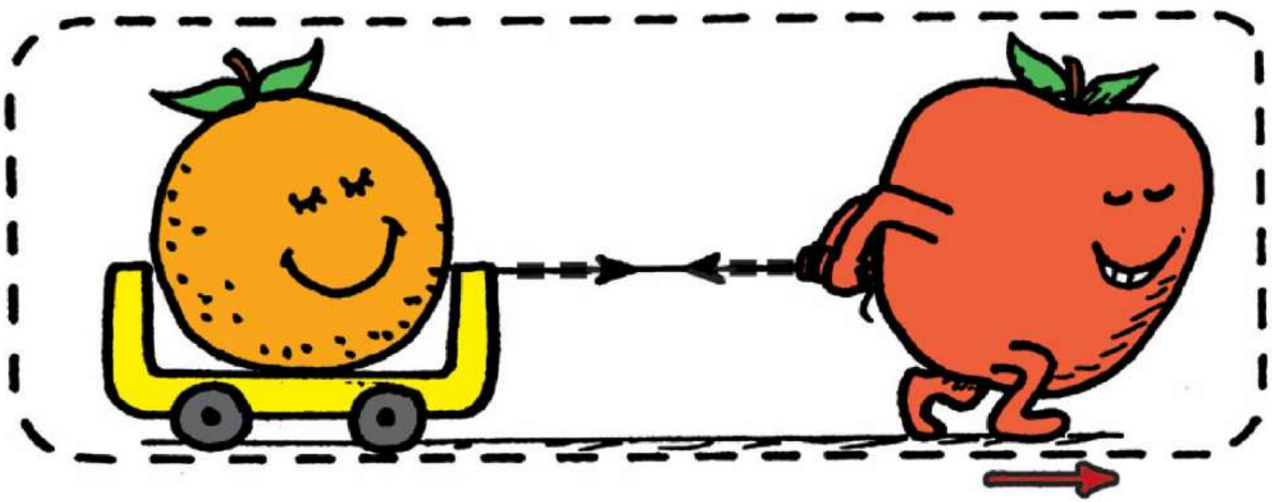
# Newton's Third Law of Motion, Continued-6

- Consider a system comprising both the orange and the apple.
  - The apple is no longer external to the system.
  - Force pair is internal to the system, which doesn't cause acceleration.
  - Action and reaction within the system cancel.
  - With no external forces, there is no acceleration of the system.



# Newton's Third Law of Motion, Continued-7

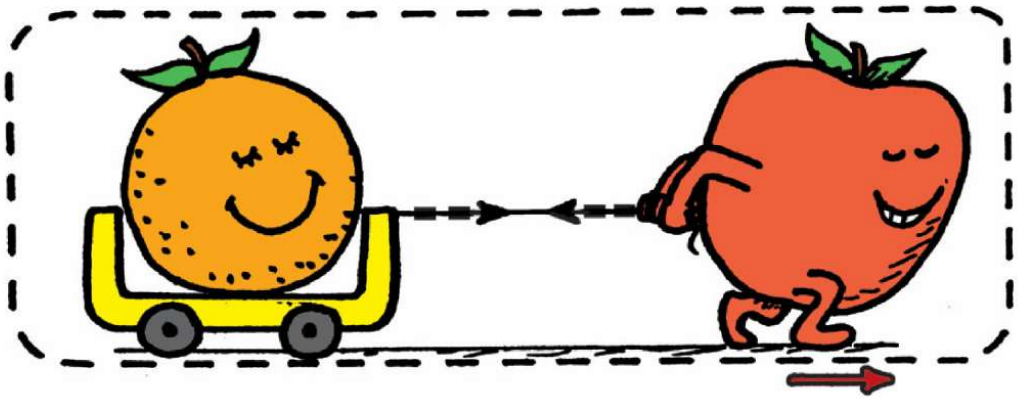
- Aha! Here's the same system, but with external force of friction on it (friction between the apple's feet and the floor).
- External frictional force of the floor accelerates the system.



# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-5

The apple-orange system will move with constant speed if

A. the orange loses mass.
B. the apple gains mass.
C. a force equal and opposite to the friction force occurs.
D. None of the above.



# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-5

The apple-orange system will move with constant speed if

C. **a force equal and opposite to the friction force occurs.**

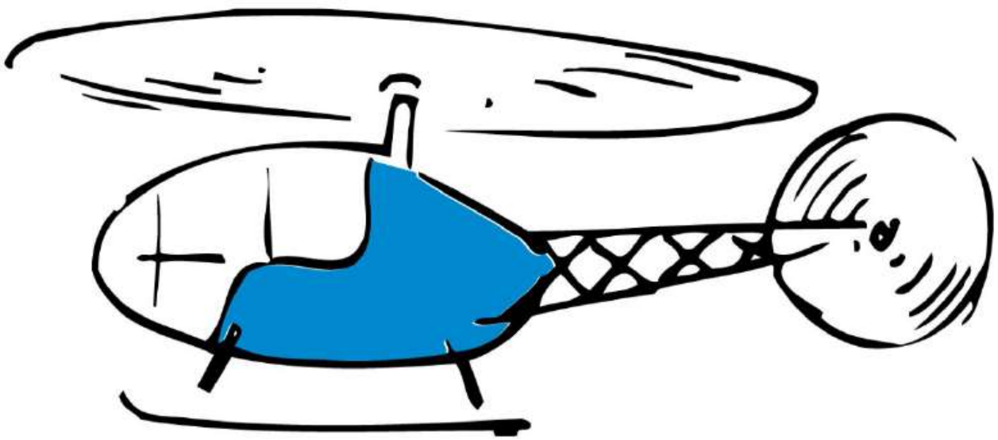
**Comment:**

Such a force may be floor friction on the cart wheels, or even a force produced by an opposing wind.

# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-6

Consider the flight of a helicopter. When lift is greater than the helicopter's weight, the helicopter

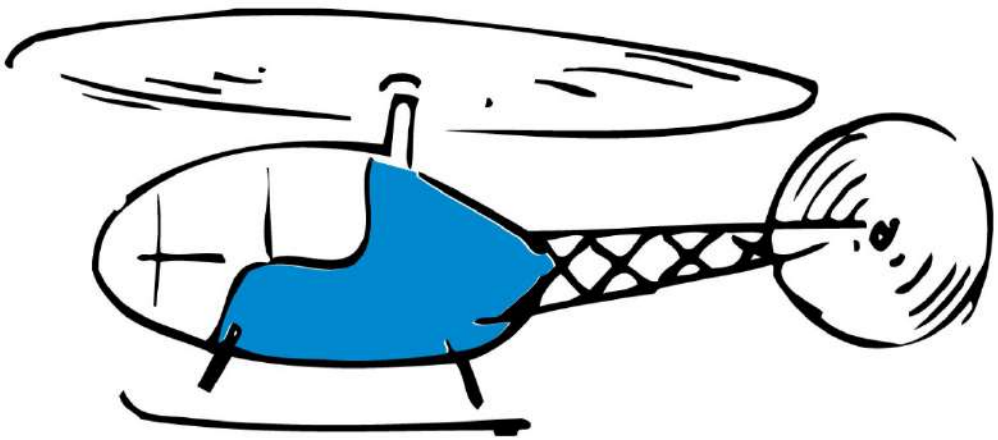
A. moves downward.
B. moves upward.
C. hovers in midair.
D. None of the above.



# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-6

Consider the flight of a helicopter. When lift is greater than the helicopter's weight, the helicopter

**B. moves upward.**



# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-7

A bird flies by

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

# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-7

A bird flies by

**B. pushing air down so that the air pushes it upward.**

# Newton's Third Law of Motion
# CHECK YOUR NEIGHBOR, Continued-8

Slightly tilted wings of airplanes deflect

A. oncoming air downward to produce lift.
B. oncoming air upward to produce lift.
C. Both A and B.
D. Neither A nor B.

# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-8

Slightly tilted wings of airplanes deflect

A. **oncoming air downward to produce lift.**

**Explanation:**

When a wing diverts air downward, it exerts a downward force on the air. The air simultaneously exerts an upward force on the wing. The vertical component of this upward force is lift. (The horizontal component is drag.)

