Section 2

Gravity and Motion

Objectives

After this lesson, students will be able to

J.1.2.1 Identify the factors that determine the strength of the force of gravity between two objects.

J.1.2.2 Describe two factors that keep the moon and Earth in orbit.

Target Reading Skill

Asking Questions Explain that changing a heading into a question helps students anticipate the ideas, facts, and events they are about to read.

Answers

Possible questions and answers:
What is gravity? *(Gravity is the force that attracts all objects toward one another.)* **What is inertia?** *(Inertia is the tendency of an object to resist a change in motion.)*

All in One Teaching Resources

- Transparency J4

Preteach

Build Background Knowledge

L1

Weight

Students have often weighed themselves or compared the weights of various objects. Ask: **What is weight?** *(Possible answer: A value that describes how heavy an object is)* Tell students that weight is related to the force of gravity. In this section, they will learn about gravity and how it relates to Earth's orbit.

Gravity and Motion

Reading Preview

Key Concepts

- What determines the strength of the force of gravity between two objects?
- What two factors combine to keep the moon and Earth in orbit?

Key Terms

- force
- gravity
- law of universal gravitation
- mass
- weight
- inertia
- Newton's first law of motion

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a question for each heading. As you read, write answers to your questions.

Gravity

Question	Answer
What is gravity?	Gravity is . . .

Lab zone Discover Activity

Can You Remove the Bottom Penny?

1. Place 25 or so pennies in a stack on a table.
2. Write down your prediction of what will happen if you attempt to knock the bottom penny out of the stack.
3. Quickly slide a ruler along the surface of the table and strike the bottom penny. Observe what happens to the stack of pennies.
4. Repeat Step 3 several times, knocking more pennies from the bottom of the stack.

Think It Over

Developing Hypotheses Explain what happened to the stack of pennies as the bottom penny was knocked out of the stack.

Earth revolves around the sun in a nearly circular orbit. The moon orbits Earth in the same way. But what keeps Earth and the moon in orbit? Why don't they just fly off into space?

The first person to answer these questions was the English scientist Isaac Newton. Late in his life, Newton told a story of how watching an apple fall from a tree in 1666 had made him think about the moon's orbit. Newton realized that there must be a force acting between Earth and the moon that kept the moon in orbit. A **force** is a push or a pull. Most everyday forces require objects to be in contact. Newton realized that the force that holds the moon in orbit is different in that it acts over long distances between objects that are not in contact.

Gravity

Newton hypothesized that the force that pulls an apple to the ground also pulls the moon toward Earth, keeping it in orbit. This force, called **gravity,** attracts all objects toward each other. In Newton's day, most scientists thought that forces on Earth were different from those elsewhere in the universe. Although Newton did not discover gravity, he was the first person to realize that gravity occurs everywhere. Newton's **law of universal gravitation** states that every object in the universe attracts every other object.

Lab zone Discover Activity

Skills Focus Developing hypotheses L2

Materials 25 pennies, thin plastic ruler or thin spatula

Time 10 minutes

Tips It may take students a few attempts before they get a procedure down for knocking out the bottom penny. Make sure that the ruler or spatula is thinner than the height of one penny.

Expected Outcome When done properly, the bottom penny is knocked out of the stack without disturbing the remaining pennies.

Think It Over The law of inertia (objects at rest tend to stay at rest) is demonstrated in this activity. The only penny being acted upon by a horizontal force is the bottom penny. As a result, the remaining pennies tend to remain undisturbed.

The force of gravity is measured in units called newtons, named after Isaac Newton. **The strength of the force of gravity between two objects depends on two factors: the masses of the objects and the distance between them.**

Gravity, Mass, and Weight According to the law of universal gravitation, all of the objects around you, including Earth and even this book, are pulling on you, just as you are pulling on them. Why don't you notice a pull between you and the book? Because the strength of gravity depends in part on the masses of each of the objects. **Mass** is the amount of matter in an object.

Because Earth is so massive, it exerts a much greater force on you than this book does. Similarly, Earth exerts a gravitational force on the moon, large enough to keep the moon in orbit. The moon also exerts a gravitational force on Earth, as you will learn later in this chapter when you study the tides.

The force of gravity on an object is known as its **weight**. Unlike mass, which doesn't change, an object's weight can change depending on its location. For example, on the moon you would weigh about one sixth of your weight on Earth. This is because the moon is much less massive than Earth, so the pull of the moon's gravity on you would be far less than that of Earth's gravity.

Gravity and Distance The strength of gravity is affected by the distance between two objects as well as their masses. The force of gravity decreases rapidly as distance increases. For example, if the distance between two objects were doubled, the force of gravity between them would decrease to one fourth of its original value.

