UNIT OVERVIEW

Force and motion are fundamental to all matter in the universe. A force is anything that can push or pull an object. Forces influence objects that are at rest or that are already in motion. The *Force and Motion* unit acquaints students with Isaac Newton's three laws of motion, which describe how forces interact with objects to influence motion. These laws involve inertia, mass, velocity, and momentum. Students will learn about several key forces, including gravity, friction, and magnetism. A force is required to do work, and generating a force requires energy. Energy can be stored as potential energy, or it can have kinetic energy—the energy of motion. Energy can also be converted and exchanged through energy transfer.

All books and Quick Reads are available at three reading levels to facilitate differentiated instruction.

- low reading level
- middle reading level
- high reading level

THE BIG IDEA

Forces and motion are integral parts of our daily lives. From kicking a soccer ball to picking up a sandwich to dropping a pencil, force and motion are always at play. Even the blood flowing through our bodies moves due to the pumping force of the heart muscle. Objects move in predictable ways, as described by the universally accepted principles of force and motion. Everything is in constant motion because forces are always at work. Even something that is at rest on Earth is orbiting the Sun and being acted upon by gravity. By learning about force and motion, students will come to understand how they can use forces to produce motions that allow them to be safe and to enjoy themselves.

Other topics

This unit also addresses topics such as: force and motion in sports, weightlessness, potential and kinetic energy of rubber bands, the difference between weight and mass, and the difference between speed and velocity.

SPARK

The spark is designed to get students thinking about the unit's topics and to generate curiosity and discussion.

Materials

- uncooked eggs
- hard-boiled eggs
- paper towels

Activity

Place students in small groups. Give each group one uncooked egg and one hard-boiled egg without revealing which egg is which. Instruct students to carefully place the two eggs on a table and to gently spin them without letting either egg fall off the table. Have students observe the motion of the eggs until they eventually come to rest. Students may notice that it is more difficult to spin one of the eggs (the uncooked egg).

Now ask students to spin each egg again. Once both eggs are spinning, have students quickly yet gently touch the top of each egg to stop it from spinning and then let go. Direct students to continue watching the eggs and observe what happens. The hard-boiled egg should remain stationary, but the uncooked egg should begin to spin again after it is stopped.

Below are questions to spark discussion.

What made the eggs start spinning?

Why did both spinning eggs eventually come to rest, even when left untouched?

Was one egg more difficult to spin than the other? Why?

Did one of the eggs start spinning again after it was stopped? If so, why?

What would have happened if one of the eggs had moved past the edge of the table? Why?

Using this experiment, how can you distinguish between uncooked and hard-boiled eggs in the future?

Use this activity to begin an introductory discussion about force and motion. Explain that inertia is the tendency for an object at rest to remain at rest and the tendency for an object in motion to remain in motion. In this spark, the liquid parts of the uncooked egg had more inertia than the solid, hard-boiled egg. Because of inertia, the uncooked egg resisted spinning and also resisted stopping once it was in motion. When the two eggs were forced to stop, the inertia of the liquid egg started the egg spinning again. Eventually, though, both eggs lost their momentum, stopped spinning, and came to rest. This was due to a force called *friction* acting against the motion of the eggs. Throughout the unit, students will learn more about forces and motion.

Vocabulary

Many of the unit's vocabulary terms are related to the spark activity and can be introduced during the spark. For vocabulary work, see the Vocabulary section in this unit guide as well as the resources listed in the *Force and Motion Unit Map.*

PRIOR KNOWLEDGE

Invite students to explain their understanding of force and motion. Also ask them to share what they know about friction, inertia, momentum, and mass. Discuss how our world would be different without forces acting on objects.

Probing Questions to Think About

Use the following questions to have students begin thinking of what they know about force and motion.

- What is an example of a force?
- Can nature act as a force to move objects? If so, what are some examples?
- Why do objects always fall to the ground?
- Is it possible to make a machine that continues to run forever (perpetual motion machine)?
- Why is it harder to pick up a brick than a pencil?
- Why do objects you throw always seem to fly in an arch?
- Why does a bicycle speed up as it rolls downhill?
- Is it harder to turn a corner at a slow or a fast speed? Why?
- Why is it easier to pull a wagon on a sidewalk than on grass?
- Why do you sometimes feel a floating sensation on a roller coaster?
- Would your weight be the same on the Moon as on Earth?

Tell students they will learn more about these topics soon.

