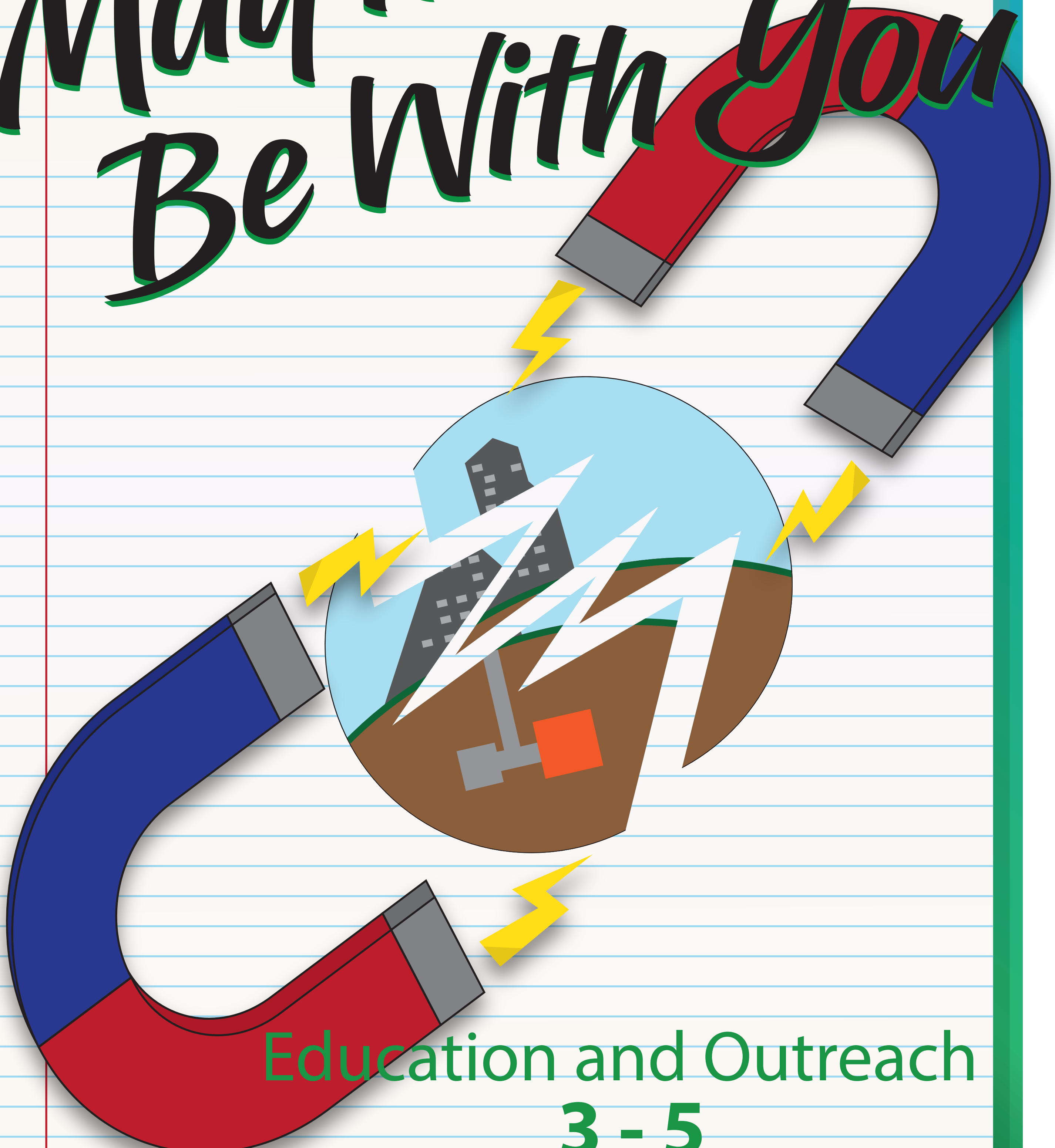
May the Force Be With You



Education and Outreach

3 - 5

Curriculum Unit

SANFORD UNDERGROUND RESEARCH FACILITY

May the Force Be With You

“Magnetism, Electricity, and Movement”

Science Focus: Constructing an Evidence-Based Explanation

Lesson #	Lesson Title	Suggested Time
1	Introducing the Unit Straw Apparatus	55 minutes
2	Magnetic Materials The Rules of Attraction	55 minutes
3	Magnetic Interactions May the Force Be With You	55 minutes
4	Magnetic Interactions A Visit to the North Pole	55 minutes
5	Practical Applications The Earth’s Magnetic Personality	55 minutes
6	Practical Applications Move it!	55 minutes
7	Electromagnets Creating Magnetism Through Electricity	55 minutes
8	Electromagnets with Switch A Real Turn Off	55 minutes
9	Pulling it all Together Building a Rudimentary Motor	55 minutes

May the Force Be With You- Grades 3-5 (Physical Science)

Students explore magnets and magnetic forces, permanent and temporary magnets, and rotational & linear motion induced by magnets. Connections are drawn to the Earth itself as a giant magnet, with north and south poles, and to the use of magnets within engineering applications. Electromagnets are central to the technology of sending a neutrino beam from Fermilab outside of Chicago, IL to a detector at the Sanford Underground Research Facility in Lead, SD.

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Magnetism, Electricity, and Movement

Matter exists as a variety of materials, each having different observable properties. Some materials exhibit the distinctive property of magnetism. Magnetism is a force that exerts either a push or pull. Magnetism can be used to explain a variety of phenomena and to develop beginning ideas about balanced and unbalanced forces and their relation to motion.

A magnet has an invisible region surrounding it called a magnetic field. The magnetic field can affect objects even when they are not directly in contact with the magnet. As the distance from a magnet increases, magnetic field strength decreases. By exploring magnets, students are introduced to the idea that there are invisible forces that occur even when objects don't physically touch.

Magnets have two poles: a north and a south pole. Like poles repel. Opposite poles attract. The orientation of magnets affects the direction of the magnetic force. If a magnetic force is exerted on an object, and there is no other force to balance it, the magnetic force can cause the object to move.

Magnets have opposite poles that can be used to determine direction and help with navigation. The north-seeking pole of a magnet is drawn toward Earth's North Pole. That's because the Earth itself is a giant magnet. The north pole of a compass needle is a magnetic north pole. It is attracted to the geographic North Pole, which is actually a magnetic south pole (opposite magnetic poles attract). This is how a compass uses a freely moving magnetic needle to indicate north.

There are two basic kinds of magnets—permanent and temporary. A permanent magnet retains its magnetic properties for a long time. A temporary magnet is created by the flow of electric current. When the electric current stops, the temporary magnet ceases to be a magnet, and its magnetic field disappears.

Magnets and electromagnets can be used to create motion.

A particle accelerator generates electric fields that accelerate the particles, and magnetic fields that steer and focus them. Plans are currently underway for a major international physics experiment, the Deep Underground Neutrino Experiment (DUNE), in which Fermilab near Chicago, IL will use a particle accelerator to direct a neutrino beam toward an underground detector at the Sanford Underground Research Facility (SURF) in Lead, SD.

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Standards Addressed in the Unit

3-PS2-1 Plan and carry out 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 for how a pattern can be used to predict future motion.

3-PS2-3 Ask questions about 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. *

5-PS1-3 Make observations and measurements to identify materials based on their properties.

5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down.

Standards with an emphasis on engineering are marked by an asterisk (*).

For more information on Engineering, see the Framework page 201and Appendix C of the South Dakota Science Standards.

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) Designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

***A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*.** (NRC, 2012)

Crosscutting Concepts

1 Patterns

2 Cause and Effect:
Mechanism and explanation

3 Scale, proportion, and quantity

4 Systems and system model

5 Energy and matter:
Flows, cycles, and conservation

6 Structure and function

7 Stability and change

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas**. (NRC, 2012)**

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Materials List

➢ **Teacher-Provided**

Lesson	Materials Needed
1	• Straw apparatus video • Straw Apparatus Document ➢ Materials to create science notebook ➢ Chart paper and markers
2	• An opaque container with a magnet inside • Two objects—one with and one without magnetic properties (e.g., one aluminum and one steel/iron nail) • Assortment of magnets: refrigerator magnets, business card magnets, button magnets, rare earth magnets (cow magnets), rectangle magnets with 5mm hole marked with silver dots to indicate like poles. • 1 package of test materials: o aluminum foil o aluminum screen o aluminum rod o brass fastener o brass washer o copper wire o golf tee o nail o paper clip o pipe cleaner o plastic drinking straw o section of VHS tape o steel washer o twist-tie o wooden toothpick

3	• 1 large and 1 small horseshoe magnet • Handouts: *Claims/Evidence Chart, Strength of Magnets Graph* • Assortment of magnets: refrigerator magnets, business card magnets, rare earth magnets (cow magnets), rectangle magnets with 5mm hole • Paperclips • Metric ruler • Index cards • 4 rectangle magnets (25 x 20 x 5 mm) with 5mm hole • 2 plastic cups (same size) • 1 wide craft stick • 1 jumbo paper clip (from box of large paper clips) • 25 washers USS standard #10
4	Maglev Train video • Handouts: *Measure the Distance Between Magnets* (with graph) Floating magnet sets: • 6 ring magnets • 1 dowel w/ base- • 1 metric ruler
5	• Handout: *Build Your Own Device* (Instruction sheet) • 2 rectangle magnets (25 x 20 x 5 mm) with a 5mm hole • 1 plastic drinking straw • 2 pieces of #20 insulated wire, 20 cm long, in 2 different colors • 1 straight pin, 2.5 cm long • 1 plastic cup • 1 piece of masking tape (to label device) ➢ Marker • Completed straw device • Small Compass

6	• Completed straw device (Lesson 5) • Rectangle magnets (25 x 20 x 5 mm) with a 5mm hole *pre-marked so like poles are indicated ➢ Stopwatch or other timekeeping device
7	• Picture/video of large junkyard electromagnet • Magnet • Paperclips • 7.6 cm long iron or steel bolt • 61 cm long 22-gauge insulated wire • 1 D-cell battery (holder optional) • Masking tape • 20 paper clips • Other magnetic objects (in small bag) • Wire cutter and stripper • Small compass

8	• Electromagnets from lesson 7
	• Small compass
	• Switches
	• Additional bagged items to test variables
	    ○ Variety of wires
	    ➢ Variety of batteries
	    ○ Variety of core materials
	• Other optional-
	    ○ Battery holders
	    ➢ Wires with alligator clips attached

9	• A remote control (RC) car or other toy • Completed straw device (Lesson 5) • Plastic cup • Rubber bands • D-cell battery • Switch • 1 insulated wire --1.5 m in length • 1 insulated wire ~20 cm in length • Small compass

Adjusting Modules to Accommodate Your Classroom Needs

Timing

The education team at SURF has done its best to develop curriculum modules that are flexible and incorporate both facilitator and student supports. As you explore this module with your students, please keep in mind that these curriculum modules are grade banded. If your students are at the lower end of the grade band, or if they come to you with limited experiences in science, you should fully expect the module to take more time than designated in the facilitator's guide. This is especially true if you teach very young students.

As an effective educator, you will know how to adjust the timing of these lessons to best fit your classroom and students. Please feel free to break any of the lessons into shorter segments, over multiple days, to accommodate the learners in your classroom.

Follow-up/Practice

Lessons in this unit include 'Follow-up/Practice' sections. These are useful (optional) resources proposed to enrich classroom practices for diverse learners. These resources are not included in the time designations of the unit; if you feel your students will benefit by pursuing these resources, please plan for additional time.

Design Principles

Effective educators alter, adjust, and change their instruction depending on who is in the classroom and the extent to which those students are succeeding. Frequently, educators will augment curriculum with additions of instructional strategies. However, please keep in mind that best practices in science education have shifted from merely *learning about* to *figuring out.* These units are designed to provide opportunities for students to figure out phenomena and design solutions to problems.

This emphasis on *figuring out* represents a revolution in how we teach science at all grade levels. In their learning, students must use all three dimensions of the science standards—crosscutting concepts (CCCs), disciplinary core ideas (DCIs), and science and engineering practices (SEPs)—in an integrated fashion in order to make sense of phenomena or design solutions to problems.

Classrooms incorporating three-dimensional learning will have students build models, design investigations, share ideas, develop explanations, and argue using evidence. All of which allow students to develop important 21st century skills such as problem solving, critical thinking, communication, collaboration, and self-management. Three-dimensional learning also helps students apply new knowledge to other situations. Every student will benefit from this instructional approach.

Important Note	
Science Notebooks Anchoring Event	**You may wish to have students set up their Science Notebooks prior to the first lesson.** As children develop and refine their understanding of science concepts, it is helpful for them to reflect on and record what they have learned. A science notebook provides them with a record of their questions, ideas, experiences, and evidence. The science notebook can also be used by the teacher to assess the development of student understanding. Science notebooks may be a printed booklet prepared by the teacher, or a bound notebook. Science Notebook support material can be found in the print masters. The anchoring event (straw apparatus) is designed to provide students with a puzzling and engaging phenomenon for which they can come to a deeper understanding over the course of the unit. Do not attempt to explain this phenomenon to students, or mention that it has anything to do with magnets. Allow them to wonder, reflect, and make sense of it on their own. In lesson 1, students are asked to draw a model of the spinning straw apparatus after viewing a video. They will repeat this at the end of the unit. For an example of a model you would hope to see at the end of the unit, see Sample Student Drawing of Straw Apparatus. The goal for the final assessment is for each student to develop more detailed, relevant science documentation in their notebook through words, pictures, and terminology.

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Lesson 1	Introducing the Unit: Straw Apparatus
Overview Standard(s) & Objectives	**Overview** This lesson consists of the presentation of an introductory phenomenon, where students see a video of a straw apparatus and attempt to explain it. Students will use their science notebooks to keep track of questions and work to develop initial models to help explain what is happening in the video. **Building Toward** 3-PS2-3 Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. Crosscutting Concept • Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change. Science and Engineering Practice • Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships. **Objectives** Students • Set up a science notebook (or section of a science notebook) for this unit. • Make observations and develop initial models to explain how a given apparatus works. • Ask questions about cause and effect relationships in the straw apparatus.
Background Information	After viewing the video, students are asked to draw a model of the spinning straw apparatus to explain how it works. What they are seeing, is a very a primitive electric motor. (*Do not share this with the class*) During this unit, students will explore each individual component. At the end, students will build their own straw apparatus.
Materials	*For class:* • Chart paper • Markers • **Video: Straw Apparatus** (1 min 30 seconds) (play without sound) *For each student:* • Science notebook • *Straw Apparatus* document (you may wish to include this as a component of the science notebook)

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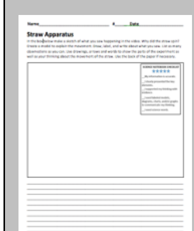
<table>
<tr><td>Prior Knowledge</td><td>None expected; however, beginning lessons may be shortened if students have extensive prior experience with magnets or magnetic interactions.</td></tr>
<tr><td colspan="2">Launch (20 minutes)</td></tr>
<tr><td>Engagement and Communication of Student Expectations

</td><td>Without explanation, show the video, Spinning Compass Motor by Kimberly Blauvelt, of a spinning straw apparatus. (1 min 30 seconds)

Included on USB in facilitators binder.

<u>Prior to turning on the projector, have the video on FULL SCREEN so title is not visible and make sure the audio is turned off.</u> Note: The term compass will not be introduced for several lessons. When referring to this use the term ‘straw device’ or ‘straw apparatus’.

Ask students to turn and talk to a partner about what they saw happening and why they think it happened.

Scientists record their ideas, questions and models in a variety of ways
1. Demonstrate how to label and date each entry. Students will use their notebooks to record their thinking throughout the unit.
2. Play the video again. Encourage students to watch for clues to help them determine what makes the straw spin.
3. Complete the Straw Apparatus Document. Direct attention to the checklist on the front. Ask students to create a model, on paper, explaining why the straw spun. They can use drawings, arrows, words, etc. to show the components of the experiment and to express their thinking about the movement of the straw. Students work independently to develop/document their model.

Students shouldn’t worry if they don’t know all the details yet. That’s what science is all about—starting from a place of not knowing. Recall the checklist on the handout. This will also be in their Science Notebook and will play a vital role in documenting their progress.</td></tr>
<tr><td colspan="2">Explore (20 minutes)</td></tr>
<tr><td>Procedure</td><td>Notice, Think, Wonder
1. Ask students to describe to a new partner what they saw/noticed, what they think may be happening and what they wondered.
2. In small groups, ask students to think of questions they have and ways they could test their ideas. What other information might they need to test their ideas?
3. Have students record their best thinking in their science notebook. After group discussions, students may wish to adjust or elaborate on their models. If possible, ask students to make additions in a different color.</td></tr>
</table>

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<table>
<tr><td>Questions</td><td>Driving Question
What makes the straw spin?
Probing Questions
Is there anything else you could add to your model?
What could you add that would show how or why?
Is there a way you could show what happened?
Is there a way you could show what caused that to happen?</td></tr>
<tr><td colspan="2">Summarize (15 minutes)</td></tr>
<tr><td>Communicate</td><td>Explain to students that they will be doing a series of investigations to test their ideas and to gather evidence about what makes the straw spin.

Record a list of ideas students have identified as being important. The list should be kept in a visible place, as it may be revised as students gather evidence throughout the unit.

