The wind pushes against the man and his umbrella. The push from the wind is a force.

# What Is a Force?

**How do forces affect the motion of an object?**

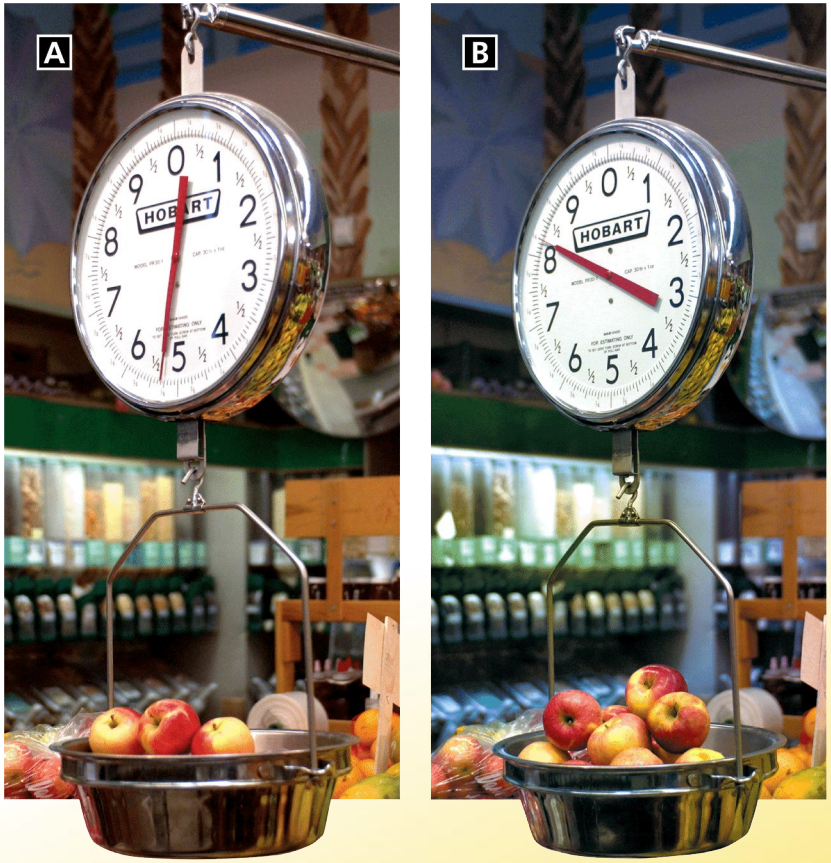
A **force** is a push or a pull that acts on an object.

**A force can cause a resting object to move, or it can accelerate a moving object by changing the object's speed or direction.**

# What Is a Force?

## Measuring Force

You may have measured forces using a spring scale. The stretch of the spring in the scale depends on the amount of weight (a type of force) acting on it.



# What Is a Force?

## Units of Force

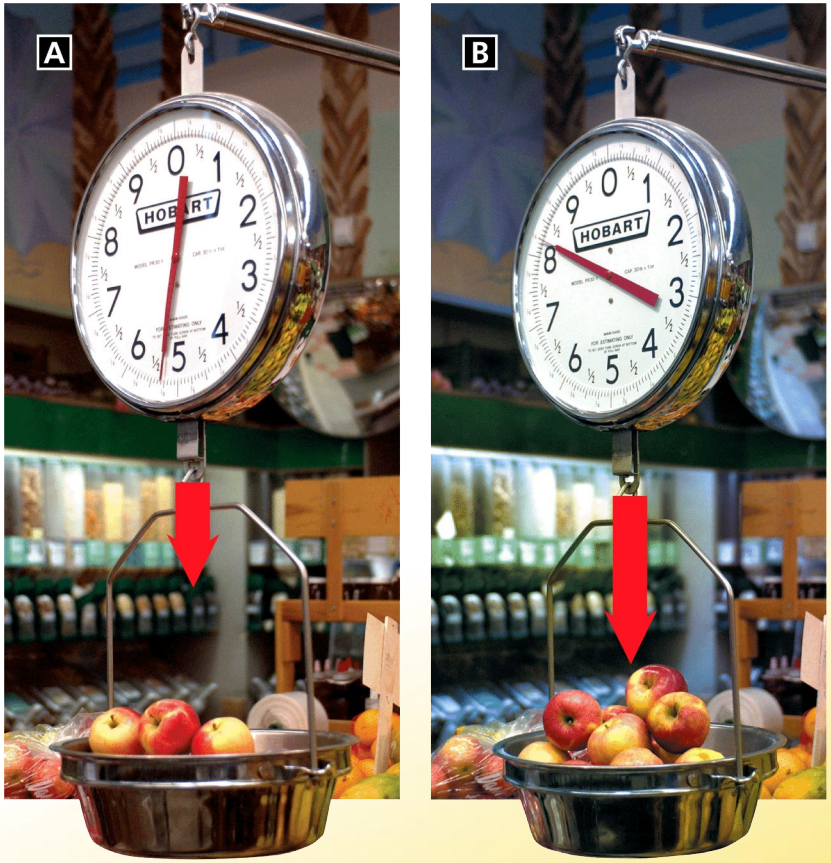
One **newton** (N) is the force that causes a 1-kilogram mass to accelerate at a rate of 1 meter per second each second (1 $m/s^2$).

