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Chapter 12 Forces and Motion

Section 12.1 Forces

(pages 356–362)

This section describes what forces are and explains how forces affect the motion of various objects.

Reading Strategy (page 356)

Relating Text and Visuals As you read about forces, look carefully at Figures 2, 3, and 5 in your textbook. Then complete the table by describing the forces and motion shown in each figure. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.

Forces and Motion		
Figure	**Is Net Force 0?**	**Effect on Motion**
2A		
2B		
3		
5A		
5B		

What is a Force? (pages 356–357)

1. A force is defined as a(n) _____ or a(n) _____ that acts on an object.
2. Is the following sentence true or false? A force can act to cause an object at rest to move or it can accelerate an object that is already moving. _____
3. How can a force change the motion of an object that is already moving?

_____

_____

4. Circle the letter of the best answer. What force causes a 1-kg mass to accelerate at a rate of 1 meter per second each second?

a. $1\ kg/m \cdot s^2$ b. 1 kg/s

c. 1 kg•m d. 1 newton

Combining Forces (pages 357–358)

5. The overall force acting on an object after all the forces are combined is the _____.
6. How do balanced and unbalanced forces affect the motion of an object?

_____

_____

_____

Friction (pages 359–360)

7. Is the following sentence true or false? Friction is a force that helps objects that are touching move past each other more easily.
_____

8. Circle the letters that identify types of friction.
   a. rolling b. gravity
   c. static d. sliding

9. The friction force that acts on objects that are at rest is _____.

10. Why is less force needed to keep an object moving than to start the object in motion? _____
_____
_____

11. Complete the table below about friction forces.

Types of Friction Forces	
Friction Force	**Example**
Static	
	Pushing a book along your desk
Rolling	

12. Is the following sentence true or false? Fluid friction is a force that opposes the motion of an object through a fluid such as water.
_____

Gravity (page 361)

13. Gravity is a(n) _____ force that pulls objects together.

14. Is the following sentence true or false? Earth's gravity acts downward toward the center of Earth. _____

15. Describe how gravity and air resistance affect the motion of a falling object. _____
_____

16. Is the following sentence true or false? Terminal velocity is the constant velocity of a falling object when the force of air resistance equals the force of gravity. _____

Projectile Motion (page 362)

17. The curved path caused by the combination of an initial forward velocity and the downward force of gravity is known as _____ motion.

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Chapter 12 Forces and Motion

Section 12.2 Newton's First and Second Laws of Motion

(pages 363–369)

This section discusses how force and mass affect acceleration. The acceleration due to gravity is defined, and mass and weight are compared.

Reading Strategy (page 363)

Building Vocabulary As you read this section, write a definition in the table for each vocabulary word you encounter. Use your own words in the definitions. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.

Matter and Motion	
Vocabulary	**Definition**
Inertia	

Aristotle, Galileo, and Newton (pages 363–364)

Match each scientist with his accomplishment.

Accomplishment

_____ 1. Italian scientist who did experiments that helped correct misconceptions about force and motion

_____ 2. Scientist who studied in England and introduced several laws describing force and motion

_____ 3. An ancient Greek philosopher who made many scientific discoveries through observation and logical reasoning

Scientist

a. Aristotle

b. Galileo

c. Newton

Newton's First Law of Motion (pages 364–365)

4. Is the following sentence true or false? According to Newton's first law of motion, an object's state of motion does not change as long as the net force acting on it is zero. _____

5. What is inertia? _____

_____

6. Is the following sentence true or false? The law of inertia states that an object in motion will eventually slow down and come to a complete stop if it travels far enough in the same direction.
_____

Newton's Second Law of Motion (pages 365–368)

7. According to Newton's second law of motion, acceleration of an object depends upon the _____ of the object and the _____ acting on it.

Match each term with its description.

Description	Term
_____ 8. A measure of the inertia of an object	a. mass
_____ 9. Net force/Mass	b. net force
_____ 10. Causes an object's velocity to change	c. acceleration

11. Is the following sentence true or false? The acceleration of an object is always in the same direction as the net force acting on the object. _____
12. Is the following sentence true or false? If the same force acts upon two objects with different masses, the acceleration will be greater for the object with greater mass. _____

Weight and Mass (pages 368–369)

13. What is weight? _____
_____

14. Write the formula used to calculate the weight of an object.
_____

15. Is the following sentence true or false? Because the weight formula shows that mass and weight are proportional, doubling the mass of an object will not affect its weight. _____
16. Complete the table below by describing the difference between mass and weight.

Mass and Weight	
Mass	**Weight**

17. On the moon, the acceleration due to gravity is only about one sixth that on Earth. Thus, an object will weigh _____ on the moon than it weighs on Earth.