Notice | Think | Wonder (questions)

As time allows, discuss the list of questions.
Which can be investigated in the classroom? How?
Which are investigable but may need special equipment not available in the classroom/school.
Are there any questions on the list that we could not investigate? Why not?</td></tr>
<tr><td>Terminology and Concepts to Solidify</td><td>At this point in the unit, students may or may not use any scientific terminology. Let them explain their ideas using their own words. Later in the unit, connections can be made between more specific science terms and student language.</td></tr>
<tr><td>Connection to Big Ideas (Phenomena)</td><td>Scientists study events and conduct a variety of experiments over time in order to explain phenomenon.</td></tr>
<tr><td>Assessment
</td><td>Straw Apparatus Document

Students should record their initial observations and explanations.

As the unit progresses, students should develop more detailed, relevant science documentation through words, pictures, and terminology.

Students will complete this document again at the conclusion of the unit so that they can look back on how their thinking changed over the course of the unit.</td></tr>
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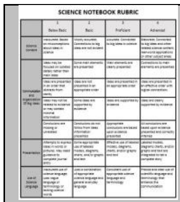
SCIENCE NOTEBOOK RUBRIC

Science Notebook Rubric

The science notebooks will become part of a portfolio of student work containing drawings, ideas, discoveries, and questions. *Consistent and specific feedback will help them improve over the course of this unit.* Teacher feedback is essential for student growth and understanding. As you examine students’ work, look for partial understanding about big science ideas in science such as magnetic force (attraction/repulsion), magnetic field, polarity, and electricity.

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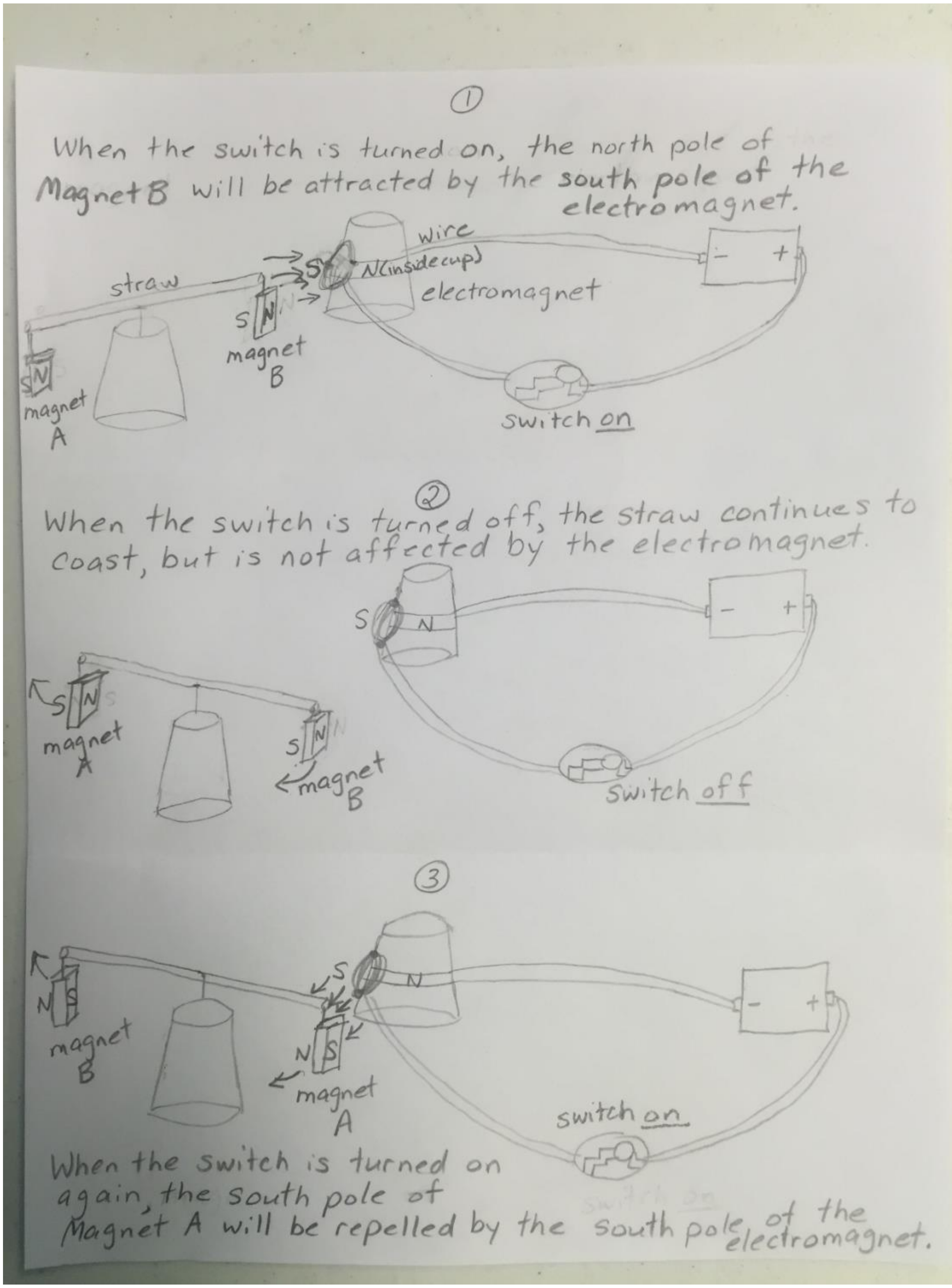
Sample Student Drawing of Straw Apparatus

This is a sample of what you would hope to see at the end of the unit, once students have gone through all of the lessons.



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<table>
<tr><th>Lesson 2</th><th>Magnetic Materials: The Rules of Attraction</th></tr>
<tr><td>Overview
Standard(s) &
Objectives</td><td>Overview
In this lesson, students will discover several properties of magnets, predict, and test objects for magnetic properties.
Building Toward
3-PS2-3 Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.
Crosscutting Concept
Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.
Science and Engineering Practice
Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships.
5-PS1-3 Make observations and measurements to identify materials based on their properties.
Science and Engineering Practice
Planning and Carrying Out Investigations- Make observations and Measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.
Objectives
Students
Identify properties of magnets.
Make and test hypotheses.
Classify objects as magnetic or nonmagnetic.
Organize information.
Distinguish between magnets and magnetic materials.</td></tr>
<tr><td>Background
Information</td><td>Magnetism can act through solid objects and push/pull on things without touching them. Magnetism is what makes electric motors spin, loudspeakers and earphones work, refrigerator doors stay closed.

Although permanent magnets can be manufactured in many different forms, they all share a common characteristic: they contain either iron, nickel, cobalt, or a combination of these elements.

Rare-earth magnets are strong permanent magnets made from alloys of rare earth elements. Developed in the 1970s and '80s, rare-earth magnets are the strongest type of permanent magnets made, producing significantly stronger magnetic fields than other types.</td></tr>
</table>

	Technically, magnets don't stick to metals at all—they stick to other magnets. Iron, nickel, and cobalt temporarily become magnets when they come close to a permanent magnet. This **induced magnetism** exists only as long as the metal is influenced by a magnetic field. As soon as the magnet moves some distance from the metal, the metal ceases to be a magnet. **Engineering Connection** Engineers, for a variety of purposes, utilize magnets; however, one frequently overlooked use is for information storage using "magnetic memory." Everyday examples include credit cards, gift cards, hotel room keys and external storage for your electronic data. In this lesson, we will look into the past and explore VCR tape. Magnets are also used in motors and acoustics. Engineers apply their understanding of magnetic fields to design satellites that withstand the effects of the earth's strong magnetic field, which can affect a satellite's orientation around the planet and disrupt sensitive electronics. Engineers design magnetic resonance imaging (MRI) techniques to create computerized images of internal human body tissues using the nuclear magnetic resonance of atoms in the body with the application of radio waves.

Materials	*For class:*
	• An opaque container with a magnet inside
	• Two objects—one with and one without magnetic properties (e.g., one aluminum and one steel/iron nail)
	For each student:
	• Science notebook
	For each group of four students:
	• Assortment of magnets: refrigerator magnets, button magnets, business card magnets, rare earth/super magnets (cow magnets), rectangle magnets with 5mm hole
	• 1 package of test materials:
	    ○ aluminum foil
	    ○ aluminum screen
	    ○ aluminum rod
	    ○ brass fastener
	    ○ brass washer
	    ○ copper wire
	    ○ golf tee
	    ○ nail
	    ○ paper clip
	    ○ pipe cleaner
	    ○ plastic drinking straw
	    ○ section of VHS tape
	    ○ steel washer
	    ○ twist-tie
	    ○ wooden toothpick

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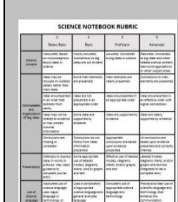
Prior Knowledge	Depending on the prior experiences of your students, you may be able to spend less time on this lesson or go deeper with the content. For example, if you are using this unit with fifth graders, and students had previous learning experiences with magnets, they may not need to spend as much time classifying objects as magnetic and nonmagnetic. Remind students of the anchoring event (straw apparatus) and refer to any observations or hypotheses students made. Explain that, in this lesson, they will have the chance to discover more about what makes the straw spin.
Launch (5 minutes)	
Engagement and Communication of Student Expectations  	Show the students the container holding the magnet, but do not tell them what is inside. Tell them a story about how you found something puzzling. Show how the container attracts one of the objects but not the other. Ask students what they think is happening. End the discussion by revealing the magnet. Explain that, for this lesson, students will be working in groups of four to decide whether something is magnetic or not. Each group will share one set of materials. Outline the procedures for collecting, using, and returning materials. You may wish to appoint a "*Materials Manager*" in each group to look after the supplies. (See *Cooperative Group Roles* sheet.) *If time is a factor, you may limit the number of objects each group must test.
Explore (35 minutes)	
Procedure  	**Using what you know** 1. Explain to students that their task is to predict whether each object is magnetic or nonmagnetic, and then to test their predictions. 2. All group members will record the information. <u>Before you test the objects:</u> •List in the table all the objects you are testing. •If you predict an object will be attracted to the magnet, write YES in the Prediction column. Otherwise, write NO in the Prediction column. 3. Provide each group of four students with a package of materials. Review any classroom norms for effective group work. Students can then begin to list each object to be tested and their predictions about whether it is magnetic or not. Remind them that it is more important for them to think about what they are learning than to worry about making 'correct' predictions. 4. Once predictions are completed, distribute magnets and have students begin testing the materials. Students record their findings.

	Teacher Tip: Make sure students have completed their predictions and recorded in their science notebook before distributing magnets. <u>After you test each object:</u> •If the object is strongly attracted to the magnet write STRONG in the Result column. •If the object is weakly attracted to the magnet, write WEAK in the Result column. •If it is not attracted to the magnet at all, write NO in the Result column.
Questions	**Driving Question** • Why do magnets attract some objects and not others? **Probing Questions** • What similarities do you notice among the magnetic objects? • What similarities do you notice among the nonmagnetic objects? • How can you use magnets to help find out what certain things are made of? • What happens when you connect a series of magnetic materials to one magnet? • What happens when you put a nonmagnetic object between a magnet and an object made of magnetic material? • What if coins were strongly magnetic? • What if everything was magnetic? • What happens if you put two magnets near each other?
Summarize (15 minutes)	
Communicate	**Class Share** Gather students and have each group share their findings. Ask students what similarities they notice among the magnetic objects and what similarities they notice among the nonmagnetic objects. Guide the discussion toward drawing conclusions and solidifying key concepts (see below). Ask them to discuss how they would distinguish between a magnet and something that is made of magnetic material. Evaluate whether students have learned that two magnets can attract one another, while two objects made of magnetic material cannot attract one another. Evaluate whether students have learned that two magnets can attract/repel each other. (You may need to demonstrate these principles) **Individual Sense-Making** Have students use words and/or pictures to create a journal entry in their science notebooks, answering the question, “Which objects are attracted to magnets?” “What do they have in common?”

	Whole Class Discussion Return to the list of ideas created in Lesson 1. Ask students if they have any items they would like to add or revise to explain what made the straw apparatus spin.
Terminology and Concepts to Solidify	**Attract** - pull toward **Repel** - push away **Magnetic** - capable of being attracted by or acquiring the properties of a magnet **Nonmagnetic** - not capable of being attracted by or acquiring the properties of a magnet **Magnet** - an object made of iron, nickel, or cobalt (or a combination of these materials) that produces a magnetic field and has the ability to attract or repel other magnetic materials **Magnetic material** - materials that respond in some way to a magnetic field There is a difference between magnets (an object that produces a magnetic field and is able to attract or repel another magnet) and magnetic material (an object that is affected by a magnet, but cannot repel like magnets). Not all metals are magnetic. In this lesson, it is important for students to discover that copper and aluminum are not magnetic. Later in the unit, they will learn that electricity moving through these materials will make them temporarily magnetic. The magnetic effect of electric current will be easier for students to comprehend if they first learn that not all metal wires are magnetic.
Connection to Big Ideas (Phenomena)	*Types of Interactions* An object must be made out of metal to be attracted to a magnet, but not all metals are attracted.
Follow Up/Practice	List further questions students have about magnets. They can share some of their questions and suggest how they might find answers to their questions. Find, or research, other things that use magnets. Encourage students to record their findings in their science notebooks, or to make a list to put in their science notebooks at a later time.
Assessment  SCIENCE NOTEBOOK RUBRIC	Observe students as they are working in groups. • How do students use the materials? • Do they generate their own ideas, or do they usually copy what other students have discovered? • Do they talk about what they think is happening? • Are all students speaking? • Do all students have access to the materials?

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	Review the entries in students' science notebooks. Look for understanding and partial understanding of the big science concepts. • Are ideas clearly organized? • Are objects correctly classified as magnetic and nonmagnetic? • Do students use specific science terminology? • What misconceptions are evident?

Common Misconceptions about Magnets

- All metals are attracted to a magnet.
- All silver colored items are attracted to a magnet.
- All magnets are made of iron.
- All larger magnets are stronger than smaller magnets.

A permanent magnet can:

- Attract or repel another permanent magnet
- Attract a magnetic material (but not repel it)

Scientists continually ask questions and seek answers, often because of new observations. It is important for students to understand that learning science is not so much a process of being right or wrong as it is of finding out new things.

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<table>
<tr><th>Lesson 3</th><th>Magnetic Interactions: May the Force Be With You</th></tr>
<tr><td>Overview Standard(s) & Objectives</td><td>
Overview
This lesson includes two activities dealing with magnets. In activity 1, students investigate a variety of magnets to see that size is not always the best indicator of strength when dealing with permanent magnets.
Activity 2 involves measuring strengths of permanent magnets and showing results in a chart or graph.
Building Toward
3-PS2-3: Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.
Crosscutting Concept
Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.
Science and Engineering Practice
Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships.
3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets.
Science and Engineering Practice
Asking Questions and Defining Problems- define a simple problem that can be solved through the development of a new or improved object or tool.
Objectives
Students

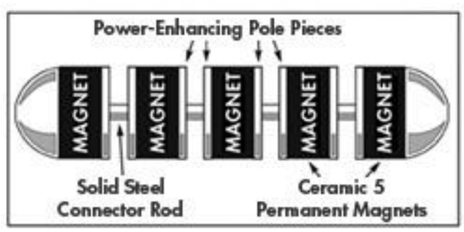
Assess the strength of different magnets and graph results.
Explain that different types of permanent magnets have different strengths (not necessarily related to size).
Use different types of magnets to demonstrate magnets can attract/repel at a distance and through different materials.

</td></tr>
<tr><td>Background Information</td><td>Size is just one of the ways one can change the strength of a magnet. However, it can get very difficult and expensive to simply make a magnet bigger. The other option is to make it BETTER. One way to make a magnet better is by carefully choosing the material from which it is made. In general, the material the permanent magnet is made from has a significant effect on the overall strength of a magnet. Other factors, not explored in this unit, include temperature and physical impact.</td></tr>
</table>

May the Force Be With You

While two magnets together are stronger than one magnet, two magnets will not be twice as strong as one. Two magnets together will be slightly less than twice as strong as one magnet, as the magnet on top will be one magnet-height's distance (or more) farther away from the object it is meant to attract.

Rare earth magnets are the strongest types of permanent magnets. They are made from alloys of rare earth elements. These magnets produce significantly stronger magnetic fields than other permanent magnets.



A cow magnet is a series of several rare earth magnets bound together as a unit. (See diagram) A cow magnet is placed in one of the cow's 4 stomachs to attract the metal that cows tend to eat. This prevents the metallic objects from causing internal damage to the cow. Without it many cows would die.

If You Want Healthy Cows, Feed Them Magnets, Gizmodo
http://gizmodo.com/if-you-want-healthy-cows-feed-them-magnets-1690931626

How Magnets Can Save a Cow's Life
http://thewifeofadairyman.blogspot.com/2010/04/how-magnet-can-save-cows-life.html

This lesson is adapted from *Magnets and Motors* from the Smithsonian/The National Academies.

