Section 1: Newton's First and Second Laws

Preview

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Key Ideas

- What makes an object speed up, slow down, or change directions?
- What determines how much an object speeds up or slows down?

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Bellringer

The concept of force explains many occurrences in our everyday lives. From your own experience, state what will happen in the following situations.

1. A marble is placed at the top of a smooth ramp. What will happen to the marble? What force causes this?
2. A marble is rolling around in the back of a small toy wagon as the wagon is pulled along the sidewalk. When the wagon is stopped suddenly by a rock under one of the wheels, the marble rolls toward the front of the wagon. Why does the marble keep going when the wagon stops? (Hint: Consider what it takes to change the velocity of the wagon and the marble.)

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Bellringer, *continued*

3. If you dropped a flat uncrumpled sheet of notebook paper and a similar piece of notebook paper that was crushed into a ball from the same height, which will reach the floor first? Why are the forces on these two pieces of paper different?

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Newton's First Law

- What makes an object speed up, slow down, or change directions?

- Objects change their state of motion only when a net force is applied.

- This principle is *Newton's first law.*

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Newton's First Law, *continued*

- Objects tend to maintain their state of motion.
- Inertia is related to an object's mass.
  - **inertia:** the tendency of an object to resist a change in motion unless an outside force acts on the object
- Seat belts and car seats provide protection.
  - When a car comes to a stop, your seat belt and the friction between you and the seat provide the unbalanced backward force that is needed to bring you to a stop as the car stops.

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Newton's Second Law

- What determines how much an object speeds up or slows down?
- Net force is equal to mass times acceleration. The unbalanced force on an object determines how much an object speeds up or slows down.

- This principle is *Newton's second law.*
- *net force = mass × acceleration,* or *F = ma*
- Force is measured in newtons (N): 1 N = 1 kg × 1 m/s^2

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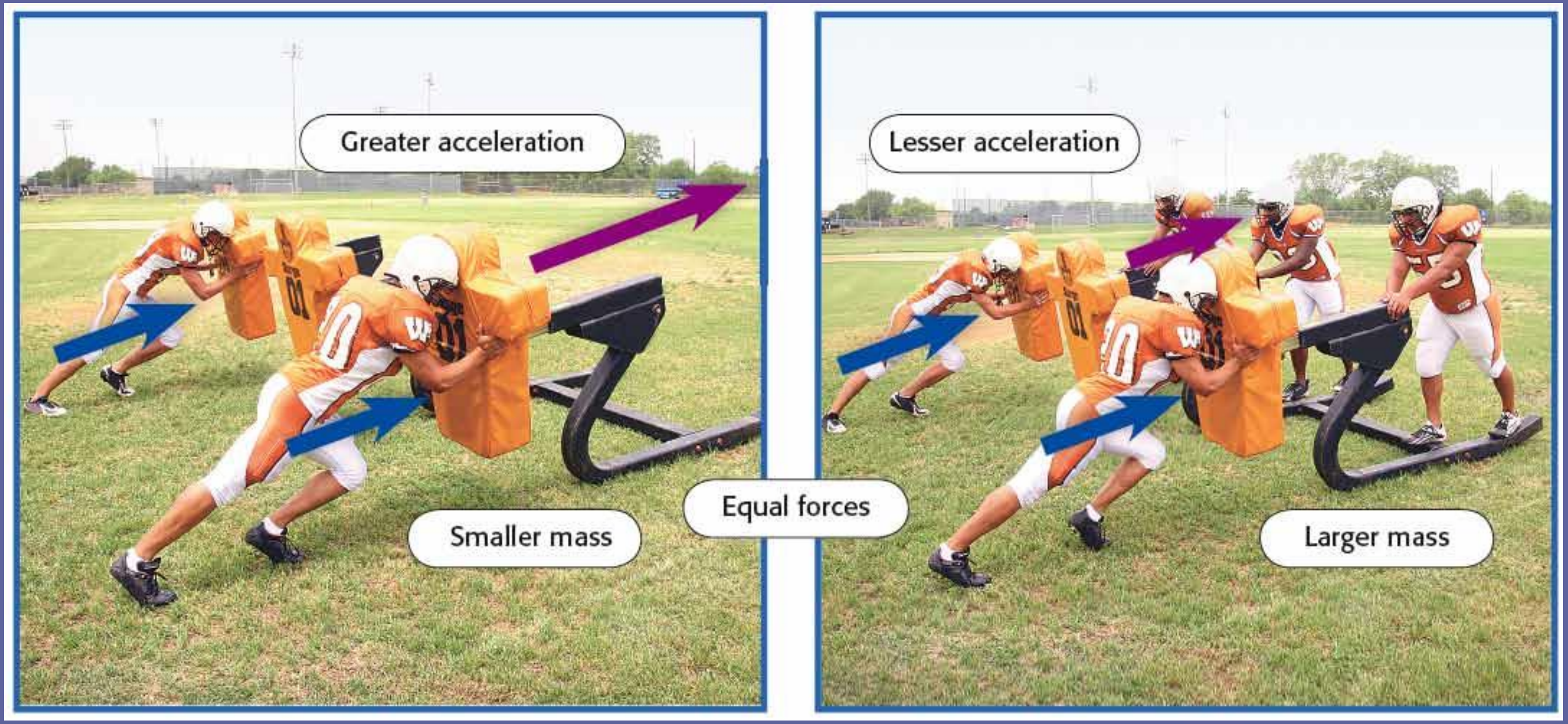
Newton’s Second Law, *continued*