$$1\ N = 1\ kg \cdot m/s^2$$

# What Is a Force?

## Representing Force

Arrows can represent a force. The lengths of the arrows show relative amounts of force.



# Combining Forces

- How do forces affect the motion of an object?
- When the forces on an object are balanced, the net force is zero, and there is no change in the object's motion.
- When an unbalanced force acts on an object, the object accelerates.

# Combining Forces

The **net force** is the overall force acting on an object after all the forces are combined.

- Forces in the same direction add together.
- Forces in opposite directions subtract from one another.

# Combining Forces

## Balanced Forces

Balanced forces are forces that combine to produce a net force of zero.

An unlimited number of individual forces can act on an object to produce a net force of zero.

# Combining Forces

The two groups pull with equal forces in opposite directions. The forces combine to make a net force of zero.

# Combining Forces

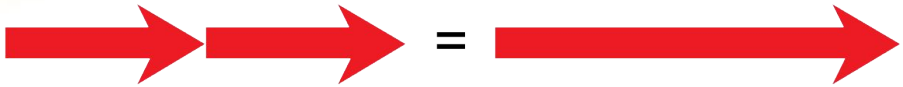
## Unbalanced Forces

An unbalanced force is a force that results when the net force acting on an object is not equal to zero.

# Combining Forces

Forces can add together or subtract from one another.

**A** Adding forces



# Combining Forces

Forces can add together or subtract from one another.

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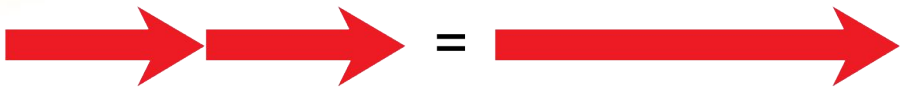
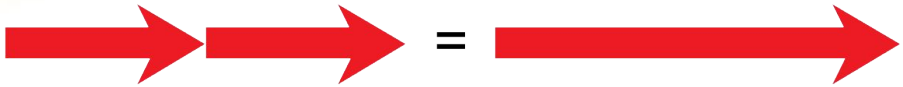


**B** Subtracting forces

# Combining Forces

Forces can add together or subtract from one another.

**A** Adding forces



**B** Subtracting forces

**C** Equal and opposite forces

# Friction

**What are the four main types of friction?**

**Friction** is a force that opposes the motion of objects that touch as they move past each other.

**There are four main types of friction: static friction, sliding friction, rolling friction, and fluid friction.**

# Friction

## Static Friction

**Static friction** is the friction force that acts on objects that are not moving.

Static friction always acts in the direction opposite to that of the applied force.

