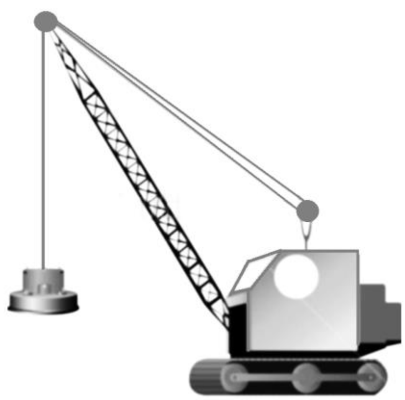
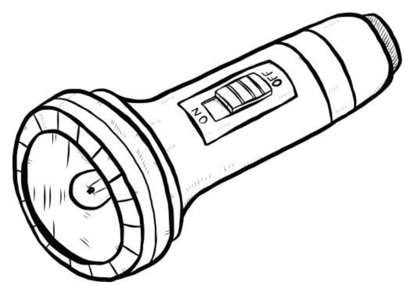
STC MAGNETS & MOTORS KIT

TEACHER GUIDE REVISIONS





Junkyard Magnets & Shake Flashlights

Exploring the relationship between electricity and magnetism

Unit Overview: Part 1

Electric Current Induces Magnetism

Lesson	Kit Curriculum	Lesson Title	Time*
A	ADDED	Eliciting Ideas: Developing initial models to explain how a junkyard magnet works	2 x 45 mins
B	Kit Lesson 2	What can magnets do?	1 x 45 mins
C	Kit Lesson 3	How can you find out what magnets do?	2 x 45 mins
D	Kit Lesson 4	Measuring Magnets	2 x 45 mins
E	Kit Lesson 7	Creating Magnetism through Electricity	2 x 45 mins
F	Kit Lesson 8	Making Magnets with Electricity + Readings/Videos	2-3 x 45 mins
G	Kit Lessons 9,10,11	Planning, conducting, and communicating results of an experiment to test the strength of an electromagnet	3 x 45 mins
H	ADDED	Revising models to explain junkyard magnet & written explanations	3-4 x 45 mins

* Lessons typically span two 45-min class periods to allow time for exploring the activity, making sense of the observations, and creating a public record of what students have learned so far. One day of the lesson would be focused on the activity itself and the second day focuses on talk and writing around these new ideas and how they help us make sense of the phenomenon.

Unit Overview: Part 2

Magnetism Induces Electric Current

Lesson	Kit Curriculum	Lesson Title	Time*
I	ADDED	Eliciting Ideas: Developing initial models to explain how a shakelight flashlight works	2 x 45 mins
J	ADDED	What's a generator? How do generators work?	2-3 x 45 mins
K	ADDED	What's a capacitor? How do capacitors work?	2-3 x 45 mins
L	ADDED	Revising models to explain the shakelight phenomenon & written explanation	2 x 45 mins

MS-PS2 Motion and Stability: Forces and Interactions

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Students who demonstrate understanding can:

MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]

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

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

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS2-2)
- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation. (MS-PS2-5)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Apply scientific ideas or principles to design an object, tool, process or system. (MS-PS2-1)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-PS2-4)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2),(MS-PS2-4)

Disciplinary Core Ideas

PS2.A: Forces and Motion
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

PS2.B: Types of Interactions
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4)
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)

Systems and System Models
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. (MS-PS2-1),(MS-PS2-4),

Stability and Change
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-PS2-1)

Connections to other DCIs in this grade-band: **MS.PS3.A** (MS-PS2-2); **MS.PS3.B** (MS-PS2-2); **MS.PS3.C** (MS-PS2-1); **MS.ESS1.A** (MS-PS2-4); **MS.ESS1.B** (MS-PS2-4); **MS.ESS2.C** (MS-PS2-2),(MS-PS2-4)

Articulation across grade-bands: **3.PS2.A** (MS-PS2-1),(MS-PS2-2); **3.PS2.B** (MS-PS2-3),(MS-PS2-5); **5.PS2.B** (MS-PS2-4); **HS.PS2.A** (MS-PS2-1),(MS-PS2-2); **HS.PS2.B** (MS-PS2-3),(MS-PS2-4),(MS-PS2-5); **HS.PS3.A** (MS-PS2-5); **HS.PS3.B** (MS-PS2-2),(MS-PS2-5); **HS.PS3.C** (MS-PS2-5); **HS.ESS1.B** (MS-PS2-2),(MS-PS2-4)

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions *(MS-PS2-1),(MS-PS2-3)*
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS2-1),*(MS-PS2-2),*(MS-PS2-5)*
WHST.6-8.1	Write arguments focused on *discipline-specific content.* (MS-PS2-4)
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *(MS-PS2-1),*(MS-PS2-2),*(MS-PS2-5)*

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-PS2-1),(MS-PS2-2),(MS-PS2-3)
6.NS.C.5	Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS2-1)
6.EE.A.2	Write, read, and evaluate expressions in which letters stand for numbers. *(MS-PS2-1),(MS-PS2-2)*
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-PS2-1),(MS-PS2-2)*
7.EE.B.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-PS2-1),(MS-PS2-2)*

PART 1 - UNIT PHENOMENON – Why does a junkyard magnet work?

TEACHER BACKGROUND

Information from: http://www.answerbag.com/q_view/1905700
Electromagnets are used in many ways for many everyday activities. Some electromagnets are used in household devices while others have more heavy-duty jobs. One heavy-duty way we use electromagnets is in junkyards.