- For equal forces, a larger mass accelerates less.



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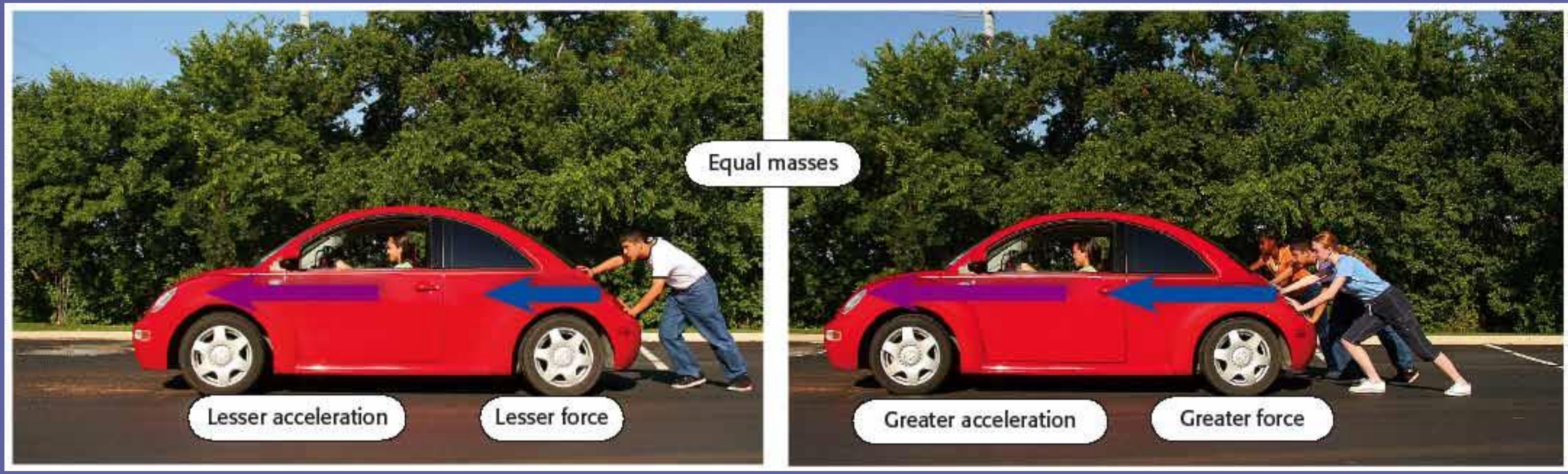
Newton's Second Law, *continued*

- For equal masses, a greater force produces a greater acceleration.



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Math Skills

Newton's Second Law

Zookeepers lift a stretcher that holds a sedated lion. The total mass of the lion and stretcher is 175 kg, and the upward acceleration of the lion and stretcher is 0.657 m/s^2. What force is needed to produce this acceleration of the lion and the stretcher?

1. List the given and unknown values.

Given: *mass, m* = 175 kg

acceleration, a = 0.657 m/s^2

Unknown: *force, F = ?* N

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Math Skills, *continued*

2. Write the equation for Newton’s second law.

force = *mass* × *acceleration*

$F = ma$

3. Insert the known values into the equation, and solve.

$F = 175\ \text{kg} \times 0.657\ \text{m/s}^2$

$F = 115\ \text{kg} \times \text{m/s}^2$

$\boxed{F = 115\ \text{N}}$

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Newton's Second Law, *continued*

- Newton's second law can also be stated as follows:
  - The acceleration of an object is proportional to the net force on the object and inversely proportional to the object's mass.

$$acceleration = \frac{force}{mass}$$

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

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Section 2: Gravity

Preview

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Key Ideas

- How are weight and mass related?
- Why do objects fall to the ground when dropped?
- What is the relationship between free-fall acceleration and mass?
- Why does a projectile follow a curved path?

