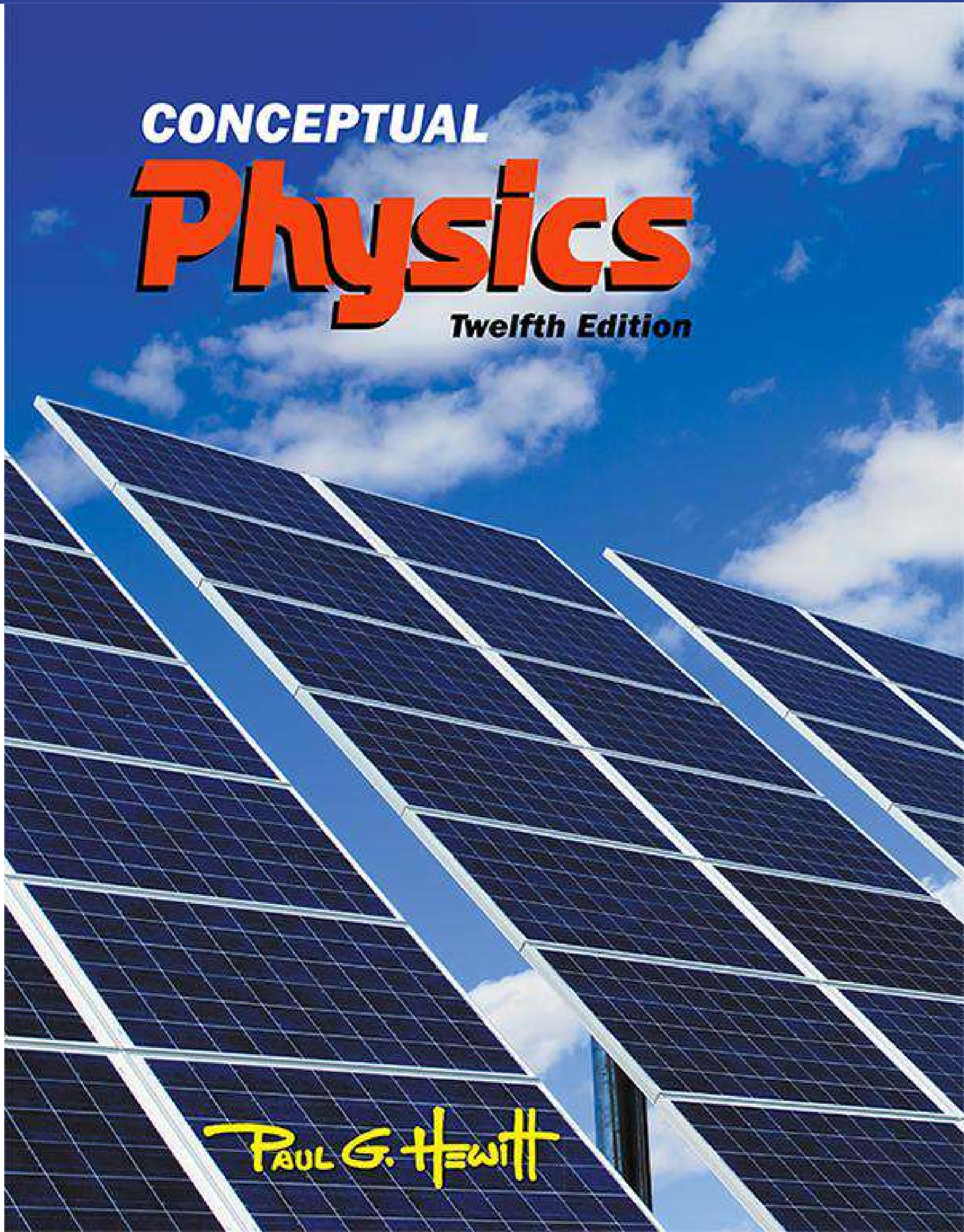
Lecture Outline

Newton's First Law of Motion—Inertia



This lecture will help you understand:

- Aristotle's Ideas of Motion
- Galileo's Concept of Inertia
- Newton's First Law of Motion
- Net Force and Vectors
- The Equilibrium Rule
- Support Force
- Equilibrium of Moving Things
- The Moving Earth

Aristotle's Ideas of Motion

Aristotle's classification of motion

- Natural motion
  - Every object in the universe has a proper place determined by a combination of four elements: earth, water, air, and fire.
  - Any object not in its proper place will strive to get there.
  - Examples:
    - Stones fall.
    - Puffs of smoke rise.