Reading Checkpoint **What is an object's weight?**

FIGURE 7
Gravity, Mass, and Distance
The strength of the force of gravity between two objects depends on their masses and the distance between them.
Inferring *How would the force of gravity change if the distance between the objects decreased?*

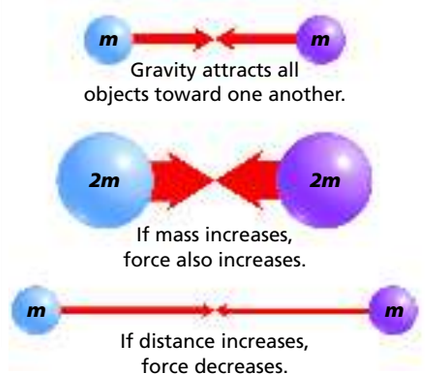
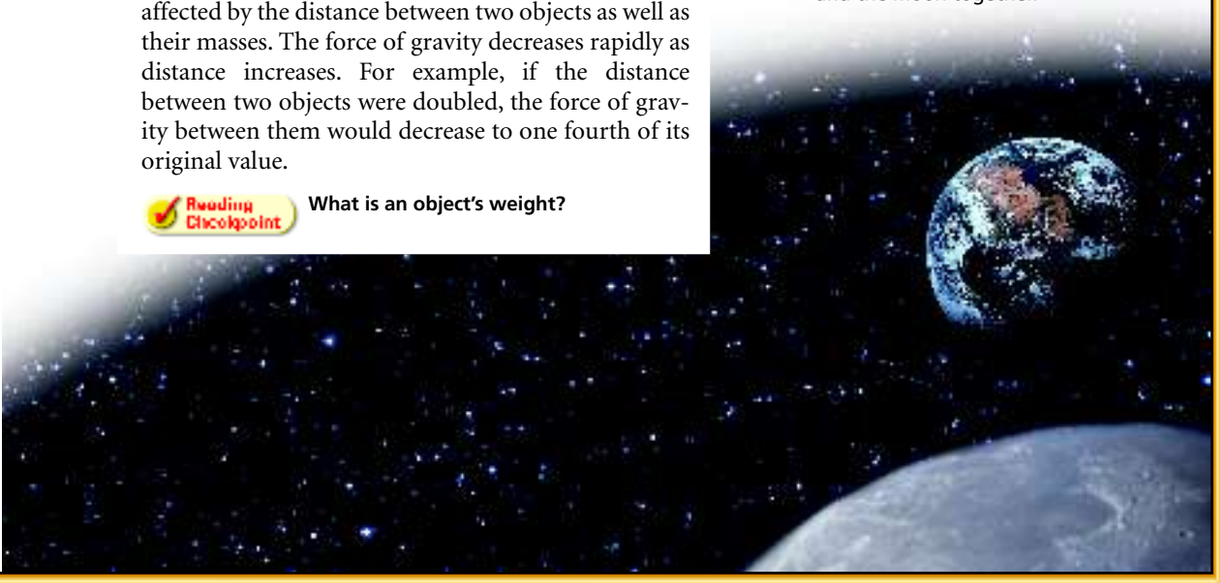


FIGURE 8
Earth Over the Moon
The force of gravity holds Earth and the moon together.



Instruct

Gravity

Teach Key Concepts L2

Gravitational Attraction

Focus Remind students that gravity is a force that attracts objects toward one another.

Teach Ask: **What is mass?** *(The amount of matter in an object)* **What other factor affects the strength of the force of gravity?** *(Distance)* Have students examine Figure 7. Ask: **What would increase the force of gravity between two objects?** *(An increase in mass or a decrease in distance)*

Apply Ask: **What would happen if the distance between Earth and the moon decreased?** *(The force of gravity between them would increase.)* **learning modality: visual**

All in One **Teaching Resources**

- Transparency J5

Independent Practice L2

All in One **Teaching Resources**

- Guided Reading and Study Worksheet: *Gravity and Motion*

Student Edition on Audio CD

Differentiated Instruction

Less Proficient Readers L1

Interpreting Illustrations Have students preview the visuals in this section. Advise them to focus on both the pictures and the captions. As they study the illustrations, suggest that they ask themselves questions such as these:

- What is being shown in this picture?
- What is the main idea of the picture?
- What new information did I learn from the caption?
- Where in the text can I find information related to this picture?

Monitor Progress L2

Drawing Have students draw a diagram of Earth and the moon, showing what would happen if their mass or the distance between them changed.