- **Uses** Electromagnets are used in junkyards to move large amounts of scrap metal, such as iron and steel. No natural magnet could ever lift such heavy scrap metal, but electromagnets are made to be strong enough with the help of electricity.
- **How Electromagnets Work** An electromagnet works like a regular magnet, but it is controlled by an electric force. The amount of electricity applied to the magnet determines the magnet's strength. Electricity is pushed into the magnet through coiled wire around the magnet's core. Stronger magnets have more electric wire.
- **Controlling the Magnet** Because electricity is utilized to control an electromagnet's strength, the user can switch the electricity on to make the magnet pick up junk and turn it off to make the magnet drop the junk.
- **Appearance** Electromagnets are made of iron. They are very large and generally circular. They hang from a crane.
- **Cranes** In a junkyard, a crane with a giant electromagnet hanging from it is lowered near junk until the force of the magnet picks up the junk. The crane is then lifted, and the junk is driven to the desired location.

Information from: http://electromagneticcrane.com/
An electromagnetic crane is a type of crane with an electromagnetic lift. Electromagnetic cranes are commonly utilized in lifting and moving various scrap metals. It does not have the mechanical 'pincers' of a regular crane, instead, it has a large flat magnet which draws the metallic materials to it. Using the principle of electromagnetic induction, these large machines are used to handle scrap ferrous metals, such as iron and steel, which can be found in junk yards and recycling plants. Beyond the area of lifting magnetic materials, another use of an electromagnetic crane is that it makes for smooth and safe stops due to its solenoid brakes (electrically controlled brakes which can be turned on and off by a solenoid). These brakes are the ones being used on movable bridges as it allows the passage of boats and barges.

How The Electromagnetic Crane Works:

An electromagnet is a type of magnet wherein the magnetic field is produced by electric current, and the field disappears whenever the current is turned off. Electromagnets are being utilized in everyday items, just like loudspeakers and doorbells. An electromagnetic crane has a large electromagnet which can be turned on and off. The electromagnet contains an iron core with a wire around it, and this wire is the medium by which the current travels. The magnetic strength of an electromagnet relies on the number of turns of the wire around the electromagnet's core, the current through the wire and the size of the iron core. Increasing these elements will result in an electromagnet which is significantly larger and stronger as compared to a natural magnet (which explains the enormous size of the crane's magnet). For the electromagnet to be turned off, the core must be made of soft iron. Therefore, turning on the electricity will enable the magnet to work, and turning off the electricity will be able to shut it down.

Theory of Magnetism

The effects of magnetism have been known and used for centuries. Yet scientists still do not know exactly what magnetism is. The theory of magnetism that follows is based on one proposed by Pierre Weiss, a French physicist, in the early 20th century.

Every magnetic substance contains domains, groups of molecules that act as magnets. Before a substance is magnetized, these domains are arranged randomly, so that the magnetism of one is cancelled by the magnetism of another. When the substance is brought within a magnetic field, the domains line up parallel to the lines of force, with all the N poles facing in the same direction.

When the magnetic field is removed, the like poles tend to repel each other. In a substance that is easily magnetized, the domains turn easily, and will return to random ordering. In a substance that is difficult to magnetize, the domains will not have enough force to disarrange themselves and the substance will remain magnetized. In modern versions of this theory, the magnetism of the domains is attributed to the spin of electrons.

How Magnets Are Made

There are four main ways to magnetize a magnetic substance: (1) bringing the substance near a magnet; (2) using electric current; (3) stroking the substance with a magnet; and (4) striking a blow to the substance while it is in a magnetic field. The first two methods were discussed above in "temporary magnets" section.

A permanent magnet can be made by stroking a magnetic substance with either the N or the S pole of a magnet. Stroking lines up the domains in the material. A piece of iron can be magnetized by holding it parallel to a compass needle (along the lines of force in the earth's field) and hitting the piece of iron with a hammer. The blow will overcome the resistance of the domains to movement, and they will line up parallel to the earth's field. To demagnetize an object, a strong magnetic field is used. In one method, the magnetic field is made to fluctuate very rapidly. In another method, the magnetized object is placed so that a line drawn between its poles would be at right angles to the field. The object is then tapped or hit until its domains are no longer lined up magnetically.

Information from: http://science.howstuffworks.com/magnetism-info2.htm

Permanent and Temporary Magnets

There are two basic kinds of magnets—permanent and temporary. A permanent magnet retains its magnetic properties for a long time. A temporary magnet acts as a magnet only as long as it is in the magnetic field produced by a permanent magnet or an electric current. Magnetic materials from which permanent magnets are made are called hard magnetic materials and those from which temporary magnets are made are called soft magnetic materials.

Permanent Magnets

A lodestone is a naturally occurring permanent magnet composed of magnetite, an iron-bearing mineral. Such magnets have been known since ancient times. Virtually all magnets used commercially today are made from synthetic magnetic materials. The most common such materials are alnicos—iron alloys containing aluminum, nickel, and cobalt. Magnetic materials containing such rare-earth elements as samarium or neodymium form very strong permanent magnets. Ferrites, which consist of ferric oxide (an oxide of iron) combined with the oxides of one or more other metals, are widely used in electronic devices. Flexible magnets are made by combining magnetic materials with plastics. Permanent magnets are typically made into U-shaped horseshoe magnets, with the poles side by side; and bar magnets, with the poles at opposite ends.

Temporary Magnets

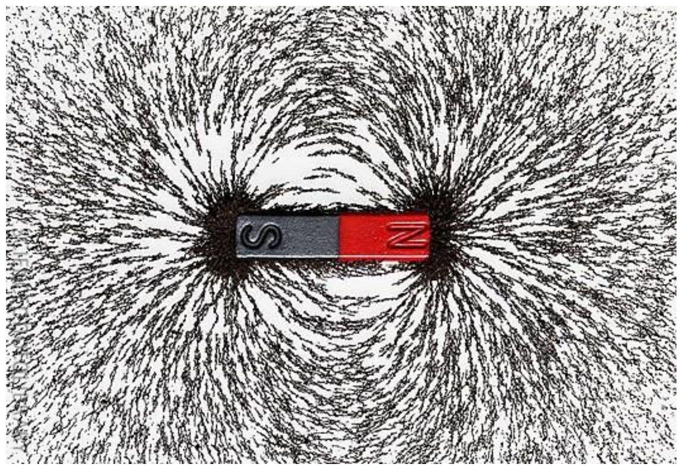
Every object that is lifted or moved by a magnet acts as a temporary magnet. Such an object ordinarily loses its magnetism when the permanent magnet is removed, although in certain cases it will retain weak magnetic properties. An electromagnet is a temporary magnet that is magnetized by the magnetic field produced by an electric current in a wire. Electromagnets have magnetic properties only while the current is flowing.

