Name _____ Class _____ Date _____

CHAPTER 1 Matter in Motion

SECTION 4

Gravity: A Force of Attraction

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is gravity?
- How are weight and mass different?

National Science Education Standards

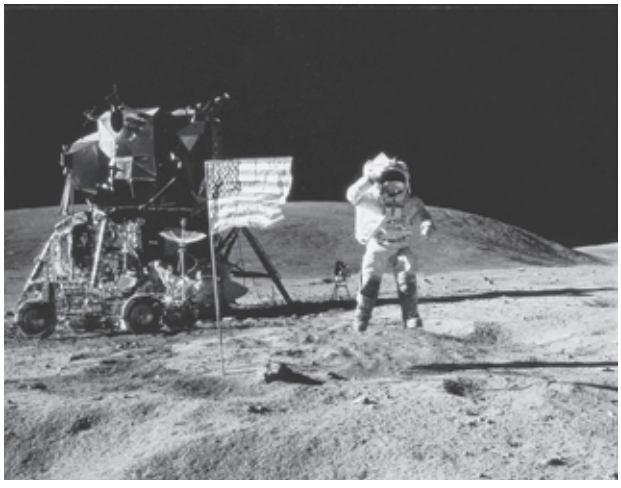
PS 2c

How Does Gravity Affect Matter?

Have you ever seen a video of astronauts on the moon? The astronauts bounce around like beach balls even though the space suits weighed 180 pounds on Earth. See the figure below. Why is it easier for a person to move on the moon than on Earth? The reason is that the moon has less gravity than Earth. **Gravity** is a force of attraction, or a pull, between objects. It is caused by their masses. ☑

All matter has mass. Gravity is a result of mass. Therefore all matter has gravity. This means that all objects attract all other objects in the universe! The force of gravity pulls objects toward each other. For example, gravity between the objects in the solar system holds the solar system together. Gravity holds you to Earth.

Small objects also have gravity. You have gravity. This book has gravity. Why don't you notice the book pulling on you or you pulling on the book? The reason is that the book's mass and your mass are both small. The force of gravity caused by small mass is not large enough to move either you or the book.



Because the moon has less gravity than Earth does, walking on the moon's surface was a very bouncy experience for the Apollo astronauts.

STUDY TIP

Discuss Ideas Take turns reading this section out loud with a partner. Stop to discuss ideas that seem confusing.

READING CHECK

1. Describe What is gravity?

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Critical Thinking

2. Infer Why can't you see two soccer balls attracting each other?

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What Is the Law of Universal Gravitation?

According to a story, Sir Isaac Newton, while sitting under an apple tree, watched an apple fall. This gave him a bright idea. Newton realized that an unbalanced force on the apple made it fall.

He then thought about the moon's orbit. Like many others, Newton had wondered what kept the planets in the sky. He realized that an unbalanced force on the moon kept it moving around Earth. Newton said that these forces are both gravity.

Newton's ideas are known as the *law of universal gravitation*. Newton said that all objects in the universe attract each other because of gravitational force. ☑

This law says that gravitational force depends on two things:

1. the masses of the objects
2. the distance between the objects

The word "universal" means that the law applies to all objects. See the figure below. ☑

READING CHECK

3. Describe What is the law of universal gravitation?

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READING CHECK

4. Identify What two things determine gravitational force?

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STANDARDS CHECK

PS 2c If more than one force acts on an object along a straight line, then the forces reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

5. Identify What is the unbalanced force that affects the motions of a falling apple and the moon?

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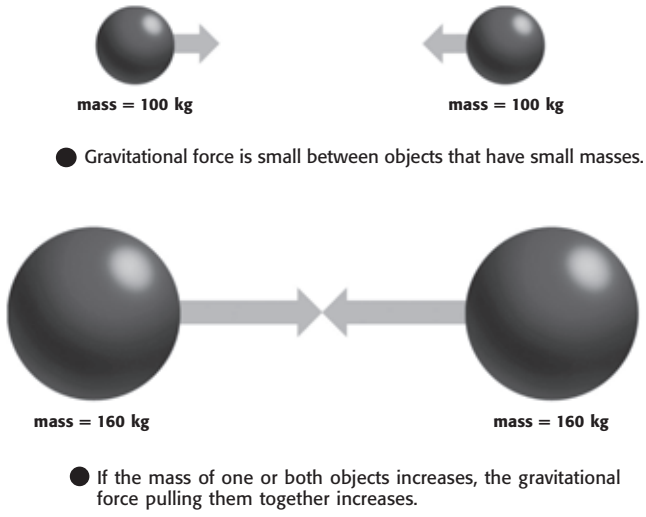
Sir Isaac Newton said that the same unbalanced force caused the motions of the apple and the moon.

