

Unit 3: Electrical and Magnetic Forces

Instructional Days: 15

Unit Summary

How can we use our understandings about magnets be used to solve problems?

In this unit of study, students 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 to define a simple design problem that can be solved with magnets. The crosscutting concept of *cause and effect*, and the *interdependence of science, engineering, and technology*, and *the influence of engineering, technology, and science on society and the natural world* are called out as organizing concepts for these disciplinary core ideas. Students are expected to demonstrate grade-appropriate proficiency in *asking questions and defining problems*. Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on 3-PS2-3, 3-PS2-4, and 3-5-ETS1-1.

Student Learning Objectives

Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. *[Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.]* **(3-PS2-3)**

Define a simple design problem that can be solved by applying scientific ideas about magnets.* *[Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.]* **(3-PS2-4)**

Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. **(3-5-ETS1-1)**

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3-PS2-3	Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other
3-PS2-4	Define a simple design problem that can be solved by applying scientific ideas about magnets
3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost
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

- 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.

Essential Questions

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

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Unit Sequence	
<i>Part A: What are the relationships between electrical and magnetic forces?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • Cause-and-effect relationships are routinely identified, tested, and used to explain change. • 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. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Identify and test cause-and-effect relationships in order to explain change. • Ask questions that can be investigated based on patterns such as cause-and-effect relationships. • Ask questions to determine cause-and-effect relationships in electric or magnetic interactions between two objects not in contact with each other. <i>(Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.)</i> • Magnetic forces could include: <ul style="list-style-type: none"> ✓ The force between two permanent magnets; ✓ The force between an electromagnet and steel paperclips; ✓ The force exerted by one magnet versus the force exerted by two magnets. • Cause-and-effect relationships could include: <ul style="list-style-type: none"> ✓ How the distance between objects affects the strength of the force ✓ How the orientation of magnets affects the direction of the magnetic force.

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Unit Sequence	
<i>Part B: How can we use our understandings about magnets be used to solve problems?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. • People’s needs and wants change over time, as do their demands for new and improved technologies. • 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. • For forces between two magnets, the size of the force depends on their orientation relative to each other. • Possible solutions to a problem are limited by available materials and resources (constraints). • The success of a designed solution is determined by considering the desired features of a solution (criteria). • Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Define a simple problem that can be solved through the development of a new or improved object or tool. • Define a simple design problem that can be solved by applying scientific ideas about magnets (e.g., constructing a latch to keep a door shut or creating a device to keep two moving objects from touching each other). • Define a simple design problem that can be solved through the development of an object, tool, process, or system, and include several criteria for success and constraints on material, time, or cost. • Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

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What It Looks Like in the Classroom

After investigating electrical and magnetic forces, students will engage in a portion of the engineering design process in order to define a simple design problem that can be solved by applying scientific ideas about magnets. This process should include the following steps:

- ✓ As a class, create a list of the properties of magnets. (See content descriptions above)
- ✓ Brainstorm a list of everyday objects that use magnets, and discuss the function of the magnet(s) in each object. For example, electric can openers have a strong magnet that attaches a can to the device as it cuts through (opens) the top of the can.
- ✓ In small groups or pairs, students discuss possible everyday problems that might be solved using magnets. For example, they could construct a latch to keep a door shut.
- ✓ As a class, determine possible criteria that might be used to determine how successful the devices might be, and discuss possible constraints (on materials, time, or cost) that might affect each group's design solution.
- ✓ Small groups or pairs should have the opportunity to create a presentation (poster, PowerPoint, drawings, or actual physical model, if time permits) to share both the design problem and solution with the class.

In this unit, students are not expected to build and test their design solutions or to optimize their designs; however, they can compare different proposals for solutions on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. The overall goal is for students to understand that engaging in engineering design will help them understand that scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process, and that as people's needs and wants change over time, so do their demands for new and improved technologies.

Engineering design is an important part of this unit of study. Students are expected to define a simple design problem that can be solved by applying scientific ideas and determine possible success criteria and constraints on time, materials, and cost. They should also compare different proposals for solutions based on how well the proposed solutions meet the criteria for success or how well each takes the constraints into account.

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

Students should be given opportunities to conduct short research projects that build knowledge about electric and magnetic forces. They should be given multiple opportunities to recall and gather information from their investigations as well as from print and digital sources. Students should use that information to answer questions, describe cause-and-effect relationships, make comparisons, and explain interactions between objects when electrical or magnetic forces are involved.

Teachers should provide a variety of texts for students to explore in order to develop students' note-taking skills. As students take notes, they should use graphic organizers, such as Venn diagrams and T-charts, to sort supporting evidence into provided categories. For example, as students read a variety of texts about forces, they can take notes and then sort the evidence they collect into categories, such as electrical and magnetic forces.

