Teacher Edition

exploring SCIENCE

FIFTH EDITION

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Part 1

PAGES	OBJECTIVES	RESOURCES	ASSESSMENTS
SECTION 4.4 ***ELECTROMAGNETISM***			
99–103	**4.4.1 Explain the relationship between electricity and magnetism.** **4.4.2 Describe how an electric current can be generated.** **4.4.3 Give examples of electromagnetic applications.** BWS Dominion (explain) **4.4.4 Formulate a biblical position on the topic of electrofishing.** BWS Ethics (evaluate)	**Activities & Lab Manual** • Activity 4.4: *Electromagnetism—Generating Electricity* (p. 37) **BJU Press Trove** • Video: *Electromagnetism* • Link: *Faraday's Electromagnetic Lab* • Link: *Build a Generator* • PPT Pres.: Section 04.4 **Materials** • hand-cranked generator with visible workings	**Student Edition** • Section 4.4 Review **Assessments** • Section 4.4 Quiz
ETHICS DAY ***ELECTRIFYING SCIENCE***			
104	**4.4.4 Formulate a biblical position on the topic of electrofishing.** BWS Ethics (evaluate)	**BJU Press Trove** • *Video: Electrofishing*	
PINE STREET POST DAY			
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CHAPTER 4 REVIEW			
105–7	**• Relate the motion of an object to the forces acting on it.** **• Diagram the contact and field forces acting on an object.** **• Develop a model for determining the relative force of gravity acting on an object.** **• Relate electricity and magnetism.** **• Relate force and mass to changes in motion. (Lab 4)**		**Student Edition** • Chapter 4 Review
CHAPTER 4 TEST			
	• Demonstrate knowledge of concepts from Chapter 4 by taking the test.		**Assessments** • Chapter 4 Test **BJU Press Trove** • Chapter 4 Test Bank

Teacher Edition Companion

Lesson 1

Teacher Edition & Student Edition pages 2–8
Activities & Lab Manual page 3

Read Section 1.1 pages 2–8

Reading Check Questions

Reading Check Questions	Pages
What is matter? anything that takes up space and has mass	5
Which part of an atom has a negative charge? an electron	6
What does the number of protons that an atom has determine? the atomic number	8

Objectives *The student will . . .*

- Describe the structure of an atom.
- Compare protons, neutrons, and electrons.
- Relate the terms *atom* and *element*.
- Explain the role of models in science. *BWS*

Biblical Worldview Shaping

- Limitations: Models are helpful for explaining and understanding concepts, yet they are imperfect and need continual refinement or replacement.

Resources

Homeschool Hub

- Biblical Worldview Scope
- Videos: "What's the Matter?"; "Modeling the Atom"

Materials

- wall signs: atom, atomic mass, atomic number, electron, element, matter, neutron, nucleus
- beaker, 100 mL and carbon, 12 g for Size of Atoms demonstration on Teacher Edition page 5
- molecular model sets (or colored candies, colored tiles, or colored paper circles) for Modeling Atoms activity on Teacher Edition page 8

Assignment

Option 1	Option 2	Option 3
❐ Study for Section 1.1 quiz.	❐ Study for Section 1.1 quiz.	❐ Study for Section 1.1 quiz.
❐ Student Edition page 8 (Section 1.1 Review)	❐ Activities & Lab Manual page 3	❐ Student Edition page 8 (Section 1.1 Review)
		❐ Activities & Lab Manual page 3

Student Edition

Activities & Lab Manual

Section Review Questions
See the Teacher Edition lesson for printed answers to Review Questions.

New to the Teacher Edition Companion?
If you haven't used this resource before, you may want to check out the opening pages (iv–vi) for a brief explanation of what's included and why.

Log in to your HomeschoolHub account for resources listed as available on Homeschool Hub.

Courses > Science 6 > Course Resources > Online Resources

See the Organizing Matter section on Teacher Edition page 5 for information about the wall signs.

Case Studies
Use the case studies in the lessons to provide an opportunity for the student to investigate specific areas of science to apply what he or she has learned in a chapter. Throughout this product, answers to the case study questions appear on the corresponding Teacher Edition page.