Materials

Launch

- 1 large and 1 small horseshoe magnet

For each student:

- Science notebook
- Handouts: *Claims/Evidence Chart, Strength of Magnets Graph*
- *Optional: Cooperative Group Roles*

Activity 1

For each pair/group of 4:

- Assortment of magnets: refrigerator magnets, business card magnets, rare earth magnets (cow magnets), rectangle magnets with 5mm hole
- Paperclips
- Metric ruler
- Index cards

<table>
<tr><td></td><td>Activity 2
For each pair/group of 4:
4 rectangle magnets (25 x 20 x 5 mm) with 5 mm hole
2 plastic cups (same size)
1 wide craft stick
1 jumbo paper clip
25 washers USS standard number 10
1 super magnet (cow magnet)—to be given to each group by the teacher.
Optional: small paper clips</td></tr>
<tr><td>Prior Knowledge</td><td>Students should understand that not all metals are magnetic.</td></tr>
<tr><td colspan="2">Launch (5 minutes)</td></tr>
<tr><td>Engagement and Communication of Student Expectations</td><td>Hold up one very large magnet and one very small magnet. Ask the class which magnet they think is stronger.
What is your evidence?
How could we find out?
Challenge students to find a way to determine the strength of magnets using the materials supplied. Write ideas in science notebook.<blockquote>Possible ideas: Students may choose to simply count the number of paperclips a magnet will hold (some will measure a chain of paperclips; others may count total number). Others may choose to count how many index cards are needed between their magnet and the paperclip before it no longer attracts. Still others might use the ruler and a paper clip to see how close or far away the magnet needs to be to the paperclip before it attracts.</blockquote>Introduce Variables
Discuss the term “variable.” A variable is any item, factor or condition that can be changed. An experiment usually has three kinds of variables: independent, dependent, and control.<blockquote>The independent variable is the <u>one</u> that is changed by the scientist. Only one independent variable may be changed at a time.

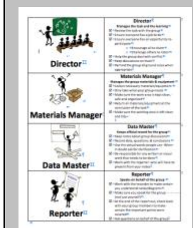
The dependent variable is the <u>one</u> that is measured or observed in the experiment.

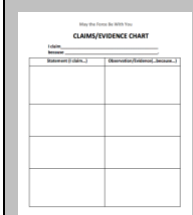
The control variables are the ones that scientists want to remain the same.</blockquote></td></tr>
</table>

May the Force Be With You

Explore (40 minutes)

Procedure





Are all (permanent) magnets the same strength?

Activity 1

1. Review the procedures for getting materials and expectations for how to return materials. It can be helpful to designate a “Materials Manager” to gather and return all supplies. For other group roles, see *Cooperative Group Roles* sheet. Distribute material for Activity 1.

Ask the students:

- *Are all magnets the same strength?*
- *Why or why not? What factors may play a role?*

Tell them that they will be investigating an assortment of magnets to determine how the size of the magnet relates to its strength. Briefly brainstorm ideas for how they might create a way to test but then leave it up to groups to define clear procedure. Having a group “Director” might facilitate this process.

2. Remind groups to list observations in their science notebooks.
3. When they have finished the activity, have them summarize their findings on the *Claims and Evidence* chart. They should save at least one or two rows for Activity 2.

Note: Students may come up with a variety of ways to test magnetic strength and discover the results are very different from group to group, or test to test. There are many factors that contribute to the variety of results. In fact, a discussion about these factors can be quite productive.

It is common to see some groups using chains of paperclips, while others use clumps of paperclips, and other individual paperclips. Whatever method the students use, they may still rank the strength of magnets in their science notebook. This activity will serve as a point of reference when discussing the terminology of variables at the end of this lesson.

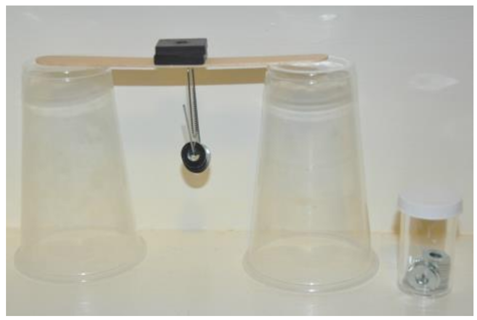
Activity 2

1. Distribute materials for Activity 2.
2. Have students predict how many washers one magnet will support. Ask them to predict how many washers two, three, and four magnets will support. These predictions should be written down before they test.

3. Tell them they are to devise a plan to determine magnetic strength using given supplies. They are to compare strengths of single magnets and groups of magnets.

4. Ask the students to consider what system they would come up with to decide this. Briefly brainstorm ideas.

Teacher Tip: Using the craft stick to span the plastic cups creates a sufficient base to support multiple magnets while testing. (See photo). Stacking magnets on top of each other will increase magnetic strength.



More Teacher Tips: Sometimes students have a hard time understanding that they are using the cup apparatus and washers to test the strength of the magnets. Emphasize that the apparatus is just needed to suspend the magnets in the air so that they can hang weights from it. The more weight you can hang from it without the weight falling, the stronger the magnets are.

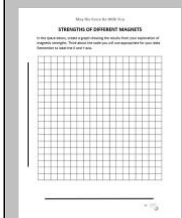
A few students may stack the magnets *along* the craft stick, or in a pyramid pattern instead of a single stack. You can direct the students to all stack the magnets the same, or you can use this as a graphing lesson: compare graphs for the single stack magnets vs. the pyramid-stacked magnets... do they look different? Why?

Students may have difficulty keeping the paperclip holding the washers intact when adding additional magnets. If the magnets on top of the craft stick repel, the whole system can be disrupted. If groups are having difficulty, ask them if there is a system they could come up with before placing magnets on top of each other to prevent that.

5. Tell students they are to decide, as a group, how they want to test their ideas. Emphasize that it will be very important to record accurate data because it will be used to create a graph later. It may be helpful to assign a "Data Master" to facilitate this process (see *Cooperative Group Roles*).

While students are conducting the magnetic strength activity, circulate among the various groups to find good examples for sharing. Students may choose different ways to solve the same problem. There is no single, correct strategy. Be careful not to tell students what to do. Let them figure it out as a group.

6. Review with students that they need to:
    - Record predictions for strength of one magnet in science notebooks.
    - Conduct the experiment for one magnet.
    - Record the data in science notebooks.
    - Repeat steps for two, three and four magnets put together.
    - Create a bar graph showing the strength of different magnets. This could be done individually or as a group.

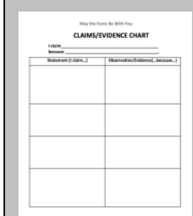


Example: The x-axis (horizontal) is number of magnets. The y-axis (vertical) is for the strength of the magnet (number of objects it can hold).

Class Share

When students finish, have the groups compare their results. Encourage them to list possible variables that could influence the results.

Individual Sense-Making



Have students add to the *Claims and Evidence* chart for Activity 2.

If students in your room have not spent time developing this skill, you may need to scaffold this first as a class conversation- then provide individual support as students work through their own claims.

Teacher Tip:

If you have a magnetic white board, you can use permanent magnets to hold up instructions, schedules, sample charts, etc. to help students make connections.

If time allows, do a class demonstration with the cow magnet (made of rare earth magnets). Ask students to predict prior to the demo. How does the strength of one cow magnet compare to the strength of your stack of 4 magnets? It may be helpful to have additional washers on hand. (There will be a huge difference with what one super magnet can hold when compared to the 4 rectangle magnets. This is a powerful illustration).

Optional Follow Up from Launch: Find a group who finishes early with a good method for determining strength. Have this group determine the strengths of the 2 different sized horseshoe magnets using the same method so they can be compared. These students can share their findings at the end of the discussion.

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<table>
<tr><td>Questions</td><td>
Driving Question
What factor(s) determine(s) the strength of a permanent magnet?
Probing Questions

What happens to the strength of the magnet as you add more layers of paper? Why?
Does the paper block the magnetic attraction?
How does this prove that forces can act at a distance?
Can you think of where magnets might impact your daily life? (Refrigerator doors, cabinet doors, purses, etc.) Does their intended purpose play a role in the type of magnet used?
Is stronger always better?

</td></tr>
<tr><td colspan="2">Summarize (10 minutes)</td></tr>
<tr><td>Communicate</td><td>
Whole Class Discussion
What was discovered during the activities? Solicit responses from all groups. If one group starts to develop a fruitful concept, lead with the question: Who can add onto Group X’s thinking?
Remind students that if they disagree with a group’s point, they must use respectful language. Teach them to use the stem: I disagree with that idea because_____________. Encourage them to explain- What? Why? How?
Be sure to support your claim with evidence from your experiment. (See Claims/Evidence Chart)
If something you noted while circling the room was not covered, solicit that group to share. Alternatively, you can ask specific students and ask them if they’d be willing to discuss their thinking with the class and give them a sticky note as a reminder. Intentional planning for sharing yields a more powerful discussion.
The students who experimented with the horseshoe magnets during the procedure time can show their results to the class. (Demonstrations can be more effective than simply reporting.)
Whole Class Discussion
Return to the list of ideas created in Lesson 1. Ask students if they have any items they would like to add or revise to explain what made the straw apparatus spin.
Define a simple design problem that can be solved by applying scientific ideas about magnets. (i.e., cow magnets) (Engineering Connection)
Can you think of where magnets might impact your daily life? (Refrigerator doors, cabinet doors, purses, etc.) Does their intended purpose play a role in the type of magnet used?
</td></tr>
</table>

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Terminology and Concepts to Solidify	**Permanent magnet**- a magnet that retains its magnetic properties in the absence of an inducing field or current **Repel**- push away **Attract**- pull towards **Poles-** either of two regions of a magnet, designated north and south, where the magnetic field is the strongest **Controlled experiment-** an experiment that isolates the effect of one variable of a system by holding constant all variables but the one under observation **Variable**- any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and control. The **independent variable** is the one that is changed by the scientist. The **dependent variable** is what you measure in the experiment and what is affected during the experiment. The **control** is held constant in order to assess or clarify the relationship between two other variables. Permanent magnets may be stronger if they are larger, they are made of different materials, or there are more of them. Permanent magnets may attract objects through other materials (craft stick, paper, etc.) Magnets can be used to attract and/or repel, hold, or move objects. This will relate to the motor concept of the anchoring event.
Connection to Big Ideas (Phenomena)	With permanent magnets, the material a magnet is made of is more important than the size when it comes to magnetic strength.
Follow Up/Practice	**Video: "Magnets" (2 minutes, 17 seconds) from Canadian Science and Technology Museum** This brief clip introduces magnets and some common uses. https://www.youtube.com/watch?v=tdBpokG4wLM

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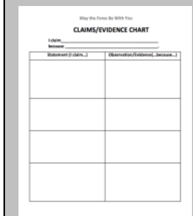
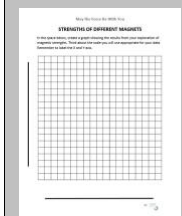
Assessment	
 May the Force Be With You **CLAIMS/EVIDENCE CHART** I claim__________ because __________ Statement (I claim…) | Observation/Evidence(…because…)	*Claims/Evidence Chart*
 May the Force Be With You **STRENGTHS OF DIFFERENT MAGNETS**	*Strength of Magnets Graph*

Lesson 4	Magnetic Interactions: A Visit to the North Pole
Overview Standard(s) & Objectives	**Overview** This lesson provides students the opportunity to investigate magnetic forces as they interact with each other, and encourages them to think about the various interactions of magnets. **Building Toward** 3-PS2-1 Plan and carry out an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. Crosscutting Concept • Cause and Effect- Cause and effect relationships are routinely identified. Science and Engineering Practice • Planning and Carrying Out Investigations- Plan and conduct and investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trails considered. 3-PS2-3: Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. Crosscutting Concept • Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change. Science and Engineering Practice • Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships. 3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets. Science and Engineering Practice • Asking Questions and Defining Problems- Define a simple problem that can be solved through the development of a new or improved object or tool. 5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down. Crosscutting Concept • Cause and Effect- Cause and effect relationships are routinely identified and used to explain change. Science and Engineering Practice • Engaging in Argument from Evidence- Support an argument with evidence, data, or a model.

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	Objectives Students • Investigate the various interactions of magnets and graph results. • Use "repel" (push) and "attract" (pull) to help gain an understanding of how magnetic forces interact. • Make predictions, record observations, take measurements, and gather data.
Background Information	During this activity, students will stack magnets with like poles facing to demonstrate the force of a push (repelling) rather than a pull. When like poles are facing each other, they will appear to "float". This is simply a matter of force balancing. The only forces on each magnet are gravity and the magnetic repulsion from the neighbors. As you add more magnets to the "floating" tower, the weight and force increases on the lowest magnets. Because of the larger force and weight, the open spaces between the consecutive magnets decreases. The top magnet must be repelled from below with a force equal in magnitude to the force of gravity on it. Each time another magnet is added to the stack, the distance between the magnets decreases. The next magnet down has not only its own weight pushing down, but the weight of the one above it as well. While a pair of magnets with like poles will repel each other, they are not stable in this condition. One magnet won't simply "float" forever above another magnet. The dowel sticking through their holes provides the needed stability.
Materials	For each student: • Science Notebook • Handouts: *Measure the Distance Between Magnets* (with graph) For each group: • 6 ring magnets • 1 dowel w/ base • 1 metric ruler For class: • Video: World's fastest Trains- MAGLEV "capable" of 3500 km/h (6 min 31 seconds)
Prior Knowledge	The strengths of magnets vary. Magnets can attract magnetic objects.

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Launch (10 minutes)	
Engagement and Communication of Student Expectations	Tell students to watch the video about Maglev Trains. ("World's Fastest Trains—MAGLEV "capable" of 3500 km/h, Time: 6:31) The USB version has been edited to remove one instance of British vernacular. https://www.youtube.com/watch?v=aIwbrZ4knpg Pay special attention to how the two different types of trains work. • How are they the same? • How are they different? Write your ideas in your science notebook. Recently, engineers have used magnets to create Maglev (short for *magnetic levitation*) Trains. These Maglev trains use the attractive and repulsive nature of magnets to **levitate** or "float" above the tracks, rather than use wheels. The first commercial high-speed maglev train, located in Shanghai, China, began transporting people in December of 2003. It averages 250 miles per hour! Tell the students that today they will conduct two experiments. In the first experiment they will discover how to place two magnets in order to create a repulsive force and an attractive force. Then they will use that information in a second experiment to make their own magnetic levitation system.
Explore (35 minutes)	
Procedure	Students will work in small cooperative groups to complete the activity. **Caution:** These magnets are brittle - they will chip, crack, or break easily if: • Dropped onto a hard surface • Allowed to smash together with another magnet • Allowed to smash together with a piece of metal **Handle magnets gently, like you do with your iPad or cell phone**. When you bring two magnets together, be prepared to have the force of attraction increase quickly and dramatically as the North pole of one gets closer to the South pole of the other. Watch your fingers so they don't get pinched! Conversely, pay attention to repelling magnets to keep them from flying away. **Determining Which Poles Attract and Repel One Another** Students will need to pay close attention to the positioning of the magnets' faces (poles) to complete the activity. Remember to keep notes in your science journal. 1. Working with your partner, place two ring magnets flat on the table. Predict what will happen when you move the side of the first magnet close to the side of the second magnet. • *Do the two magnets attract or repel?* • *What happens if you bring them face to face? Do they attract or repel?*

2. Flip one of the ring magnets over and bring it close to the face of the second magnet.
    - *Do they attract or repel?*
    - *What conclusions can you make?*
3. Introduce like and opposite poles.
    - Like poles repel.
    - Opposite poles attract.

Stacking Ring Magnets

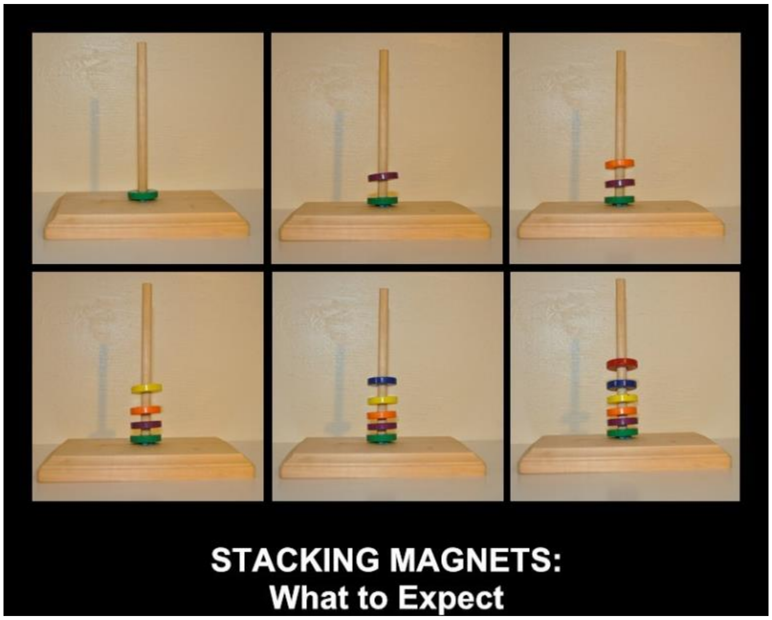
From your experiment with the ring magnets, you now know how the poles of two magnets behave when you bring them close to one another.

1. First you need a holder for the ring magnets.
2. Slide one ring magnet gently onto the holder.
   (It will sit on the base of the holder.)
3. Carefully slide the second ring magnet onto the holder.
   What happens? A third?

Provide time for students to experiment with multiple magnets.

4. Now, challenge students to fill their holder with only "floating" magnets.
5. As they work, students will measure (in mm) the gaps between the repelling magnets to see what happens as more are added.

Circulate while groups are working. Assist any who are having trouble meeting the expectations. Students should be stacking the magnets so that the like poles repel. Students will also practice measuring the gaps between magnets in millimeters.



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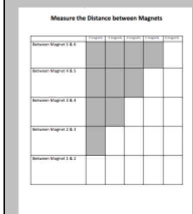

Measure the Distance between Magnets

Measuring Distance

As they work, have students measure (in mm) and record the data from their "floating" stack in the *Distance Between Magnets* sheet.