SCIENCE BACKGROUND FOR TEACHERS – GENERAL CONTENT KNOWLEDGE

(from free, online e-book A Framework for K-12 Education www.nap.edu)

Forces of Magnetism & Electromagnetism

All forces between objects arise from a few types of interactions: gravity, electromagnetism, and strong and weak nuclear interactions. Collisions between objects involve forces between them that can change their motion. Any two objects in contact also exert forces on each other that are electromagnetic in origin. These forces result from deformations of the objects' substructures and the electric charges of the particles that form those substructures (e.g., a table supporting a book, friction forces).



Electric current flows through the wire, turning it into an electromagnet. The magnetic field around the wire interacts with the needle in the compass, causing it to move.

Forces that act at a distance (gravitational, electric, and magnetic) can be explained by force fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). Gravitational, electric, and magnetic forces between a pair of objects do not require that they be in contact. These forces are explained by force fields that contain energy and can transfer energy through space. These fields can be mapped by their effect on a test object (mass, charge, or magnet, respectively). Electric forces and magnetic forces are different aspects of a single electromagnetic interaction. Such forces can be attractive or repulsive, depending on the relative sign of the electric charges involved, the direction of current flow, and the orientation of magnets. The forces' magnitudes depend on the magnitudes of the charges, currents, and magnetic strengths as well as on the distances between the interacting objects. All objects with electrical charge or magnetization are sources of electric or magnetic fields and can be affected by the electric or magnetic fields of other such objects. Attraction and repulsion of electric charges at the atomic scale explain the structure, properties, and transformations of matter and the contact forces between material objects (link to PS1.A and PS1.B). Coulomb's law provides the mathematical model to describe and predict the effects of electrostatic forces (relating to stationary electric charges or fields) between distant objects.

Objects in contact exert forces on each other (friction, elastic pushes and pulls). Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact—for example, magnets push or pull at a distance. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

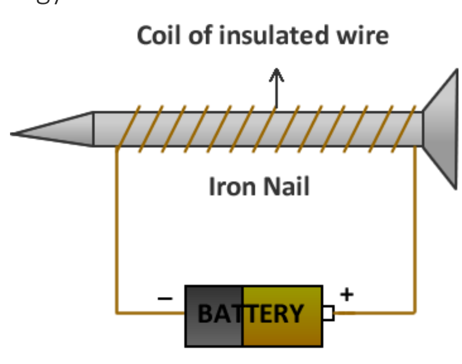
Energy Story related to Magnetism & Electromagnetism

At the macroscopic scale, energy manifests itself in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy. Historically, different units were introduced for the energy present in these different phenomena, and it took some time before the relationships among them were recognized. Energy is best understood at the microscopic scale, at which it can be modeled as either motions of particles or as stored in force fields (electric, magnetic, gravitational) that mediate interactions between particles. This last concept includes electromagnetic radiation, a phenomenon in which energy stored in fields moves across space (light, radio waves) with no supporting matter medium.

Electric and magnetic fields also contain energy; any change in the relative positions of charged objects (or in the positions or orientations of magnets) changes the fields between them and thus the amount of energy stored in those fields. When a particle in a molecule of solid matter vibrates, energy is continually being transformed back and forth between the energy of motion and the energy stored in the electric and magnetic fields within the matter. Matter in a stable form minimizes the stored energy in the electric and magnetic fields within it; this defines the equilibrium positions and spacing of the atomic nuclei in a molecule or an extended solid and the form of their combined electron charge distributions (e.g., chemical bonds, metals).

Energy stored in fields within a system can also be described as potential energy. For any system where the stored energy depends only on the spatial configuration of the system and not on its history, potential energy is a useful concept (e.g., a massive object above Earth's surface, a compressed or stretched spring). It is defined as a difference in energy compared to some arbitrary reference configuration of a system. Any change in potential energy is accompanied by changes in other forms of energy within the system, or by energy transfers into or out of the system.

At the macroscopic scale, energy manifests itself in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy. Energy is also stored in the electric fields between charged particles and the magnetic fields between magnets, and it changes when these objects are moved relative to one another. Stored energy is decreased in some chemical reactions and increased in others.



SIMPLE ELECTROMAGNET

A. ELICITING IDEAS & INITIAL MODELS (added lesson, not in TG)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS* (See below)*
Why can the magnet start and stop working?	Junkyard magnets picks up hub caps. The hub caps stick to each other. The junkyard magnet can drop the hubcaps. Magnet will pick up washers. The magnet can't drop the washers.	Magnets attract objects.	(Initial models & hypotheses about the causes of the phenomenon)	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact MS-PS2-3: Factors that affect the strength of magnetic forces

Teacher Background

For the explanation of the junkyard magnet, see the teacher explanation pages. Briefly, there are key science ideas students will develop an understanding of in this unit beginning today:

1. Forces, such as magnetism, act at a distance. These forces fields that extend from an object and can be mapped and represented.

2. Non-magnetic metals can temporarily become magnetic if an electric current is passed through them. When the current stops, the metal loses its temporary magnetic properties. This can be partially explained using the idea of energy transfer and the particulate nature of matter.