CHAPTER 4

Objectives

- Relate the motion of an object to the forces acting on it.
- Diagram the contact and field forces acting on an object.
- Develop a model for determining the relative force of gravity acting on an object.
- Relate electricity and magnetism.
- Relate force and mass to changes in motion. (Lab 4)

Overview

Chapter 4 introduces students to several important and inextricably linked concepts in physics: force, work, energy, and motion. The chapter will examine how these concepts are related, then focus on different kinds of forces. The chapter closes by taking a closer look at two particular types of forces: gravity and electromagnetism.

If a force is a push or a pull, how can forces be balanced?

Section 4.1

Objectives

4.1.1 Recall the definition of a force.

4.1.2 Relate force, energy, and work.

4.1.3 Determine whether the forces acting on an object are balanced or unbalanced.

4.1.4 Predict the motion of an object on the basis of the forces acting on it.

4.1.5 Explain the basis for predictability in motion. BWS

Biblical Worldview Shaping

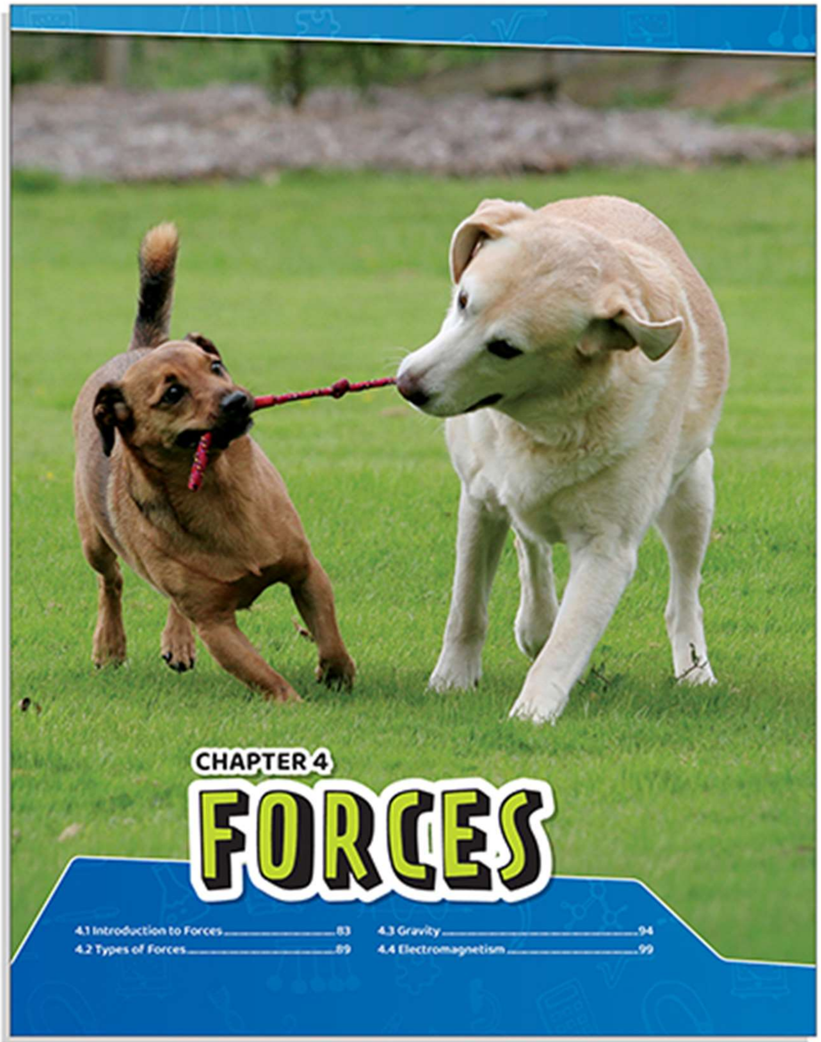
Foundations (explain): Unlike other perspectives, a biblical worldview perfectly explains the consistency of the laws of nature. (4.1.5)

Printed Resources

- Activity 4.1: *Introduction to Forces—Identifying When Forces Are at Work* (pp. 31–32)
- Assessment: *Introducing Forces and Motion* preassessment
- Assessment: Section 4.1 Quiz

Digital Resources

- Video: *Forces and Motion*
- Link: *Forces and Motion—Basics*



Materials

- book
- stress ball

Section Overview

- Section 4.1 begins by defining *force*. It then explains how a force applied through a distance can do work on an object. Afterward, the section examines the different ways an object's motion may change in response to different applications of force.