Aristotle's Ideas of Motion, Continued

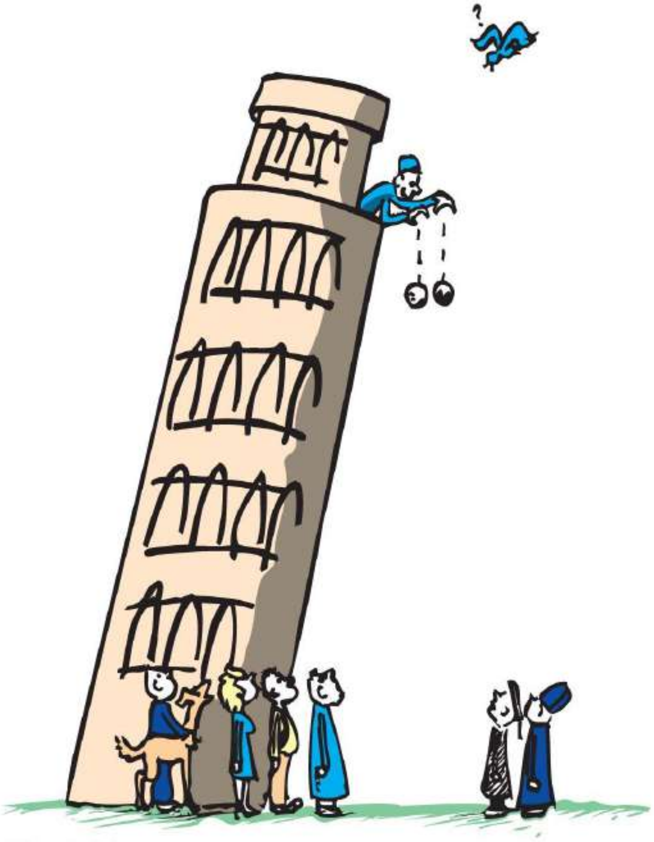
- Natural motion (continued)
  - Straight up or straight down for all things on Earth
  - Beyond Earth, motion is circular
  - Example: The Sun and Moon continually circle Earth
- Violent motion
  - Produced by external pushes or pulls on objects
  - Example: Wind imposes motion on ships.

Galileo's Concept of Inertia

Galileo demolished Aristotle's assertions in the 1500s.

Galileo's discovery:

- Objects of different weight fall to the ground at the same time in the absence of air resistance.
- A moving object needs no force to keep it moving in the absence of friction.



Galileo's Concept of Inertia, Continued

Force

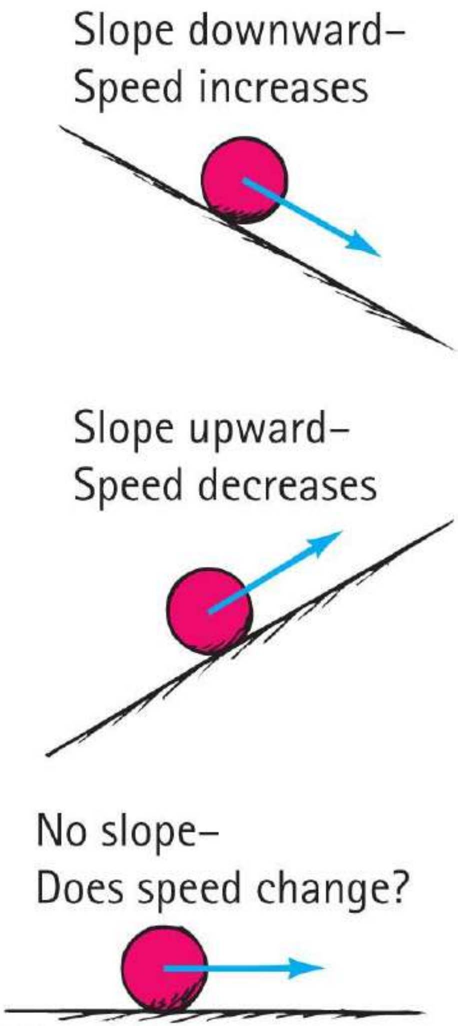
- is a push or a pull.

Inertia

- is a property of matter to resist changes in motion.
- depends on the amount of matter in an object (its *mass*).

Galileo's Concept of Inertia, Continue-1

- Balls rolling on downward-sloping planes pick up speed.
- Balls rolling on upward-sloping planes lose speed.
- So a ball on a horizontal plane maintains its speed indefinitely.
- If the ball comes to rest, it is not due to its "nature," but due to friction.



Galileo's Concept of Inertia
CHECK YOUR NEIGHBOR

The use of inclined planes for Galileo's experiments helped him to

A. eliminate the acceleration of free fall.
B. discover the concept of energy.
C. discover the property called inertia.
D. discover the concept of momentum

Galileo's Concept of Inertia
CHECK YOUR ANSWER

The use of inclined planes for Galileo's experiments helped him to

C. **discover the property called inertia.**

Comment:

Note that inertia is a *property* of matter, not a reason for the behavior of matter.

