

Unit 2: Forces and Motion

Instructional Days: 20

Unit Summary***How do equal and unequal forces on an object affect the object?***

In this unit of study, students are able to determine the effects of balanced and unbalanced forces on the motion of an object. The crosscutting concepts of patterns and cause and effect are identified as organizing concepts for these disciplinary core ideas. In the third-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency by planning and carrying out investigations. Students are expected to use these practices to demonstrate understanding of the core ideas.

Student Learning Objectives

Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. *[Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.]* **(3-PS2-1)**

Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. *[Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [Assessment Boundary: Assessment does not include technical terms such as period and frequency.]* **(3-PS2-2)**

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3-PS2-1	Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object
3-PS2-2	Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion
PS2.A	Each force acts on one particular object and has both strength and a direction
PS2.B	Objects in contact exert forces on each other

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Enduring Understandings

- How do forces affect motion?
- How do forces and objects interact with one another?

Essential Questions

- If the forces acting on an object are balanced, the object will not move.
- Forces of different strengths acting on an object will cause the object to move.
- The motion of an object can be observed and measured
- Motion can be predicted based on patterns observed in the past.

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Unit Sequence	
<i>Part A: How do scientists play soccer?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • Science investigations use a variety of methods, tools, and techniques. • Cause-and-effect relationships are routinely identified. • Objects in contact exert forces on each other. • Each force that acts on a particular object has both strength and a direction. • An object at rest typically has multiple forces acting on it, but they add to zero net force on the object. • Forces that do not sum to zero can cause changes in the object's speed or direction of motion. <i>(Qualitative and conceptual, but not quantitative, addition of forces are used at this level.)</i> 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Identify cause-and-effect relationships. • Plan and conduct investigations collaboratively to produce data to serve as the basis for evidence. • Use fair tests in which variables are controlled and the number of trials considered. • Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. <i>(Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is also limited to gravity being addressed as a force that pulls objects down.) Examples could include:</i> <ul style="list-style-type: none"> ✓ <i>An unbalanced force on one side of a ball can make it start moving.</i> ✓ <i>Balanced forces pushing on a box from both sides</i>

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Unit Sequence	
Part B: <i>Can we use patterns that we observed to predict the future?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • Science findings are based on recognizing patterns. • Patterns of change can be used to make predictions. • The patterns of an object’s motion in various situations can be observed and measured. • When past motion exhibits a regular pattern, future motion can be predicted from it. <i>(Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)</i> 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Make predictions using patterns of change. • Make observations and/or measurements to produce data to serve as the basis of evidence for an explanation of a phenomenon. • Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion. <i>(Assessment does not include technical terms such as period and frequency.) Examples of motion with a predictable pattern could include:</i> <ul style="list-style-type: none"> ✓ <i>A child swinging in a swing.</i> ✓ <i>A ball rolling back and forth in a bowl.</i> ✓ <i>Two children on a seesaw.</i>

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What It Looks Like in the Classroom

In this unit of study, students look for cause-and-effect relationships as they investigate the effects of balanced and unbalanced forces on the motion of an object. They learn that objects in contact exert forces on each other, and these forces have both strength and direction. When forces are balanced, there is no change in the motion or the position of an object. In other words, an object at rest typically has multiple forces acting on it, but the forces balance out to equal a zero net force on the object. For example, if two children stand with their hands together and push against each other, the pushing force each exerts balances to a net zero effect if neither child moves. Pushing a box from both sides also demonstrates a balanced force if the forces do not produce any change in motion or position of the box.

When forces are unbalanced, however, there is a change in the motion and/or position of the object the forces are acting on. If the same two children from the example above were pushing against each other, and one child moves his/her hands, arms, or feet forward while the other child moves backward, this would demonstrate an unbalanced force. The first child is pushing with greater force than the second.

Through planning and conducting investigations, students will come to understand that forces that result in changes in an object's speed or direction of motion are unbalanced. Students can observe everyday examples on the playground, with seesaws and swings and by kicking and throwing soccer balls. As they conduct investigations and make observations, students should identify the cause-and-effect relationships at work and identify the objects that are exerting forces on one another. They should also use qualitative descriptions when identifying the relative strength (greater than, less than, equal) and direction of the forces, even if an object is at rest.

Investigating the effects of forces on objects will also give students opportunities to observe that patterns exist everywhere. Patterns are found in shapes, structures, natural environments, and recurring events. Scientists and engineers analyze patterns to make predictions, develop questions, and create solutions. As students have opportunities to observe forces interacting with objects, they will ask questions and analyze and interpret data in order to identify patterns of change in the motion of objects and to make predictions about an object's future motion. When students are on the playground, they can observe multiple patterns of change in the back-and-forth motion of a child swinging on a swing or in the up-and-down motion of a seesaw. In the classroom, students can observe a variety of objects, such as marbles rolling back and forth in bowls or tops spinning across the floor.