ENGAGE

Introducing Forces and Motion

Use a **Socratic question** to preassess students' understanding of the relationship between force and motion.

How are force and motion related? Accept any answers at this time. Be sure to note any misconceptions that may need to be addressed during the lesson.

Use the **video** *Forces and Motion* to engage students' interest in these important topics in physics.

GAME DAY!

Imagine that you're playing in a soccer game. You receive a pass, dribble forward a few steps, and then shoot. The perfectly placed shot arches high over the goalie's outstretched fingertips and into the net.

Goal! But why did the ball move when you kicked it? Why did it fly in a curve over the goalie instead of continuing in a straight line? Answering questions like these requires us to investigate the mysterious world of forces.

4.1 INTRODUCTION TO FORCES

ESSENTIAL QUESTION IF A FORCE IS A PUSH OR A PULL, HOW CAN FORCES BE BALANCED?

Force

The simple answer to the questions in the chapter opener is that forces were at work on the soccer ball. A **force** is a push or a pull on an object. When a force is pushing or pulling something, we say that the force is *exerted* on the object. The metric unit for forces is the *newton*, which is abbreviated as N. In the soccer scenario the most obvious force being exerted happens when you kick the ball. Your foot exerts a force on the ball, and the ball moves as a result. There are other, less obvious forces at work in that scenario as well. The muscles in your leg exert forces on your bones to move your leg and foot. Gravity exerts a downward force on the ball in flight. Friction and air resistance work to slow down the ball as it moves. We'll look at these kinds of forces and others in the sections that follow.

Another thing to note about the soccer scenario is the *motion* of the ball. Remember, motion is a change in an object's position. In this case the ball's motion changed from rolling along the ground as you dribbled it to flying through the air after you kicked it. Your kick—the force you exerted—changed the motion of the ball. That's usually what a force does: it changes the motion of the object that it's exerted on. An object's motion can be changed in one of three ways. Like a soccer kick, a force can start an object moving or make it go faster. A force can also make an object go slower or even come to a stop, like receiving a pass. Lastly, as when deflecting a corner kick, a force can change the direction of an object's motion.

Questions
- What is a force?
- Are forces and energy related?
- What is the difference between balanced and unbalanced forces?
- How can I predict an object's motion on the basis of the forces acting on it?
- Why is motion predictable?

Terms
force
work
balanced forces
unbalanced force

INSTRUCT

Organizing Notes

Use **KWL Charts** to help students keep track of the concepts covered in this lesson.

Forces in the Real World

Do a **visual analysis** of the image on this page and the images throughout this section to get students thinking about forces. Students should realize that many of the concepts presented in this section are things that they already understand from their everyday experiences—we're just putting new names to them!

Why is the boy kicking the ball? He wants to make it move.

Use the terms *change*, *force*, and *motion* to explain what the boy is doing to the ball. The boy changes the motion of the ball by exerting a force on it.

Can you think of other examples where forces are exerted to change motion?

Can you think of an example where a force is exerted on an object but the object doesn't move?

Be sure to correct any misconceptions.

> **What If There Is No Change in Motion?**
> An applied force is required to change an object's motion, but applying a force doesn't require an object's motion to change! Students will see later in this section and in Section 4.2 that some applied forces *don't* change an object's motion.

Introducing the Newton

Use a **discussion** to introduce this unfamiliar unit to students and help them comprehend the magnitude of a single newton of force.

A newton is the amount of force needed to change the motion of a 1 kg (2.2 lb) object (mass) by 1 m/s (speed) in 1 second (time). Is 1 kg a lot of mass or a little? a little

Is 1 m/s a lot of speed or a little? a little

Do you think it would be easy or difficult to get a resting 1 kg object moving at 1 m/s? easy

What do you think then? Is one newton a relatively large amount of force or a relatively small amount of force? One newton is a relatively small amount of force.

Use an example to help students understand the relationship between pounds and newtons as units.

If a pound is about 4.5 newtons, what would the weight of a 5-pound bag of sugar be in newtons? about 22 newtons

> **"Weight" in Grams**
> Food packaging often confuses the concepts of weight and mass and the units for quantifying them. Food-packaging labels often list the grams and ounces of substances. These are units of mass (grams) and weight (ounces), and weight is a force. This labeling is done because many people are unfamiliar with the newton. Also, since we use most of our food on the surface of Earth, the relationship between mass and weight is consistent.