Newton's First Law of Motion

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

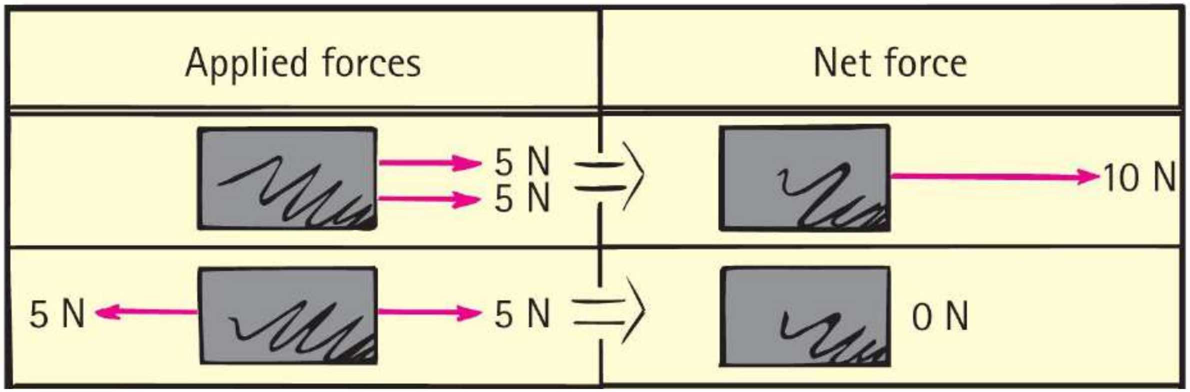
Net Force

Vector quantity

- a quantity whose description requires both magnitude (how much) and direction (which way)
- can be represented by arrows drawn to scale, called vectors
  - length of arrow represents magnitude and arrowhead shows direction
  - Examples: force, velocity, acceleration

Net Force, Continued

- Net force is the combination of all forces that act on an object.
  - Example: Two 5-N pulls in the same direction produce a 10-N pull (net force of 10 N). If the pair of 5-N pulls are in opposite directions, the net force is zero.



Net Force
CHECK YOUR NEIGHBOR

A cart is pulled to the right with a force of 15 N while being pulled to the left with a force of 20 N. The net force on the cart is

A. 5 N to the left.
B. 5 N to the right.
C. 25 N to the left.
D. 25 N to the right.

Net Force
CHECK YOUR ANSWER

A cart is pulled to the right with a force of 15 N while being pulled to the left with a force of 20 N. The net force on the cart is

A. **5 N to the left.**

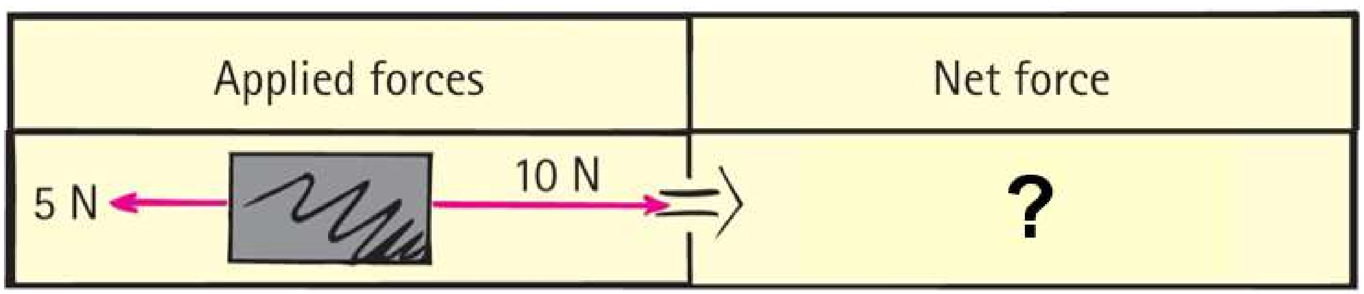
The two forces are in opposite directions, so they subtract.

The direction is determined by the direction of the larger force

Net Force
CHECK YOUR NEIGHBOR, Continued

What is the net force acting on the box?