VOCABULARY

Use the terms below for vocabulary development throughout the unit. They can be found in boldface in the nonfiction book, the Quick Reads, and/or other core resources. These terms and definitions are available on *Vocabulary Cards* for student practice.

Core Science Terms

These terms are crucial to understanding the unit.

direction	the way or course toward which something moves or faces
distance	the amount of space between things
electromagnetism	the combined force of electricity and magnetism
energy transfer	the movement of energy from one object to another or the change of energy from one form to another
force	the strength or energy that moves an object
friction	a force that slows down moving things

gravity	the force that pulls things toward the center of Earth or any other object that has mass
inertia	the tendency of an object to resist change in the direction or speed of its motion
kinetic energy	the energy that a moving body has because of its motion
magnetism	a force that pushes and pulls certain metals
mass	the amount of matter, measured on Earth by its weight
momentum	the strength or force that keeps something moving
motion	the act of going from one place to another; movement
potential energy	the energy a body has because of its position, electrical charge, or structure; stored energy
speed	the rate of movement
weight	how heavy something is, determined by the pull of gravity on the object's mass
work	the act of using force to move something over a certain distance

Other Key Science Terms

The following vocabulary is not essential for comprehending the unit, but may enrich students' vocabulary.

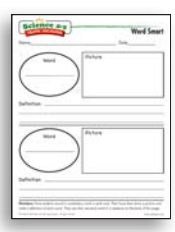
attract	to pull toward
balanced	in a state in which equal and opposite forces cancel each other out
chemical energy	energy made by a change in a substance or a combination of substances
electricity	energy created by moving charged particles
energy	the power to do work, make a change, or move objects
engine	a machine with moving parts that uses power to create motion; a motor
generator	a machine that turns potential and kinetic energy into electricity
heat energy	a form of energy that is transferred from an object with a higher temperature to an object with a lower temperature
law	a statement about results that always occur under certain circumstances

light energy	a form of radiant energy that allows us to see
lines of force	invisible lines of magnetic force that flow through and around a magnet
magnetic field	an area around a magnet or a moving electrical charge within which a magnetic force acts
reaction	an equal, opposite response to a force being applied
repel	to force or push away
rest	a pause during which no force is moving an object
sound energy	a form of energy that allows us to hear
velocity	the rate of movement in a certain direction
weightless	experiencing little or no noticeable gravitational pull

Vocabulary Activities

You may choose to introduce all the terms that will be encountered in the unit before assigning any of the reading components. *Vocabulary Cards* with the key science terms and definitions are provided. Dots on the cards indicate the reading levels of the nonfiction book or the Quick Reads in which each term can be found. If no dots appear, the term comes from elsewhere in the unit. Students can use these cards to review and practice the terms in small groups or pairs. The cards can also be used for center activity games such as Concentration.

For further vocabulary practice and reinforcement, you can choose from the vocabulary *graphic organizers*. To build customized vocabulary lessons with terms related to Force and Motion, or to use a pre-made lesson based on this Science A–Z unit, see **VocabularyAZ.com**



Students can use the *Word Smart* vocabulary graphic organizer to organize information about the science terms. You may want to assign each student one to three words to share his or her Word Smart knowledge with classmates. Students who have the same word should first compare their Word Smart sheets with each other and then report to the larger group.

The science terms can be used in oral practice. Have students use each term in a spoken sentence.

It is also useful to have students create a science dictionary in a notebook in which they will enter terms from each unit as it is taught.

UNIT MATERIALS

Each unit provides many resources related to the unit topic. These resources are essential to teaching the Big Idea and core concepts of the unit and will prepare students for the *Unit Quiz*. Over time, additional resources will be added to the unit that will supplement and enrich students' understanding.

SPECIAL NOTE: To best prepare students for the Unit Quiz, we recommend at least using the nonfiction book and vocabulary resources with your students. Using additional resources will reinforce the concepts and details addressed in the Unit Quiz. The *Process Activities* are hands-on experiments, explorations, and projects that will engage students in the application of unit concepts. The *Quick Reads* are magazine-like fact sheets that will help students develop a deeper understanding of several topics related to the unit.

For a complete list of materials provided with the unit, see the *Force and Motion Unit Map*.

BACKGROUND AND MISCONCEPTIONS

Use this section as a resource for more background knowledge on unit content and to clarify the content for students if misconceptions arise. Refer to Using the Internet below for more ways to extend the learning.