# Friction

## Sliding Friction

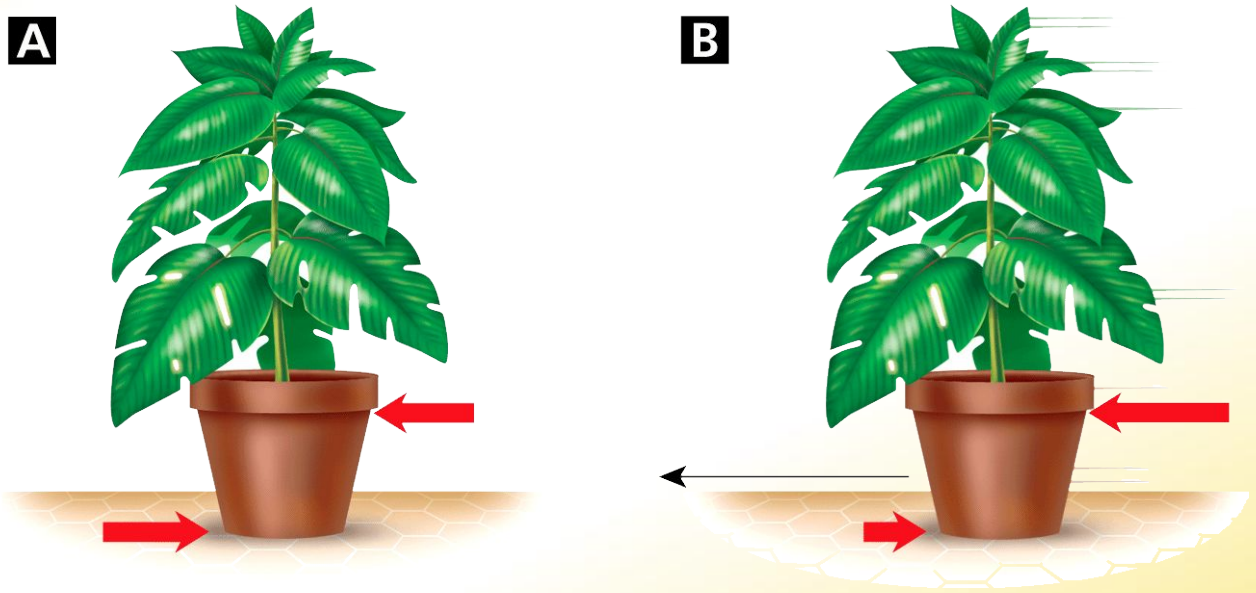
**Sliding friction** is a force that opposes the direction of motion of an object as it slides over a surface.

Sliding friction is less than static friction.

# Friction

A. Static friction–the potted tree does not move.

B. Sliding friction–when the tree moves, sliding friction acts to oppose the direction of motion.



# Friction

## Rolling Friction

**Rolling friction** is the friction force that acts on rolling objects.

The force of rolling friction is about 100 to 1000 times less than the force of static or sliding friction.

# Friction

Ball bearings in these wheels greatly reduce friction by replacing sliding friction with rolling friction.

# Friction

## Fluid Friction

- **Fluid friction** opposes the motion of an object through a fluid.
- Fluid friction acting on an object moving through the air is known as **air resistance.**
- Fluid friction increases as the speed of the object moving through the fluid increases.

# Gravity

- In what direction does Earth's gravity act?
- Earth's gravity acts downward toward the center of Earth.

# Gravity

- How do gravity and air resistance affect a falling object?
- Gravity causes objects to accelerate downward, whereas air resistance acts in the direction opposite to the motion and reduces acceleration.