# Newton's Third Law of Motion CHECK YOUR NEIGHBOR, Continued-9

Compared with a lightweight glider, a heavier glider would have to push air

A. downward with greater force.
B. downward with the same force.
C. downward with less force.
D. None of the above.

# Newton's Third Law of Motion
# CHECK YOUR ANSWER, Continued-9

Compared with a lightweight glider, a heavier glider would have to push air

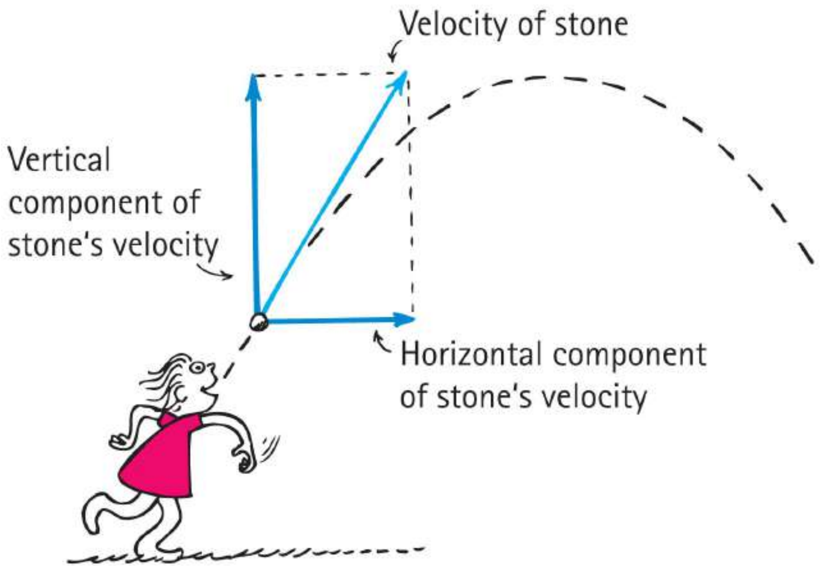
A. **downward with greater force.**

**Explanation:**

The force on the air deflected downward must equal the weight of the glider.