Answers

Figure 7 The force of gravity between the objects would increase.

Reading Checkpoint The force of gravity on an object

Go Online SCILINKS NSTA

For: Links on gravity
Visit: www.SciLinks.org
Web Code: scn-0612

Download a worksheet that will guide students' review of Internet resources on gravity.

Inertia and Orbital Motion

Teach Key Concepts L1

Inertia

Focus Remind students that gravity pulls all objects toward each other.

Teach Ask: **Why does a baseball continue to move after a pitcher lets go of it and stops applying force?** *(The ball has inertia.)* **Why would the ball eventually hit the ground?** *(Gravity pulls it down.)*

Apply Ask students if they have ever seen a magician pull a tablecloth off a table, leaving the dishes that were on top of it in place? Ask: **What role does inertia play in this magic trick?** *(The inertia of the dishes causes them to resist a change in motion—in this case, to resist being moved at all.)* **learning modality: logical/mathematical**

All in One Teaching Resources

- Transparency J6

Math Analyzing Data

Math Skill Making and Interpreting Graphs

Focus Tell students that to overcome gravity, rockets burn a great deal of fuel when they launch.

Teach Show students that the force of gravity can be located by moving a finger along the *x*-axis until it reaches the appropriate distance, and then upward until it reaches the curve. From there, moving horizontally to the left will take them to the *y*-axis where they will find the force of gravity at that distance.

Answers

1. Force of gravity on the rocket in millions of newtons and distance from planet's center in planetary radii
2. 4 million newtons
3. 1 million newtons
4. It decreases.

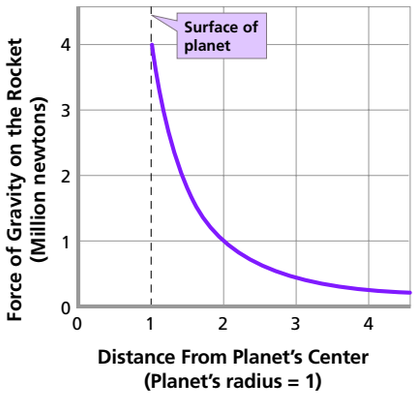
Math Analyzing Data

Gravity Versus Distance

As a rocket leaves a planet's surface, the force of gravity between the rocket and the planet changes. Use the graph at the right to answer the questions below.

1. **Reading Graphs** What two variables are being graphed? In what units is each variable measured?
2. **Reading Graphs** What is the force of gravity on the rocket at the planet's surface?
3. **Reading Graphs** What is the force of gravity on the rocket at a distance of two units (twice the planet's radius from its center)?
4. **Making Generalizations** In general, how does the force of gravity pulling on the rocket change as the distance between it and the planet increases?

Gravity and Distance



Go Online SCILINKS NSTA

For: Links on gravity
Visit: www.SciLinks.org
Web Code: scn-0612

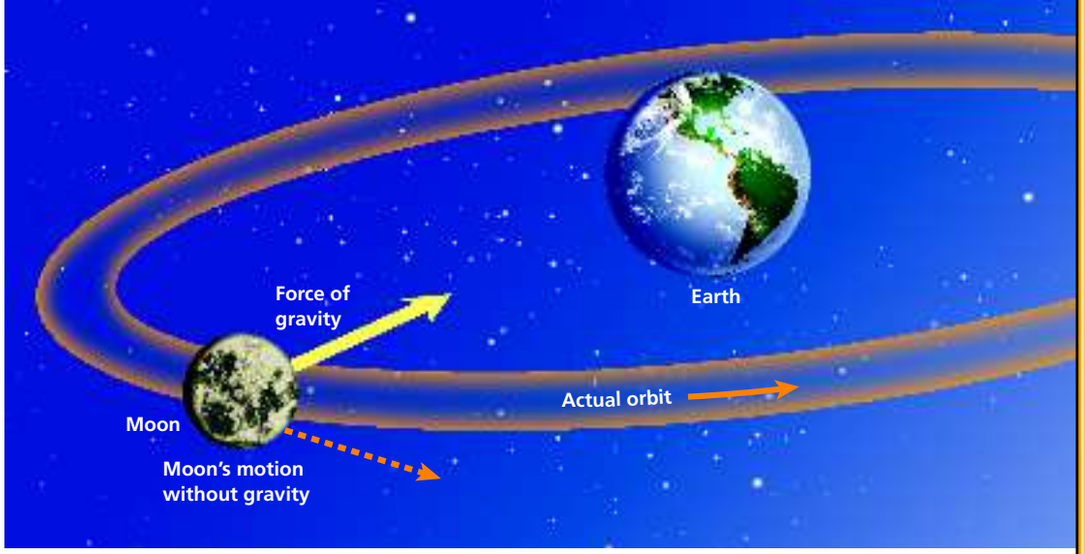
Inertia and Orbital Motion

If the sun and Earth are constantly pulling on one another because of gravity, why doesn't Earth fall into the sun? Similarly, why doesn't the moon crash into Earth? The fact that such collisions have not occurred shows that there must be another factor at work. That factor is called inertia.