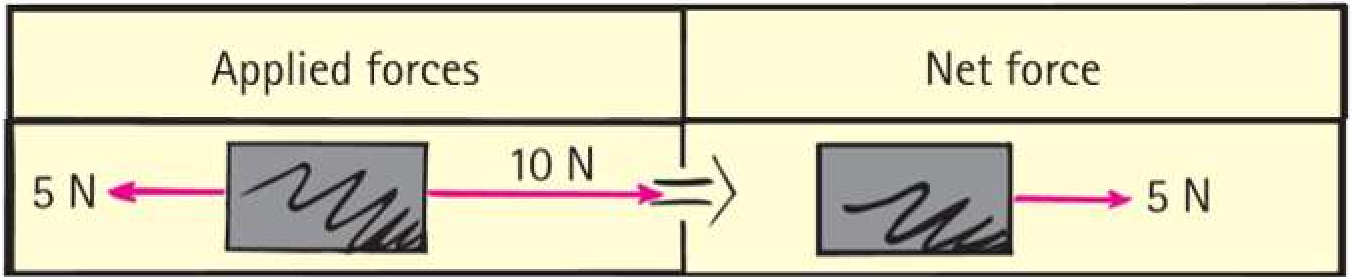
A. 15 N to the left
B. 15 N to the right
C. 5 N to the left
D. 5 N to the right



Net Force
CHECK YOUR ANSWER, Continued

What is the net force acting on the box?

D. 5 N to the right



Vectors

Vector quantity

- has magnitude and direction.
- is represented by an arrow.
- Example: velocity, force, acceleration

Scalar quantity

- has magnitude.
- Example: mass, volume, speed

Vectors, Continued

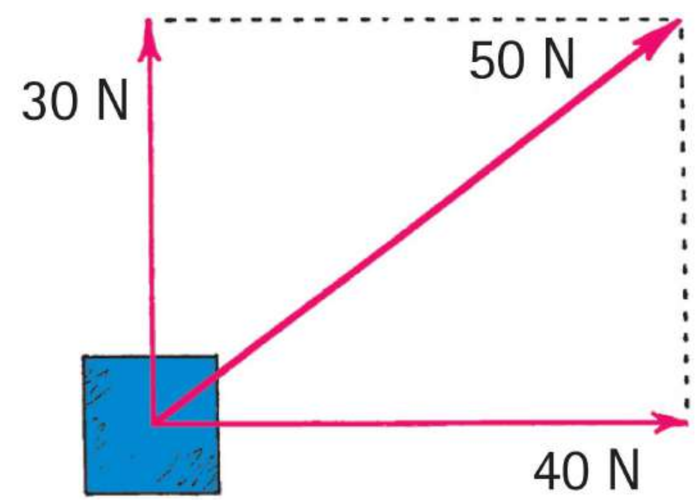
Resultant

- The sum of two or more vectors
  - For vectors in the same direction, add arithmetically.
  - For vectors in opposite directions, subtract arithmetically.
  - Two vectors that don't act in the same or opposite direction:
    - use parallelogram rule.
  - Two vectors at right angles to each other
    - use Pythagorean Theorem: $R^2 = V^2 + H^2$.

Vectors
CHECK YOUR NEIGHBOR

Referring to the figure, which of the following are true statements?

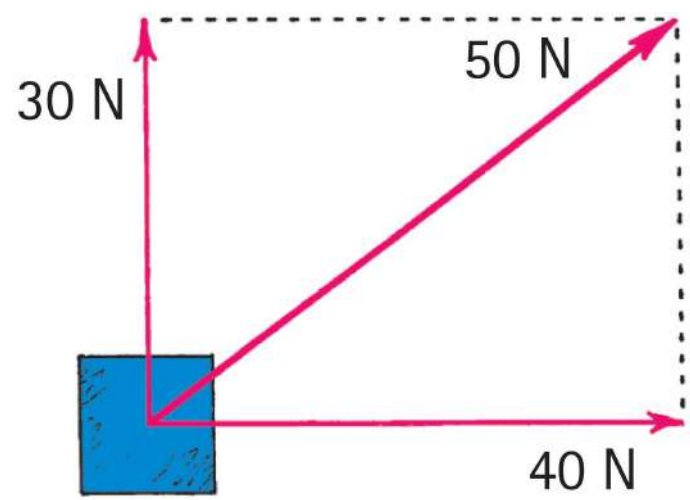
A. 50 N is the resultant of the 30- and the 40-N vectors.
B. The 30-N vector can be considered a component of the 50-N vector.
C. The 40-N vector can be considered a component of the 50-N vector.
D. All of the above are correct.



Vectors
CHECK YOUR ANSWER

Referring to the figure, which of the following are true statements?