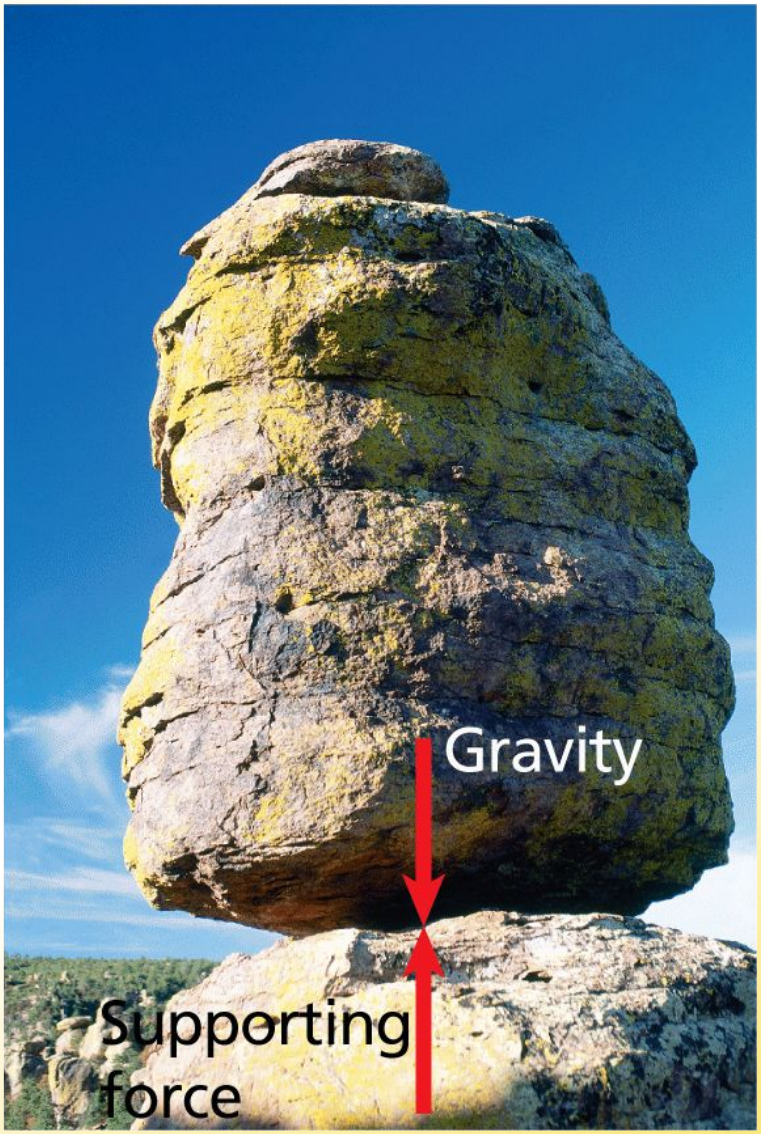
## Gravity

**Gravity** is a force that acts between any two masses.

- Gravity is an attractive force.
- Gravity can act over large distances.

## Gravity

Earth exerts an attractive, downward force on this boulder. The supporting rock exerts an upward force on the boulder. The forces are balanced.



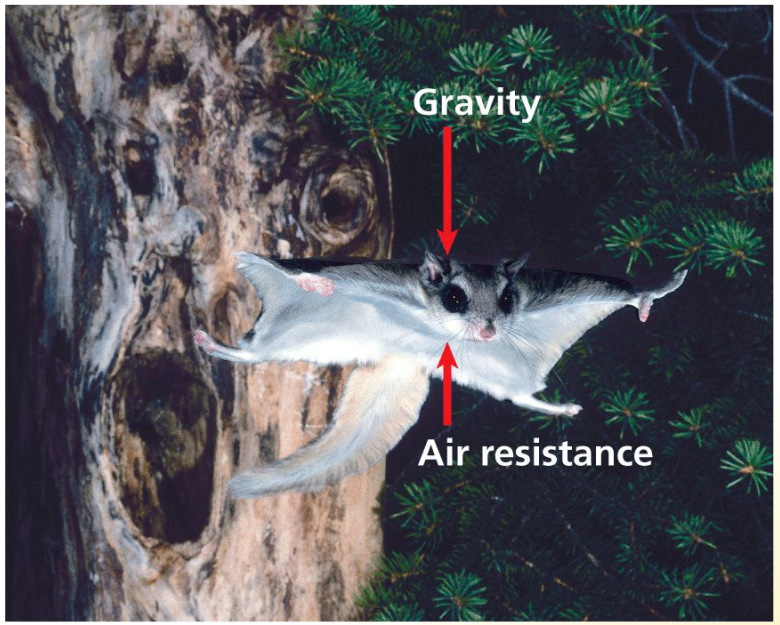
# Gravity

## Falling Objects

- Both gravity and air resistance affect the motion of a falling object.
- As objects fall to the ground, they accelerate and gain speed.
- **Terminal velocity** is the constant velocity of a falling object when the force of air resistance equals the force of gravity.

# Gravity

This flying squirrel takes advantage of air resistance to slow its fall and increase the distance covered in the jump.



# Projectile Motion

**Why does a projectile follow a curved path?**

**The combination of an initial forward velocity and the downward vertical force of gravity causes the ball to follow a curved path.**

# Projectile Motion

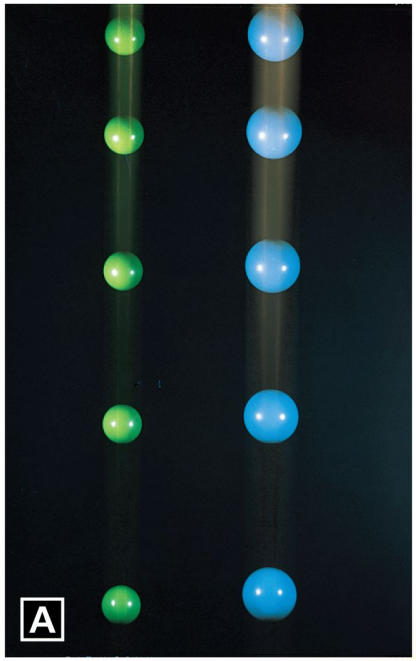
A thrown ball follows a curved path.

**Projectile motion** is the motion of a falling object (projectile) after it is given an initial forward velocity.

Air resistance and gravity are the only forces acting on a projectile.