Next Generation Science Standards (NGSS)

Performance Standards
MS-PS2-5: Fields exist bet. objects exerting forces on each other even though the objects are not in contact
MS-PS2-3: Factors that affect the strength of magnetic force

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Developing and Using Models - • Develop a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.	PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)

Materials

- Junkyard magnet Video clip #1 https://www.youtube.com/watch?v=XBWy9gzGGd4 (found also at http://goo.gl/aXnN8P)
- Junkyard magnet video clip #2 https://www.youtube.com/watch?v=N9XoUGxM2h0 (found also at http://goo.gl/qCUXAK)
- Model scaffold sheet (1 copy per student or per partner pair)
- Pencils (colored pencils optional)
- Chart paper and markers (for recording initial observations and ideas)
- magnets and washers per pair

Procedure – Day 1

1. **Opening – Whole Group (5 minutes)**
    a. Introduce the new unit using the junkyard magnet video #2 explaining that in this unit we will be exploring and testing different ideas to explain how this junkyard magnet works.
    b. Play video clip and have students write down 2 things they observe about the junkyard magnet in their notebook and any questions they have.

2. **Phenomenon Observations – Whole Group (10 mins)**
    a. Next play video clip #1. Give students time to make specific observations. Pair-share observations in partners before sharing out to create a list.
    b. On chart paper, create a class list of observations from the video (things students can directly see or hear). *Option: Have students come up and write on the chart (instead of the teacher leading the writing). A student recorder can write the whole list or students can take turns.*

3. **Initial Observations – Partner (15 minutes)**
    a. Pass out magnets and washers per pair of students.
    b. Have students make some observations about how many washers they can pick up and how this is similar or different than the junkyard magnet they observed in the video.
    c. As students work, teacher circulates and asks any of the following questions:
        i. What do you notice about the washers near the magnet? Why do you think they do that? How far away from the washers can the magnet be to still work?
        ii. What do you think is making the washers stick together? Why do you think they won't stick to each other when the magnet isn't there?
        iii. What is similar to the video? Different?

> Junkyard Magnet Observations
>
> - The magnet picks up the metal hubcaps.
> - The hub caps stick to each other when they are touching the magnet
> - The junkyard magnet can drop the hubcaps.
>
> Magnet & Washer Observations
>
> - Magnet will pick up washers.
> - The magnet can't drop the washers unless we pull them off.
>
> Questions
>
> - The small magnet can't drop the washers but the junkyard magnet can, how come? How can a magnet stop pulling?
> - What makes something magnetic?
> - Why aren't all metals magnetic?
> - Why do magnets mess up computers?

4. Individual Ideas – Science Notebook Entry (10 minutes)
    a. Students write about what they observed today with the magnets and washers and how it is similar or different to the junkyard magnet video. Many students may be beginning their personal theories of how the junkyard magnet works and how it can seemingly turn on and off even though the magnets they explored with are only "on".
    b. Encourage students to make a sketch and complete a few sentences about today's introduction to the unit in their science notebook. Sentence starters for notebook entry:
        i. The magnet caused the washers to ________ because....
        ii. The junkyard magnet caused the metal to __________ because…
        iii. These two magnets are similar when they…
        iv. These two magnets are different because....

Procedure – Day 2

1. Opening – Whole Group (5 minutes)
    a. Reintroduce junkyard magnet video clip http://goo.gl/aXnN8P and have students read over their notebook entry from part 1 of this lesson. Refer to the list of observations and questions from the previous day.

2. Recording Initial Hypotheses – Whole Group (15 mins)
    a. Think-Pair-Share: Why can the junkyard magnet start and stop working? What's happening that we can't see that could cause this? Set a timer for 3 or 4 minutes and have the video replaying during this time. Students watch, think, and partner share about this question.
    b. Listen in as students share to hear the different kinds of ideas or hypotheses. Think about who you want to call on to share out in whole group – look for a variety of ideas even if they are opposing or different.
    c. Have students share their ideas and create a list. Students may find it helpful to refer to this list and the list of observations created in Part 1 as they get to work on their models in the next step.

> Our Initial Ideas
> How does a junkyard magnet work?
>
> - The magnet can pick up some metals and this magnetism must go through them to grab more and more hubcaps.
> - Unlike the small magnet, the junkyard magnet can drop the hubcaps, maybe the magnet has a switch to turn it on and off?
> - It has to be a really big magnet because a bigger magnet would be strong enough to lift cars and scrap and other junkyard stuff
> - The junkyard magnet has to move down near the pile of metal to pick it up - it has to be close to the metal.

3. Developing Models (25 minutes)
    a. Pass out model scaffold sheets (1 per student or 1 per pair).
    b. Explain to students that their job is to show what they can observe from the video on their paper and label the parts they draw. More importantly, it's to somehow represent or draw what they can't see that they think is causing the magnet to work this way. How can the junkyard magnet pick up and drop off metal pieces with our little magnet could only pick them up?

c. As students discuss and work in pairs, circulate and observe the different hypotheses students have, encouraging students to represent what they can't see but they think is happening.
d. Midway through this time, select 2 pairs or students to share one specific piece (not the whole thing) of their model with the class under the doc cam. Have a reason for the student(s) to share. For example, maybe two different students/pairs did clear representations of magnetism since it's not something we can directly observe and their representations are different. Another example could be how students are explaining causes in words and in their model. This sharing step mid-point during model development helps students see each other's' work and perhaps get some ideas or questions they have to add to their own models.

Public Record from Activity

4. Review and Complete Public Records
   a. Ask for any final ideas to add to the list of initial ideas.
   b. Create a list of questions students have about this junkyard magnet or magnets in general. Students can put up sticky notes with their questions on a question chart or they can come up and write the question. This list of question can serve as a place to frame future activities as they find evidence and answers to their questions.

Planning for Future Instruction

After this lesson, use student work and what you remember from student talk during the lesson to fill out a Rapid Survey of Student Thinking (RSST). This tool helps teachers keep track of the partial ideas, alternative understanding, everyday language, and experiences that students have and which can be used in future lesson s to help students make changes to their understanding over time.

Rapid Survey of Student Thinking (RSST)

Directions: Complete the RSST either during class or right after a class.