Force through a Distance

The concept of applying a force through a distance should be intuitively familiar to students. Think of the family car: If the gas pedal is depressed only slightly, a small force is applied as the car moves and its motion changes slowly. If the gas pedal is depressed all the way to the floor, a much larger force is applied to the car and its motion changes rapidly.

Work or Not Work?

Use a **demonstration** to get students thinking about the physics definition of work. Choose a volunteer, then have the student push as hard as possible against a classroom wall.

Are you exerting a force on the wall? How do you know? Yes. A push is a type of force.

Did the wall move as you pushed it? no

Did you do any work on the wall? How do you know? No. Work requires a force to be exerted through a distance, and the wall did not move, so no work was done on it.

The reason why the wall doesn't move when pushed will be explained in more detail in Section 4.2.

DIFFERENTIATED INSTRUCTION

Is Light Speed Attainable?

Advanced students may be interested in the question of how much force is necessary to get a rocket moving at the speed of light, as we often see being done in science fiction movies. The short answer is that moving an object at light speed is not possible using current technology, even if we ignore the challenges imposed by Einstein's theory of relativity. Even the most powerful rocket engine now in use would require an immensely long period of time to accelerate a rocket even close to light speed. And since rockets must burn fuel to create the thrust necessary to gain speed, they must take the necessary fuel with them. You can see the problem here: increasing speed requires more fuel, which increases the mass of the rocket, which makes it more difficult to change the rocket's motion. It's a conundrum that science fiction movies can creatively ignore, but real scientists can't!

Forces, Energy, and Work

Recall that energy is the ability to do work. Since the soccer ball is in motion, it has kinetic energy. Kinetic energy is the energy of motion. When you kick a ball, you apply a force, which adds kinetic energy. A scientist would say that you did work on the ball. Scientists define the concept of work in two different ways. **Work** is a change in energy, and work is done when a force moves an object over a distance. How does this apply to the soccer game in the chapter opener?

Sports, like soccer, require energy. In soccer, we add or remove energy by applying forces with our feet when kicking the ball. Think about the kicked ball again. As you kicked it, your kicking foot was in motion. That means that it had kinetic energy. The rolling ball had kinetic energy too. But when you kicked the ball, it flew away, moving faster than it did before. It had more kinetic energy after you kicked it. Where did that extra kinetic energy come from? It had to come from your foot! You did work on the ball by applying a force over a distance. That tells us that kinetic energy can be transferred from one object to another as a force is exerted. The amount of energy transferred depends on the strength of the force and the distance over which it is exerted. A strong force exerted over a short distance may have the same effect as a weaker force exerted over a longer distance. We can apply a force over a distance of one centimeter, and the ball will roll away slowly. But if we apply the same force over a distance of ten centimeters, the ball will fly away with greater speed.

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Now ask for a volunteer to slide a book along the length of a table.

Was a force exerted on the book? How do you know? Yes. The book's motion changed.

Did the book move as it was pushed? yes

Was work done on the book? How do you know? Yes. Since a force was applied through a distance, work was done.

Let's think about another example from the world of sports. Think about throwing a baseball or softball. This time, it's your hand that exerts a force on the ball as you throw it. Your hand does work on the ball. But think about the distance involved. Does your hand contact the ball over a longer or shorter distance compared to kicking a ball? Your hand is in contact for a longer distance! This explains why professional baseball pitchers can routinely throw fastballs at 95 mph (153 kph).

Balanced and Unbalanced Forces

You've probably played tug-of-war before. Imagine a team in blue playing tug-of-war against a team in red. The blue team pulls with all their might in one direction, while the red team does the same but in the opposite direction. If the two teams are equally matched, the flag tied to the middle of the rope may remain motionless. How is that possible if both teams are exerting large forces on the rope?

The rope in our imaginary game of tug-of-war doesn't move because the forces acting on it are *balanced*. **Balanced forces** occur when two or more forces are exerted so that the forces cancel out, or balance, each other. Balanced forces can't change the motion of the object on which they act. To change an object's motion, the forces acting on it must be *unbalanced*. **Unbalanced forces** occur when one force acting on an object is greater than the other forces. If there is only one force on an object, it is always unbalanced. An unbalanced force always changes an object's motion. Your kicked soccer ball is an example of an unbalanced force in action. The force that your foot exerted on the ball was greater than the other forces acting on it, so the ball moved in the direction your foot sent it. Likewise, the tug-of-war rope stays motionless, but when one team weakens, creating unbalanced forces, the rope will move one way or the other.