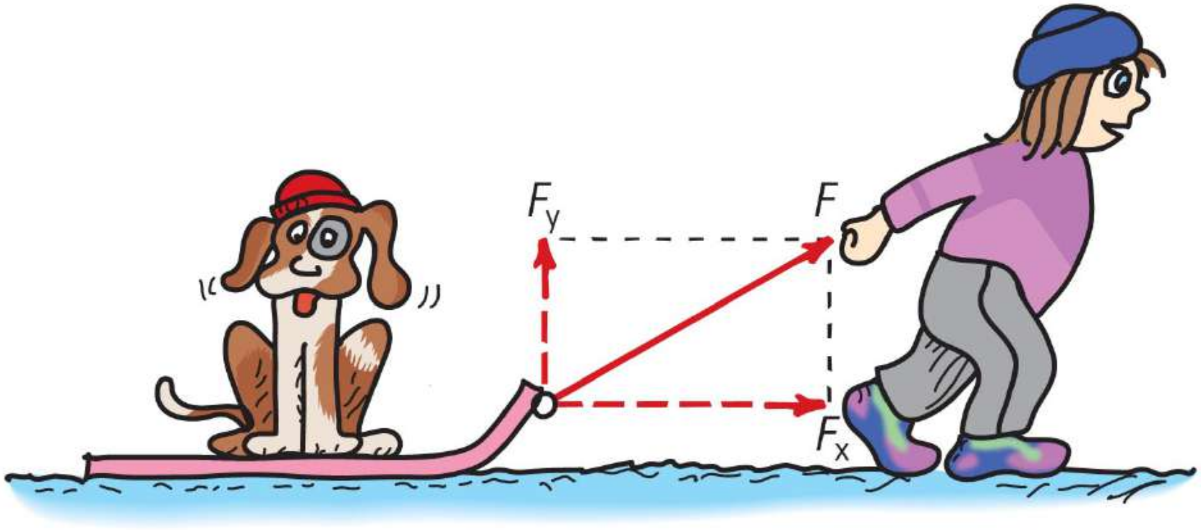
# Vectors

- Vector components
  - Vertical and horizontal components of a vector are perpendicular to each other.
  - Determined by resolution.



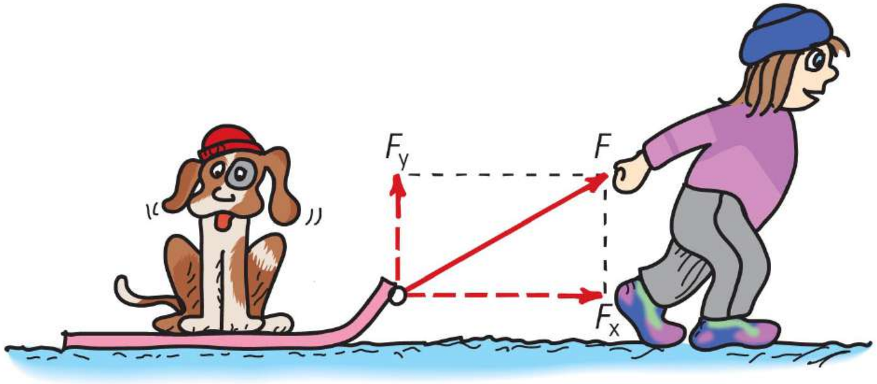
# Vectors, Continued

- Nellie Newton pulls on the sled as shown.
  - Which component of her force *F* is greater?
  - What two other forces (not shown) act on the sled?



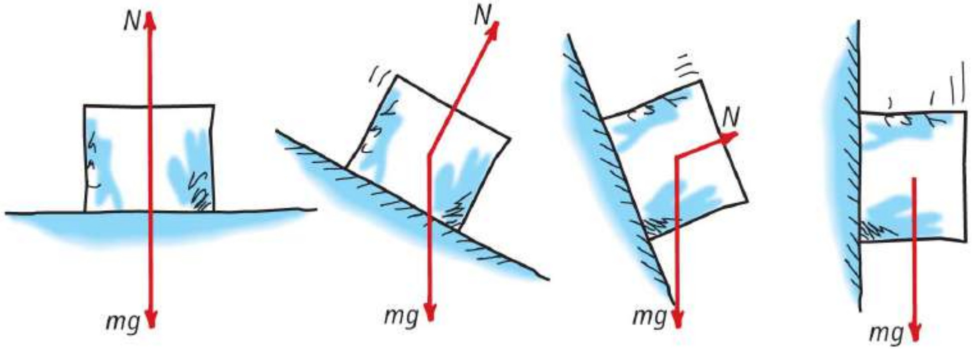
# Vectors, Continued-1

- Nellie Newton pulls on the sled as shown.
  - Which component of her force *F* is greater?
    - **The horizontal component $F_x$ is greater.**
  - What two other forces (not shown) act on the sled?
    - **Weight *mg* and normal *N* also act on the sled.**