Throughout this unit, as students plan and carry out investigations, it is extremely important that they routinely identify cause-and-effect relationships and look for patterns of change as objects interact. As students interact with objects, such as when they push a door closed, bounce a ball, or roll a ball down a ramp, they may ask, "What caused the changes that I observed? How can I change the way in which the object moved?" Students need to have many experiences in order to deepen their understanding of the cause-and-effect relationships between balanced and unbalanced forces on the motion of an object, and they should be guided to plan and conduct fair tests, testing only one variable at a time.

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Connecting with English Language Arts/Literacy and Mathematics*English Language Arts*

- In order to integrate the CCSS for ELA into this unit, students need opportunities to read content-specific texts to deepen their understanding of force and motion. As they read, teachers should pose questions such as, “What interactions can you identify between the objects in the text?” and “What patterns of motion are described in the text?” Students should be encouraged to answer questions and cite evidence from the text to support their thinking.
- To further support the integration of the ELA standards, students can also conduct short research projects about simple force-and-motion systems and the interactions that occur among forces and objects within the systems. For example, students could be asked to conduct a short study by bouncing a ball 10 times and identifying the patterns they observe. Next students could predict, based on the patterns they saw, what would happen if they bounced the ball 10 more times. Students then could draw a model of the force and motion system, identifying the structures and forces that interact within the system. This would also give students the opportunity to develop note-taking skills and use multiple sources to collect information about force and motion.

Mathematics

- In order to integrate the Common Core State Standards for Mathematics, students can use measurement tools in a variety of ways to conduct investigations. Students could find the mass of an object in order to understand that the heavier something is, the greater the force needed to cause a change in its motion. Students could use rulers or tape measures to measure the distance an object moves. Student can then record and analyze their data to determine patterns of change and explain cause-and-effect relationships, while reasoning abstractly and quantitatively.

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Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: [All Standards, All Students/Case Studies](#) for vignettes and explanations of the modifications.)

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

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Research on Student Learning

Students believe constant speed needs some cause to sustain it. In addition, students believe that the amount of motion is proportional to the amount of force; that if a body is not moving, there is no force acting on it; and that if a body is moving there is a force acting on it in the direction of the motion. Students also believe that objects resist acceleration from the state of rest because of friction -- that is, they confound inertia with friction ([NSDL, 2015](#)).

Prior Learning**Kindergarten Unit 1: Pushes and Pulls**

- Pushes and pulls can have different strengths and directions.
- Pushing or pulling on an object can change the speed or direction of the object's motion and can start or stop it.
- When objects touch or collide, they push on one another and can change motion.
- A bigger push or pull causes things speed up or slow down more quickly.

Grade 1 Unit 1: Patterns of Change in the Sky

- Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted.

Future Learning**Grade 4 Unit 5: Energy Transfer**

- Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when water meets a beach.
- Waves of the same type can differ in amplitude (height) and length (the spacing between wave peaks).

Grade 5 Unit 6: Interactions Within the Earth, Sun and Moon System

- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

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Grade 6 Unit 4: Force and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, the object's motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.
- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short term but is tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.
- Water continually cycles among land, ocean, and the atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- The complex patterns of the changes in the movement of water in the atmosphere are determined by winds, landforms, and ocean temperatures and currents; which are major determinants of local weather patterns.
- Global movements of water and its changes in form are propelled by sunlight and gravity.
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.
- Water's movements—both on land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

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Connections to Other Units

In **Unit 1, Weather and Climate**, students identified patterns that can help them make predictions about the weather. They will build on their understanding of patterns as they interact with objects in order to identify the patterns of change in an object's motion and use those patterns to make predictions.

In **Unit 3, Electric and Magnetic Forces**, students will further develop an understanding of forces. They will determine the effects of balanced and unbalanced forces on the motion of an object and the cause-and-effect relationships of electrical or magnetic interactions.

Sample of Open Education Resources

[Puffing Forces:](#) Students will predict and observe what happens when a force is applied to an object, and compare the relative effects of a force of the same strength on objects of different weights by using a straw to gently puff air at a ping pong ball then a golf ball and measuring the distance the ball travels with a ruler. Students will repeat this procedure using a harder puff. This lesson was adapted from the Utah Education Network <http://www.uen.org/Lessonplan/preview?LPid=14858>

[Robo Arm:](#) This fun activity is one of five in a series of space based engineering challenges developed by NASA and Design Squad where students are engaged in implementing the Engineering Design process to build a robotic arm that can lift a cup off a table using cardboard strips, brass fasteners, paper clips, straw, string, tape and a cup. The activity includes an instructor's guide, questioning techniques, discussion questions, extension activity, a rubric, and 3 short video clips that enhance the purpose of the activity and its relevance to NASA.