Balanced and Unbalanced Forces

Use a **demonstration** to illustrate balanced and unbalanced forces. Hold a stress ball motionless in the palm of your hand.

Are there any forces acting on this ball? Some students may recognize that gravity is acting on the ball.

Since the ball's motion is not changing, what must be true about any forces acting on the ball? They must be balanced.

What do I need to do to change the ball's motion? You must exert an unbalanced force on it.

Select a volunteer to catch the ball as you toss it.

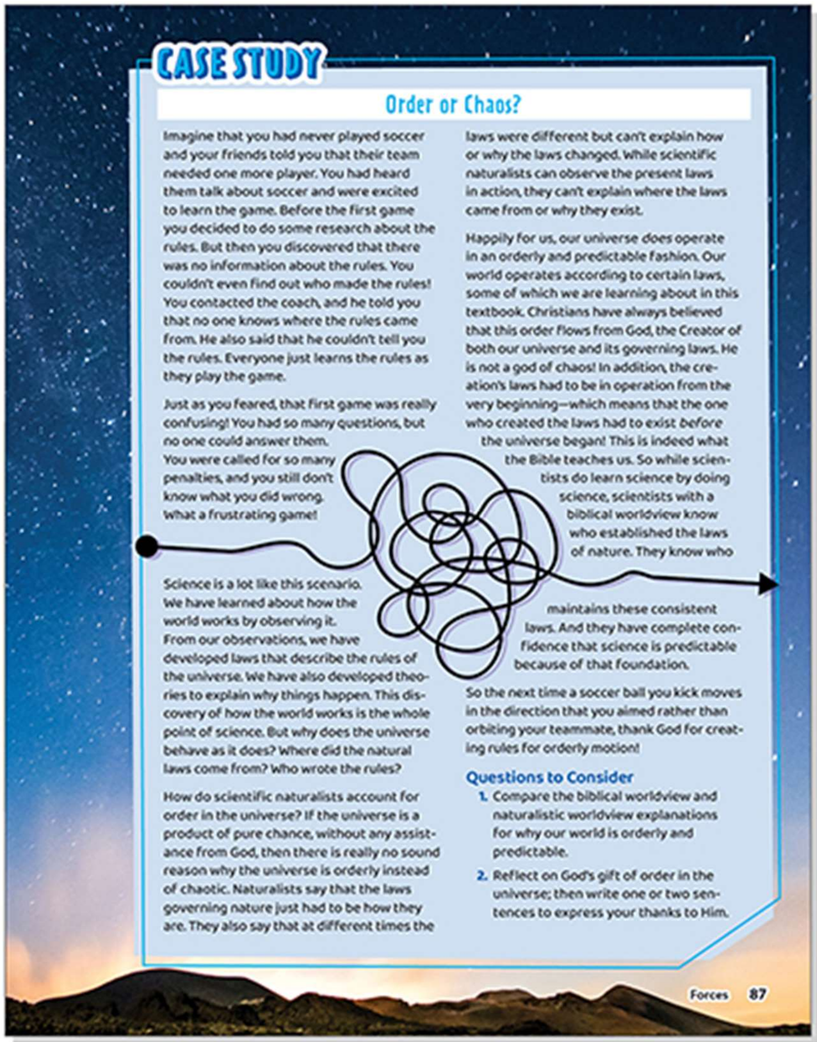
Watch carefully as I toss the ball.

(Now toss the ball to the student.)

What is one unbalanced force that you observed? You exerted a force on the ball to toss it.

How do you know it was unbalanced? the ball's motion changed

In which directions did the unbalanced forces on the ball act? First, one force acted in the direction the ball was tossed. (Students may add that an upward force was applied as well since the ball started upward as well as forward.) Second, the student had to apply a force to catch the ball. We know this because the ball's motion changed again. This force was applied in the opposite direction of the ball's motion. Third, some students may recognize that gravity acted on the ball while it was in flight. We know this because the ball's motion changed from an upward flight to a downward flight. Gravity acted downward or in a direction perpendicular to the ball's forward motion.



CASE STUDY

Order or Chaos?