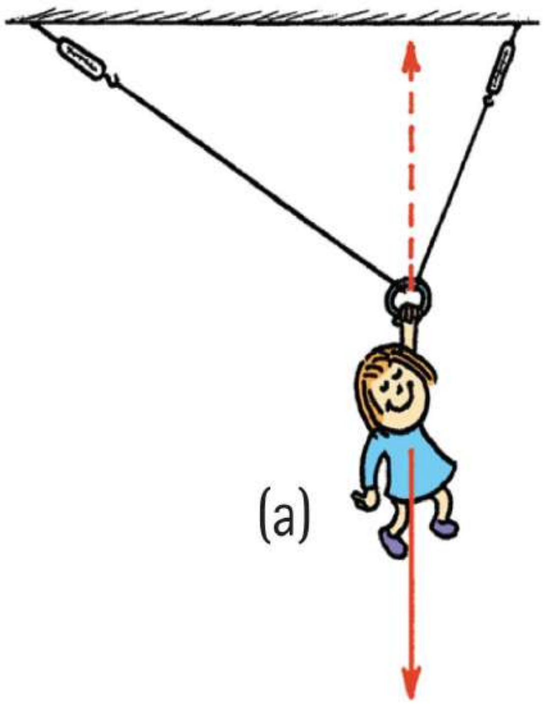
D. **All of the above are correct.**



Vectors, Continue-1

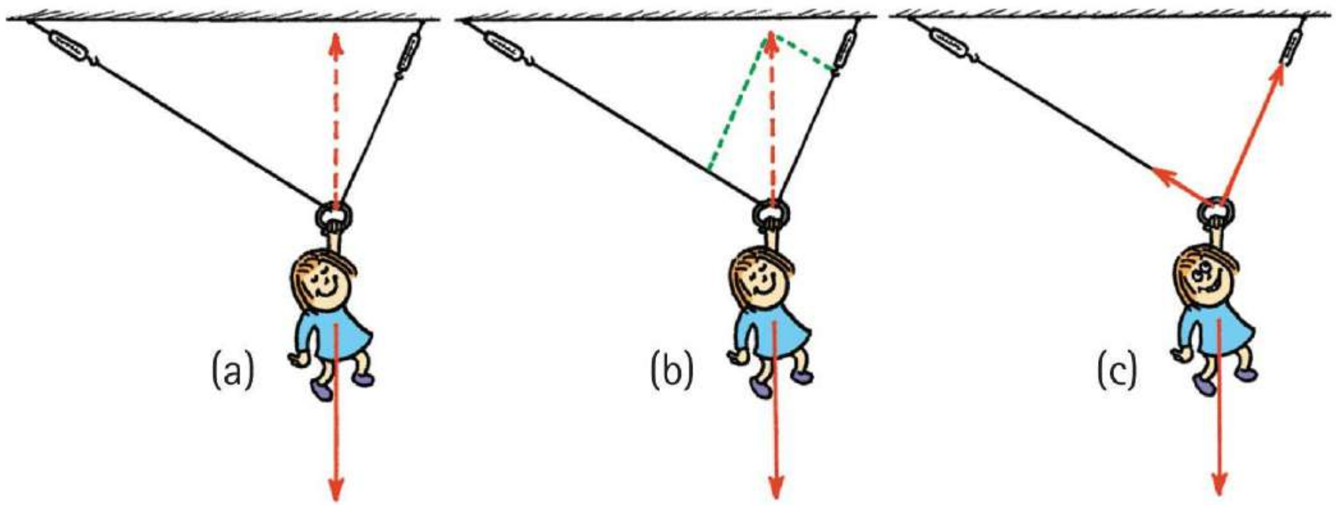
Nellie Newton hangs from a rope as shown.

- Which side has the greater tension?
- There are three forces acting on Nellie:
  - her weight, *mg*,
  - a tension in the left-hand side of the rope,
  - and a tension in the right-hand side of the rope.


(a)

Vectors, Continue-2

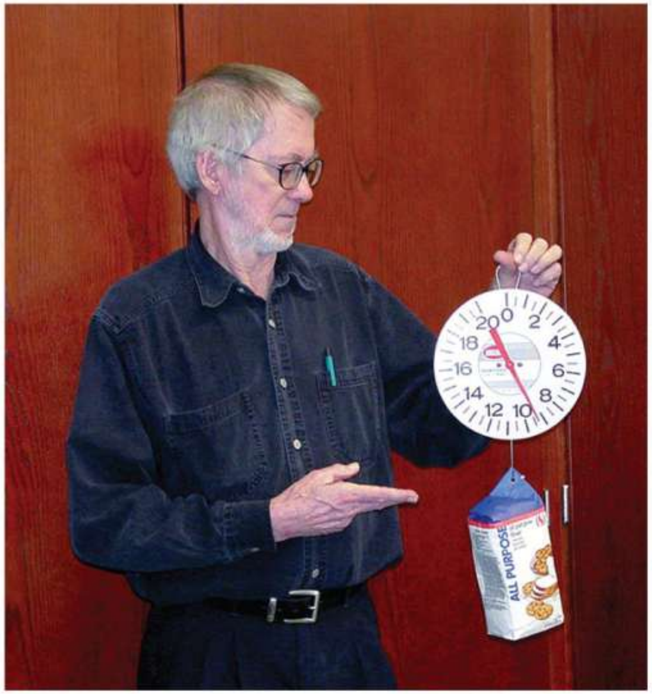
- Because of the different angles, different rope tensions will occur in each side.
- Nellie hangs in equilibrium, so her weight is supported by two rope tensions, adding vectorially to be equal and opposite to her weight.
- The parallelogram rule shows that the tension in the right-hand is greater than the tension in the left-hand side of the rope.