# Projectile Motion

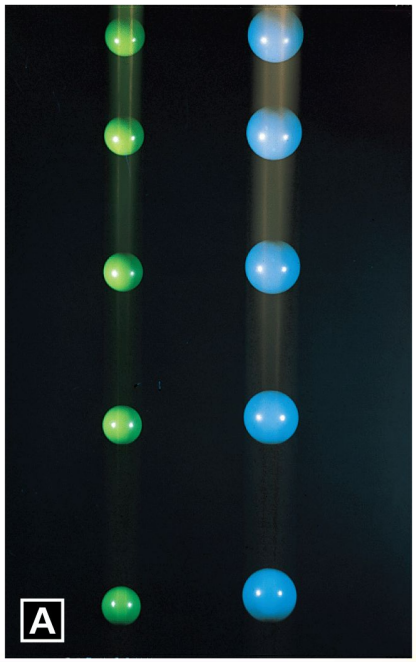
A. Their masses are different, but the blue and green balls fall at the same rate.

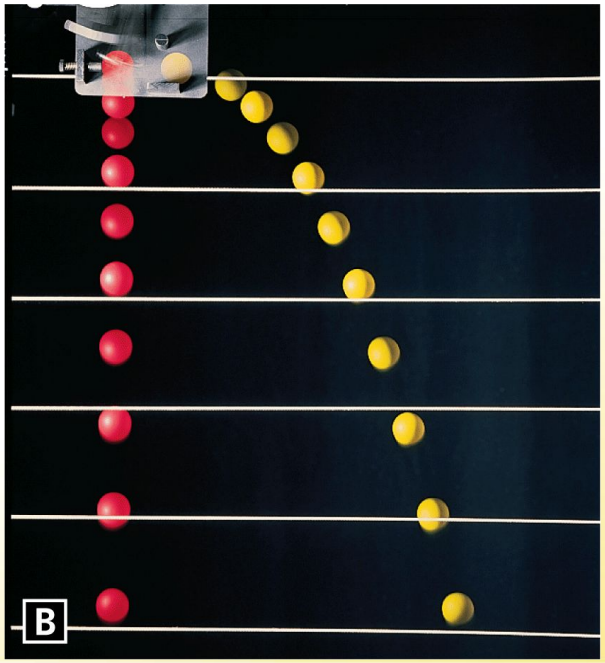


# Projectile Motion

A. Their masses are different, but the blue and green balls fall at the same rate.

B. The yellow ball is a projectile, following a curved path.



## Assessment Questions

1. If an object is at rest, which of the following statements must be true?
   a. There are no forces acting on the object.
   b. There is no friction acting on the object.
   c. The forces acting on the object are unbalanced.
   d. The net force acting on the object is zero.

## Assessment Questions

1. If an object is at rest, which of the following statements must be true?

   a. There are no forces acting on the object.

   b. There is no friction acting on the object.

   c. The forces acting on the object are unbalanced.

   d. The net force acting on the object is zero.

   ANS: D

## Assessment Questions

2. Which of the following is not a type of friction?
   a. static friction
   b. sliding friction
   c. fluid friction
   d. pull friction

## Assessment Questions

2. Which of the following is not a type of friction?
   a. static friction
   b. sliding friction
   c. fluid friction
   d. pull friction

ANS: D

## Assessment Questions

3. In which direction does Earth's gravitational force act?

   a. opposite the direction of motion
   b. downward toward the center of Earth
   c. upward away from the center of Earth
   d. in the direction of motion

## Assessment Questions

3. In which direction does Earth's gravitational force act?

   a. opposite the direction of motion
   b. downward toward the center of Earth
   c. upward away from the center of Earth
   d. in the direction of motion

   ANS: B

## Assessment Questions

4. A ball thrown into the air follows a projectile course due to the initial velocity and the
   a. force of gravity.
   b. effect of air resistance.
   c. motion of Earth beneath it.
   d. mass of the ball.

## Assessment Questions

4. A ball thrown into the air follows a projectile course due to the initial velocity and the
   a. force of gravity.
   b. effect of air resistance.
   c. motion of Earth beneath it.
   d. mass of the ball.

   ANS: A

## Assessment Questions

1. The SI unit for force is 1 kg•m/s$^2$, also called one kepler.

   True
   False

## Assessment Questions

1. The SI unit for force is 1 kg•m/s$^2$, also called one kepler.

   True
   False

   ANS:F, newton