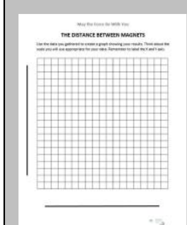
6. *What is keeping the magnets from touching each other?*
7. *What happened to the distance between magnets as more magnets were added to the stack?*
8. *What patterns do you notice?*

Get them thinking about the forces acting on the system. Why is there a large gap between magnets at the top of the stack vs the bottom of the stack? Why does the gap size change near the bottom of the stack as more magnets are added?

Teacher Tip

During the Explore time, ask questions to get students thinking about what other force may be acting on the magnet without telling them about gravity. See if they can come up with that on their own.

Part 2-Graph – this will require extra time, please plan accordingly


THE DISTANCE BETWEEN MAGNETS

Create a graph representing the distances between magnets. This could be done individually or as a group.

The x-axis (horizontal) is for the number of magnets on the dowel. The y-axis (vertical) is for the distance between magnets- in mm.

*The goal is for students to notice some type of a pattern. (Bigger gap between magnets near the top, smaller gap between magnets at the bottom, or as they look across rows, the numbers decrease)

Each time a magnet is added to the stack "floating", the space is decreased by what appears to be roughly half. As more are added, this continues. In this particular case, precision is not the goal. Encourage students to look for and describe the pattern they notice.

Samples at end of lesson.

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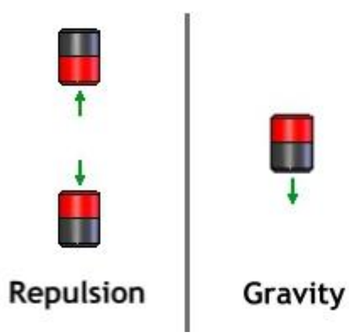
<table>
<tr><td>Questions</td><td>
Driving Question
How do opposing forces affect objects?
Probing Questions

Do you have the same result no matter how you put the magnets on the dowel?
Why does the magnet appear to “float” on one side and not the other?
What happens to the spaces between the magnets as you add more?
What patterns do you notice?
Are the magnets really “floating”? Explain.
What causes the magnets to behave that way?
What would happen if there were no dowel?

</td></tr>
<tr><td colspan="2">Summarize (10 minutes)</td></tr>
<tr><td>Communicate


</td><td>
Group Share
After all groups have completed the activity, groups will partner with another group to compare results. Then those combined groups will report to the whole group when the class gathers. Groups may wish to choose a “Communicator” to present their results (see Cooperative Group Roles sheet).

What did you observe?
How did the magnets act when stacked with like poles facing each other?
What happened to the distance between the magnets when more were added?
What happens if you remove a magnet from the stack? Two? Can you explain why?
What forces are acting on this system?

Balanced and Unbalanced Forces
As a class, discuss the forces acting on this system. (The most basic)
Repulsion-push away
Gravity- pull down


</td></tr>
</table>

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	Teacher: There are different forces at work here. The first is the magnetic force of the repelling action. When additional magnets are added on top of the first set, then the weight of the magnet and the pull of gravity come into play, decreasing the distance between the magnets below the top magnet. **Whole Class Discussion** Return to the list of ideas created in Lesson 1. Ask students if they have any items they would like to add or revise to explain what made the straw apparatus spin. **Define a simple design problem that can be solved by applying scientific ideas about magnets. (Engineering Connection)** We learned about Maglev Trains; can you think of others? (Magnets in your headphones help to turn stored music back into sounds you can hear; magnet strips can hold metal bathroom items, kitchen knives, or spice containers; magnet wands pick up sharp tacks that have spilled; magnets can also be used to separation mixtures that include iron; magnetic name tags prevent piercing skin and clothing; magnetic clasps keep some bags closed; magnets in the motor of an electric toothbrush help keep our teeth clean and healthy; even door alarms use magnets; you might have a type of body scan called NMR (nuclear magnetic resonance) which creates detailed images of your insides using patterns of magnetic fields; magnets are used to recycle your metal trash (steel cans are strongly magnetic but aluminum cans are not, so a magnet is an easy way to separate the two different metals).
Terminology and Concepts to Solidify	**Balanced Forces-** are two **forces** acting in opposite directions on an object, and equal in size. Since these two forces are of equal size and in opposite directions, they balance each other. **Repel**-push away **Attract**-pull toward **North pole** -the pole that points toward the north when magnet is freely suspended. The north pole of one magnet will attract the south pole of another magnet. Conversely, the north pole of one magnet will repel the north pole of another magnet. **Force-** the push or pull that makes something happen **Gravity**- the natural force that attracts objects toward the center of the earth Magnets have a north and south pole: like poles repel; opposites attract. Magnets repel or attract based on their orientation. Magnetic forces can be used to move objects.

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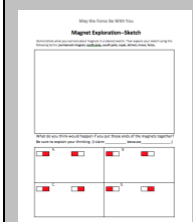
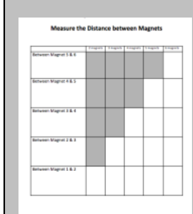
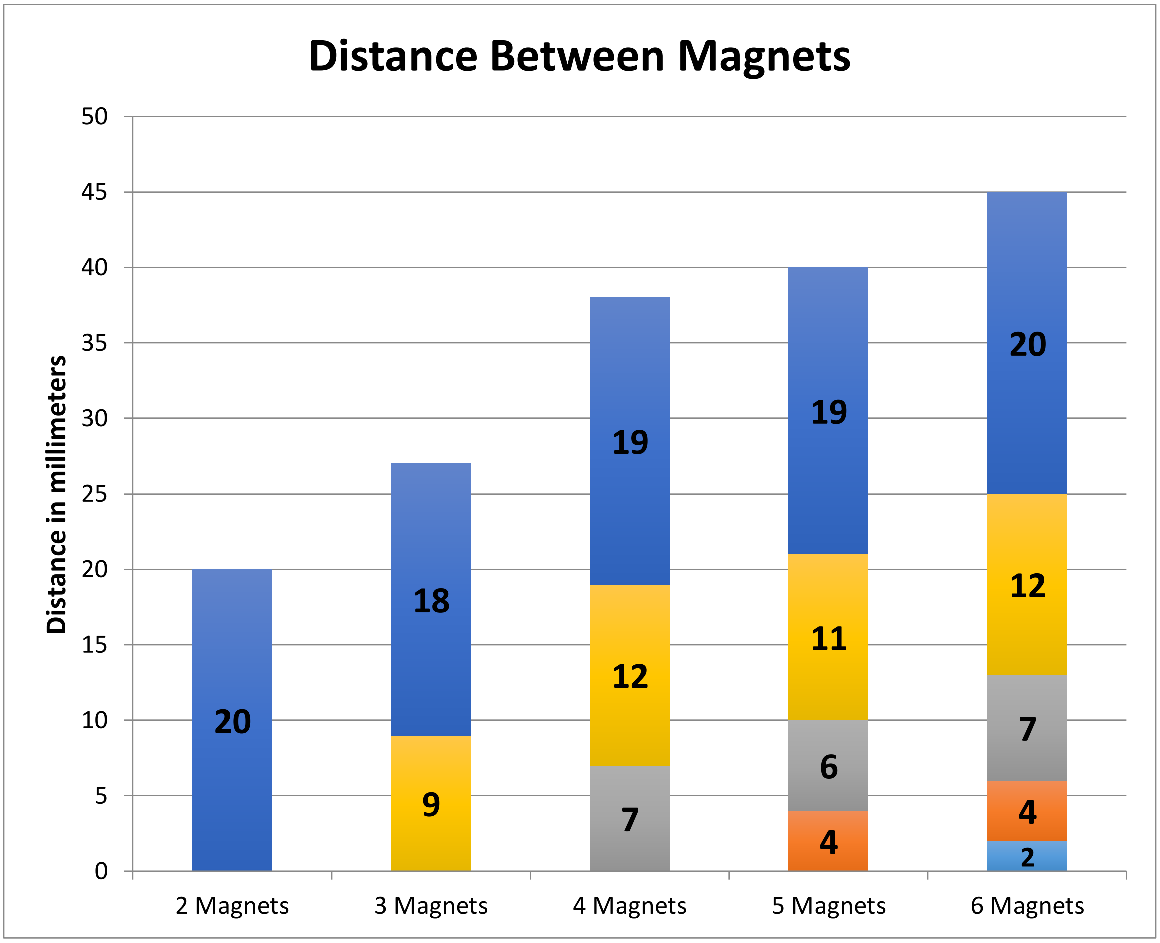
Connection to Big Ideas (Phenomena)	*Types of Interactions* *Forces and Motion* Interactions of an object with another object can be explained and predicted using the concept of forces, which can cause a change in motion of one, or both, of the interacting objects. An individual force acts on one particular object and is described by its strength and direction.
Follow Up/Practice 	*Magnet Exploration Sketch Handout* (See Print Masters) may be used as home learning or follow up activity to further explore magnetic interactions. **Reading Activities** **Magnets and Magnetism for Grade 3** https://www.ck12.org/na/Magnets-and-Magnetism-Gr-3-1/lesson/Magnets-Gr-3-SCIGR3 **Learning Games** **Magnet Hunt Game** https://fielddaylab.wisc.edu/play/magnet/ In this interactive game students to use their knowledge of magnets and magnetic fields- as well as a toolbox filled with compasses, iron filings, and magnetic film to a locate buried magnets. Through play, students explore and deepen their understanding of magnetism and electromagnetic conduction. (It is strongly recommended to complete the tutorial before jumping into the game. To progress through the tutorial, click on the speech bubble at the bottom of the screen after reading each prompt) **Spinning Levitating Pencil** https://www.yout-ube.com/watch?v=33e8bfUqK2o
Assessment 	*Activity Table: Measure the Distance Between Magnets (in mm)* • *What happened to the distance between magnets when additional magnets were added?* • *What patterns do you see in your data?*

Sample-Measure the Distance Between Magnets

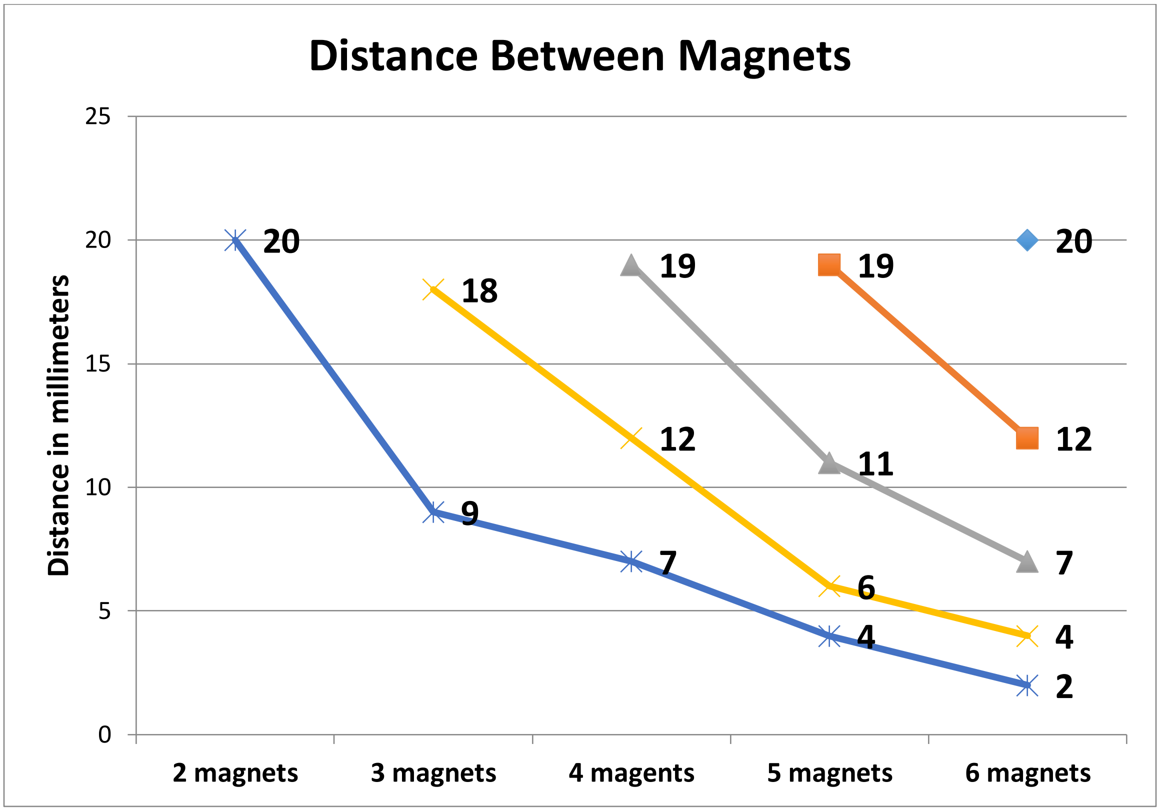
	2 magnets	3 magnets	4 magnets	5 magnets	6 magnets
Between Magnet 5 & 6					20
Between Magnet 4 & 5				19	12
Between Magnet 3 & 4			19	11	7
Between Magnet 2 & 3		18	12	6	4
Between Magnet 1 & 2	20	9	7	4	2

(In mm)

Sample-Stacked Bar Chart



Sample Line Chart



May the Force Be With You

<table>
<tr><th>Lesson 5</th><th>Practical Applications: The Earth's Magnetic Personality
(Build Your Own Straw Device)</th></tr>
<tr><td>Overview
Standard(s) &
Objectives</td><td>

Overview

In this lesson students will be given materials to build their own straw device.

Building Toward

3-PS2-2: Make observations and/or measurements of an object's motion to provide evidence for how a pattern can be used to predict future motion.

Crosscutting Concept

- Patterns- Patterns of change can be used to make predictions.

Science and Engineering Practice

- Planning and Carrying out Investigations- 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-PS2-3: Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

Crosscutting Concept

- Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.

Science and Engineering Practice

- Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships.

3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets.

Science and Engineering Practice

- Asking Questions and Defining Problems- Define a simple problem that can be solved through the development of a new or improved object or tool.

Objectives

Students

- Work with a group to build their own straw device to be used during this unit.

</td></tr>
</table>

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<table>
<tr><td>Background Information</td><td>Magnets have opposite poles that can be used to determine direction and help with navigation. The north-seeking pole of a magnet is drawn toward Earth's North Pole. That's because the Earth itself is a giant magnet. The north pole of a compass needle is a magnetic north pole. It is attracted to the geographic North Pole, which is actually a magnetic south pole (opposite magnetic poles attract). This is how a compass uses a freely moving magnetic needle to indicate north.

The device being built today is a rudimentary compass. When it is balanced, it should align north-south just as a compass needle would. When all groups are finished and put their devices in a similar area, they should all be pointing the same/similar direction. Teachers <u>should not</u> refer to it as a compass until after the students have built their own. This allows the opportunity for students to make their own connections.</td></tr>
<tr><td>Materials</td><td>For each student:
Science Notebook
Activity 1
For each pair or small group:
Handout: Build Your Own Device (Instruction sheet)
2 rectangle magnets (25 x 20 x 5 mm) with a 5mm hole
(Each magnet has one face marked with a silver dot that indicates like poles)
1 plastic drinking straw
2 pieces of #20 insulated wire, 20 cm long, in 2 different colors
1 straight pin, 2.5 cm long
1 plastic cup
1 piece of masking tape (to label device)
➢ Marker
For groups who struggle:
Several premade straw devices (Optional, but strongly recommended.)
Activity 2
For each pair or small group:
Completed straw device
Small Compass</td></tr>
<tr><td>Prior Knowledge</td><td>Magnets attract and repel depending on their orientation.

A handheld compass points north.</td></tr>
</table>

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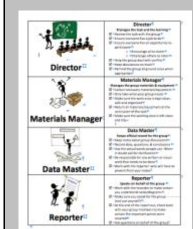
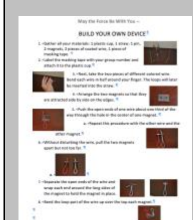
<table>
<tr><th colspan="2">Launch (5 minutes)</th></tr>
<tr><td>Engagement and Communication of Student Expectations

</td>
<td>Refer to the Anchoring Event (Initial Video) and show the students a sample device you have created. It is helpful to do this yourself first to know which parts the students may find difficult.

Tell students that today they will build a device like the one used in the video they watched at the beginning of the unit.

The goal is to create a device that functions as described in the instructions.

To do this, each group will need to:
• Designate cooperative group roles. (Materials Manager, Reporter, Data Master, and Director)
• Use materials safely. (Rule #1 in Science: SAFETY FIRST)
• Work cooperatively to create your device.
• Follow instructions for building carefully.
• Pay close attention to the positioning of the magnets in relationship to each other.
• Ensure that the straw balances. Follow tips on balancing in your document.

Note: The pin <u>rests</u> on top of the cup. <u>Do not</u> push it into the cup.

• Discuss with your group observations made as you assembled your device as later you will report to the class.</td></tr>
<tr><th colspan="2">Prepare to Explore (40 minutes)</th></tr>
<tr><td>Procedure
</td>
<td>Build Your Device
1. Distribute the materials to students.
2. Hand out Build Your Own Device instructions. Emphasize that it is extremely important to follow directions carefully.
3. Tell students to pay close attention to the direction of the magnets in relation to one another.
4. Once completed, the straw must balance freely on top of the cup.

Teacher Tips: It will be very important for students to follow the directions exactly as written to have a device that will behave correctly for future experiments. You may wish to have additional devices premade for those who have difficulty.

