

Unit Summary

Is it possible to exert on an object without touching it?

Students use *cause and effect*; *system and system models*; and *stability and change* to understand ideas that explain why some materials are attracted to each other while others are not. Students apply ideas about gravitational, electrical, and magnetic forces to explain a variety of phenomena including beginning ideas about why some materials attract each other while others repel. In particular, students develop understandings that gravitational interactions are always attractive but that electrical and magnetic forces can be both attractive and negative. Students also develop ideas that objects can exert forces on each other even though the objects are not in contact, through fields. Students are expected to consider the influence of science, engineering, and technology on society and the natural world. Students are expected to demonstrate proficiency in *asking questions*, *planning and carrying out investigations*, *designing solutions*, and *engaging in argument*. Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS2-3, MS-PS2-4, and MS-PS2-5.

Student Learning Objectives

Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. *[Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and is limited to qualitative evidence for the existence of fields.] (MS-PS2-5)*

Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. *[Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.] (MS-PS2-3)*

Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. *[Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.] (MS-PS2-4)*

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Unit Sequence	
Part A: Can you apply a force on something without touching it?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> Fields exist between objects that exert forces on each other even though the objects are not in contact. The interactions of magnets, electrically charged strips of tape, and electrically charged pith balls are examples of fields that exist between objects exerting forces on each other, even though the objects are not in contact. Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively). Cause-and-effect relationships may be used to predict phenomena in natural or designed systems. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Students will conduct an investigation and evaluate an experimental design to produce data that can serve as the basis for evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. Students will identify the cause-and-effect relationships between fields that exist between objects and the behavior of the objects.

Unit Sequence	
Part B: How does a Maglev train work?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> Factors affect the strength of electric and magnetic forces. Devices that use electric and magnetic forces could include electromagnets, electric motors, and generators. Electric and magnetic (electromagnetic) forces can be attractive or repulsive. The size of an electric or magnetic (electromagnetic) force depends on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. Cause-and-effect relationships may be used to predict the factors that affect the strength of electrical and magnetic forces in natural or designed systems 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Students will ask questions about data to determine the effect of the strength of electric and magnetic forces that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. Students will perform investigations using devices that use electromagnetic forces. Students will collect and analyze data that could include the effect of the number of turns of wire on the strength of an electromagnet or the effect of increasing the number or strength of magnets on the speed of an electric motor.

Unit Sequence	
Part C: <i>If I were able to eliminate air resistance and dropped a feather and a hammer at the same time, which would land first?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> Gravitational interactions are always attractive and depend on the masses of interacting objects. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass. Evidence supporting the claim that gravitational interactions are attractive and depend on the masses of interacting objects could include data generated from simulations or digital tools and charts displaying mass, strength of interaction, distance from the sun, and orbital periods of objects within the solar system. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Students construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. Students use models to represent the gravitational interactions between two masses.

What it Looks Like in the Classroom
<p>Students will conduct investigations of fields that exist between objects exerting forces on each other, even though the objects are not in contact. Through first-hand experiences or simulations, students will observe and evaluate the behavior of objects and record evidence of fields that exist and are responsible for the observed behavior of the objects. Students can investigate the interactions between magnets, electrically charged strips of tape, and/or electrically charged pith balls. Through hands-on investigations or simulations, students will be able to observe how the motion or behavior of objects change when they are exposed to electric or magnetic fields. For example, a pith ball could be suspended from a lightweight string and students can apply a charge to a balloon, comb, or plastic rod and make observations about the motion of the pith ball when these objects are placed in close proximity to the ball. The same type of investigation could be conducted with magnets or strips of electric tape. If instruction starts with students making these observations, students could then generate questions that they could use to ask questions about the cause-and-effect relationships that could explain their observations. A short research project could be conducted to provide data that students would use to help them answer their self-generated questions.</p> <p>Students will investigate magnetic and electric forces to determine the nature of the force (repulsive, attractive, or both), and factors that affect the strength of the forces. Before beginning the investigations, students will generate questions that will be used to guide their investigations. Depending on the nature of their questions, students may need to cite specific textual evidence to support the generation of a hypothesis. During the investigation, students will identify cause-and-effect relationships and use their understanding of these relationships to make predictions about what would happen if a variable in the investigation were changed. They will also determine the impact of distance on the strength of a force. Investigations may include the use of electromagnets, electric motors, or generators. During these investigations, students will collect data that they will use to answer their self-generated questions.</p> <p>Students will investigate magnetic and electric forces to determine the nature of the force (repulsive, attractive, or both), and factors that affect the strength of the forces. Before beginning the investigations, students will generate questions that will be used to guide their investigations. Depending on the nature of their questions, students may need to cite specific textual evidence to support the generation of a hypothesis. During the investigation, students will identify cause-and-effect relationships and use their understanding of these relationships to make predictions about what would happen if a variable in the investigation were changed.</p>