The Equilibrium Rule: Example

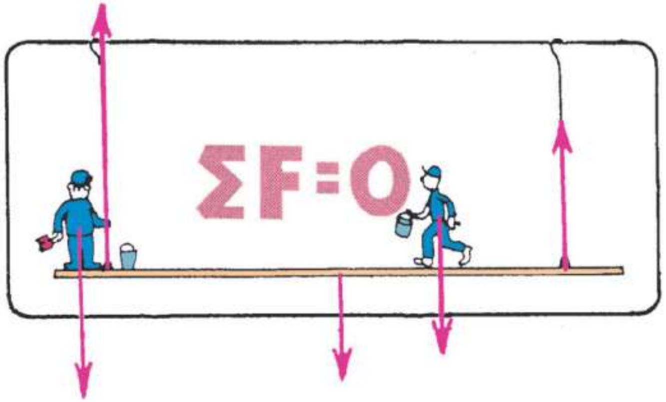
A string holding up a bag of flour

- Two forces act on the bag of flour:
  - Tension force in string acts upward.
  - Force due to gravity acts downward.
- Both are equal in magnitude and opposite in direction.
  - When added, they cancel to zero.
  - So, the bag of flour remains at rest.



The Equilibrium Rule

- The vector sum of forces acting on a nonaccelerating object equals zero.
- In equation for: $\Sigma F = 0$.



The red arrows represent force vectors. The sum of the two upward force vectors minus the sum of the three bottom force vectors, equals zero. We say the forces cancel to zero, and the system of Burl, Paul, and the staging is in equilibrium.

The Equilibrium Rule
CHECK YOUR NEIGHBOR

The equilibrium rule, $\sum F = 0$, applies to

A. vector quantities.
B. scalar quantities.
C. Both of the above.
D. None of the above.

The Equilibrium Rule
CHECK YOUR ANSWER

The equilibrium rule, $\sum F = 0$, applies to

A. vector quantities.

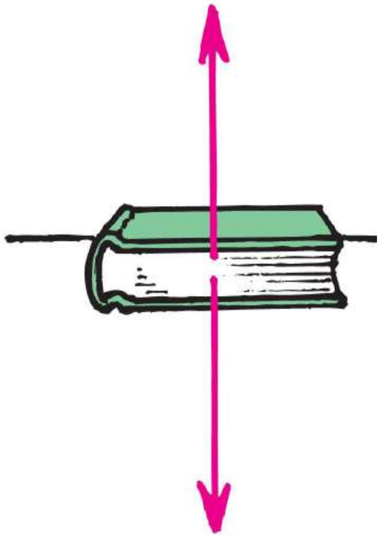
Explanation:

Vector addition accounts for + and - quantities. So, two vectors in opposite directions can add to zero.

Support Force

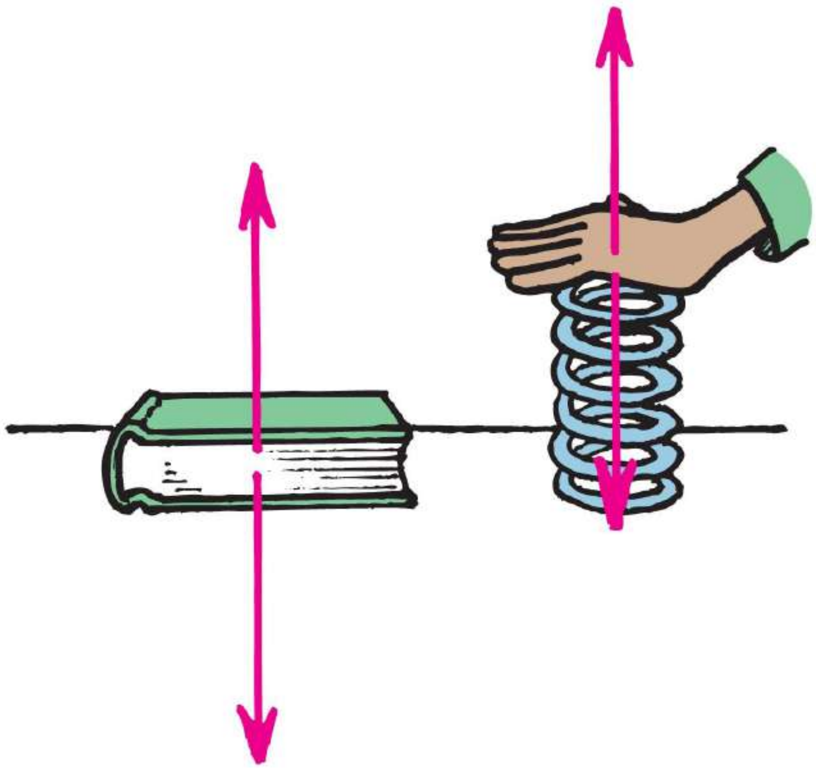
- Support force (normal force) is an upward force on an object that is opposite to the force of gravity.