Q: *If a body in motion remains in motion until a force acts on it, why do things eventually stop? Is it because they used up all their energy?*

A: Objects eventually stop because a force—such as friction or gravity—acts against the object's motion. Once an object is in motion, the energy that was used to initiate the motion is irrelevant. In the absence of forces acting against that motion, a moving object would, in fact, continue to move forever! This is true of a bouncing ball, a speeding car, a galloping horse, and a shooting star.

Q: *If I want to keep an object moving, do I need to keep applying a force?*

A: In theory, no. According to Newton's first law, a body in motion will remain in motion. An object will keep moving at the same velocity as long as it doesn't receive any additional pushes or pulls. Objects do not stop because of a lack of force; they stop because a different force is being applied. For example, friction is a force that acts against an object's motion. If you slide a book across a table, it will eventually come to rest because friction is pushing on it in the opposite direction of its motion. Reducing friction by applying oil or flour to the table would allow the book to travel farther given the same amount of force.

Q: *Are speed, velocity, and acceleration the same thing?*

A: No. They are related but are not exactly the same. Speed measures the rate of motion—how fast something is going. Velocity is the speed an object is moving *in a certain direction*. Acceleration is the measurement of the *change* in velocity over time. A change in acceleration can be a change in an object's speed or direction. According to Newton's second law, a force is required to accelerate an object.

Q: *When an object is at rest, are any forces acting on it?*

A: Yes. Even when an object is stationary, the force of gravity is pulling it toward Earth's center. Friction is helping to hold it in place against a surface. At the same time, whatever the object is sitting on opposes the force of gravity and holds the object up. This force is called the *normal force*. In addition, other forces, such as air movement, could be acting on the object but are not strong enough to overcome the object's inertia.

Q: *Do heavier objects fall to the ground faster than lighter object?*

A: No and yes. In the absence of air resistance, objects of all sizes and weights, when dropped from the same height, will hit the ground at the same time. Without air resistance, objects experience *free fall*. During free fall, objects with more mass experience greater force due to gravity, but this greater force is offset by the increased inertia of the larger mass. Because of this tradeoff, the objects hit the ground at the same time. In the presence of an appreciable amount of air resistance, more massive objects will fall faster than smaller objects. In this case, air resistance is strong enough to slow down smaller objects, whereas the larger, more massive objects continue to accelerate. Also, objects of similar mass will fall at different rates if one encounters more air resistance than the other due to its shape. This is the case when comparing the drop rate of a crumpled paper and a paper airplane.

Q: *Why do astronauts on a space station orbiting Earth float?*

A: Astronauts look as though they are floating, but they are actually falling. *Free fall* occurs when gravity is the only force acting on objects. In free fall, no contact forces are acting to oppose the force of gravity. The space station, the astronauts, and all of the objects within the space station are falling together at the same rate in a curved pattern, or orbit, so the people are not held down, as they would be on Earth. This is why astronauts feel weightless in space.

Q: *Is there gravity in outer space?*

A: Yes, definitely! There is some amount of gravity everywhere in outer space. Gravity is what keeps planets in orbit around the Sun and what keeps the Moon in orbit around Earth. Gravity is an attraction between two objects. Larger masses have stronger gravitational pulls. The Moon's gravity is strong enough to create ocean tides on Earth. The Sun is so large that its gravitational pull reaches beyond our own solar system. Even entire galaxies exert gravity on one another. However, this pull decreases as the distance between two masses increases.

Q: *Is it true that I would weigh less if I were standing on the Moon?*

A: Yes. Weight is a measurement of the amount of force an object exerts because of gravity. The more massive something is, the more gravitational pull it will exert. If you step on a scale, you are basically squeezing the springs in the scale between yourself and the floor—gravity is pulling you down, while the force of the floor is pushing you up (*normal* force). The more mass you have, the more you squeeze the springs of the scale, so the more you weigh. On the Moon, the force of gravity is one-sixth as strong as the force of gravity on Earth. Since the force of gravity is weaker on the Moon, it would pull down on you much less than the force of gravity on Earth. If you were to step on the same scale on the Moon, you would squeeze the springs less and therefore weigh less. Your mass would not change, but your weight would. If you could stand on Jupiter, you would weigh much more than on Earth.