If the straw does not move freely, it is not balanced. Students may need to move the magnets a bit to achieve the balancing act needed to promote free movement.</td></tr>
</table>

<table>
<tr><td></td><td>
Be prepared to demonstrate troubleshooting of the straw device for students. They may need to adjust the balance of the straw by pushing in or pulling out the magnets a bit at the end of the straw. They may also need to adjust its upright position by twisting one or both magnets slightly.
Have extra straws on hand in case students poke more than two holes in the straw they are given.
In theory, all the straws should be pointing the same direction.
*Be sure that the devices are far enough away from each other that the magnets are not influencing nearby devices.
Those groups that finish early may assist any groups that are having difficulty.
</td></tr>
<tr><td>Questions</td><td>
Driving Questions

What forces are acting on the straw device?
What evidence do you have for that force?

Probing Questions

In this case, why do you think it was important for everyone to follow the same directions?
What challenges or problems did you experience as you created your device?
What do you notice about the device you have created? (The goal is to get students to notice that the straw aligns itself north-south)
What common device does this mimic?

</td></tr>
<tr><td colspan="2">Summarize (10 minutes)</td></tr>
<tr><td>Communicate</td><td>
To see and do
Pass out the small compasses to pairs/small groups. Have the students lay the compasses down flat. Now point in the direction your straw compass is pointing. Why do you suppose these devices are pointing in the same direction?
Compare devices via a gallery walk around the room. The goal is for students to notice how they all point in a similar direction.
Whole Class Discussion

Why do you suppose all/most/many are facing the same direction?
Can you think of any other item in real life that behaves this way?

Some students may notice that their device behaves like a compass. Others may have little to no experience with compasses to make such connections. Students will have the opportunity to read more about earth being a giant magnet. (See follow up)
</td></tr>
</table>

	Individual Sense-Making In their science notebooks, have students write a summary of what their group did and what they noticed as they built their straw device. Remind them to include observations they made about the straw and how it behaved once it was balanced. **Define a simple design problem that can be solved by applying scientific ideas about magnets. (i.e., compasses) (Engineering Connection)** Think of a list of ways compasses are used to help people navigate (on boats, hiking, driving, flying) Students may wish to research history and types of compass design. **Teacher Tip** Groups need to store their devices safely for use in the future. Get out cereal boxes or whatever storage supply is being used and have students put the straw components inside. (Make sure each device is visibly marked with a group number).
Terminology and Concepts to Solidify	**Compass-** an instrument having a magnetized needle (swinging freely on a pivot) which points to magnetic north **North seeking pole (of a magnet)-** the pole that points toward the north when magnet is freely suspended. The north pole of one magnet will attract the south pole of another magnet. Conversely, the north pole of one magnet will repel the north pole of another magnet. **North Pole**- (geographic) The northernmost point on the Earth's surface **Magnetic North Pole**- Located near but some distance away from the geographic North Pole. This is the direction in which a compass will point. **South seeking pole (of a magnet)-** the pole that points toward the south when magnet is freely suspended. The south pole of one magnet will attract the north pole of another magnet. It will repel the south pole of another magnet. **South Pole**- (geographic) The southernmost point on the Earth's surface **Magnetic South Pole**- Located near but some distance away from the geographic South Pole **Magnetic field**- an invisible region that surrounds a magnet or current carrying wire The earth is a giant permanent magnet with a north and south pole. Like poles repel; opposite poles attract. The magnetic force of a magnetic field is strongest at the poles. The end of a freely pivoted magnet will always point in the North-South direction. This is how compasses work.

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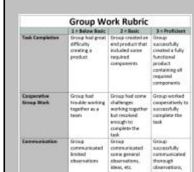
<table>
<tr><td>Connection to Big Ideas (Phenomena)</td><td>This activity is the first piece of what students witnessed in the initial video. They will build on this in subsequent lessons.

Magnetic forces between a pair of objects do not require that the objects be in contact.</td></tr>
<tr><td>Follow Up/Practice</td><td>Magnets from My School House
This reading contains information and basic illustrations on magnets. There is also a short quiz students can take and correct on computer.
http://www.myschoolhouse.com/courses/O/1/33.asp

Electric and Magnetic Forces and the Modern Day Compass, Read Works, Grade 5, Lexile: 1190L, Passage and Questions Set
http://www.readworks.org/passages/electric-and-magnetic-forces-and-modern-day-compass

How Does a Compass Work? From Live Science
http://www.livescience.com/32732-how-does-a-compass-work.html</td></tr>
<tr><td>Assessment


<table><tr><th colspan="4">Group Work Rubric</th></tr><tr><th></th><th>1 = Below Basic</th><th>2 = Basic</th><th>3 = Proficient</th></tr><tr><td>Task Completion</td><td>Group had great difficulty creating a product</td><td>Group created an end product that included some required components</td><td>Group successfully created a fully functional product containing all required components</td></tr><tr><td>Cooperative Group Work</td><td>Group had trouble working together as a team</td><td>Group had some challenges working together but resolved enough to complete the task</td><td>Group worked cooperatively to successfully complete the task</td></tr><tr><td>Communication</td><td>Group communicated limited observations</td><td>Group communicated some general observations, ideas, etc.</td><td>Group successfully communicated thorough observations, ideas, etc.</td></tr></table></td><td>Students will work in groups to create a straw device that balances. In this case, the majority of time will be spent correctly making the device to use in other experiments. The Group Work Rubric can be used to assess cooperative processes.</td></tr>
</table>

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<table>
<tr><th>Lesson 6</th><th>Practical Applications: Move it!</th></tr>
<tr><td>Overview
Standard(s) &
Objectives</td><td>

Overview

In this lesson students will use the device from the previous session to further investigate magnetic forces.

Building Toward

3-PS2-1 Plan and carry out an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Crosscutting Concept

- Cause and Effect- Cause and effect relationships are routinely identified.

Science and Engineering Practice

- Planning and Carrying Out Investigations- Plan and conduct and investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trails considered.

3-PS2-2: Make observations and/or measurements of an object's motion to provide evidence for how a pattern can be used to predict future motion.

Crosscutting Concept

- Patterns- Patterns of change can be used to make predictions.

Science and Engineering Practice

- Planning and Carrying out Investigations- 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-PS2-3: Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

Crosscutting Concept

- Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.

Science and Engineering Practice

- Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships.

3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets.

Science and Engineering Practice

- Asking Questions and Defining Problems- Define a simple problem that can be solved through the development of a new or improved object or tool.

</td></tr>
</table>

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	Objectives Students • Begin to think about the ways in which magnets can be used to induce motion.
Background Information	The device built previously is a straw compass that can be moved by using magnets to repel, attract, or a combination of both. Magnets should have one pole marked to help with the inquiry process. The activity is adapted from Building a Compass, Magnets and Motors, from Smithsonian/The National Academies National Science Resources Center.
Materials	For each student: • Science Notebook For each pair or small group: • Completed straw device (Lesson 5) • 2 rectangle magnets (25 x 20 x 5 mm) with a 5mm hole *pre-marked so like poles are indicated ➢ Stopwatches or other timekeeping device
Prior Knowledge	Magnets can attract or repel based on their orientation. The north pole of one magnet attracts the south pole of a second magnet, while the north pole of one magnet repels the other magnet's north pole. Because the straw compasses have two magnets, they have two north and south poles. This does not interfere with the operation of the straw compasses, but it may provoke some interesting questions and observations from students as they experiment with them.
Launch (5 minutes)	
Engagement and Communication of Student Expectations	Tell students: Today you will use the device you built earlier to further investigate the power of magnets. First, you will have a chance to explore the effect of magnets on your straw device. You will need to use a magnet to make the straw move without touching it. After you've discovered some different ways you can move the straw, your task will be to find a way to make the straw spin as quickly as possible.
Explore (30 minutes)	
Procedure	**Move it** • How many different ways can you make your device move without touching it or blowing on it? 1. Gather the necessary materials. 2. Use materials safely. (Rule #1 in Science: SAFETY FIRST) 3. Work cooperatively to use a magnet to make your device move. 4. Pay close attention to the positioning of the magnets in relationship to each other.

5. It is easy to get your straw compass off balance. Reposition as necessary.
6. Remind students to keep track of methods, observations, and results in their science notebooks.

Whole Class Discussion

About 10-15 minutes into the exploration time, stop the class to discuss the methods they have used to successfully make the straw compass move. What worked well? What didn't? (Ask table by table)

Some students might have only gotten the straw compass to move back and forth, while others might have induced spinning. During this discussion it is important to discuss spinning as a movement.

Next, students should be encouraged to refine their technique. Encourage them to make the straw spin with as little hand movement as possible. Once this has been accomplished, students should attempt to make the straw compass spin as quickly as possible using that technique.

- How can you make the device spin using only one magnet?
- How can you make it spin using the magnet but without moving your hand?
- Can you make it spin efficiently?
- How fast can you make it spin?
- What strategy can you use to make it spin faster?

Students may want to use timepieces to help decide "speed" of the straw device. Students will actually time the rotations. They will need to come up with a system, such as counting how many rotations there are in ten seconds.

Individual Sense-Making

Remember to record your observations in your science notebook. The title of today's lesson is called Move It. Use science terminology when you can.

Teacher Tips

If groups are having difficulty with their devices, check to make sure it is balancing. The straw should NOT touch the cup. If this is happening, try moving the position of the pin, or adjusting the magnets on each end until it balances. If a straw has many holes, it may need to be replaced.

The rectangular magnets each have a silver dot on one face. The faces with silver dots will indicate like poles. When two silver dots face each other, they should repel. A silver dot facing no dot should attract. Students will need to pay close attention to the placement of the dots in this activity.

*If class data is going to be compared, each team should agree on the amount of time to be measured.

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Questions	**Driving Question** • How many different ways can you make your device move without touching it? **Probing Questions** • What directions can you make it move? • What variables affect the movement of the straw device? • Can you make it spin the other direction? • How fast can you make it spin? • Can you change the speed of the straw spinning? • What force is acting on the device to make it move? • How do you know? What is your evidence?
Summarize (20 minutes)	
Communicate	**Whole Class Discussion** • What did you learn when you tried to move the device with the magnet? • What were the different strategies you tried that proved effective in making your straw spin? • What forces were evident? How did you know? (Use the stem: I claim _________ because _________________________________.) The goal is for students to notice how they could use the force of attraction to move the straw in one direction by rotating a magnet. They should also notice they could do the same with repelling magnets to cause movement. We see that magnets can make certain things move (pushing or pulling). How might this relate to the video of the straw apparatus? **Whole Class Discussion** Return to the list of ideas created in Lesson 1. Ask students if they have any items they would like to add or revise to explain what made the straw apparatus spin. **Define a simple design problem that can be solved by applying scientific ideas about magnets. (i.e., straw apparatus) (Engineering Connection)**
Terminology and Concepts to Solidify	**Repel**- push away **Attract** -pull toward **Poles**- either of two regions of a magnet, designated north and south, where the magnetic field is the strongest

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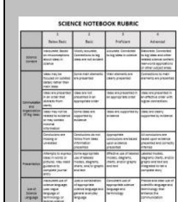
	Magnetic field- an invisible region that surrounds a magnet or current carrying wire Magnets can be used to make objects move via attraction. Magnets can be used to make objects move via repulsion. Magnets can be used to make objects move via a combination of attraction and repulsion.
Connection to Big Ideas (Phenomena)	*Forces and Motion* *Balanced and unbalanced forces determine an objects motion.* *The sizes of the magnetic forces depend on the properties of the objects, their distance apart and their orientation relative to each other.* This activity may allow for connections to the initial video, as the magnets will help make the straw device move.
Follow Up/Practice	**Design Challenge:** Design an object that can be pushed or pulled on a course by using magnets. You may not touch the object. Students could make a more open-ended journal entry, such as a connection to other spinning objects and the forces that act upon them (merry-go-round, wind turbine, pinwheel …) **Why Earth is a Magnet** https://www.ck12.org/physical-science/Why-Earth-Is-a-Magnet-in-Physical-Science/ **The Earth is a Magnet** http://www.explainthatstuff.com/magnetism.html
Assessment 	*Science Notebook Rubric*

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Lesson 7	Electromagnets
Overview Standard(s) & Objectives	**Overview** In this lesson, students build an electromagnet. Students make a simple electromagnet by wrapping a wire around a bolt and attaching the ends of the wire to a battery to make an electric circuit. As current flows through the coil, a magnetic field is produced, and the bolt is magnetized. Students further explore this concept by using a small compass. **Building Toward** 3-PS2-3 Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. Crosscutting Concept • Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change. Science and Engineering Practice • Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships. 3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets. Science and Engineering Practice • Asking Questions and Defining Problems- Define a simple problem that can be solved through the development of a new or improved object or tool. 5-PS1-3 Make observations and measurements to identify materials based on their properties. Science and Engineering Practice • Planning and Carrying Out Investigations- Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. **Objectives** Students • Construct an electromagnet. • Conduct an experiment with an electromagnet. • Observe that electricity and magnetism are closely related. • Gain an understanding of the basic relationship between magnetic fields and electricity.

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<table>
<tr><td>Background Information</td><td>Electromagnets are temporary magnets and work only when electricity passes through the coil of wire.

By simply wrapping wire that has an electrical current running through it around a bolt, you can make an electromagnet. When the electric current moves through the wire, it makes a magnetic field. If you coil the wire around and around, it will make the magnetic force stronger, but it will still be weak. Putting a piece of iron or steel inside the coil makes the magnet strong enough to attract objects.</td></tr>
<tr><td>Materials</td><td>For each student:
• Science notebook
Launch
• Picture/video of large junkyard electromagnet
• Magnet
• Paperclips
Explore
<u>For each group:</u>
• 7.6 mm long iron or steel bolt
• 61 cm long 22-gauge insulated wire
• 1 D-cell battery (holder optional)
CAUTION: Batteries can get hot. Typically, battery holders are not used with students at first as they tend to leave connected and drain the battery.
• Masking tape
• 20 paper clips & other magnetic objects
• Wire cutter and stripper
• Small Compass
*To save time, you can strip the ends of the wire for each pair of students.</td></tr>
<tr><td>Prior Knowledge</td><td>Before doing this activity, it is helpful if students have built simple electric circuits with batteries and flashlight bulbs. Basic knowledge of batteries and their uses as well as the concept of a circuit is helpful, but not necessary. The big idea with circuits is electricity flows through a circuit that is complete (with no holes or gaps).

Simple Circuit from MIT’s Scratch Ed
https://scratch.mit.edu/projects/11486153/
To illustrate that point quickly, here is an easy interactive to show how a light bulb lights up when the switch is on due to closing the circuit.</td></tr>
</table>

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<table>
<tr><th colspan="2">Launch (10 minutes)</th></tr>
<tr><td>Engagement and Communication of Student Expectations</td><td>
Show a picture/video of a “junkyard” magnet moving items made of metal.

Video: Junkyard Heavy Electric Magnet Machine Picking Up Scrap In Our Truck Fun For Kids (26 seconds) https://www.youtube.com/watch?v=XBWy9gzGGd4

• What is this magnet used for?
• How do they get the metal to fall off?

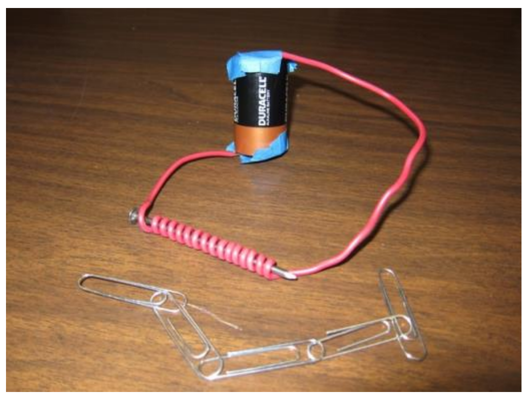
Show a magnet with paper clips stuck to it.

• How can I get this magnet to “let go” of these paper clips?
• Do you think you can make a magnet that you can turn on and off like the big magnet in the junkyard?

Today we are going to explore making a magnet and see if we can turn the magnet on and off.

*If necessary, review electric circuits with the students.
</td></tr>
<tr><th colspan="2">Explore (30 minutes)</th></tr>
<tr><td>Procedure

</td><td>
Students build a simple electromagnet



Students will use their materials to build an electromagnet. Give students time to try to figure it out on their own, using prior knowledge. Make suggestions and support where needed. After approximately 5 minutes, you will likely need to stop class and model assembly of an electromagnet.

1. Wrap the wire in a tight, even coil around the bolt. Leave 3 or 4 inches of wire loose at each end. Keep wrapping the wire until you get to the end of the bolt. (There may be as many as 3 or 4 layers of wire all the way up and down on short bolts.)

2. Tape one end of the wire to the positive (+) end of the battery. Place a piece of tape to the other end of the wire. When you need to turn on the electromagnet, apply the taped wire to the negative end (-) of the battery.

***Be sure to disconnect your electromagnet when it is not in use. Leaving the wires connected will create heat and drain your battery.
</td></tr>
</table>

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<tr>
<td></td>
<td>
Use your electromagnet to pick up a paperclip. What happens? Unhook one of the wires from the battery. Will your electromagnet pick up a paper clip now? Why? What do you need flowing through the wire to make the iron bolt act like a magnet?
How many paper clips will your electromagnet hold? Can you hang clips on both ends of the bolt? Why?
After using the electromagnet, remove the bolt. Can the bolt still pick things up? How many paper clips or staples can it pick up? Try dropping the bolt a couple of times on the floor. How might this affect whether or not you can pick up any paper clips? How many paper clips can the bolt pick up after being dropped?
Encourage students to write notes/observations in their science notebooks.
Testing for Magnetic Field (coiled wire only- no core)
This is called an electromagnetic coil.