- Example: A book on a table compresses atoms in the table, and the compressed atoms produce the support force.



Understanding Support Force

- When you push down on a spring, the spring pushes back up on you.
- Similarly, when a book pushes down on a table, the table pushes back up on the book.



Support Force
CHECK YOUR NEIGHBOR

When you stand on two bathroom scales with one foot on each scale and with your weight evenly distributed, each scale will read

A. your weight.
B. half your weight.
C. zero.
D. more than your weight.

Support Force
CHECK YOUR ANSWER

When you stand on two bathroom scales with one foot on each scale and with your weight evenly distributed, each scale will read

B. **half your weight.**

Explanation:

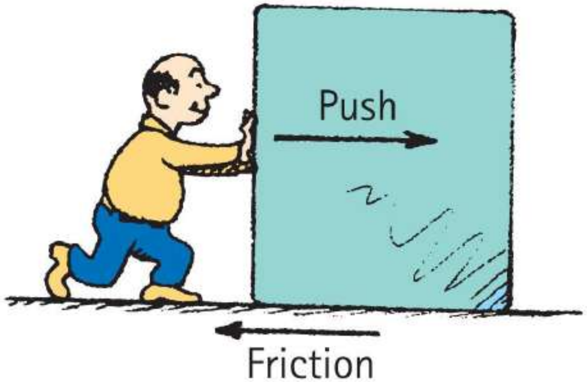
- You are at rest, so $\sum F = 0$.
- Forces from both scales add to cancel your weight.
- Force from each scale is one-half your weight.

Equilibrium of Moving Things

- Equilibrium: a state of no change with no net force acting
  - Static equilibrium
  - Example: hockey puck at rest on slippery ice
  - Dynamic equilibrium
  - Example: hockey puck sliding at constant speed on slippery ice

Equilibrium of Moving Things, Continued

- Equilibrium test: whether something undergoes ***change*** in motion
  - Example: A crate at rest is in static equilibrium (no change in motion).
  - Example: When pushed at a steady speed, it is in dynamic equilibrium (no change in motion).



Equilibrium of Moving Things
CHECK YOUR NEIGHBOR

A bowling ball is in equilibrium when it

A. is at rest.
B. moves steadily in a straight-line path.
C. Both of the above.
D. None of the above.

Equilibrium of Moving Things
CHECK YOUR ANSWER

A bowling ball is in equilibrium when it

C. **Both of the above.**

Explanation:

Equilibrium means no *change* in motion, so there are two options:

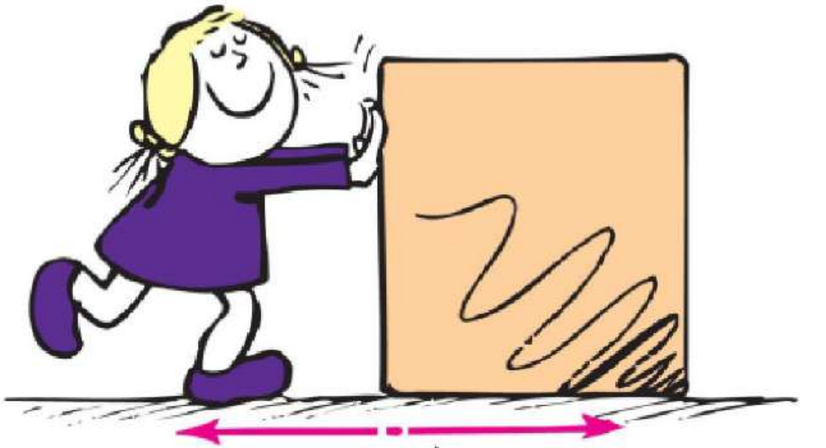
If at rest, it continues at rest.