Categories	Trends in student understandings, language, experiences [sample sentence starters included below]	Instructional decisions based on the trends of student understanding
Partial understandings What facets/ fragments of understanding do students already have?	List partial understandings: What approximate % of your students have these partial understandings?	★ Star the ideas on the list that need action. Instructional options: • Do further eliciting of initial hypotheses to clarify your understanding of students' partial understandings • Do 10-minute whole class whole class conversation of 2-3 key points elicited • Write multiple hypotheses on board and/or develop an initial consensus model
Alternative understandings What ideas do students have that are inconsistent with the scientific explanation?	List alternative understandings: What, if any, experiences or knowledge bases are they using to justify these explanations?	★ Star the ideas on the list that you *really* need to pay attention to based on the following criteria… 1. Which alt. conceptions seem deeply rooted (kids seem sure about)? 2. What % of kids think this? 3. Which are directly related to final explanation (not just a "side-story") Instructional options: • Do further eliciting about what experiences/frames of reference students are drawing on • Pose "what if" scenario to create conceptual conflict about validity of alt. ideas • Challenge students to think further/give them a piece of evidence to reason with • Target a lesson using "Teaching Practice 3" to address this alt. conception
Everyday language What terms did you hear students use that you can connect to academic language in upcoming lessons?	Cite examples: What approximate % of your students use these terms and phrases?	★ Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: • Use this language to reframe your essential question in students' terms • Use as label in initial models that you make public. Work in academic versions of these words into public models and discussions later.
Experiences students have had that you can leverage What familiar experiences did students describe during the elicitation activity?	What was the most common everyday or familiar experience that kids related to the essential question or task? What were the less common experiences students cited?	★ Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: • Re-write the essential question to be about this experience • Make their prior experiences a central part of the next set of classroom activities • If kids cannot connect science idea to familiar experiences they've had, then provide a shared experience all kids can relate to (through lab, video, etc.)

B. LESSON TWO: WHAT CAN MAGNETS DO? (TG pp 11 -14)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS*
What can magnets do?	Magnets stick together. Magnets can also push each other. Magnets even stick together when they are inside and outside the sides of the plastic cup. The magnets can stay on the string when it is vertical. It matters which ends of the magnets you put together.	Magnetic forces can be attractive or repulsive Magnets have two poles. Like poles attract and opposite poles repel.	Objects in the junkyard are attracted to the large magnet	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Next Generation Science Standards (NGSS)
Performance Standards
MS-PS2-5: Fields exist bet. objects exerting forces on each other even though the objects are not in contact

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Asking Questions • Ask questions that can be investigated within the scope of the classroom with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	PS2.B: Types of Interactions • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• *Cause and effect relationships* may be used to predict phenomena in natural or designed systems. (MS-PS2-5)

INTRODUCING THE LESSON:

In today's lesson students will explore properties of magnets by manipulating them along with other materials (plastic cup, string, straw, etc.) to see what magnets can do. You may wish to replay the junkyard magnet video clip to re-orient students to the phenomenon and explain that in the prior lesson many students were thinking about how to draw magnetism and how magnets work so today we will have time together to explore magnets.

OBSERVING:

In pairs or groups: Students explore and record their observations of magnets. Each group of students is provided with magnets, wooden stick, piece of string and a plastic cup with lid. Each group should record at least five observations. As students are exploring circulate among the groups and ask questions that assess and advance their thinking.

> Questions to ask students as they explore magnets in partners/groups:
>
> - What are you noticing?
> - Would it still work if…? Why/why not?
> - Where have you seen magnets used?
> - How could you use a magnet to keep a cabinet door closed?

Whole class: Record one observation on a class summary chart. Ask for a second observation that is similar to the first; i.e. demonstrates magnets pushing, pulling or poles and continue recording similar observations. Ask for a new observation that shows something different magnets can do and continue recording related observations. Add a third column on the chart for the remaining observations.

LEARNING:

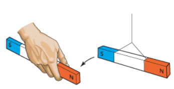
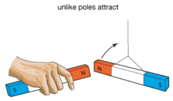
Think, Pair, Share – What can magnets do? Ask the students to use the observations on the chart to summarize what they have learned about magnets. Have students complete one of the short ½ page reading (copies can be taped into their science notebook – decide which reading you prefer students to have). Record the students' learning from observations and reading on the class summary chart. Record the students' learning on a class summary chart.

(OPTIONAL: Make observations of a magnetic field in this video: https://www.youtube.com/watch?v=CgDYx3B8c_I or this video https://www.youtube.com/watch?v=snNG481SYJw . Preview these videos and decide if you think this is just enough information or too much information right now. You can use these videos later on as well.)

CONNECTING:

A/B Partners – How does our learning help us understand the junkyard magnet phenomena? Partner A shares their ideas and Partner B responds by agreeing disagreeing or adding on to their idea. Partner B shares their ideas and Partner B responds. Ask students to share their partner's thinking and record their connections on the class summary chart.

Summary table row displayed in the classroom may look something like this…

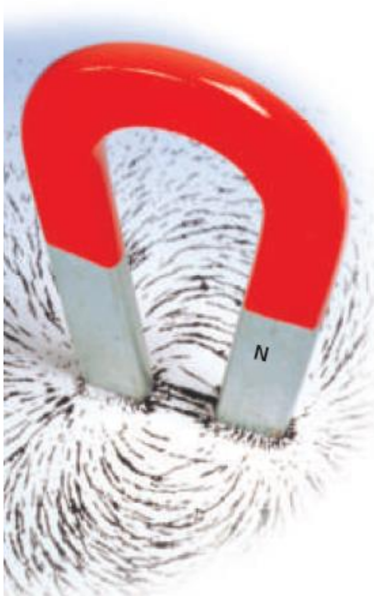
Activity	Observations	Learning	Connection
Exploring Magnets Question: What can magnets do?  unlike poles attract  like poles repel	Pull: ▪ Magnets stick together ▪ Magnets pull even if there is plastic between them Push: ▪ Magnets push each other. ▪ Magnets stay in place on the string even if you hold it up by one end Poles: ▪ You can make two magnets pull or push if flip around the magnet that is touching the other magnet	Magnets can push and pull other objects that are magnets. Magnets have poles that will pull (attract) together or push (repel) apart. Magnets have north and south poles	The junkyard magnet has a magnet that can pull on the metal hubcaps to pick them up.