They will also determine the impact of distance on the strength of a force. Investigations may include the use of electromagnets, electric motors, or generators. During these investigations, students will collect data that they will use to answer their self-generated questions. Investigations can take place in the classroom, outdoor environment, or museums and other public facilities with available resources and when appropriate. Students will frame a hypothesis based on observations and scientific principles about the behavior of electromagnetic forces and carry out investigations to collect data about the factors that affect the strength of electric and magnetic forces. Examples of investigations could include the effect of the number of turns of wire on the strength of an electromagnet or the effect of increasing the number or strength of magnets on the speed of an electric motor. Students will analyze both numerical and symbolic data and use these data to determine the factors that affect the strength of electric and magnetic fields. Students will conclude this portion of the unit by citing specific textual evidence to support the analysis of information they access while reading science and technical texts or online sources about electric and magnetic forces, attending to the precise details of explanations or descriptions.

The next portion of this unit will focus on gravitational forces. Students will construct and present oral and written arguments using evidence to support the claim that gravitational interactions are always attractive and depend on the masses of interacting objects. Students will also understand that there is gravitational force between any two masses, but it is very small except when one or both of the objects have large mass. Because of this, gravitational fields will only be observed through the observation of simulations, the use of models, or the analysis of data. These could include simulations or digital tools and charts displaying mass, strength of interactions, distance from the sun, and orbital periods of objects within the solar system. Models used need to represent gravitational interactions between two masses within and between systems.

Connecting English Language Arts/Literacy and Mathematics

- English Language Arts/Literacy*
- Cite specific textual evidence to support analysis of information about science and technical texts regarding *the factors that affect the strength of electric and magnetic forces*, attending to the precise details of explanations or descriptions.
 - Write arguments focused on evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
- Mathematics*
- Reason abstractly and quantitatively while using data to determine the factors that affect the strength of electric and magnetic forces.

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)

Research on Student Learning

Students tend to think of force as a property of an object ("an object has force," or "force is within an object") rather than as a relation between objects. In addition, students tend to distinguish between active objects and objects that support or block or otherwise act passively. Students tend to call the active actions "force" but do not consider passive actions as "forces". Teaching students to integrate the concept of passive support into the broader concept of force is a challenging task even at the high-school level.

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. Students tend to hold on to these ideas even after instruction in high-school or college physics. Specially designed instruction does help students change their ideas.

Research has shown less success in changing middle-school students' ideas about force and motion. Nevertheless, some research indicates that middle-school students can start understanding the effect of constant forces to speed up, slow down, or change the direction of motion of an object. This research also suggests it is possible to change middle-school students' belief that a force always acts in the direction of motion.

Students have difficulty appreciating that all interactions involve equal forces acting in opposite directions on the separate, interacting bodies. Instead they believe that "active" objects (like hands) can exert forces whereas "passive" objects (like tables) cannot. Alternatively, students may believe that the object with more of some obvious property will exert a greater force. Teaching high-school students to seek consistent explanations for the "at rest" condition of an object can lead them to appreciate that both "active" and "passive" objects exert forces. Showing high-school students that apparently rigid or supporting objects actually deform might also lead them to appreciate that both "active" and "passive" objects exert forces ([NSDL, 2015](#)).

