Section 2

Integrating Physics

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.

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?*

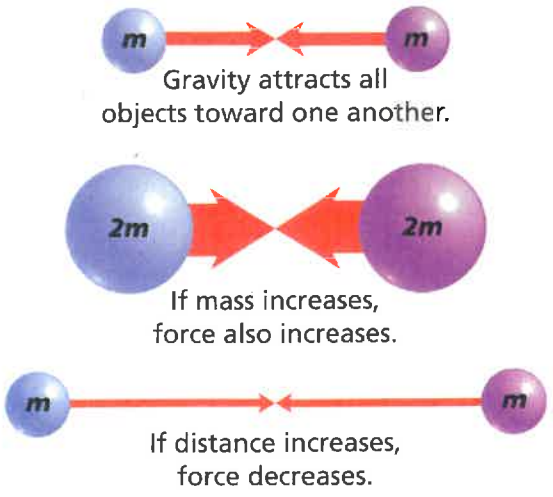
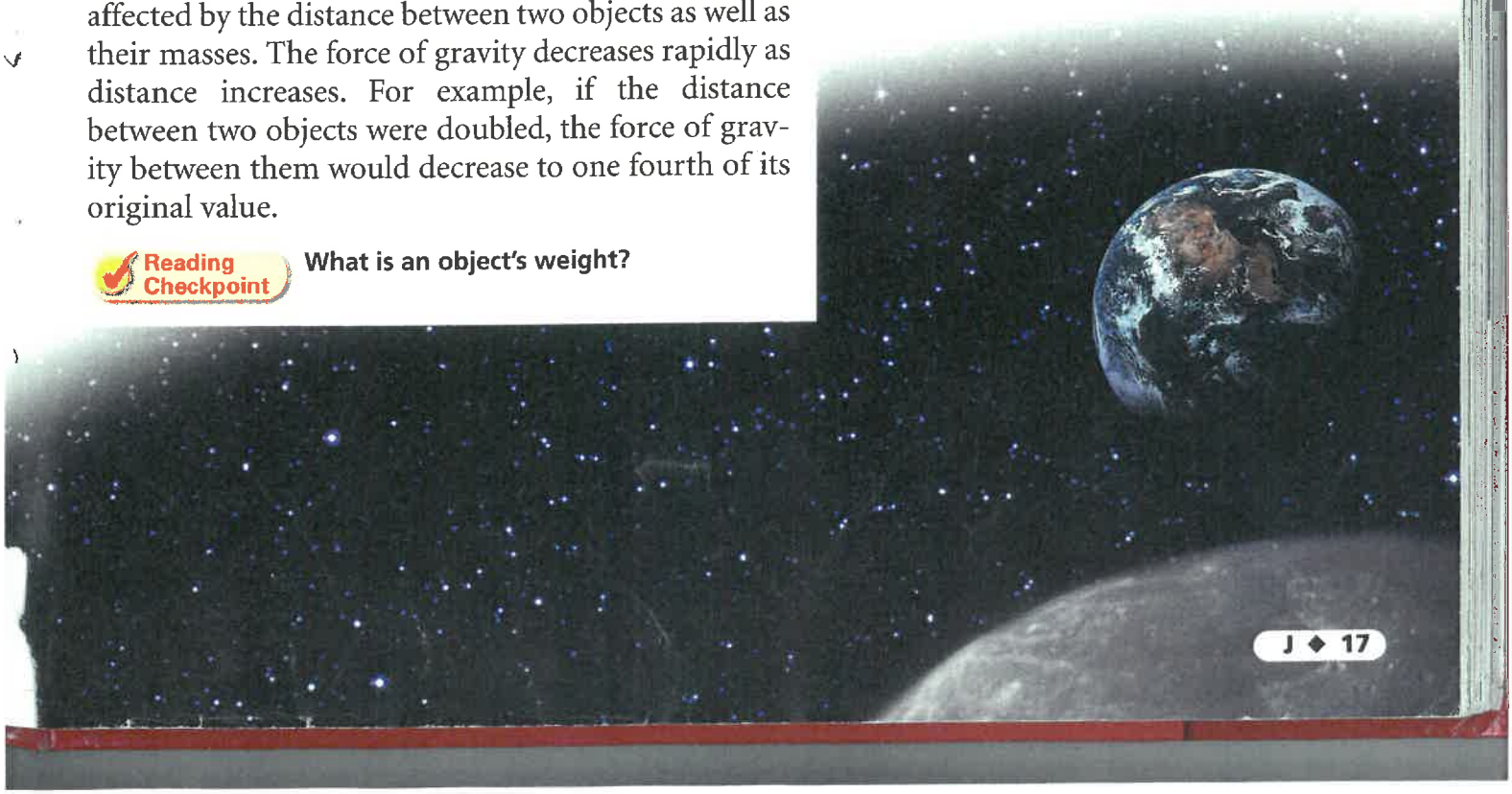


FIGURE 8
Earth Over the Moon
The force of gravity holds Earth and the moon together.