With the electromagnet off, move the compass near the wire. What happens?
Now place the compass under the wire so that the wire runs the same direction as the needle is pointing. (You may have to bend the wire to do this) Then turn the electromagnet on. What happens? Why do you think this happens?

What happens when you turn the electromagnet off?
Encourage students to explore the effects of moving the compass closer or farther from the wire and placing it at different points in the circuit.
</td>
</tr>
<tr>
<td>Questions</td>
<td>
Driving Question
How can you make a magnet that you can turn on and off like the big magnet in the junkyard?
Probing Questions

Do you think an electromagnet will be attracted to the same things as a regular magnet?
Will it be attracted to all metal things?
Can you identify what an object might be made of based on whether or not it is attracted to an electromagnet?
Will it be attracted to other magnets?
What happens to the electromagnet if you disconnect one of the wires from the battery?
What is traveling through the wires? Where does it come from?

</td>
</tr>
</table>

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Summarize (15 minutes)

Communicate

Students will begin to see the connection between electricity and magnetism and how moving charges (electrical currents) are recognized to be the source of magnetic fields.

Remind students that circuit is a word similar to circle. Electric currents travel in a loop (like a circle) that must be connected (no gaps) in order to work.

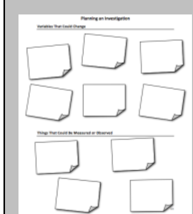
Whole Class Discussion

Return to the list of ideas created in Lesson 1. Ask students if they have any items they would like to add or revise to explain what made the straw apparatus spin.

Define a simple design problem that can be solved by applying scientific ideas about magnets. (i.e., junkyard electromagnets)

What other jobs (large or small) could electromagnets be used for?

Evaluate. Have students draw a horizontal line in their science notebook below their observations. Tell students this is their “line of learning”. Allow time for students to reflect on what they have learned about electromagnets. Encourage students to write as much as they can below the line of learning.



Determine variables. Brainstorm with students what variables you can change when building the electromagnet. Have students use the handout, *Planning an Investigation*, or have them write their variables on sticky notes. Ask them to report out their ideas. Collect answers on the board or have students post their sticky notes on a pre-made poster. That way all students have a variety of variables to choose from for their investigation.

You may wish to review the list of important ideas being recorded throughout the unit and make any additions or revisions based on new learning.

In the next lesson, you will have an opportunity to further test the strength of an electromagnet.

Before the end of class, make sure each group has selected at least 1 variable to test.

Have groups list “what if” questions on the board. Discuss which questions are testable based on available supplies. If you have the materials on hand, students may test their experiment. If not, it is an untestable question, and they will need to change their experiment.

If students choose a different size of battery (A, AA, AAA, C) remember they are all the same voltage as the D batteries included in the kit. If you have access to other size batteries that can be a powerful lesson; as students tend to think the bigger a battery is the more voltage they have. This is not the case with 9 or 6-volt batteries.

If students are using multiple batteries, make sure the batteries are lined up positive to negative.

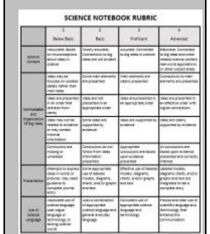
	There is one wire stripper, extra coated wires, and extra D batteries in the kit. If students are changing the type of wire, be sure they use the same length of wire as the original (61 cm) so that only one variable is changed. Prior to testing their experiment, have students write their prediction in their science notebook. Have them use a pen or colored pencil to discourage changing their prediction later.)
Terminology and Concepts to Solidify	**Permanent magnet-** a magnet that retains its magnetic properties in the absence of an inducing field or current **Temporary magnet**- perform like magnets when in the presence of a magnetic field, but lose that ability when not in a magnetic field **Electric current**- flow of electric charge through a circuit **Circuit-** a closed conducting circle or loop through which current can flow **Magnetic field**- an invisible region that surrounds a magnet or current carrying wire **Electromagnet-** a kind of temporary magnet that uses an electric current to generate a magnetic field; a magnet consisting essentially of a coil of insulated wire wrapped around a steel or iron core that is magnetized only when current flows through the wire Electric current flowing through a wire produces a magnetic field. The magnetism produced by an electromagnet can be turned on and off. Magnetic fields are invisible, but we have methods to investigate them.
Connection to Big Ideas (Phenomena)	Understanding how electromagnets work helps to more fully explain the movement of the straw in the video from the anchoring event. Electromagnets are useful because you can turn the magnet on and off by completing or interrupting the circuit, respectively.
Follow Up/Practice	**How Stuff Works Electromagnet** http://science.howstuffworks.com/electromagnet.htm (Taken from above site) What do a wrecking yard, a rock concert, and your front door have in common? **Bill Nye Explains How an Electromagnet Works (1 minute, 3 seconds)** https://www.youtube.com/watch?v=sFC7-WVNUP8 **Electricity for Kids** http://www.explainthatstuff.com/electricity.html **Great Electricity Resource with Interactive Games** http://www.primaryhomeworkhelp.co.uk/revision/Science/electricity.htm

May the Force Be With You

Assessment

Group Work Rubric			
	1 = Below Basic	2 = Basic	3 = Proficient
Task Completion	Group had great difficulty creating a product	Group created an end product that included some required components	Group successfully created a fully functional product containing all required components
Cooperative Group Work	Group had trouble working together as a team	Group had some challenges working together but resolved enough to complete the task	Group worked cooperatively to successfully complete the task
Communication	Group communicated limited observations	Group communicated some general observations, ideas, etc.	Group successfully communicated thorough observations, ideas, etc.

Group Work Rubric



SCIENCE NOTEBOOK RUBRIC

Science Notebook Rubric

Compare student science notebook entries above and below the “line of learning” (See Evaluate in the Communicate Section)

Lesson 8	Electromagnets (Continued)- A Real Turn Off
Overview Standard(s) & Objectives	**Overview** In this lesson, students will add a mechanical switch to their electromagnets and devise their own method for testing the strength of an electromagnet. **Building Toward** 3-PS2-3 Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. Crosscutting Concept • Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change. Science and Engineering Practice • Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships. 3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets. Science and Engineering Practice • Asking Questions and Defining Problems- Define a simple problem that can be solved through the development of a new or improved object or tool. 5-PS1-3 Make observations and measurements to identify materials based on their properties. Science and Engineering Practice • Planning and Carrying Out Investigations- Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. **Objectives** Students • Explain that when the switch is open, electricity cannot flow through the circuit. However, when the switch is closed it should complete the circuit. • Manipulate a variety of variables in an attempt to increase the strength of the electromagnet. • Gain an understanding of the basic relationship between magnetic fields and electricity. • Explain that electricity and magnetism are related.

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<table>
<tr><td>Background Information</td><td>Electromagnets are temporary magnets and work only when electricity passes through the coil of wire.

By simply wrapping wire that has an electrical current running through it around a bolt, you can make an electromagnet. When the electric current moves through a wire, it makes a magnetic field. A magnetic field is the area of influence exerted by a magnetic force. This field is normally focused along two poles. The magnetic field around a straight wire is not very strong. If you coil the wire around and around, it will make the magnetic force stronger, but it will still be weak. Putting a piece of iron or steel inside the coil makes the magnet strong enough to attract objects.</td></tr>
<tr><td>Materials</td><td>For each student:
Science notebook
For each group:
Electromagnets from lesson 7
Small compass
Switches
Additional items to test variables are in bags in the kit. Teachers may provide other items as well.
Variety of wires
Variety of batteries
Variety of core materials
(Other optional)-battery holders, wires with alligator clips attached</td></tr>
<tr><td>Prior Knowledge</td><td>Students should have participated in lesson 7 and have built their own electromagnet.</td></tr>
<tr><td colspan="2" align="center">Launch (10 minutes)</td></tr>
<tr><td>Engagement and Communication of Student Expectations</td><td>Tell the students that they are going to be working with the electromagnets again today, but they will make them a little more sophisticated. (Depending on materials available students could also use battery holders, alligator clips to facilitate testing of multiple batteries etc.)

Discuss how students believe the electromagnet from lesson 7 could be improved. Brainstorm and list ideas on board. If no one suggests a switch…
What would you need if you had to turn your electromagnet on and off more quickly/reliably?
Briefly discuss how adding a switch will require an extra length of wire. In their science notebooks, have students diagram what an electromagnet with a switch would look like. Then have students ‘check’ their idea. (Using finger to trace flow of electricity)</td></tr>
</table>

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*If your students are comfortable working with each other you may choose to have them switch notebooks with a neighbor to complete the 'check'.

With their finger (starting at the negative end of the battery), follow the flow of electricity through the circuit. Imagine the switch is closed.

- Can electricity make its way through the entire circuit? (With the switch closed, student should be able to trace a complete circuit)
- What if the switch is open? Then what happens to the flow of electricity? (With the switch open, the flow of electricity will stop at the switch and fail to make a complete circuit)
- Does it matter where in the circuit the switch is located? (The switch can be located on either side of the battery and still be effective)

Explore (30 minutes)

Procedure

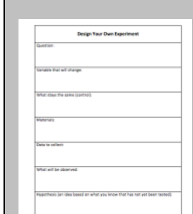
Add a switch to an electromagnet

Students will add a switch to their electromagnets.

1. Obtain an extra length of wire and a switch.
2. Find the end of the wire that is not attached to the battery. (Off position)
3. Connect that wire to one side of your switch.
4. Complete the circuit by adding the new length of wire to the opposite side of the switch.
5. When the switch is open, electricity cannot flow through the circuit. However, when the switch is closed it should complete the circuit.
6. Use your finger to trace the flow of electricity in the circuit. If you do not have a complete circuit, try again.

Students can then use the compass to test for the presence of a magnetic field.

Determine how a variable changes the strength of the electromagnet


Design Your Own Experiment

Design Your Own Experiment
Question:
Variable that will change:
What stays the same (control):
Materials:
Data to collect:
What will be observed:
Hypothesis (an idea based on what you know that has not yet been tested):

Have students pick one variable and experiment how manipulating the variable changes the strength of the electromagnet (e.g., How many paperclips can be picked up?). They use the *Designing Your Own Experiment* handout to plan the experiment. Before students can begin, have them see you for approval of the experiment.

<u>Stress the importance of multiple trials.</u> Record all data in science notebooks.

You may wish to have groups select specific tasks, such as "Director," "Materials Manager," "Data Master," and "Communicator." (See Cooperative Group Roles)

Reminder: If adding more batteries, make sure all the batteries "face" the same direction in the circuit.

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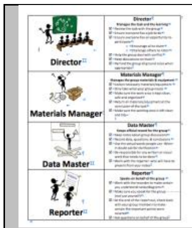	**Class Share** Ideally, students should determine how to graph their results. Depending on their experience, you may need to scaffold this part. For example, graph number of wraps and average number of objects held. For those with limited graphing ability, a data chart will suffice. Students report out their findings to whole class. The class compares all findings. Students attempt to make connections between what they found and the other groups' findings. **Extension:** Based on results from the different groups, have students build the strongest possible electromagnet by changing several variables at once. As students work, circulate first to address any procedural questions and then to listen to what students are talking about and to ask probing questions (see below) to further their thinking.
Questions	**Driving Question** • What factors influence the strength of an electromagnet? **Probing Questions** • How can you measure the strength of your electromagnet? • How many turns of the wire does it take to pick up a paper clip? • Are more turns better? • Is an electromagnet a temporary magnet or a permanent magnet? Why? *Be able to explain your thinking with evidence.
Summarize (15 minutes)	
Communicate	**Develop and use a model to explain phenomenon** Give students some time to individually answer these questions in their science notebooks. • How does the electromagnet work? • What are the elements of the system we are studying? • What has changed? What is the same? • What patterns do you see? After writing, have students talk about their answers with their table group. Allow them to add ideas from others to their science notebook entry (in a different color) Conclude with a whole class discussion about the questions above.

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	Whole Class Discussion Return to the list of ideas created in Lesson 1. Ask students if they have any items they would like to add or revise to explain what made the straw apparatus spin. **Define a simple design problem that can be solved by applying scientific ideas about magnets. (i.e., junkyard electromagnets) (Engineering Connection)** How does the addition of a more sophisticated switch make an electromagnet more usable?
Terminology and Concepts to Solidify	**Permanent magnet**- a magnet that retains its magnetic properties in the absence of an inducing field or current **Temporary magnet**- perform like magnets when in the presence of a magnetic field, but lose that ability when not in a magnetic field **Electric current-** flow of electric charge through a circuit **Circuit-** a closed conducting circle or loop through which current can flow **Magnetic field-** An invisible region that surrounds a magnet or current carrying wire **Electromagnet-** a kind of temporary magnet that uses an electric current to generate a magnetic field; a magnet consisting essentially of a coil of insulated wire wrapped around a steel or iron core that is magnetized only when current flows through the wire Electric current flowing through a wire produces a magnetic field. The magnetism produced by an electromagnet can be turned on and off. Magnetic fields are invisible, but we have methods to investigate them.
Connection to Big Ideas (Phenomena)	*The strength of the electromagnet is directly related to the number of times the wire coils around the core.* *The material used for the core can also affect the strength of the magnet.* Students will also need to understand how switches work to fully explain the movement of the straw in the video from the anchoring event. Turning the switch on and off allows the straw compass to "coast" before being attracted again by the electromagnet. You may wish to review the list of important ideas being compiled throughout the unit and have students make any additions or revisions based on this lesson.

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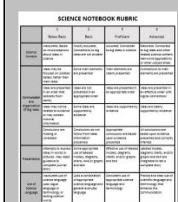
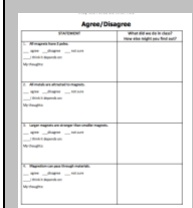
Follow Up/Practice	**Electricity, Magnets, and Circuits from PhET Lab** http://phet.colorado.edu/en/simulations/category/physics/electricity-magnets-and-circuits **Electromagnet Strength** This simulation shows how a selected rod attracts paper clips with controllable variables. (Students should be encouraged to make a prediction before running the simulation.) This will help students determine how different variables affect the strength of the electromagnet. https://iwant2study.org/lookangejss/05electricitynmagnetism_21electromagnetism/ejss_model_EMStrengthpaperclips/EMStrengthpaperclips_Simulation.xhtml
Assessment  SCIENCE NOTEBOOK RUBRIC  Agree/Disagree	Use *Science Notebook Rubric* to evaluate summary. Agree/Disagree

<table>
<tr><th>Lesson 9</th><th>Pulling it all Together</th></tr>
<tr><td>Overview Standard(s) & Objectives</td><td>

Overview

In this lesson, students will use an electromagnetic coil and a switch to investigate ways to make the straw device (from lesson 6) rotate. Students will learn about an exciting experiment at Sanford Underground Research Facility that uses a magnet-powered accelerator.

Building Toward

3-PS2-3 Ask questions about cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

Crosscutting Concept

- Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.

Science and Engineering Practice

- Asking Questions and Defining Problems- Ask questions that can be investigated based on patterns such as cause and effect relationships.

3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets.

Science and Engineering Practice

- Asking Questions and Defining Problems- Define a simple problem that can be solved through the development of a new or improved object or tool.

Objectives

Students

- Gain an understanding of the basic relationship between magnetic fields and electricity.
- Explain how electricity and magnetism are related.
- Conduct an experiment with an electromagnet.
- Review the concept of magnetic attraction and repulsion.
- Begin to understand how an electric motor functions.
- Distinguish between observations and inferences or interpretations.
- Illustrate how data can be obtained by making non-visual observations.
- Explain that scientists pose questions, test, and revise hypotheses based on evidence.
- Recognize that science is uncertain because it is a human activity.
- Understand that science does not prove or conclude – it is always a work in progress.
- Demonstrate that science is a collaborative enterprise, and that scientific uncertainty can be reduced through collaboration.

</td></tr>
</table>

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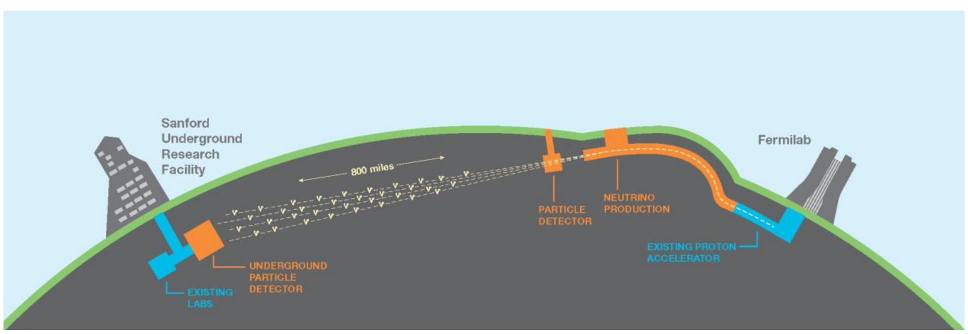
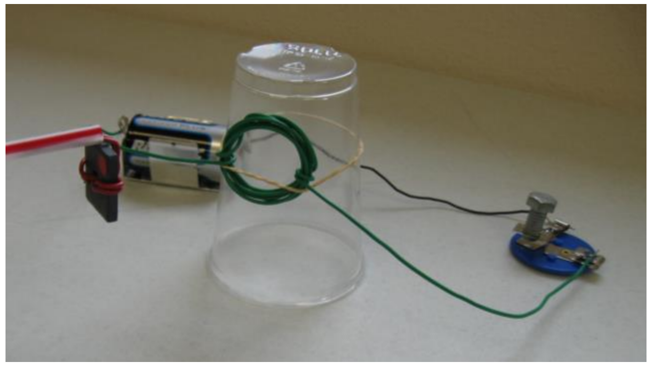
Background Information	The idea behind an electric motor is fairly straightforward. The basic components include electricity, magnetism, and a way to turn the electricity on and off at the right moment. By turning on and off the electricity flowing to the electromagnet at just the right moment, the electromagnet can be made to attract a magnet on the straw device and then allow it to coast. An electric motor is all about magnets and magnetism: A motor uses magnets to create motion. The motor in this lesson does not have an automatic switch- the switch is operated at the proper moment by the student. *This activity is adapted from Magnets and Motors from the Smithsonian/The National Academies. **Particle Accelerators** How does a particle accelerator work? Particle accelerators use electric fields to speed up and increase the energy of a beam of particles, which are steered and focused by magnetic fields. The Deep Underground Neutrino Experiment (DUNE), at Sanford Underground Research Facility (SURF), will be the target for a Neutrino Beam from the particle accelerator at Fermilab in Illinois (800 miles away) **Video: How to Make a Neutrino Beam (1 minute 45 seconds)** This animation from Fermilab explains how the neutrino beam is created. https://www.yout-ube.com/watch?v=U_xWDWKq1CM *Neutrinos* are teeny, tiny, nearly massless particles that travel at near light speeds. **Video: What is a neutrino? From Minute Physics (1 minute 24 seconds)** This brief animation explains what a neutrino is. https://www.yout-ube.com/watch?v=lAAmAbJvvJg *Neutrinos* are one of the fundamental particles that make up the universe. Studying neutrinos is difficult. They are tough to detect since they interact so weakly with other particles. 