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Bellringer

Recall that weight is defined as a measure of the gravitational force exerted on an object. Use knowledge you have about gravity to answer the questions in the following situations.

1. Elvis is a student whose mass is 70 kg. On Earth's surface, Elvis weighs about 690 N. Suppose Elvis could stand on the surface of the following bodies in the solar system. In the blanks provided, match Elvis's weight with the letter of the appropriate body. (**Hint:** Earth has a mass of 6.0×10^{24} kg.)

Planet	Elvis's weight
a. Jupiter ($m = 1.9 \times 10^{27}$ kg)	780 N _______
b. Venus ($m = 4.9 \times 10^{24}$ kg)	113 N _______
c. Neptune ($m = 1.0 \times 10^{26}$ kg)	260 N _______
d. Mercury ($m = 3.3 \times 10^{23}$ kg)	1800 N _______
e. Earth's moon ($m = 7.4 \times 10^{22}$ kg)	620 N _______

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Bellringer, *continued*

2. Suppose Elvis is in orbit around Venus at a distance twice as far from the planet's center as the surface of Venus is. Would you expect his weight to be greater than, less than, or equal to his weight on the surface of the planet?

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Weight and Mass

- How are weight and mass related?

- Weight is equal to mass times free-fall acceleration.

- **weight:** a measure of the gravitational force exerted on an object

- *weight = mass x free-fall acceleration,* or $w = mg$

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Weight and Mass, *continued*

- Weight is measured in newtons.
- Weight is different from mass.
  - mass = a measure of the amount of matter in an object
  - weight = the gravitational force an object experiences because of its mass

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Law of Universal Gravitation

- Why do objects fall to the ground when dropped?

- All objects in the universe attract each other through the force of gravity.

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Law of Universal Gravitation, *continued*

- Newton's *law of universal gravitation* gives the size of the gravitational force between two objects:

$$F = G\frac{m_1 m_2}{d^2}$$

  - m_1 and m_2 are the masses of the two objects
  - d is the distance between the two objects
  - G is a constant

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Law of Universal Gravitation, *continued*

- All matter is affected by gravity.
  - Two objects, whether large or small, always have a gravitational force between them.
  - When something is very large, like Earth, the force is easy to detect.
- Gravitational force increases as mass increases.
- Gravitational force decreases as distance increases.

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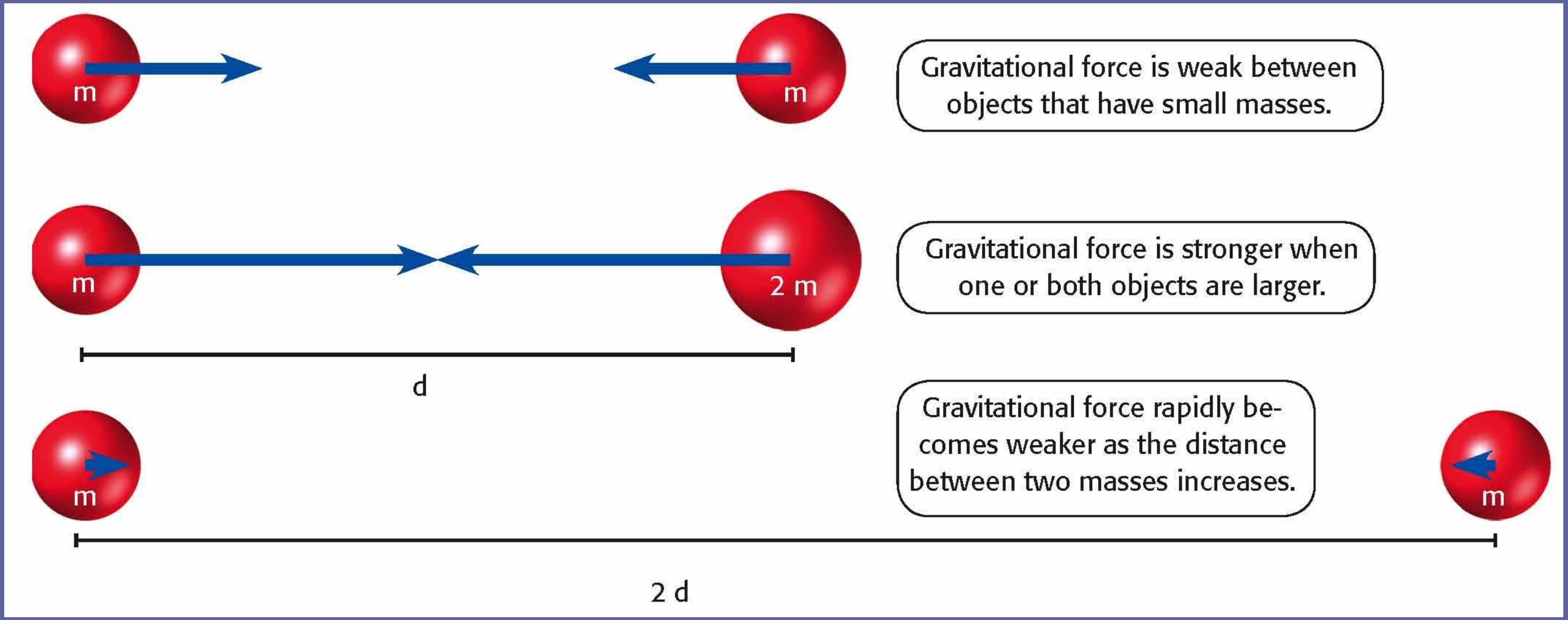
Law of Universal Gravitation, *continued*