Planning for Future Instruction

After this lesson, use student work and what you remember from student talk during the lesson to fill out a Rapid Survey of Student Thinking (RSST). This tool helps teachers keep track of the partial ideas, alternative understanding, everyday language, and experiences that students have and which can be used in future lesson s to help students make changes to their understanding over time. This RSST will be more focused around student understanding of magnets and the properties of magnets. You may also want to note questions students have that could relate to one of the next few lessons on magnets and magnetism.

Magnetic Fields

You know that charges can attract or repel particles among atoms. But atoms can also be attracted and repelled. This happens often inside iron, cobalt, steel, and nickel.



A magnet is anything that attracts other things made from iron, steel, and certain other metals. **Magnetism** is a force that can push or pull certain metals that are near a magnet.

Magnets are surrounded by an invisible field. This field of attraction is a magnetic field. A **magnetic field** is the place around a magnet where the force of magnetism can be felt. The shape of a magnetic field depends on the shape of the magnet.

Magnetic Poles

These iron filings show the field of attraction between the opposite poles of two magnets.

These iron filings show the repelling force between like poles of two magnets.

Magnets have two poles. One is called north, and one is called south. The force of a magnet is strongest at the poles.

You remember that two rubbed balloons push each other away when they are close. This is because two like charges repel each other. Magnets are similar to that. If the north pole of one magnet is close to the north pole of another, the magnets repel each other. If you put a north pole near a south pole, they will pull toward each other.

You can break a magnet into two pieces, and each piece will have a new north and a new south pole. Magnets always have opposite poles.

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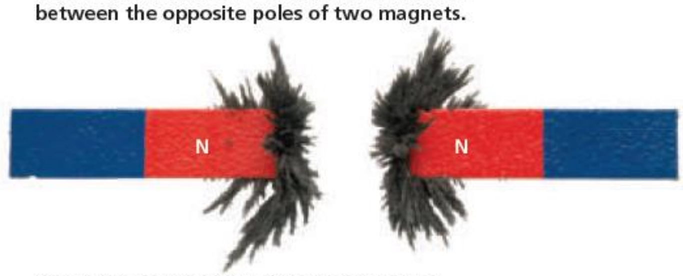

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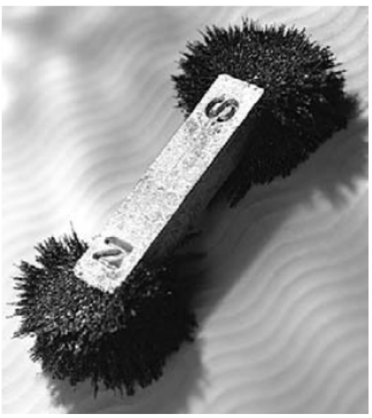
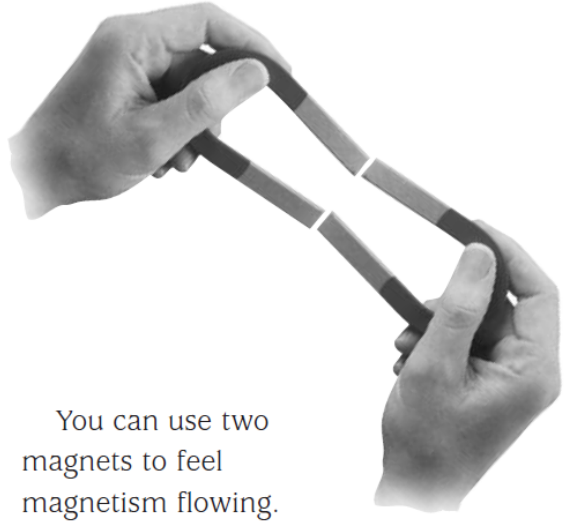
You can break a magnet into two pieces, and each piece will have a new north and a new south pole. Magnets always have opposite poles.

Magnetism and Magnets

Magnetism is an invisible **force**. A force is anything that pushes, pulls, or moves an object. Magnetism is a special force that only pulls on some metals, such as iron. A magnet will not push or pull plastic or tin.

Magnetism flows in one direction through a magnet, no matter what shape the magnet is. It flows in one end and out the other. The ends of a magnet are called **magnetic poles**. Every magnet has a north and a south pole. The force flows out the north pole and back in the south pole.





You can use two magnets to feel magnetism flowing. The north pole of one magnet will stick to the south pole of the other. Now, try to push the two north poles together. It feels almost like trying to connect two hoses that are both spraying water. The magnetic force pushes the north poles apart, because the magnetic forces are flowing against each other. Two north poles will always **repel** each other. So will two south poles.

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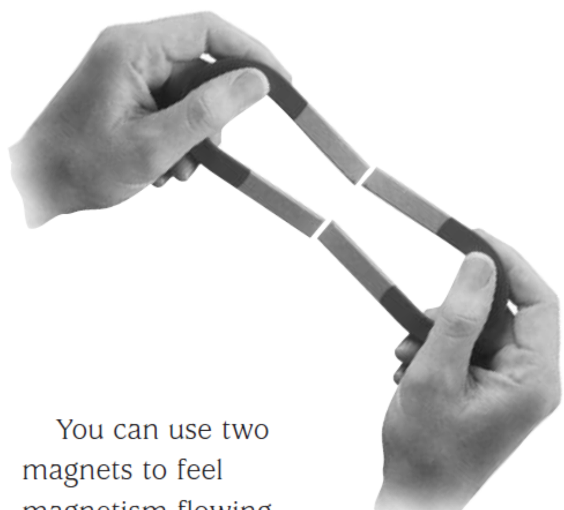