May the Force Be With You

Materials	*For each student:* • Science notebook **Launch** • A remote control (RC) car or other toy **Explore** For each group: • Completed straw device (Lesson 5) • Plastic cup • Rubber bands • D-cell battery • Switch • 1 insulated wire --1.5 m in length • 1 insulated wire ~20 cm in length • Small compass
Prior Knowledge	Students should have participated in all lessons of this unit.
Launch (10 minutes)	
Engagement and Communication of Student Expectations	Pull out a remote and send a car or other toy across the classroom. Ask students what is making the car move. Believe it or not, you now have enough knowledge to build a very simple electric motor! Electric motors are all around us-everything from toy cars to the mechanism that makes cell phone vibrate. The basic components include electricity, magnetism, and a way to turn the electricity on and off at the right moment to produce motion. Ask students to think back to some of the things they have studied in this unit that relate to those components. Refer to the chart of important ideas. Have students turn and talk to a partner, then ask them to write specific examples in their science notebook.
Explore (30 minutes)	
Procedure  Can You Make a Simple Motor?	**Can You Make a Motor?** 1. Use the straw device from lesson 5. 2. Next, create a magnetic coil using a piece of wire that is 1.5 m long; create the coil by wrapping it around a D-cell sized battery. Leave 3-4 inches loose at each end. Show students a sample coil (in kit).

3. Attach the coil to the side of the inverted plastic cup with the two rubber bands. Connect the coil to the battery and the switch. With the 20-cm wire, connect the switch and the battery. Position the coil two finger-widths away from the north-seeking pole of the magnet of the straw device.



Teacher Tips: The coil should be placed towards top of cup at magnet height (see photo). If a magnet is too close to the coil it will attract the straw device. When this happens, it will need to be rebalanced. Make sure the straw device will still spin freely.

- What effect does the coil have on the magnet when the switch is open (off)?

Push the switch to the closed (on) position so that electricity will run through the coil.

- What effect does the coil have on the magnet when the switch is closed?
- Is the north magnet attracted to or repelled by the coil?
- Which pole of the electromagnet do you think is closer to the straw device? What makes you think that?

4. Now, position the south-seeking pole magnet next to the coil. Can you predict what will happen when you turn the switch on? Try it!

- Using this information, can you make the straw device spin?
- Can you make it spin more quickly? What method did you use?

As students work, circulate first to address any procedural questions and then to listen to what students are talking about and to ask probing questions (see below) to further their thinking.

If the class chooses to compare which group can move the straw motor the fastest, you will need to come up with a standard for timekeeping-so everyone is using the same method.

The timing when using the switch is very important. The electromagnet repels one magnet and attracts the other.

Extension: For students who figure out how to make the straw compass spin quickly, challenge them to see if they can get it to spin in the reverse direction.

May the Force Be With You

Questions	**Driving Question** • How does each component of the apparatus allow you to control/influence the spin of the straw? **Probing Questions** • What effect does the coil have on the magnet when the switch is off (open)? • What effect does the coil have on the magnet when the switch is on? • Is the north magnet attracted to or repelled by the coil? • Which pole of the electromagnet do you think is closer to the straw device? What makes you think that? • Can you make it spin more quickly? What method did you use? • How does this set-up represent a motor?
Summarize (15 minutes)	
Communicate  May the Force Be With You Name_____ #____ Date_____ UNIT POST-ASSESSMENT	**Class share** • What method did you use to get the straw to spin? An electric motor is all about magnets and magnetism: A motor uses magnets to create motion. • How does this set-up represent a motor? The basic components of an electric motor include: electricity, magnetism, and a way to turn the electricity on and off at the right moment to create motion. o The electricity from the battery flows through the coil of wire creating an electromagnet and, thus, a magnetic field. o The magnetic field from the electromagnet is attracted to or repelled from the permanent magnets in the straw compass. o This cycle continues creating a rapid spinning motion! **Define a simple design problem that can be solved by applying scientific ideas about magnets. (i.e., electric motor)** • Where else might you find electric motors? • Name any advantages in an electric motor? (magnets are easily obtained, relatively lightweight, simple, durable, low cost, etc) • Name any drawbacks to an electric motor? (magnets easily broken, may not be strong enough to move something heavy, can corrode, etc) **Individual sense-making** Distribute blank *Straw Apparatus Document*. Students should create a final entry explaining how and why the straw spun. They can use drawings, arrows, words, etc. to express their thinking about the straw motor and how it works. Keep copies of students' final models to look at changes in thinking during this unit. These can be compared to the students' initial ideas to document growth.

May the Force Be With You

	<u>Tie to SURF--Neutrino Beams</u> To study neutrinos more effectively, scientists produce high-intensity neutrino beams using proton accelerators. These accelerators use electric fields to speed up and increase the energy of a beam of particles, which are steered and focused by magnetic fields. (See Follow Up Section for additional details) **Define a simple design problem that can be solved by applying scientific ideas about magnets. (i.e., particle accelerators) (Engineering Connection)**
Terminology and Concepts to Solidify	**Permanent magnet**- a magnet that retains its magnetic properties in the absence of an inducing field or current **Temporary magnet**- perform like magnets when in the presence of a magnetic field, but lose that ability when not in a magnetic field **Electric current-** flow of electric charge through a circuit **Circuit-** a closed conducting circle or loop through which current can flow **Magnetic field**- an invisible field that surrounds a magnet or current carrying wire Electric current flowing through a wire produces a magnetic field. The magnetism produced by an electromagnet can be turned on and off. This process can induce motion through attraction, repulsion, and coasting. Magnetic fields are invisible, but we have methods to investigate them.
Connection to Big Ideas (Phenomena)	*Forces and Motion* *Types of Interaction* The concept of magnetic force as it relates to compasses, electromagnets and electrical circuits enabled the straw compass motor to spin. Throughout the unit students worked to use observation and measurement to determine the effect of balanced and unbalanced forces on an objects motion, and to determine its future motion. Students used scientific ideas to ask questions and conduct investigations about cause and effect relationships pertaining to gravitational, electric and magnetic interactions.
Follow Up/Practice 	**This information could be shared at another time and may be easily incorporated into a reading/writing period if necessary.** Students may use the *Graffiti Page* as they watch the videos. Then, distribute the *Deep Underground Neutrino Experiment Reading Passage*. After gathering this new information, have students complete the *EXIT Card*.

May the Force Be With You

To introduce the videos, share the following information:

The Sanford Underground Research Facility (SURF) is currently partnering with Fermilab in Illinois on a major project involving over 1000 scientists from around the world. This will include Fermilab's particle accelerator, which will send a beam of neutrinos to a detector deep underground at the SURF, an 800-mile journey. Because neutrinos travel close to the speed of light, this will only take a fraction of a second! As this is a difficult concept to grasp just reading about it, these brief videos do a lovely job of explaining!

Small Particles, Big Science: The International LBNF/DUNE Project (2 minutes)
This gives a great overview of the collaborative project in the works between SURF and Fermilab.
https://www.youtube.com/watch?v=AYtKcZMJ_4c

How does a particle accelerator work? Particle accelerators use electric fields to speed up and increase the energy of a beam of particles, which are steered and focused by magnetic fields. There is an illustration of this in the video below:

How to Wrangle a Particle, from Symmetry Magazine and Fermilab (1 min 50 secs)
http://www.symmetrymagazine.org/article/how-to-wrangle-a-particle
This informative short video from Fermilab explains the important role that magnets play in the particle accelerator. The particle accelerator is what will send a beam of neutrinos to SURF in the future.

How to Make a Neutrino Beam (1 minute 45 seconds)
This animation from Fermilab explains how the neutrino beam is created.
https://www.yout-ube.com/watch?v=U_xWDWKq1CM

What is a neutrino? From Minute Physics (1 minute 24 seconds)
This brief animation explains what a neutrino is.
https://www.yout-ube.com/watch?v=lAAmAbJvvJg

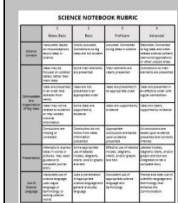
After watching the videos, share the Reading Passage: EXTREME SCIENCE: DEEP UNDERGROUND NEUTRINO EXPERIMENT as now they have had some background information to help them better grasp what is going on at the lab.

SURF Overview (on USB) 2 minutes 56 seconds

Sanford Underground Research Facility in Lead, South Dakota, is an underground science laboratory built in the former Homestake gold mine.

Magnetic Circular Accelerator
https://www.youtube.com/watch?v=r8zRe6wEUhc
The video above provides enough information for a teacher to create a demo showing a circular accelerator.

May the Force Be With You

	The Scale of the Universe 2 http://htwins.net/scale2/ This interactive site allows students to see both how large and how small the universe is. To get an idea of how small a neutrino is, students move the cursor to the left. (Note: both high energy neutrinos and neutrinos are included.) Once they have looked at the micro universe, they can then move the cursor back to the right to explore the macro universe!
Assessment  SCIENCE NOTEBOOK RUBRIC	**Straw Apparatus Document** Use the *Science Notebook Rubric* to evaluate explanation of “compass motor” (anchoring event)

Print Masters

Name_______________________________ #_____ Date____________________

Straw Apparatus

In the box below make a sketch of what you saw happening in the video. Why did the straw spin? Create a model to explain the movement. Draw, label, and write about what you saw. List as many observations as you can. Use drawings, arrows and words to show the parts of the apparatus as well as your thinking about the movement of the straw. Use the back of the paper if necessary.

SCIENCE NOTEBOOK CHECKLIST

★★★★★

__My information is accurate.

__I clearly presented the key elements.

__I supported my thinking with evidence.

__I used labeled models, diagrams, charts, and/or graphs to communicate my thinking.

__I used science words.

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SCIENCE NOTEBOOK RUBRIC

	1 Below Basic	2 Basic	3 Proficient	4 Advanced
Science Content	Inaccurate; Based on misconceptions about ideas in science	Mostly accurate; Connections to big ideas are not evident	Accurate; Connected to big ideas in science	Elaborate; Connected to big ideas and other related science content, real-world applications, or other subject areas
Communication and Organization Of Big Ideas	Ideas may be focused on isolated details rather than main ideas	Some main elements are presented	Main elements are clearly presented	Connections to main elements are presented
	Ideas are presented in an order that distracts from clarity	Ideas are not presented in an appropriate order	Ideas are presented in an appropriate order	Ideas are presented in an effective order with logical connections
	Ideas may not be related to evidence or may contain minimal information	Some ideas are supported by evidence	Ideas are supported by evidence	Ideas are clearly supported by evidence
	Conclusions are missing or unrelated	Conclusions do not follow from ideas information presented	Appropriate conclusions are based upon evidence presented	All conclusions are based upon evidence presented and correctly inferred
Presentation	Attempts to express ideas in words or pictures. May need guidance to complete journal entry	Some appropriate use of labeled models, diagrams, charts, and/or graphs and text	Effective use of labeled models, diagrams, charts, and/or graphs and text	Labeled models, diagrams charts, and/or graphs and text are integrated to tell a complete story
Use of Science Language	Inaccurate use of science language; uses vague language or terminology or lacking science words	Uses a combination of appropriate science language and general everyday language	Consistent use of appropriate science language and terminology	Precise and clear use of scientific language and terminology that enhance the communication

May the Force Be With You

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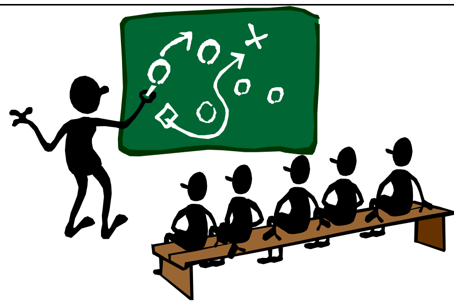
<tr>
<td>

Director
</td>
<td>

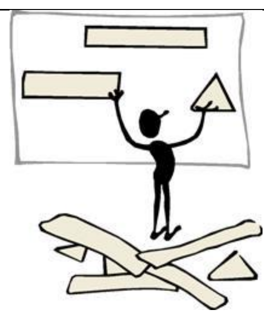
Manages the task and the learning

☑ Review the task with the group
☑ Ensure everyone has a job to do
☑ Ensure everyone has an opportunity to participate
- Encourage all to share
- Challenge others to listen

☑ Help the group deal with conflict
☑ Keep discussions on track
☑ Remind the group of ground rules when appropriate
</td>
</tr>
<tr>
<td>

Materials Manager
</td>
<td>

Manages the group materials & equipment

☑ Collect necessary materials/equipment
☑ Only take what your group needs
☑ Make sure the work area is kept clean, safe and organized
☑ Return all materials/equipment at the conclusion of the task
☑ Make sure the working area is left clean and tidy
</td>
</tr>
<tr>
<td>

Data Master
</td>
<td>

Keeps official record for the group

☑ Keep notes about group discussions
☑ Record data, questions, & conclusions
☑ Use the actual words people use- When in doubt ask for clarification
☑ Be responsible for any written or visual work that needs to be done
☑ Work with the reporter- who will have to present from your notes
</td>
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<td>

Reporter
</td>
<td>

Speaks on behalf of the group

☑ Work with the recorder to make certain you understand notes/diagrams
☑ Make sure you speak for the group (not just yourself)
☑ At the end of the report out, check back with your group members to make certain the important points were covered
☑ Ask questions on behalf of the group
</td>
</tr>
</table>

Rules of Attraction

Test Object	Attraction Prediction (Yes or No)	Result (Strong, Weak, No)

CLAIMS/EVIDENCE CHART

I claim ____________________because ____________________.

Statement (I claim…)	Observation/ Evidence (…because…)

STRENGTHS OF DIFFERENT MAGNETS

In the space below, create a graph showing the results from your exploration of magnetic strengths. Think about the scale you will use appropriate for your data. Remember to label the X and Y-axis.

Measure the Distance Between Magnets (in mm)

	2 magnets	3 magnets	4 magnets	5 magnets	6 magnets
Between Magnet 5 & 6					
Between Magnet 4 & 5					
Between Magnet 3 & 4					
Between Magnet 2 & 3					
Between Magnet 1 & 2					

THE DISTANCE BETWEEN MAGNETS

Use the data you gathered to create a graph showing your results. Think about the scale you will use appropriate for your data. Remember to label the X and Y-axis.

Magnet Exploration--Sketch

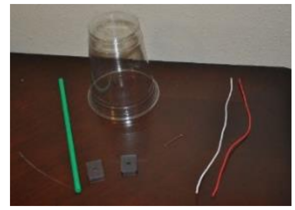
Demonstrate what you learned about magnets in a labeled sketch. Then explain your sketch using the following terms: **permanent magnet, north pole, south pole, repel, attract, move, force.**

What do you think would happen if you put these ends of the magnets together? Be sure to explain your thinking. (I claim __________ because______________.)

A. 	B. 
C. 	D. 

BUILD YOUR OWN DEVICE

1. Gather all your materials: 1 plastic cup, 1 straw, 1 pin, 2 magnets, 2 pieces of coated wire, 1 piece of masking tape.



2. Label the masking tape with your group number and attach it to the plastic cup.

3. Take the two pieces of different-colored wire. Bend each wire in half around your finger.

4. Arrange the magnets so that they are attracted side by side on the edges.

5. Push the open ends of one wire about one third of the way through the hole in the center of one magnet. Repeat this procedure with the other wire and the other magnet.

6. Without disturbing the wire, pull the two magnets apart but not too far.

7. Separate the open ends of the wire and wrap each end around the long sides of the magnet to hold the magnet in place.

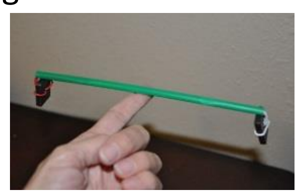
8. Bend the loop part of the wire up over the top of each magnet.

9. Double-check your work. Make sure the sides of the magnets away from the loop will attract each other. When the looped ends of the magnets are pointing in opposite directions, the magnets should attract.

10. If they repel (push away) go back to Step 5. Remove the wire from one of the magnets, turn it over and rewire it. Then go to Step 9 to check again.