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Free Fall

- What is the relationship between free-fall acceleration and mass?

- In the absence of air resistance, all objects falling near Earth's surface accelerate at the same rate regardless of their mass.

- **free fall:** the motion of a body when only the force of gravity is acting on the body

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Free Fall, *continued*

- Air resistance can balance weight.
  - **terminal velocity:** the constant velocity of a falling object when the force of air resistance is equal in magnitude and opposite in direction to the force of gravity
- Astronauts in orbit are in free fall.

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Projectile Motion

- Why does a projectile follow a curved path?

- Projectile motion has two components—horizontal and vertical. When the two motions are combined, they form a curved path.

- **projectile motion:** the curved path that an object follows when thrown, launched, or otherwise projected near the surface of Earth

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Projectile Motion, *continued*

- Projectile motion has a horizontal component.
  - After you have thrown a ball, no horizontal forces are acting on the ball (if air resistance is ignored). So, the horizontal component of velocity of the ball is constant after the ball leaves your hand.

- Projectile motion also has a vertical component.
  - When you throw a ball, gravity pulls it downward, which gives the ball vertical motion. In the absence of air resistance, gravity on Earth pulls objects that are in projectile motion downward with an acceleration of 9.8 m/s^2, just as it pulls down all falling objects.

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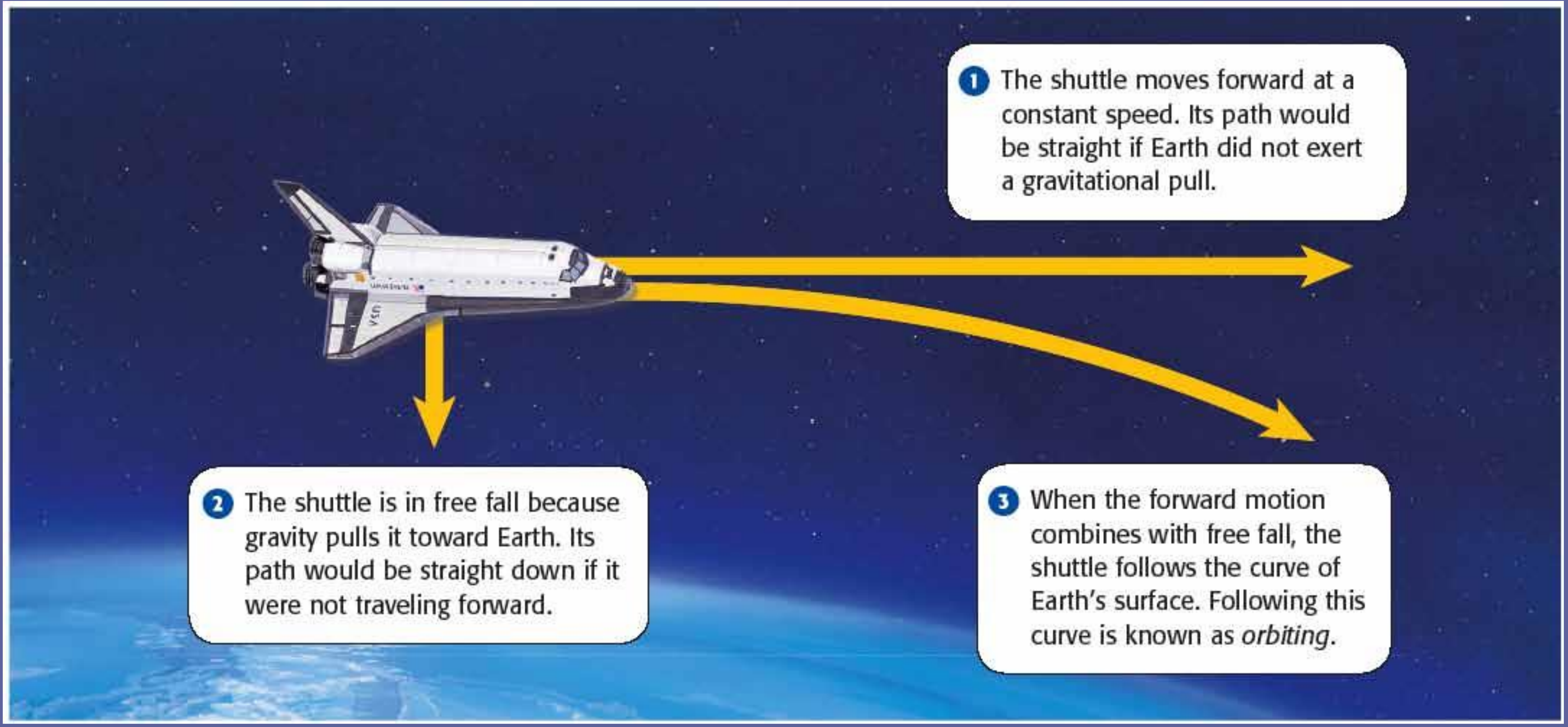
Projectile Motion, *continued*

- Orbiting is projectile motion.



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Section 3: Newton's Third Law

Preview

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Key Ideas

- What happens when an object exerts a force on another object?
- How do you calculate the momentum of an object?
- What is the total momentum after objects collide?

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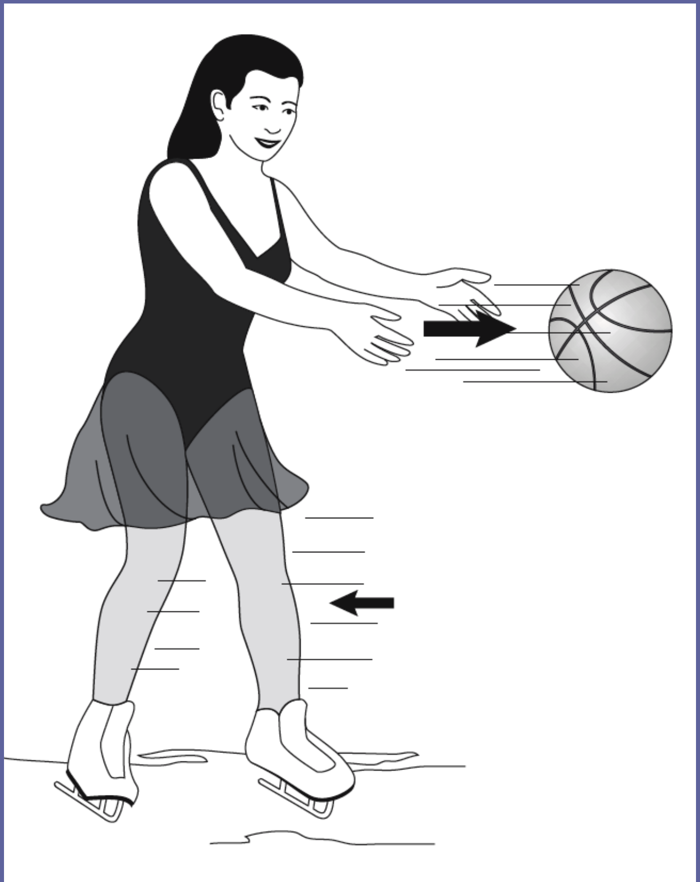
Bellringer

You have learned that forces account for changes in the motion of objects. Using what you have learned, explain what happens in the following situation.