How Does Mass Affect Gravity?

Imagine an elephant and a cat. Because the elephant has a larger mass than the cat does, gravity between the elephant and Earth is larger. So, the cat is much easier to pick up than the elephant. The gravitational force between objects depends on the masses of the objects. See the figure below.



The arrows indicate the gravitational force between two objects. The length of the arrows indicates the magnitude of the force.

TAKE A LOOK

6. Compare Is there more gravitational force between objects with small masses or objects with large masses?

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Mass also explains why an astronaut on the moon can jump around so easily. The moon has less mass than Earth does. This gives the moon a weaker pull on objects than the pull of Earth. The astronaut is not being pulled toward the moon as much as he is by Earth. So the astronaut can jump higher and more easily on the moon.

The universal law of gravitation can let us predict what happens to gravity when mass changes. According to the universal law of gravitation, suppose there is a 5 N force of gravity between two objects. If the mass of one object doubles and the other stays the same, the force of gravity also doubles.

Let's try a problem. The force due to gravity between two objects is 3 N. If the mass of one object triples and the other stays the same, what is the new force of gravity?

Solution: Since the mass of one object tripled and the other stayed the same, the force of gravity also triples. It is 9 N.

Math Focus

7. Infer Two objects of equal mass have a force of gravity of 6 N between them. Imagine the mass of one is cut in half and the other stays the same, what is the force due to gravity?

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How Does Distance Affect Gravity?

The mass of the sun is 300,000 times bigger than that of Earth. However, if you jump up, you return to Earth every time you jump rather than flying toward the sun. If the sun has more mass, then why doesn't it have a larger gravitational pull on you?

This is because the gravitational force also depends on the distance between the objects. As the distance between two objects gets larger, the force of gravity gets much smaller. And as the distance between objects gets smaller, the force of gravity gets much bigger. This is shown in the figure below.

Although the sun has tremendous mass, it is also very far away. This means that it has very little gravitational force on your body or on small objects around you. The sun does have a large gravitational force on planets because the masses of planets are very large.

Critical Thinking

8. Analyze The sun is much more massive than Earth. Why is the force of gravity between you and the sun so much less than Earth's gravity and you?

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● Gravitational force is large when the distance between two objects is small.

TAKE A LOOK

9. Describe Use the diagram to describe the effect of distance on gravitational force.

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● If the distance between two objects increases, the gravitational force pulling them together decreases rapidly.

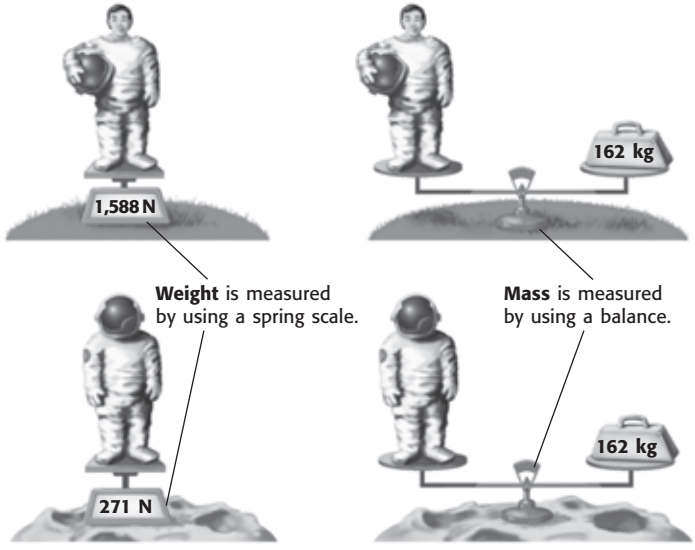
The length of the arrows indicates the magnitude of the gravitational force between two objects.

What Is the Difference Between Mass and Weight?

You have learned that gravity is a force of attraction between objects. **Weight** is a measure of the gravitational force on an object. The SI unit for weight is the newton (N).

Mass is a measure of the amount of matter in an object. This seems similar to weight, but it is not the same. An object's mass does not change when gravitational forces change, but its weight does. Mass is usually expressed in kilograms (kg) or grams (g). ☑

In the figure below, you can see the difference between mass and weight. Compare the astronaut's mass and weight on Earth to his mass and weight on the moon.



READING CHECK

10. Contrast How is mass different from weight?

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TAKE A LOOK

11. Identify What is the weight of the astronaut on Earth? What is the weight of the astronaut on the moon?

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Gravity can cause objects to move because it is a type of force. But gravity also acts on objects that are not moving, or *static*. Earth's gravity pulls objects downward. However, not all objects move downward. Suppose a framed picture hangs from a wire. Gravity pulls the picture downward, but tension (the force in the wire) pulls the picture upward. The forces are balanced so that framed picture does not move.