Inertia The tendency of an object to resist a change in motion is **inertia.** You feel the effects of inertia every day. When you are riding in a car and it stops suddenly, you keep moving forward. If you didn't have a seat belt on, your inertia could cause you to bump into the car's windshield or the seat in front of you. The more mass an object has, the greater its inertia. An object with greater inertia is more difficult to start or stop.

Isaac Newton stated his ideas about inertia as a scientific law. **Newton's first law of motion** says that an object at rest will stay at rest and an object in motion will stay in motion with a constant speed and direction unless acted on by a force.

Reading Checkpoint **What is inertia?**



Orbital Motion Why do Earth and the moon remain in their orbits? **Newton concluded that two factors—inertia and gravity—combine to keep Earth in orbit around the sun and the moon in orbit around Earth.**

As shown in Figure 9, Earth's gravity keeps pulling the moon toward it, preventing the moon from moving in a straight line. At the same time, the moon keeps moving ahead because of its inertia. If not for Earth's gravity, inertia would cause the moon to move off through space in a straight line. In the same way, Earth revolves around the sun because the sun's gravity pulls on it while Earth's inertia keeps it moving ahead.

FIGURE 9
Gravity and Inertia
A combination of gravity and inertia keeps the moon in orbit around Earth. If there were no gravity, inertia would cause the moon to travel in a straight line.
Interpreting Diagrams *What would happen to the moon if it were not moving in orbit?*

Section 2 Assessment

Target Reading Skill **Asking Questions** Use your graphic organizer about the headings to help answer the questions below.

Reviewing Key Concepts

1. **a.** **Summarizing** What is the law of universal gravitation?
   b. **Reviewing** What two factors determine the force of gravity between two objects?
   c. **Predicting** Suppose the moon were closer to Earth. How would the force of gravity between Earth and the moon be different?
2. **a.** **Identifying** What two factors act together to keep Earth in orbit around the sun?
   b. **Applying Concepts** Why doesn't Earth simply fall into the sun?
   c. **Predicting** How would Earth move if the sun (including its gravity) suddenly disappeared? Explain your answer.

Writing in Science

Cause and Effect Paragraph Suppose you took a trip to the moon. Write a paragraph describing how and why your weight would change. Would your mass change too?

Writing in Science

Writing Mode Exposition

Scoring Rubric

4 Exceeds criteria; includes a detailed explanation of how and why weight would change and tells why mass does not change
3 Meets all criteria but does not go beyond requirements
2 Includes an explanation of weight changes but does not mention mass
1 Is incomplete and inaccurate

Lab zone Teacher Demo

Demonstrating Inertia L1

Materials quarter; clean, dry coffee mug; 3 × 5 index card

Time 10 minutes

Focus Review Newton's first law of motion by reminding the class that an object at rest will stay at rest until acted upon by a force.

Teach Place an index card over the top of a coffee mug. Place a quarter on top of the card, centering it over the mug. Quickly pull the card out from under the quarter. The quarter will fall into the mug. Ask: **What kept the quarter from moving with the card?** *(Inertia, which made the quarter "remain at rest")* **Why didn't the quarter move with the card it was sitting on?** *(The sideways pulling force was acting on the card, only.)*

Apply Ask how this demonstration is related to orbital motion. *(An object moving in space will resist a change in motion—much as the quarter did—and try to keep moving in a straight line.)* **learning modality: visual**

Monitor Progress L2

Answers

Figure 9 Earth's gravity would pull it directly toward Earth.

Reading Checkpoint The tendency of an object to resist a change in motion

Assess

Reviewing Key Concepts

1. a. Every object in the universe attracts every other object. **b.** The masses of the objects and the distance between them **c.** It would increase.
2. a. Inertia and gravity **b.** Earth's inertia causes it to tend to move in a straight line. **c.** Earth would move in a straight line because no gravitational force would counteract its inertia.

Reteach L1

Use the diagrams in this section to summarize how objects stay in orbit.

All in One Teaching Resources

- Section Summary: *Gravity and Motion*
- Review and Reinforce: *Gravity and Motion*
- Enrich: *Gravity and Motion*