An ice skater holding a basketball is standing on the surface of a frozen pond. The skater throws the ball forward. At the same time, the skater slides on the ice in the opposite direction.



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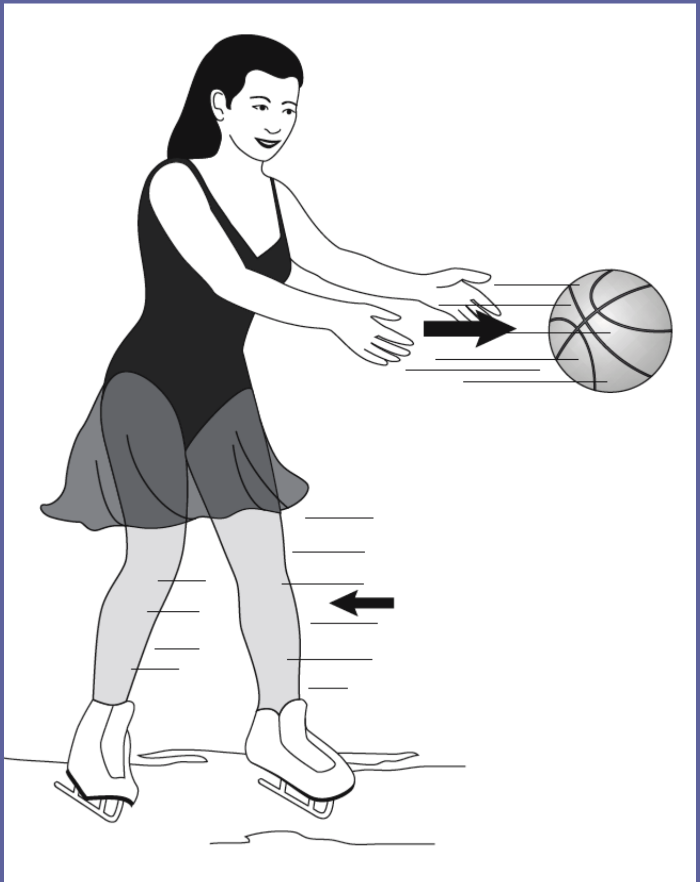
Bellringer, *continued*

1. Is the force on the ball greater than, less than, or equal to the opposite force on the skater? Explain your answer.

2. Is the acceleration of the ball greater than, less than, or equal to the acceleration of the skater? (Hint: Remember Newton's Second Law.) Explain your answer.



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Action and Reaction Forces

- What happens when an object exerts a force on another object?

- When one object exerts a force on a second object, the second object exerts a force equal in size and opposite in direction on the first object.

- This is *Newton's third law.*

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Action and Reaction Forces, *continued*

- Forces always occur in pairs.
  - For every *action* force, there is an equal and opposite *reaction* force.
- Forces in a force pair do not act on the same object.
- Equal forces don't always have equal effects.
  - Example: The action force of Earth pulling on an object and causing it to fall is much more obvious than the equal and opposite reaction force of the falling object pulling on Earth.

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Momentum

- How do you calculate the momentum of an object?

- For movement along a straight line, momentum is calculated by multiplying an object's mass and velocity.

- *momentum = mass x velocity,* or $p = mv$

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Momentum, *continued*

- **momentum:** quantity defined as the product of the mass and velocity of an object
  - SI units of momentum = kilograms times meters per second (kg•m/s).
  - Momentum and velocity are in the same direction.
- Momentum increases as mass and velocity increase.
- Force is related to change in momentum.
  - As the period of time of the momentum's change becomes longer, the force needed to cause this change in momentum becomes smaller.

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Math Skills

Momentum

Calculate the momentum of a 6.00 kg bowling ball moving at 10.0 m/s down the alley toward the pins.

1. List the given and unknown values.

Given: *mass, m* = 6.00 kg

velocity, v = 10.0 m/s *(toward the pins)*

Unknown: *momentum, p* = ? kg • m/s (and direction)

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Math Skills, continued

2. Write the equation for momentum.

momentum = mass x velocity

$p = mv$

3. Insert the known values into the equation, and solve.

$p = mv = 6.00\ \text{kg} \times 10.0\ \text{m/s}$

$p = 60.0\ \text{kg} \cdot \text{m/s}$ *(toward the pins)*

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Conservation of Momentum

- What is the total momentum after objects collide?

- The total momentum of two or more objects after a collision is the same as it was before the collision. In other words, the total amount of momentum in an isolated system is conserved.

- This principle is the *law of conservation of momentum.*

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