Critical Thinking

12. Contrast What forces act on a framed picture on a shelf?

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Section 4 Review

NSES PS 2c

SECTION VOCABULARY

gravity a force of attraction between objects that is due to their masses **mass** a measure of the amount of matter in an object	**weight** a measure of the gravitational force exerted on an object; its value can change with the location of the object in the universe

1. **Identify** What is gravity? What determines the gravitational force between objects?

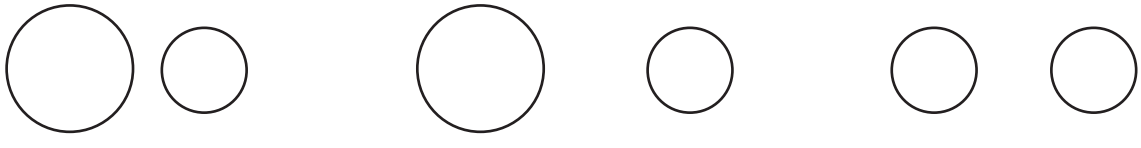
2. **Describe** A spacecraft is moving toward Mars. Its rocket engines are turned off. As the spacecraft nears the planet, what will happen to the pull of Mars's gravity?

3. **Summarize** An astronaut travels from Earth to the moon. How does his mass change? How does his weight change? Explain.

4. **Applying Concepts** An astronaut visits Planet X. Planet X has the same radius as Earth but has twice the mass of Earth. Fill in the table below to show the astronaut's mass and weight on Planet X. (Hint: Newton's law of universal gravitation says that when the mass of one object doubles, the force due to gravity also doubles.)

	Earth	Planet X
Mass of astronaut	80 kg	
Weight of astronaut	784 N	

5. **Select** Each of the spheres shown below is made of iron. Circle the pair of spheres that would have the greatest gravitational force between them. Below the spheres, explain the reason for your choice.



Review

1. Friction makes it harder to get objects moving and keep them moving.
2. Static friction is friction between two surfaces that are not moving. Kinetic friction is between moving surfaces. Possible examples: Friction between the floor and a refrigerator that is being pushed but is not moving is static friction. Friction between the floor and a refrigerator that has started to slide is an example of kinetic friction.
3. Sketch should show smoother surfaces; peaks and valleys have less relief.
4. Grease, oil, and wax are lubricants. They reduce the friction between surfaces that touch.
5. Friction always acts in a direction opposite the direction of motion.
6. The car would not stop. Friction between the tires and the road is needed to start or stop.
7. The forces must be unbalanced, because the object starts moving (it is accelerating).

SECTION 4 GRAVITY: A FORCE OF ATTRACTION

1. force of attraction between objects caused by their masses
2. Their masses are small, so they don't have much gravity.
3. All objects in the universe attract each other because of gravitational force.
4. masses of objects, distance between objects
5. gravity
6. Gravitational force is greater between objects with large masses.
7. 3 N
8. We are on Earth, but the sun is very, very far away.
9. As the distance between two objects increases, the gravitational force decreases. As the distance between two objects decreases, the gravitational force increases.
10. Mass is the amount of matter in an object, but weight is the amount of gravitational force on an object.
11. 1,588 N on Earth, 271 N on the moon
12. Gravity pulls down, and the shelf pushes up.

Review

1. Gravity is a force of attraction between objects. It is determined by the masses of objects and the distance between them.
2. It will get larger.
3. The astronaut has the same mass on Earth and the moon, but the astronaut has a greater weight on Earth than the moon. The mass does not change, because it is the amount of matter in the astronaut. The weight is greater on Earth because Earth's gravity is greater.
4.

	Earth	Planet X
Mass of astronaut	80 kg	80kg
Weight of astronaut	784 N	1,568 N

5. Student should circle the first pair. The reason given should be that the spheres are the largest pair of masses separated by the smallest distance.

Chapter 2 Forces and Motion

SECTION 1 GRAVITY AND MOTION

1. The cannonballs hit the ground at the same time.
2. Golf ball should be drawn at the same heights as the table tennis ball.
3. 29.4 m/s; after the third second, the ball is moving 9.8 m/s faster than it was at the end of the second second. Then, 19.6 m/s + 9.8 m/s = 29.4 m/s.
4. $v_{final} = g \times t$

   $v_{final} = 9.8 \frac{m/s}{\cancel{s}} \times 2 \cancel{s} = 19.6$ m/s
5. $t = \frac{v_{final}}{g}$

   $t = \frac{98 \cancel{m/s}}{\frac{9.8 \cancel{m/s}}{s}} = 10$ s
6. the flat paper
7. The crumpled paper has a greater net force acting on it.
8. when the force of air resistance equals the force of gravity