11. Insert the looped ends of the wires into the ends of the straw.

12. Balance the straw on your finger.



13. Very carefully note the spot where your finger is balancing the straw.

14. Push the pin down through the straw at that balancing place so that the end just goes a tiny bit all the way through, showing 5mm of pin beneath the straw. If more than one or two holes are made in the straw, the pin will slip. If you put two holes in the straw and still cannot get it to balance, try another straw.

15. Turn the plastic cup upside down and GENTLY place the pin ON TOP of the cup. (IMPORTANT: DO NOT push pin INTO the cup!)

16. Balance the straw on top of the cup.

17. Push or pull the magnets a little bit at the ends of the straw as needed. Rotating or twisting slightly may help. Adjust one thing at a time until a balance is reached.

Group Work Rubric

	1 = Below Basic	2 = Basic	3 = Proficient
Task Completion	Group had great difficulty creating a product	Group created an end product that included some required components	Group successfully created a fully functional product containing all required components
Cooperative Group Work	Group had trouble working together as a team	Group had some challenges working together but resolved enough to complete the task	Group worked cooperatively to successfully complete the task
Communication	Group communicated limited observations	Group communicated some general observations, ideas, etc.	Group successfully communicated thorough observations, ideas, etc.

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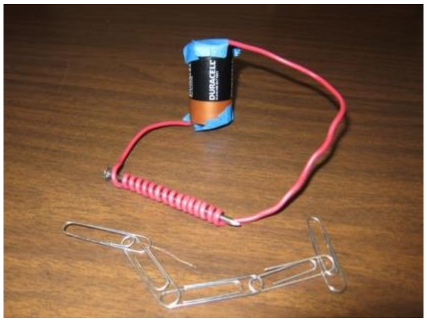
BUILD AN ELECTROMAGNET



1. Wrap the wire in a tight, even coil around the bolt. Leave 3 or 4 inches of wire loose at each end. Keep wrapping the wire until you get to the end of the bolt. (There may be as many as 3 or 4 layers of wire all the way up and down on short bolts.)

2. Tape one end of the wire to the positive (+) end of the battery. Place a piece of tape to the other end of the wire. When you need to turn on the electromagnet apply the taped wire to the negative end (-) of the battery.

******Be sure to disconnect your electromagnet when it is not in use. Leaving the wires connected will create heat and drain your battery.***

EXPLORE

Use your electromagnet to pick up a paperclip. What happens? Unhook one of the wires from the battery. Will your electromagnet pick up a paper clip now? Why? What do you need flowing through the wire to make the iron bolt act like a magnet?

- How many paper clips will your electromagnet hold? Can you hang clips on both ends of the bolt? Why?

After using the electromagnet, remove the bolt. Can the bolt still pick things up? How many paper clips or staples can it pick up? Try dropping the bolt a couple of times on the floor. How might this affect whether or not you can pick up any paper clips? How many paper clips can the bolt pick up after being dropped?

Remember to write notes/observations in your science notebooks.

Testing for Magnetic Field (coiled wire only- no core)

3. With the electromagnet off, move the compass near the wire. What happens?
4. Now place the compass under the wire so that the wire runs the same direction as the needle is pointing. (You may have to bend the wire to do this) Then turn the electromagnet on. What happens? Why do you think this happens?

- What happens when you turn the electromagnet off?

Explore the effects of moving the compass closer or farther from the wire and placing it at different points in the circuit. This is called an *electromagnetic coil.*

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Planning an Investigation

Variables That Could Change

Things That Could Be Measured or Observed

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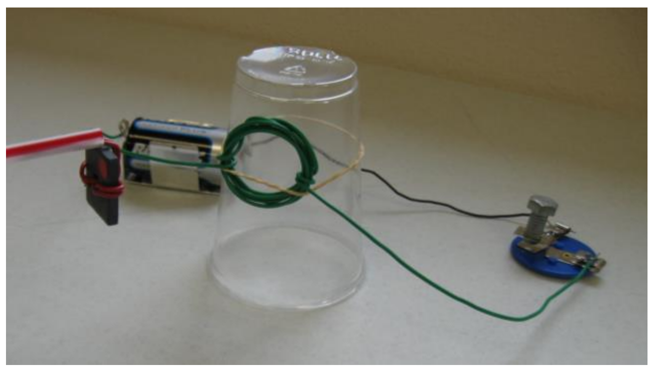
Design Your Own Experiment
Question:
Variable that will change:
Variables that will stay the same:
Materials:
Data to collect:
What will be observed:
Hypothesis (an idea based on what you know that has not yet been tested):

Can You Make a Simple Motor?

1. Use the straw device from lesson 5.

2. Next, create a magnetic coil using a piece of wire that is 1.5 m long; create the coil by wrapping it around a D-cell sized battery. Leave 3-4 inches loose at each end. Show students a sample coil (in kit).

3. Attach it to the side of the inverted plastic cup with the two rubber bands. Connect the coil to the battery and the switch. With the 20-cm wire, connect the switch and the battery. Position the coil two finger-widths away from the north-seeking pole of the magnet of the straw device.



- What effect does the coil have on the magnet when the switch is open?

Push the switch to the closed position so that electricity will run through the coil.

- What effect does the coil have on the magnet when the switch is closed?
- Is the north magnet attracted to or repelled by the coil?
- Which pole of the electromagnet do you think is closer to the straw device? What makes you think that?

4. Now, position the south-seeking pole magnet next to the coil. Can you predict what will happen when you turn the switch on? Try it!

- Using this information, can you make the straw device spin?
- Can you make it spin more quickly? What method did you use?

Agree/Disagree

STATEMENT	What did we do in class? How else might you find out?
1. **All magnets have 2 poles.** ___ agree ___disagree ___ not sure ____I think it depends on: My thoughts:	
2. **All metals are attracted to magnets.** ___ agree ___disagree ___ not sure ____I think it depends on: My thoughts:	
3. **Larger magnets are stronger than smaller magnets.** ___ agree ___disagree ___ not sure ____I think it depends on: My thoughts:	
4. **Magnetism can pass through materials.** ___ agree ___disagree ___ not sure ____I think it depends on: My thoughts:	

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GRAFFITI PAGE

In the space below, write down important science words or phrases that jump out at you while watching the science video. What did you learn? What are key elements to remember? You may use colored pencils, markers, pens, or crayons.

EXIT CARD

Name: ____________________

3 IMPORTANT FACTS I LEARNED ABOUT THE SANFORD UNDERGROUND RESEARCH FACILITY

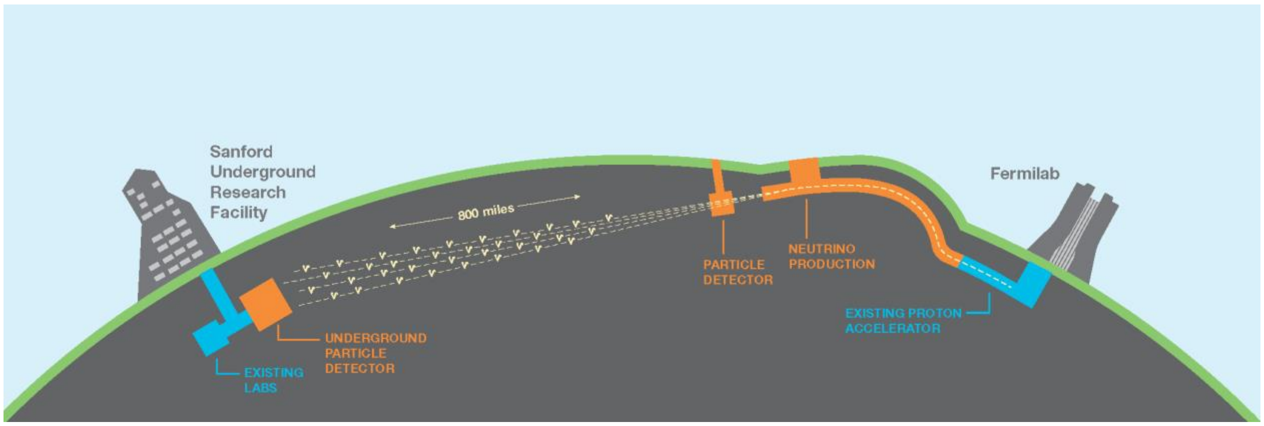
2 QUESTIONS I STILL HAVE

1 CONNECTION I CAN MAKE TO MY LIFE

May the Force Be With You

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Read the following article to learn more about the DUNE experiment at the Sanford Underground Research Facility. Be sure to use the text features to help you gather information and better understand what will happen.



The Sanford Underground Research Facility (SURF) in Lead, SD, partners with Fermilab in Batavia, Illinois, on a major project involving more than 1000 scientists from around the world. This will require Fermilab's particle accelerator, which will send a beam of neutrinos to a detector deep underground at SURF. Particle accelerators use electric fields to speed up and increase the energy of a beam of particles, which are steered and focused using magnetic fields. Because neutrinos travel close to the speed of light, it will only take a fraction of a second to travel the 800 miles! (.004 seconds in fact.)

Neutrinos are one of the fundamental particles that make up the universe. *They* are teeny, tiny, nearly massless particles that travel at near light speeds. They are so small that they are less than 1/500,000th of an electron. Because of their minute size, neutrinos are often referred to as "ghost particles." Studying *neutrinos* is difficult. They are tough to detect for many reasons: 1) they are so tiny, 2) they have no charge, and 3) they interact very weakly with other particles.

In fact, *neutrinos* interact so weakly that they can travel through 100,000 earths before interacting at all! Because they hardly ever collide with other particles and have no charge, they can only be detected indirectly. On rare occasions, they interact with charged particles that we *can* detect and measure. Therefore, detectors must be *huge* to increase the chance of finding any evidence of neutrinos.

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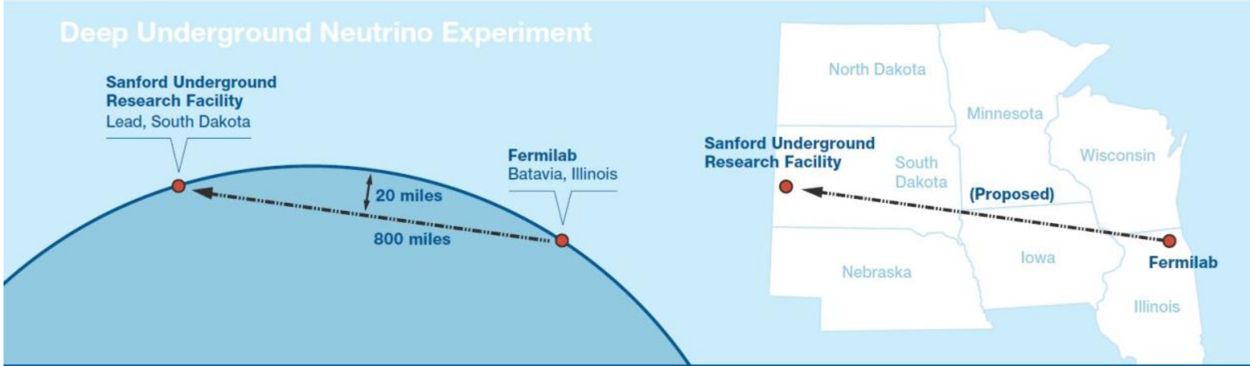
The detector at SURF will be a scientific feat that involves a lot of problem solving, including how to build massive caverns for big experiments like the Long-Baseline Neutrino Facility and associated Deep Underground Neutrino Experiment (LBNF/DUNE). Geologists have studied the rock at SURF and it turns out it is strong and solid, making it perfect for excavating large caverns. It also has very little radiation to interfere with the signals in the detectors. Two caverns, each more than 500 feet long, will house 70,000 TONS of liquid argon. Another cavern that is more than 600 feet long will house utilities. Engineers will need to remove about 800,000 TONS of rock! It will take about 3 years to move all that earth.

Since argon is a noble gas, they have to cool it to make it liquid. The temperature of the argon must be kept at -301 degrees Fahrenheit! That's another challenge: Keeping all that gas that cold so it stays a liquid for a very long time! As you can imagine, there are many innovative minds at work on this project.

There is another strange thing about neutrinos. There are three known types, or flavors, of neutrinos. These neutrinos can change between flavors as they travel, which is a mystery to scientists. Scientists are eager to learn more about this. They will be sending one type of neutrino beam from Illinois to South Dakota, but anticipate that when the neutrinos arrive, some will change flavors along the way.

Construction on LBNF/DUNE is set to begin in 2017 and years of work are involved in preparation. In fact, it is not expected to start until 2026. Once the detector is up and running, it will be ready to receive the beam of neutrinos sent from Fermilab for at least ten years so scientists will have enough data to make new discoveries. During that time they hope to learn more about neutrinos, which will help us better understand the origins of our universe.



The proposed Long-Baseline Neutrino Facility would send neutrinos straight through the earth from Fermilab in Batavia, Illinois, to the Sanford Underground Research Facility in Lead, South Dakota. Scientists would use the neutrino beam for the proposed Deep Underground Neutrino Experiment. The neutrinos travel straight through rock and don't require a tunnel for their 800-mile-long trip.

Name________________________________ #_____ Date____________________

Straw Apparatus

During this unit, you have had some time to practice thinking like a scientist. You have also learned new terminology. In the box below, make a labeled sketch of what you saw happening. Why did the straw spin? Create a model explaining the movement. Drawings, arrows, and words may be used to show your thinking and demonstrate your new knowledge. Remember to use the checklist below.

SCIENCE NOTEBOOK CHECKLIST

★★★★★

__My information is accurate.

__I clearly presented the key elements.

__I supported my thinking with evidence.

__I used labeled models, diagrams, charts, and/or graphs to communicate my thinking.

__I used science words.

SCIENCE NOTEBOOK OVERVIEW

Scientists use journals or notebooks to record their ideas, questions, and models in a variety of ways. Like scientists, students will use their notebooks to record their thinking throughout the unit. The science notebook is a special place where students may record data, make observations, create graphs, use charts, attach information, draw sketches, label diagrams, keep handouts, etc. Teachers may also want to take advantage of the notebooks to enhance the science content focus with literacy skills (restate main idea/detail, write a poem about your science topic sharing your learning, write a letter from the point of view of an element, etc.) Students enjoy having a special booklet for science.

Science notebooks may be created by making copies of the following templates along with the unit handouts and putting them into folded or stapled booklets. Multiple copies of specific pages can be made. Notebooks may be made simply using folded construction paper as a cover (9” x 18”) with blank 8 ½” x 11” paper inside. (A science notebook may also be a spiral notebook or composition book that is set up during the first days of school with numbered pages containing a Table of Contents, Glossary, and/or Index.) If the templates are used as a packet or booklet to give to students, the Science Notebook Rubric may be included inside the front cover so students will understand expectations. Make sure the science notebook is large enough to handle attaching handouts with glue stick or tape. Teachers may want to read through the unit to see which sheets they want to attach in the booklet, and which they might collect separately or send as homework. Some teachers use one booklet per unit; others use one for the whole year.

Note: There is only one general Science Notebook page for notes and drawings (after Table of Contents). This page has a checklist included on the document to remind students of expectations for entries. Teachers will want to run several copies for students to use (2 per lesson minimum is recommended). Alternatively, checklists are available at the end of the document if teachers already have a science notebook system in place.

SCIENCE NOTEBOOK

Name: ______________________

Teacher: ___________________

SANFORD UNDERGROUND RESEARCH FACILITY

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SCIENCE NOTEBOOK RUBRIC

	1 Below Basic	2 Basic	3 Proficient	4 Advanced
Science Content	Inaccurate; Based on misconceptions about ideas in science	Mostly accurate; Connections to big ideas are not evident	Accurate; Connected to big ideas in science	Elaborate; Connected to big ideas and other related science content, real-world applications or other subject areas
Communication and Organization Of Big Ideas	Ideas may be focused on isolated details rather than main ideas	Some main elements are presented	Main elements are clearly presented	Connections to main elements are presented
	Ideas are presented in an order that distracts from clarity	Ideas are not presented in an appropriate order	Ideas are presented in an appropriate order	Ideas are presented in an effective order with logical connections
	Ideas may not be related to evidence or may contain minimal information	Some ideas are supported by evidence	Ideas are supported by evidence	Ideas are clearly supported by evidence
	Conclusions are missing or unrelated	Conclusions do not follow from ideas information presented	Appropriate conclusions are based upon evidence presented	All conclusions are based upon evidence presented and correctly inferred
Presentation	Attempts to express ideas in words or pictures. May need guidance to complete journal entry	Some appropriate use of labeled models, diagrams, charts, and/or graphs and text	Effective use of labeled models, diagrams, charts, and/or graphs and text	Labeled models, diagrams charts, and/or graphs and text are integrated to tell a complete story
Use of Science Language	Inaccurate use of science language; uses vague language or terminology or lacking science words	Uses a combination of appropriate science language and general everyday language	Consistent use of appropriate science language and terminology	Precise and clear use of scientific language and terminology that enhance the communication

Table of Contents

Page(s)	Title/Topic	Date(s)

May the Force Be With You

Date______________________________ Page ________

SCIENCE NOTEBOOK CHECKLIST

★★★★★

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__I used science words.

SCIENCE NOTEBOOK PROCESS

My question: ____(Question)

Today I/we want to find out ___________________________________ (Problem)

I think ____________________ will happen *because*______________ (Prediction)

I noticed/observed____ (Observation)

I claim ____*because*

____ (Claims & Evidence)

Today I learned ____(Conclusion)

I wonder ____(Reflection)

Questions I have now are ______________________ (Next Steps/New Questions)

SCIENCE NOTEBOOK CHECKLIST

Name____________________

SCIENCE NOTEBOOK CHECKLIST

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