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Chapter 12 Forces and Motion

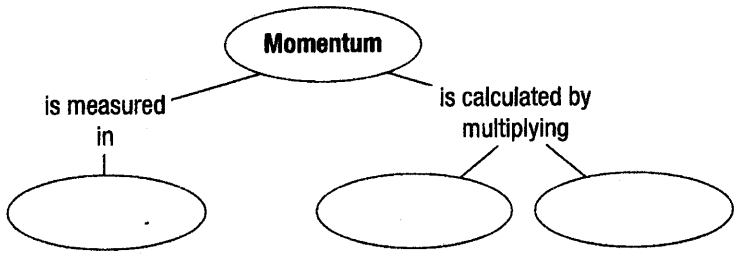
Section 12.3 Newton's Third Law of Motion and Momentum

(pages 372–377)

This section describes action-reaction forces and how the momentum of objects is determined.

Reading Strategy (page 372)

Summarizing As you read about momentum in this section, complete the concept map to organize what you learn. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.



Newton's Third Law (page 373)

1. According to Newton's third law of motion, what happens whenever one object exerts a force on a second object? _____

_____

2. The equal and opposite forces described by Newton's third law are called _____ and _____ forces.

3. Circle the letters that identify each sentence that is true about action-reaction forces.
   a. Newton's second law describes action-reaction forces.
   b. Forces always exist in pairs.
   c. Action-reaction forces never cancel.
   d. All action-reaction forces produce motion.

4. Is the following statement true or false? Action-reaction forces do not cancel each other because the action force is always greater than the reaction force. _____

Momentum (pages 374–375)

5. Circle the letter of each factor that affects the momentum of a moving object.
   a. mass b. volume c. shape d. velocity

6. If two identical objects are moving at different velocities, the object that is moving faster will have _____ momentum.

7. Your in-line skates are sitting in a box on a shelf in the closet. What is their momentum? _____
8. Is the following sentence true or false? An object with a small mass can have a large momentum if the object is traveling at a high speed. _____
9. Write the momentum formula, including the correct units.

_____

10. Circle the letter of the object that has the greatest momentum.
    a. a 700-gram bird flying at a velocity of 2.5 m/s
    b. a 1000-kilogram car traveling at 5 m/s
    c. a 40-kilogram shopping cart rolling along at 0.5 m/s
    d. a 300-kilogram roller coaster car traveling at 25 m/s

Conservation of Momentum (pages 376–377)

11. What does conservation of momentum mean? _____

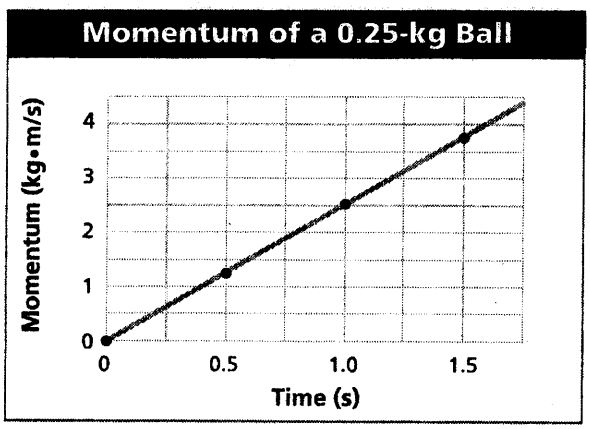
_____

12. Is the following sentence true or false? Objects within a closed system can exert forces on one another, but other objects and forces cannot leave or enter the system. _____
13. According to the law of conservation of momentum, what happens to the total momentum of a system if no net force acts on the system?

_____

14. Is the following sentence true or false? In a closed system with two objects, the loss of momentum of one object equals the gain in momentum of the other object. _____

For questions 15 and 16, refer to the graph below.



15. The momentum of the ball at one second is _____.
16. What is the speed of the ball at 0.5 seconds? Show your calculation. *Hint:* Solve the momentum formula for velocity.

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Chapter 12 Forces and Motion

Section 12.4 Universal Forces

(pages 378–382)

This section defines four forces that exist throughout the universe. Each force is described and its significance is discussed.

Reading Strategy (page 378)

Comparing and Contrasting As you read this section, compare two universal forces by completing the table. For more information on this Reading Strategy, see the **Reading and Study Skills** in the **Skills and Reference Handbook** at the end of your textbook.