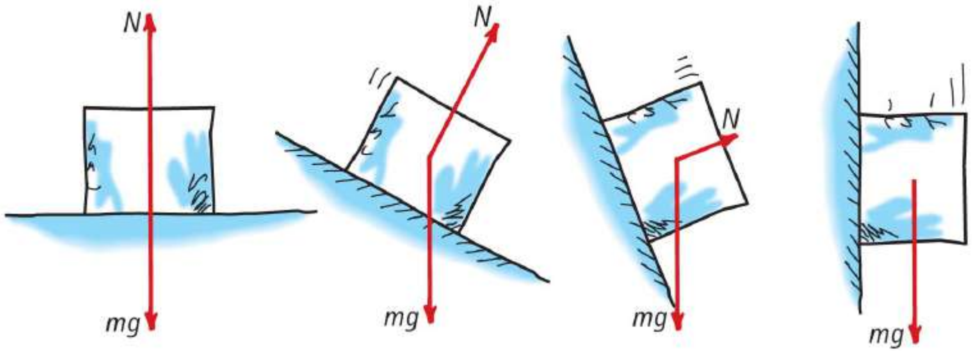
# Vectors, Continued-2

- Two forces act on the block of ice.
  1. As the ramp is raised, which force remains constant?
  2. As the ramp is raised, how does the magnitude of *N* change?
  3. When the ramp is raised 90 degrees (vertical) what is the net force on the block?



# Vectors, Continued-3

- Two forces act on the block of ice.
  1. As the ramp is raised, which force remains constant? ***mg***
  2. As the ramp is raised, how does the magnitude of *N* change? ***N* decreases with increased angle of the ramp.**
  3. When the ramp is raised 90 degrees (vertical) what is the net force on the block? **The net force is *mg*!**

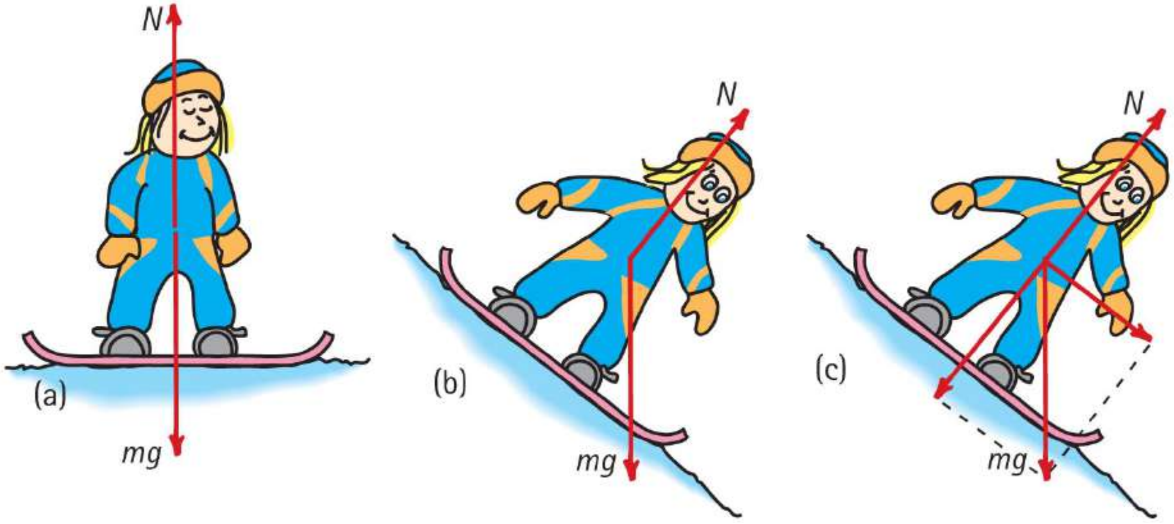


# Vectors, Continued-4

(a) Can you see that *N* and *mg* are equal and opposite?

(b) Can you see that *N* is less on the incline?

(c) Can you see that the resultant of *N* and *mg* is the force propelling Nellie down the hill? And can you see which component of *mg* is equal and opposite to *N*?



# Summary of Newton's Three Laws of Motion

- Newton's first law of motion (the law of inertia)
  - An object at rest tends to remain at rest; an object in motion tends to remain in motion at constant speed along a straight-line path.
- Newton's second law of motion (the law of acceleration)
  - When a net force acts on an object, the object will accelerate. The acceleration is directly proportional to the net force and inversely proportional to the mass.
- Newton's third law of motion (the 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.