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C: LESSON THREE: HOW CAN YOU FIND OUT WHAT MAGNETS CAN DO? (TG pp15 – 19)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS*
What are the characteristics of materials attracted to magnets?	None of the non-metal objects are attracted to the magnet. Some of the metals are attracted to the magnet. Some of the metals aren't attracted to the magnet.	A magnet attracts and repels. Magnetic materials attract. Some metals are attracted to a magnet.	The junkyard magnet picks up metals that are attracted to a magnet and won't pick up other objects.	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Next Generation Science Standards (NGSS)
Performance Standards
MS-PS2-5: Fields exist bet. objects exerting forces on each other even though the objects are not in contact

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Asking Questions • Ask questions that can be investigated within the scope of the classroom with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	PS2.B: Types of Interactions • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• *Cause and effect relationships* may be used to predict phenomena in natural or designed systems. (MS-PS2-5)

INTRODUCING THE LESSON:

In today's lesson students will test various materials to see if they are attracted by magnets (magnetic) or not (non-magnetic). Students may be surprised to find out that some metals are not magnetic. Use a few student ideas or question they have from lesson one to introduce today's lesson. Some students may have asked "Why are somethings magnetic?" or "Are all metals magnetic?" which would be good intro questions for today's lesson. The purpose of these investigations is to show students that they relate to their own ideas and questions and can help us understand a part of the explanation for the phenomenon.

OBSERVING:

Students predict and test which materials are attracted to a magnet and record their results on a data table. As students are exploring circulate among the groups and ask questions that assess and advance their thinking.

Questions to ask students as they explore magnets in partners/groups:

- What similarities do you notice among the magnetic objects?
- What do you think makes an object magnetic?
- How can you use magnets to help find out what certain things are made of?
- Why would you want some things nonmagnetic?
- Why would you want some things magnetic?

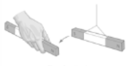
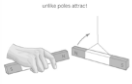
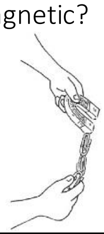
LEARNING:

Think, Pair, Share – What do you think makes an object magnetic? Ask the students to use the data they collected to summarize what they have learned about which objects are attracted to magnets.

CONNECTING:

A/B Partners – How does our learning today help us understand the junkyard magnet phenomena? Partner A shares their ideas and Partner B responds by agreeing disagreeing or adding on to their idea. Partner B shares their ideas and Partner B responds. Ask students to share their partner's thinking and record their connections on the class summary chart.

Summary table row displayed in the classroom may look something like this (lesson 2 shown as well) …

Activity	Observations	Learning	Connection to Phenomenon
Exploring Magnets Question: What can magnets do?  	Pull: ▪ Magnets stick together ▪ Magnets pull even if there is plastic between them Push: ▪ Magnets push each other. ▪ Magnets stay in place on the string even if you hold it up by one end Poles: ▪ You can make two magnets pull or push if flip around the magnet that is touching the other magnet	Magnets can push and pull other objects that are magnets. Magnets have poles that will pull (attract) together or push (repel) apart. Magnets have north and south poles	The junkyard magnet has a magnet that can pull on the metal hubcaps to pick them up.
Testing Materials Question: Which materials are magnetic? 	Magnetic: Recording tape, Steel nail, Steel washer, Twist-tie (metal) Non-Magnetic: Aluminum foil, wire, Brass brad, washer, Copper wire, Golf tee Not all objects were magnetic. We thought more of the metals would be magnetic but they were not.	Some metals are magnetic but other metals are not magnetic. A magnet attracts and repels. Magnetic materials attract. Some metals are attracted to a magnet.	The junkyard magnet picks up metals that are attracted to a magnet and won't pick up other objects. (Maybe they use a crane with a claw to pick up non-magnetic scrap?)

Planning for Future Instruction

This RSST will be more focused around student understanding of magnets and the properties of magnets. You may also want to note questions students have that could relate to one of the next few lessons on magnets and magnetism. How are students' ideas changing? What ideas are they wrestling with? What questions do they have? What are you wondering about student understanding?

D: LESSON FOUR: MEASURING MAGNETS (TG pp 21-25)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS*
What can increase the strength of magnets?	Adding more magnets makes them stronger. The more magnets you add each magnet adds less to the strength of the magnet.	The number of magnets affect the strength of the magnetic force. Magnets can be combined to form stronger magnets.	The junkyard magnet is effective at picking up heavy objects because it is a large magnet and the bigger the magnet, the stronger the magnet	MS-PS2-3: Factors that affect the strength of magnetic forces

Next Generation Science Standards (NGSS)
Performance Standards
MS-PS2-3: Factors that affect the strength of magnetic force

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Using Mathematics and Computational Thinking • Use mathematical representations to describe and/or support scientific conclusions and design solutions.	PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3)

INTRODUCING THE LESSON:
In today's lesson students will test the strength of a magnetic field. They will observe that more magnets make the field stronger (as indicated by the number of washers it can hold up). The purpose of these investigations is to show students that they relate to their own ideas and questions and can help us understand a part of the explanation for the phenomenon.

OBSERVING:
In this lesson students conduct an experiment to find out the strength of different combinations of magnets, record the results in a table and graph the data. As students are exploring circulate among the groups and ask questions that assess and advance their thinking.

Questions to ask students as they explore magnets in partners/groups:
- What are you noticing?
- Do any of the results surprise you? Why?
- Does the strength of the magnets increase by the same amount each time you add a magnet? Why not?
- What would happen if …?

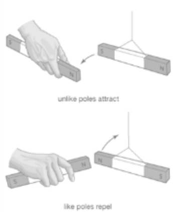
LEARNING:
Consensus – What did you learn about the strength of magnets from our observations? Provide students with three to five minutes of private think and write time before working with their groups. Each group should record what they learned on one post-it note after discussing and coming to consensus on their ideas. Post their learning on the class summary chart.