EXTENSION ACTIVITIES

Using the Internet

Most search engines will yield many results when the term *force* or *motion* is entered. You can also perform a more specific search, such as for information on Isaac Newton and his three laws of motion. Be aware that some sites may not be educational or intended for the elementary classroom. More specific inquiries are recommended, such as:

- force and motion in sports
- Galileo's theories of motion
- law of universal gravity
- electricity and magnetism
- energy and work
- inertia and momentum
- physics for kids
- friction in shoes
- weightlessness
- kinetic vs. potential energy

Below are some links with excellent resources for students and/or teachers.

Rader's Physics4Kids website is written for children and contains explanations of force, acceleration, motion, energy, work, and mass. The site also contains quizzes for students to assess their knowledge of force and motion. *www.physics4kids.com/files/motion_intro.html*

Physics in Sports Connection uses athlete video clips to explain and illustrate Newton's law of universal gravity and his three laws of motion. The site includes questions about the video clips that will stimulate student thinking about force and motion.
http://archive.ncsa.illinois.edu/Cyberia/VideoTestbed/Projects/NewPhysics/page_1.html

Read all about Newton's laws on the NASA website designed for educators and students. This site includes grade-specific links to suggested force and motion activities and demonstrations, plus a page for students at a lower reading level. *www.grc.nasa.gov/WWW/K-12/airplane/newton.html*

Kids will enjoy learning about the physics of skateboarding on this website published by the Exploratorium in San Francisco, CA. Like all other objects, Newton's Laws—as well as friction and momentum—apply to skateboards. *www.exploratorium.edu/skateboarding*

The UCLA Physics & Astronomy K–6 Connection is published by two scientists with the goal of bringing astronomy and physics into elementary classrooms. It supplies teachers with the knowledge they need to teach students. Click on the Physics Table of Contents link to reach content about force and motion. The site includes teaching tips and classroom activities. *www.physics.ucla.edu/k-6connection*

The Physics Classroom website presents tutorials that explain force and motion with helpful illustrated diagrams. The site also contains worksheets and activities that can be used in the classroom. Some content may be too advanced for elementary school students or may require additional instruction. *www.physicsclassroom.com/Class*

Projects and Activities

- **Inquiry Science/Project:** Take students outside to the school playground. Ask them to observe common playground equipment such as a swing set, a teeter-totter, and a slide. Have students choose one piece of playground equipment and design a hypothetical experiment on force and motion that improves the way the equipment works. For example, increasing the length of the chains on a swing will increase the maximum height a rider can reach. Adding a lubricant to a slide will reduce friction and allow the rider to go faster.
- **Inquiry Science/Project:** Experiment with the relationship between force, mass, and acceleration (refer to Isaac Newton's famous equation, $F = m \times a$). Use balls of various sizes and weights (e.g., Ping-Pong, golf, tennis, and baseball). Drop the balls from various heights into smoothed sand, such as from the top of a play structure in a playground. Balls with more mass will cause larger impact craters in the sand than balls with smaller mass. In addition, dropping balls from a greater height will cause them to accelerate more and will cause larger impact craters in comparison to balls dropped closer to the ground. Measuring the width and depth of the impact craters will give students a means of comparing the amount of force that was applied to the ground when each ball struck it.

- **Writing:** Have students write a brief biography of Isaac Newton. Encourage them to include dates of his important discoveries and events in his life that may have influenced his thinking on force and motion. For more information on writing biographies, visit Writinga-z.com.
- **Guest:** Invite a physicist or engineer to the classroom to discuss force and motion and how it impacts our daily lives. Ask the speaker to focus on an everyday item, such as a car, and how engineers work to reduce friction and drag so that cars can do more work using less fuel for energy.
- **Art:** Have students view paintings related to forces and motion, such as *The Hammer and the Feather* by Alan Bean (*www.alanbeangallery.com/hammerfeather-new.html*). Ask them to describe what is happening in each painting and what concept(s) of force and motion each painting is illustrating. Supply students with colored pencils, markers, paint, and construction paper so they can make their own version of a famous painting.
- **Technology:** Invite students to explore the following website: *http://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html*. This simulation allows students to launch various projectiles at a target. Students can experiment with changing variables such as initial speed, mass, and diameter of the object as well as whether or not wind resistance is present during the simulation.
- **Field Trip:** Attend a sporting event, such as a soccer game or a gymnastics competition. Have students take notes and record sketches of forces and motions they observe. Back in class, encourage them to share and explain their examples using Newton's laws of motion.
- **Research/Home Connection:** Students can conduct research as a family/home project or in the library/media center to extend the learning about a topic in one of the *Quick Reads*.