Imagine that you had never played soccer and your friends told you that their team needed one more player. You had heard them talk about soccer and were excited to learn the game. Before the first game you decided to do some research about the rules. But then you discovered that there was no information about the rules. You couldn't even find out who made the rules! You contacted the coach, and he told you that no one knows where the rules came from. He also said that he couldn't tell you the rules. Everyone just learns the rules as they play the game.

Just as you feared, that first game was really confusing! You had so many questions, but no one could answer them. You were called for so many penalties, and you still don't know what you did wrong. What a frustrating game!

Science is a lot like this scenario. We have learned about how the world works by observing it. From our observations, we have developed laws that describe the rules of the universe. We have also developed theories to explain why things happen. This discovery of how the world works is the whole point of science. But why does the universe behave as it does? Where did the natural laws come from? Who wrote the rules?

How do scientific naturalists account for order in the universe? If the universe is a product of pure chance, without any assistance from God, then there is really no sound reason why the universe is orderly instead of chaotic. Naturalists say that the laws governing nature just had to be how they are. They also say that at different times the laws were different but can't explain how or why the laws changed. While scientific naturalists can observe the present laws in action, they can't explain where the laws came from or why they exist.

Happily for us, our universe *does* operate in an orderly and predictable fashion. Our world operates according to certain laws, some of which we are learning about in this textbook. Christians have always believed that this order flows from God, the Creator of both our universe and its governing laws. He is not a god of chaos! In addition, the creation's laws had to be in operation from the very beginning—which means that the one who created the laws had to exist *before* the universe began! This is indeed what the Bible teaches us. So while scientists do learn science by doing science, scientists with a biblical worldview know who established the laws of nature. They know who maintains these consistent laws. And they have complete confidence that science is predictable because of that foundation.

So the next time a soccer ball you kick moves in the direction that you aimed rather than orbiting your teammate, thank God for creating rules for orderly motion!

Questions to Consider

1. Compare the biblical worldview and naturalistic worldview explanations for why our world is orderly and predictable.
2. Reflect on God's gift of order in the universe; then write one or two sentences to express your thanks to Him.

Forces 87

Case Study: Order or Chaos?

Use the **case study** to give students an opportunity to think about why our world is orderly and predictable rather than chaotic. An orderly, predictable universe tells us much about the one who created it and poses many significant challenges for those who hold to a naturalistic worldview. You could use the case study questions as a prompt for a class discussion.

Case Study Answer

1. According to a biblical worldview, orderliness and predictability flow out of God's orderly and predictable character. A naturalistic worldview has no satisfactory explanation for why the universe has the laws it does instead of, for example, some other set of laws or even no laws at all. (4.1.5, p. 87)

APPLY

Mini Lab: Balancing Act

Use the **mini lab** to give students an opportunity to see how balanced forces work in the real world.

If you do not have access to spring scales, the objectives of this mini lab can be met using the link *Forces and Motion—Basics*, an online balanced forces simulator.

This is a pared-down version of a mini lab in BJU Press *Physics* Fourth Edition. In a physics course students will explore the effects of forces that are not acting directly opposite each other.

Mini Lab Answers

1. newton, the metric unit of force
2. steady
3. 10 N
4. Students should indicate their expectation of what the scales will read and why.
5. Students should observe that the force on each of the paired scales is less than that on the single scale, but the total forces between the paired scales are approximately equal to the force on the single scale.
6. The combined values on the paired scales should come to 10 N.
7. The strengths of the balanced forces acting on an object depend on the number of forces involved. While the strength of each force may vary, the sums of the forces acting in opposite directions must be equal.

Identifying Forces

Use the Section 4.1 **Activity**: *Introduction to Forces—Identifying When Forces Are at Work* to give students practice in identifying examples of forces being applied to change motion.

If a force is a push or a pull, how can forces be balanced?

Forces are balanced when they act on a single object but with equal magnitude and in opposite directions. Like the tug-of-war example on page 85, balanced forces cannot change an object's motion, even if the forces involved—such as two teams pulling on a tug-of-war rope with all their might—are quite large.

mini LAB

Balancing Act

ESSENTIAL QUESTION: **ARE BALANCED FORCES ALWAYS EQUAL IN STRENGTH?**

Is it true that balanced forces will not change an object's motion? Let's find out!

Procedure

A. Hook two spring scales together so that you and a partner can pull them in opposite directions.

B. While your partner keeps his or her spring scale steady, pull on your spring scale until your partner's scale reaches 10 N.