Universal Nuclear Forces			
Force	**Acts on Which Particles?**	**Acts Over What Distance?**	**Relative Strength**
Strong nuclear			
Weak nuclear			

1. What are the four universal forces?
   a. _____ b. _____
   c. _____ d. _____

Electromagnetic Forces (pages 378–379)

2. Is the following sentence true or false? Electromagnetic force is associated with charged particles. _____
3. Name the only two forces that can both attract and repel. _____
   _____
4. Objects with like charges _____ one another, and objects with opposite charges _____ one another.
5. Circle the letters of the sentences that correctly describe magnets or magnetic forces.
   a. Magnetic forces act on certain metals.
   b. Magnets have two poles, north and south.
   c. Two poles that are alike attract each other.
   d. Magnetic forces can both attract and repel.

Nuclear Forces (pages 379–380)

6. The force that holds particles in the nucleus together is the _____.
7. What evidence suggests that nuclear forces have a powerful force of attraction? _____
   _____

8. Circle the letter of the best answer. Over extremely short distances, approximately how many times stronger is the strong nuclear force than the electric force of repulsion?
   a. 10 b. 100 c. 1000 d. 10,000
9. Compare and contrast the strong and weak nuclear forces. _____

Gravitational Force (pages 380–382)

10. State Newton's law of universal gravitation. _____
11. Circle the letter of each sentence that is true about gravitational force.
    a. The closer two objects are to one another, the weaker the gravitational force.
    b. The farther apart two objects are, the weaker the gravitational force.
    c. The greater the mass of an object, the stronger its gravitational force.
    d. Earth's gravitational force is stronger than the gravitational force of the sun.
12. The gravitational force of attraction between two objects depends on _____ and _____.
13. Is the following sentence true or false? Gravity is the weakest universal force, but it is the most effective force over long distances. _____
14. The sun's mass is much greater than the mass of Earth, so the sun's gravitational force is much _____ than that of Earth.
15. Why does the moon orbit Earth in a nearly circular path? _____
16. Is the following sentence true or false? The gravitational pull of the moon is the primary cause of Earth's ocean tides. _____
17. Is the following sentence true or false? An artificial satellite in a high orbit will slow down and lose altitude due to the pull of Earth's gravity. _____
18. List four uses of artificial satellites. _____

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Chapter 12 Forces and Motion

Section 12.2 Newton's First and Second Laws of Motion

(pages 363–371)

Math Skills Using Newton's Second Law

Content and Vocabulary Support

Newton's First Law of Motion

Newton's first law of motion states that the motion of an object does not change as long as the net force acting on the object is zero. In other words, an object at rest tends to remain at rest, and an object in motion tends to remain in motion. For example, a soccer ball lying on the ground does not move until a force, such as a kick, causes it to move. Once in motion, it will continue to move until another force, such as friction or a wall, causes it to slow down or stop. Newton's first law is also called the law of inertia. **Inertia** is the tendency of an object to resist a change in its motion.

Newton's Second Law of Motion

Objects change their motion, or accelerate, when unbalanced forces are applied to them. For example, if a rolling soccer ball starts to roll up a slope, it will decrease in velocity until it stops. Then, it will roll back down the slope at an increasing velocity. Two forces—inertia and gravity—are acting on the ball. They are acting together when the ball is rolling down the slope and against each other when the ball is rolling up the slope. Their combined force on the ball is the net force.

Newton's second law of motion states that the acceleration of an object is equal to the net force acting on it divided by the object's mass. **Mass** is a measure of the inertia of an object and depends on the amount of matter the object contains. Newton's second law can be expressed by the equation:

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}, \text{ or } a = \frac{F}{m}$$

An object with less mass or greater net force has greater acceleration.

Weight

Weight is the force of gravity acting on an object. The equation for weight is:

$$\text{Weight} = \text{Mass} \times \text{Acceleration due to gravity, or } W = mg$$

Acceleration due to gravity (g) is 9.8 m/s^2.

Name _____ Class _____ Date _____

Section 12.2 Newton's First and Second Laws of Motion

Solved Examples

Example 1: Erin threw a 3.0-kilogram ball with a net force of 210 newtons. What was the ball's acceleration?

Given: Net force (F) = 210 N
Mass (m) = 3.0 kg

Unknown: Acceleration (a)

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

Solution: $a = \frac{210\ \text{N}}{3.0\ \text{kg}} = 70\ \text{N/kg}$

The answer, 70 N/kg, can also be expressed as 70 m/s^2, because the unit N/kg equals m/s^2.

Example 2: A 1,200-kilogram car accelerates at 4.5 m/s^2. What is the net force of the car?

Given: Mass (m) = 1,200 kg
Acceleration (a) = 4.5 m/s^2 = 4.5 N/kg

Unknown: Net force (F)

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

Solution: Solve the equation for F, and substitute the given values:

$$F = a \times m;\ F = 4.5\ \text{N/kg} \times 1{,}200\ \text{kg} = 5{,}400\ \text{N}$$

Example 3: Find the mass of a person whose weight is 490 N.