If in motion, it continues at a steady rate in a straight line.

Equilibrium of Moving Things
CHECK YOUR NEIGHBOR, Continued

You push a crate at a steady speed in a straight line. If the friction force is 75 N, how much force must you apply?

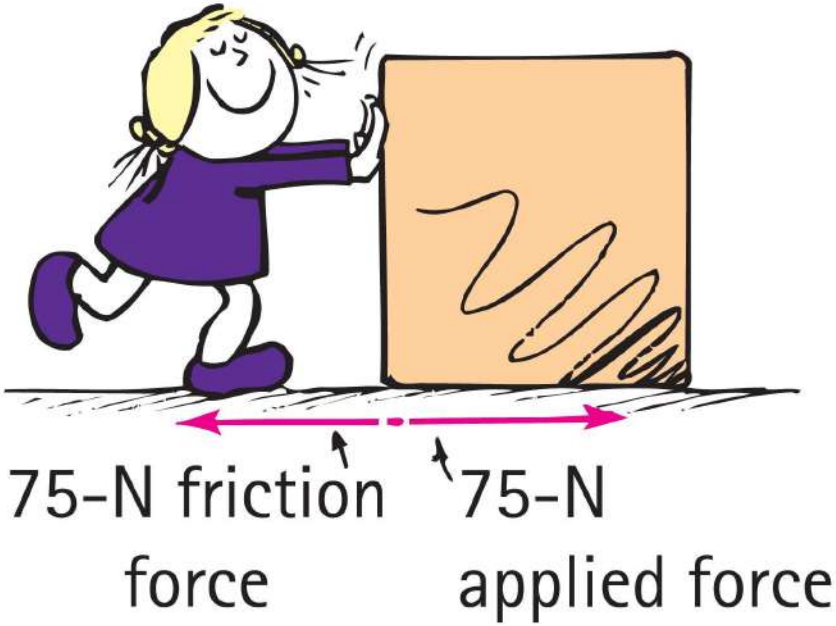
A. More than 75 N.
B. Less than 75 N.
C. Equal to 75 N.
D. Not enough information.



Equilibrium of Moving Things
CHECK YOUR ANSWER, Continued

You push a crate at a steady speed in a straight line. If the friction force is 75 N, how much force must you apply?

C. **Equal to 75 N.**



Explanation:

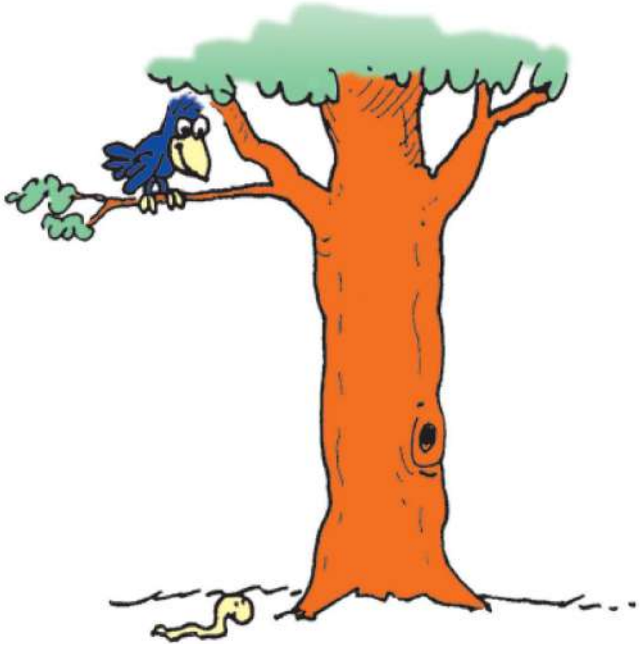
The crate is in dynamic equilibrium, so, $\Sigma F = 0$.

Your applied force balances the force of friction.

The Moving Earth

Copernicus proposed that Earth was moving, circulating the Sun.

- This idea was refuted by people.
- Example: If Earth moved, how could a bird swoop from a branch to catch a worm?
- Solution: As it swoops, due to inertia, it continues to move sideways at the speed of Earth along with the tree, worm, etc.



The Moving Earth
CHECK YOUR NEIGHBOR

You are riding in a vehicle at a steady speed and toss a coin straight upward. Where will the coin land?

A. Behind you.
B. Ahead of you.
C. In your hand.
D. There is not enough information.

The Moving Earth
CHECK YOUR ANSWER

You are riding in a vehicle at a steady speed and toss a coin straight upward. Where will the coin land?

C. **In your hand.**

Explanation:

Due to the coin's inertia, it continues sideways with the same speed as the vehicle in its up-and-down motion, which is why it lands in your hand.