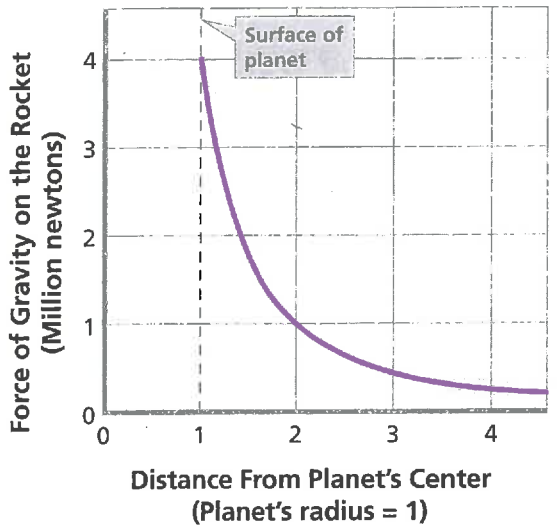
Math Analyzing Data

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



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.

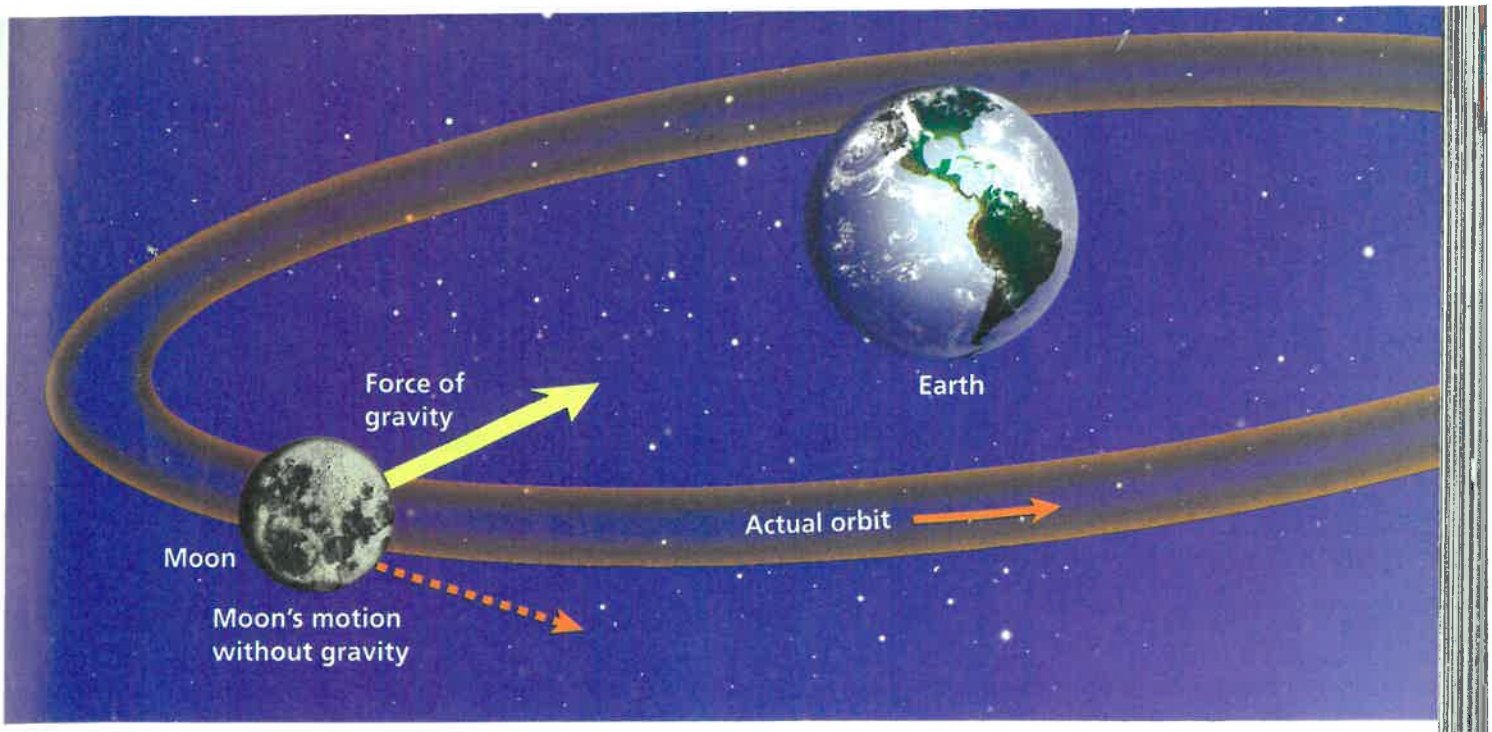
Inertia The tendency of an object to resist a change in motion is **inertia.** You feel the effects of inertia every day. When you are riding in a car and it stops suddenly, you keep moving forward. If you didn't have a seat belt on, your inertia could cause you to bump into the car's windshield or the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

Go Online NSTA SCILINKS

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



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?