Mathematics

Students should use measurement tools in a variety of ways as they conduct investigations. They could find the mass of an object in order to understand that the more mass an object has, the greater the force needed to attract, repel, or move it. Students then reason mathematically as they analyze their data to determine patterns of change that can be used to support explanations of cause-and-effect relationships. Students might also use algebraic reasoning during investigations. For example, when measuring magnetic strength by increasing the number of magnets, students can use multiplication to make predictions about possible outcomes. So, if a paper clip moves toward a single magnet when it is 2 centimeters away, then students might predict that the paper clip will move toward a double magnet when it is 4 centimeters away. Or, if the paper clip moved towards a set of four magnets at a distance of 8 centimeters, then students might predict that the paper clip will move toward a single magnet when it is 2 centimeters away.

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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

Elementary-school students are usually aware of the behavior of magnets but may not explain the behavior in terms of forces (i.e., they may think of a magnet sticking to or moving towards another magnet but may not recognize this as the effect of a pull or force). Students of all ages may think of gravity and magnetism interchangeably. They may refer to magnetism as a "type of gravity," but they may also explain gravity in terms of the earth acting like a magnet on objects. Students may think that magnets do not work in a place where there is no air, just like they think about gravity. Students of all ages may also confuse electrostatic and magnetic effects. For example, they may predict that north magnetic poles repel positively charged objects.

Students do not readily recognize the magnetic effect of an electric current. Some think of the wire, rather than the electric current as being the cause of the magnetic effect. Students may think that insulation around the wire prevents the existence of magnetic forces when current flows ([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 its 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 makes things speed up or slow down more quickly.
- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (*secondary*)

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.

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Future Learning**Grade 4 Unit 7: Using Engineering Design with Force and Motion Systems**

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (*secondary*)

Grade 6 Unit 5: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.
- Gravitational forces are always attractive. 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—e.g., Earth and the sun.
- 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).

Connections to Other Units

In **Unit 2, Force and Motion**, students planned and conducted investigations to determine the effects of balanced and unbalanced forces on the motion of an object. As they made observations, they identified patterns of change in order to describe cause-and-effect relationships in simple force-and-motion systems.

Sample of Open Education Resources

[Investigating the Magnetic Force Field: Calculating the Magnetic Pull of a Magnet by Varying Distances](#): Students will investigate the magnetic pull of a bar magnet at varying distances with the use of paper clips. Students will hypothesize, conduct the experiment, collect the data, and draw conclusions. As a class, students will then compare each team's data and their interpretation of the results.

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Teacher Professional Learning Resources**Connections Between Practices in NGSS, Common Core Math, and Common Core ELA**

The presenter was Sarah Michaels from Clark University. In this seminar Dr. Michaels talked about connecting the scientific and engineering practices described in A Framework for K–12 Science Education with the Common Core State Standards in Mathematics and English Language Arts.

Engineering Design as a Core Idea

The presenter was Cary Sneider, Associate Research Professor at Portland State University in Portland, Oregon. The seminar focused on the Core Idea of Engineering, led by Cary Sneider, Associate Research Professor at Portland State University. Cary explained the overall NGSS engineering components for K-2, MS and HS, and went through a number of practical examples of how teachers could develop modules and investigations for their students to learn them. Cary also spoke about the ways in which teachers could include cross-cutting engineering concepts to a number of classroom subjects. The seminar concluded with an overview of NSTA resources about NGSS available to teachers by Ted, and a Q & A session with Cary.

Visit the resource [collection](#).

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

NGSS Core Ideas: Motion and Stability: Forces and Interactions

The presenters were Alicia Alonzo from Michigan State University and Alex Robinson, a teacher at Thornapple Kellogg High School in Middleville, Michigan. The program featured strategies for teaching about physical science concepts that answer questions such as "How can one explain and predict interactions between objects and within systems of objects?"

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](#).

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Appendix A: NGSS and Foundations for the Unit

Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. *[Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.]* **(3-PS2-3)**

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The performance expectations above were developed using the following elements from the NRC document [A Framework for K-12 Science Education](#):

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Analyzing and Interpreting Data</p> <ul style="list-style-type: none"> Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS3-1) <p>Asking Questions and Defining Problems</p> <ul style="list-style-type: none"> Ask questions that can be investigated based on patterns such as cause and effect relationships. (3-PS2-3) 	<p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> 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. (3-PS2-3),(3-PS2-4) 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Cause and effect relationships are routinely identified, tested, and used to explain change. (3-PS2-3) <p>-----</p> <p>-----</p> <p style="text-align: center;">Connections to Engineering, Technology, and Applications of Science</p>

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<ul style="list-style-type: none"> Define a simple problem that can be solved through the development of a new or improved object or tool. (3-PS2-4) Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1) 	<p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1) 	<p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. (3-PS2-4)
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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. (3-PS2-3) RI.3.1</p> <p>Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. (3-PS2-3) RI.3.3</p> <p>Describe the logical connection between particular sentences and paragraphs in a text (e.g., comparison, cause/effect, first/second/third in a sequence). (3-PS2-3) RI.3.8</p> <p>Ask and answer questions about information from a speaker, offering appropriate elaboration and detail. (3-PS2-3) SL.3.3</p>	<p style="text-align: center;">N/A</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