Prior Learning

By the end of Grade 5, students understand that:

- Objects in contact exert forces on each other.
- Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.
- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

Future Learning

Physics and Chemistry

- Newton's second law of motion ($F=ma$) and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.
- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.
- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Connections to Other Units

Grade 6 Unit 6: Astronomy

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.
- 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 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.
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

Grade 6 Unit 7: Weather and Climate

- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.
- Global movements of water and its changes in form are propelled by sunlight and gravity.
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

Grade 7 Unit 8: Earth Systems

- 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.
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Sample of Open Education Resources

[Electromagnetic Power!](#) Students investigate the characteristics of electromagnetism and then use what they learn to plan and conduct an experiment on electromagnets.

[Inspector Detector Challenge:](#) Students use the engineering design process to design and build magnetic-field detectors, and use them to find hidden magnets. Parallels are drawn to real-world NASA missions and how NASA scientists use magnetic field data from planets and moons. The website has video clips, teaching suggestions, a student handout, and a link to the pdf of the Teacher's Guide for Mission: Solar System. The Inspector Detector challenge is a series of activities that form a unit in the Mission: Solar System collection. * NOTE: The Teacher's Guide does not contain the lesson plan. You will need to click on the Student Handout heading of the website to download the "Inspector Detector Challenge Leader's Notes". Or you can go to the Design Squad webpage

Appendix A: NGSS and Foundations for the Unit
<p>Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. <i>[Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and is limited to qualitative evidence for the existence of fields.] (MS-PS2-5)</i></p>
<p>Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. <i>[Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.] (MS-PS2-3)</i></p>
<p>Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. <i>[Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Assessment does not include Newton’s Law of Gravitation or Kepler’s Laws.] (MS-PS2-4)</i></p>

The Student Learning Objectives above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> Use mathematical representations of phenomena to describe explanations. (HS-PS2-4) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3) <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5) 	<p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4) <p>PS2.A: Forces and Motion</p> <ul style="list-style-type: none"> If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by 	<p>Patterns</p> <ul style="list-style-type: none"> Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) <p>Cause and Effect</p> <ul style="list-style-type: none"> Systems can be designed to cause a desired effect. (HS-PS2-3) Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-5)

	<p>changes in the momentum of objects outside the system. (HS-PS2-3)</p> <p>ETS1.A: Defining and Delimiting an Engineering Problem</p> <ul style="list-style-type: none"> Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary) (HS-PS2-3) <p>ETS1.C: Optimizing the Design Solution</p> <ul style="list-style-type: none"> Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary HS-PS2-3) <p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-5) Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-5) <p>PS3.A: Definitions of Energy</p> <ul style="list-style-type: none"> “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary HS-PS2-5) 	<p>-----</p> <p>Connections to Nature of Science</p> <p>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</p> <ul style="list-style-type: none"> Theories and laws provide explanations in science. (HS-PS2-4) Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-4)
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English Language Arts	Mathematics
<p>Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-5), (HS-PS2-3) WHST.11-12.7</p> <p>Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5) WHST.11-12.8</p> <p>Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-5) WHST.11-12.9</p>	<p>Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-5),(HS-PS2-4) HSN.Q.A.1</p> <p>Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-5),(HS-PS2-4) HSN.Q.A.2</p> <p>Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-5),(HS-PS2-4) HSN.Q.A.3</p> <p>Reason abstractly and quantitatively. (HS-PS2-4) MP.2</p> <p>Model with mathematics. (HS-PS2-4) MP.4</p> <p>Interpret expressions that represent a quantity in terms of its context. (HS-PS2-4) HSA.SSE.A.1</p> <p>Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-4) HSA.SSE.B.3</p>