1. What does the N in 10 N represent?
2. At this point, are your spring scales in motion or steady, that is, motionless?
3. How much force does your spring scale read?

Equipment

- spring scales, 20 N (3)

Now think about what might happen if you hook two spring scales to your partner's scale. If you repeat Step B while pulling on two spring scales, will they read the same amount of force as before?

4. Make a prediction about how much force will be read on the two spring scales. Will each read more force, less force, or the same amount of force as in Step B?

C. Repeat Step B by pulling on the two spring scales that are connected to your partner's spring scale.

5. Was your prediction in Question 4 correct? Explain.
6. What is the *combined* force value of the paired scales?
7. Write a summary of what you have learned from this exercise about the strengths of the balanced forces acting on an object.

4.1 SECTION REVIEW

1. What is a force?
2. How are force and energy related?
3. What two factors determine how much the kinetic energy of an object will change when a force is exerted on it?
4. Which type of forces can change an object's motion, balanced or unbalanced?
5. A student pushes a stationary lab cart with 50 N of force to the left. At the same moment a second student pushes on the other side of the cart with 45 N of force to the right. How will the cart's motion change in response to these forces?

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ASSESS

Section 4.1 Review

Assign the section review as a **formative assessment** to help students solidify their understanding of Section 4.1.

Section 4.1 Quiz

Use the Section 4.1 Quiz as a **formative assessment** to check students' understanding of Section 4.1.

Section 4.1 Review Answers

1. A force is a push or pull on an object. (4.1.1, p. 83)
2. Energy is needed for an object to exert a force on another object, and as the force is exerted, work is done on the second object, transferring energy from one object to the other. (4.1.2, p. 84)
3. the strength of the force and the distance over which it is exerted (4.1.2, pp. 84–85)
4. unbalanced (4.1.3, p. 85)
5. The cart will move to the left. (4.1.4, pp. 85–86)

4.2 TYPES OF FORCES

ESSENTIAL QUESTION: DO OBJECTS HAVE TO BE TOUCHING TO EXERT A FORCE ON EACH OTHER?

Have you ever moved a magnet closer and closer to another magnet sitting on a desk? Suddenly, the second magnet leaps toward the magnet in your hand—snap! It moves without you touching it. But you *do* have to touch a soccer ball in some manner to get it to move. This suggests that there are at least two kinds of forces at work in our world. Are there more?

One way to classify forces is based on whether objects must touch for the force to be exerted. A **contact force** is a force that acts only when two objects touch, or contact, each other. A **field force** can act over a distance—an object does not have to touch another object to exert a force on it. Field forces are sometimes called *noncontact forces*. Two important field forces are gravity and electromagnetism. We'll examine those two forces in the next two sections. For now, let's consider some examples of contact forces.

Questions

- How can I determine what kinds of forces are at work on an object?
- How are contact and field forces different?
- How can I show the forces that are acting on an object?

Terms

contact force
field force
free-body diagram

ENGAGE

Thinking about Force and Motion

Use a **turn and talk** to get students thinking about the types of forces that might cause an object to move. Show two wooden blocks stacked one upon the other on a desk or table. Point to the top block and ask:

What can I do to get this block moving?

Invite students to discuss possible answers with a neighbor, then choose one or two students to share their suggestions. Most students will suggest picking up the block or some other means that requires touching the block. Use a ruler to flick the bottom block from under the stack, causing the top block to fall downward.

Was a force applied to the top block? How can you tell? Yes. The block moved, and a change in motion requires the application of a force.

Did I touch the top block to get it moving? no

What can we learn from this demonstration? Some forces can operate even if they do not act directly on an object.

Do objects have to be touching to exert a force on each other?

Section 4.2

Objectives

4.2.1 **Differentiate between contact and field forces.**

4.2.2 **Determine the types of forces at work on an object.**

4.2.3 **Create a force diagram to show the forces that are acting on an object.**

Printed Resources

- Activity 4.2: *Types of Forces—Classifying Forces* (pp. 33–34)
- Assessment: Section 4.2 Quiz

Materials

- wooden blocks (2)
- ruler
- wall signs: normal force, tension, elastic force, friction/drag
- images of forces in action

Section Overview

- Section 4.2 introduces students to various types of contact forces and how to depict them using free-body diagrams. The section also introduces the concept of field forces. The Lesson Plan Overview has this section planned as a two-day lesson.