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Teacher Professional Learning Resources**Using the NGSS Practices in the Elementary Grades**

The presenters were Heidi Schweingruber from the National Research Council, Deborah Smith from Penn State University, and Jessica Jeffries from State College Area School District. In this seminar the presenters talked about applying the scientific and engineering practices described in A Framework for K–12 Science Education in elementary-level classrooms.

Continue the discussion in the [community forums](#).

Teaching NGSS in K-5: Constructing Explanations from Evidence

Carla Zembal-Saul, Mary Starr, and Kathy Renfrew, provided an overview of the NGSS for K-5th grade. The web seminar focused on the three dimensional learning of the NGSS, while introducing CLAIMS-EVIDENCE-REASONING (CER) as a framework for introducing explanations from evidence. The presenters highlighted and discussed the importance of engaging learners with phenomena, and included a demonstration on using a KLEWS chart to map the development of scientific explanations of those phenomena.

View the resource [collection](#).

Continue discussing this topic in the [community forums](#).

NSTA Web Seminar: NGSS Core Ideas: Motion and Stability: Forces and Interactions

Dr. Alonzo began the presentation by providing an overview of how disciplinary core ideas fit into the overall structure of NGSS. Then she and Mr. Robinson discussed common student preconceptions related to Motion and Stability: Forces and Interactions. They also showed how this disciplinary core idea progresses across grade bands. Participants had the opportunity to ask questions and discuss ideas for classroom application with other participating teachers.

View the resource [collection](#).

Continue discussing this topic in the [community forums](#).

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Science Object: Newton's First Law

This Science Object is the second of four Science Objects in the Force and Motion SciPack. It provides a conceptual and real-world understanding of Newton's First Law of Motion. All objects will maintain a constant speed and direction of motion unless an unbalanced outside force acts upon it. When an unbalanced force acts on an object, its speed or direction (or both) will change. The tendency of objects to maintain a constant speed and direction of motion (velocity) in the absence of an unbalanced force is known as inertia. Even in the most familiar, everyday situations, frictional forces can complicate the analysis of motion, although the basic principles still apply.

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Appendix A: NGSS and Foundations for the Unit		
<p>Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. <i>[Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.]</i> (3-PS2-1)</p>		
<p>Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion. <i>[Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [Assessment Boundary: Assessment does not include technical terms such as period and frequency.]</i> (3-PS2-2)</p>		
<p>The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-PS2-1) Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2) 	<p>PS2.A: Forces and Motion</p> <ul style="list-style-type: none"> Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) (3-PS2-1) 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Cause and effect relationships are routinely identified. (3-PS2-1) <p>Patterns</p> <ul style="list-style-type: none"> Patterns of change can be used to make predictions. (3-PS2-2) <p>-----</p> <p style="text-align: center;">-----</p> <p style="text-align: center;">Connections to Nature of Science</p> <p>Science Knowledge is Based on</p>

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	<ul style="list-style-type: none"> The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2) <p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> Objects in contact exert forces on each other. (3-PS2-1) 	<p>Empirical Evidence</p> <ul style="list-style-type: none"> Science findings are based on recognizing patterns. (3-PS2-2) <p>Scientific Investigations Use a Variety of Methods</p> <ul style="list-style-type: none"> Science investigations use a variety of methods, tools, and techniques. (3-PS2-1)
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English Language Arts	Mathematics
<p>Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. RI.3.1 (3-PS2-1)</p> <p>Conduct short research projects that build knowledge about a topic. W.3.7 (3-PS2-1),(3-PS2-2)</p> <p>Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories. W.3.8 (3-PS2-1),(3-PS2-2)</p>	<p>Reason abstractly and quantitatively. MP.2 (3-PS2-1)</p> <p>Use appropriate tools strategically. MP.5 (3-PS2-1)</p> <p>Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. 3.MD.A.2 (3-PS2-1)</p>

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Common Vocabulary	
Rest	Applied force
Sound	Climate
Speed	Collide
Swing	Collision
Zigzag motion	Controlled
Circular motion	Force
Change of direction	Force strength
Change of motion	Friction
Change of speed	Sum
Contact	Unbalanced force
Flow	Independent
Unit device	Measurement of motion
Surrounding	Conservation