Given: Weight (W) = 490 N
Acceleration due to gravity (g) = 9.8 m/s^2 = 9.8 N/kg

Unknown: Mass (m)

Equation: $W = mg$

Solution: Solve the equation for m, and substitute the given values:

$$m = \frac{W}{g};\ m = \frac{490\ \text{N}}{9.8\ \text{N/kg}} = 50\ \text{kg}$$

Name _____ Class _____ Date _____

Section 12.3 Newton's Third Law of Motion and Momentum

(pages 372–377)

Analyzing Momentum

Content and Vocabulary Support

Momentum

Momentum is the product of an object's mass and velocity. The larger the mass of an object or the faster it is moving, the larger its momentum. If an object has large momentum, it is hard to stop. Imagine trying to stop a car rolling very slowly down a slope. It would be hard to do because of the large mass of the car, not because of the car's velocity. It would also be hard to stop an object with a small mass but great velocity, such as a baseball traveling more than 100 kilometers per hour. The baseball's speed would give it large momentum.

Momentum Formula

The formula for calculating the momentum of an object is:

$$\text{Momentum} = \text{Mass} \times \text{Velocity}$$

Momentum is measured in units of kilogram-meters per second, written kg·m/s. For example, the momentum of a golf ball with a mass of 0.05 kilograms and a speed of 58 meters per second is:

$$\text{Momentum} = 0.05\ \text{kg} \times 58\ \text{m/s} = 2.9\ \text{kg·m/s}$$

The equation for momentum can be rewritten to find mass or velocity if momentum is known:

$$\text{Mass} = \frac{\text{Momentum}}{\text{Velocity}}$$

$$\text{Velocity} = \frac{\text{Momentum}}{\text{Mass}}$$

Law of Conservation of Momentum

According to the **law of conservation of momentum**, within a system total momentum does not change. If one object loses momentum, another object gains momentum. Thus, momentum is conserved. For example, a baseball bat loses velocity and momentum when it hits a ball. However, the ball gains velocity and momentum when the bat strikes it.

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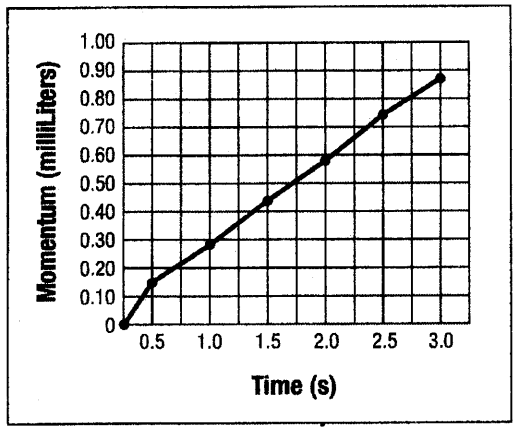
Section 12.3 Newton's Third Law of Motion and Momentum

Data

A teacher is demonstrating the relationship between velocity and momentum. She drops a 0.03-kilogram object from the school roof to the lawn below. The graph shows the momentum of the object from the time it leaves the roof until it lands on the lawn.

Momentum of 0.03-kg Object in Free Fall



The table shows the momentum of several cars. Each has a different mass, but all are traveling at the same constant velocity.

Momentum of Cars with a Velocity of 20 m/s		
Car	*Mass (kg)*	*Momentum (kg·m/s)*
Car A	1,400	28,000
Car B	?	27,200
Car C	1,280	25,600
Car D	1,140	?
Car E	1,050	21,000

Name _____ Class _____ Date _____

Practice Exercises

Exercise 1: What is the acceleration of a 1,500-kilogram truck with a net force of 7,500 newtons?

Exercise 2: A runner with a mass of 60 kilograms accelerates at 2.2 m/s^2. What is the runner's net force?

Exercise 3: Find the mass of a flying discus that has a net force of 1.05 newtons and accelerates at 3.5 m/s^2.

Exercise 4: Ian has a mass of 58.0 kilograms. What is his weight?

Exercise 5: Find the mass of a book that has a weight of 14.7 newtons.

Name _____ Class _____ Date _____

Questions

1. a. **Describing** Based on the graph, describe how momentum changes with time for an object in free fall.

b. **Calculating** Use the object's momentum and mass to calculate its velocity at 1.0 second and 3.0 seconds.

c. **Relating Cause and Effect** What causes the momentum of the object to change as it falls?

2. a. **Identifying** Identify the car with the smallest momentum and the car with the largest momentum. What is the mass of each of these cars?

b. **Calculating** Based on its momentum and velocity, calculate the mass of car B. Based on its mass and velocity, calculate the momentum of car D.

c. **Controlling Variables** How could you increase the momentum of car E to equal the momentum of car A?