CONNECTING:

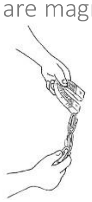
Post the chart of student ideas about the junkyard magnet phenomena in front of the class. In pairs students should select one idea from the chart that they agree with and have evidence to support from the last three lessons and one idea they now disagree with supported by evidence. During the student discussions, listen to the students' thinking and select three to four productive ideas to bring forward in a large group discussion. Add these ideas to the class summary chart.

Summary table row displayed in the classroom may look something like this (lessons B & C shown also):

<table>
<tr><th>Activity</th><th>Observations</th><th>Learning</th><th>Connection to Phenomenon</th></tr>
<tr><td>Exploring Magnets

Question: What can magnets do?

</td><td>Pull:
Magnets stick together
Magnets pull even if there is plastic between them
Push:
Magnets push each other.
Magnets stay in place on the string even if you hold it up by one end
Poles:
You can make two magnets pull or push if flip around the magnet that is touching the other magnet</td><td>Magnets can push and pull other objects that are magnets.

Magnets have poles that will pull (attract) together or push (repel) apart. Magnets have north and south poles</td><td>The junkyard magnet has a magnet that can pull on the metal hubcaps to pick them up.</td></tr>
<tr><td>Testing Materials

Question: Which materials are magnetic?
</td><td><table><tr><th>Magnetic</th><th>Non-Magnetic</th></tr><tr><td>Recording tape
Steel nail
Steel washer
Twist-tie (metal)</td><td>Aluminum foil, wire
Brass brad, washer
Copper wire
Golf tee (wood)</td></tr></table>Not all objects were magnetic. We thought more of the metals would be magnetic but they were not.</td><td>Some metals are magnetic but other metals are not magnetic.

A magnet attracts and repels. Magnetic materials attract. Some metals are attracted to a magnet.</td><td>The junkyard magnet picks up metals that are attracted to a magnet and won't pick up other objects.

(Maybe they use a crane with a claw to pick up non-magnetic scrap?)</td></tr>
<tr><td>Measuring Magnets
Question: How can we make magnets stronger?

(sketch of activity here)</td><td>Adding more magnets makes them stronger – For example 1 magnet held __ washers but 4 magnets held __ washers.

(tape graph from student here to remind students what they graphed – student graph sheet in TG pp 25)</td><td>The number of magnets affect the strength of the magnetic force.

Magnets can be combined to form stronger magnets.</td><td>The junkyard magnet is effective at picking up heavy objects because it is a large magnet and the bigger the magnet, the stronger the magnet</td></tr>
</table>

Planning for Future Instruction

This RSST will be more focused around student understanding of magnets and the properties of magnets. You may also want to note questions students have that could relate to one of the next few lessons on magnets and magnetism. How are students' ideas changing? What ideas are they wrestling with? What questions do they have? What are you wondering about student understanding?

E: LESSON SEVEN: CREATING MAGNETISM THROUGH ELECTRICITY (TG pp 43 – 47)

Focus Question	*What will students*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS*
How can you use electricity to make a magnet?	The compass needle moves when it is near an electric circuit.	When a current flows through an electric circuit it causes magnetism. Before the circuit is closed it is not magnetic.	The junkyard magnet is a temporary magnet. It can pick up and drop objects that are attracted to a magnet.	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Next Generation Science Standards (NGSS)

Performance Standards

MS-PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Developing and Using Models - • Develop a model to describe unobservable mechanisms.	PS2.B: Types of Interactions • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-5)

INTRODUCING THE LESSON:

In today's lesson students will observe that an electric current induces a magnetic field as indicated by the motion of the needle on a compass. The purpose of these investigations is to show students that they relate to their own ideas and questions and can help us understand a part of the explanation for the phenomenon. Lessons E and F give students information to understand how the junkyard magnet can "turn on" and "turn off". Introduce this lesson using a student question about how the junkyard magnet can turn on/off and/or student model(s) that attempt to explain this unobservable mechanism.

OBSERVING:

In this lesson students build an electric circuit, which lights a bulb and causes a compass needle to move. As students are exploring circulate among the groups and ask questions that assess and advance their thinking. Have magnets on hand to have students explore how magnets influence a compass so they see that a compass is an indicator for a magnetic field.

Ask the students to write in their notebooks what they observed while working with the circuits and compasses. After drawing what they OBSERVE, then add in what they can't see that they think might be making the compass needle move (developing a model).

Questions to ask students as they explore magnets in partners/groups:

- What are you noticing?
- Why does the compass move when it is near the electric circuit?
- What happens with the compass when you turn the circuit off with the switch?
- What would happen if …?

After groups/pairs have explored making a circuit and how a compass needle is affected when the circuit is turned on and off, try a demonstration with multiple compasses arranged around a wire in a circuit under a doc cam. See what happens to the compass needles. Do they all move together in the same direction and at the same angle? Why or why not would this happen? (Use the reading from the prior lesson about magnetic fields.)

LEARNING:

Think, Pair, Share – How can you use electricity to make a magnet? Ask the students to use the observations on the chart to summarize what they have learned about magnets. Record the students' learning on a class summary chart.

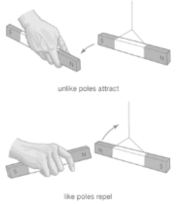
CONNECTING:

A/B Partners – How does our learning help us understand the junkyard magnet phenomena? Partner A shares their ideas and Partner B responds by agreeing disagreeing or adding on to their idea. Partner B shares their ideas and Partner B responds. Ask students to share their partner's thinking and record their connections on the class summary chart.

Planning for Future Instruction:

This RSST will be more focused around student understanding of circuits and the relationship between electric current and magnetism. How are students' ideas changing? What ideas are they wrestling with? What are they surprised by? What questions do they have? What are you wondering about student understanding? What do you think students need more information about? (And will they get it in an upcoming lesson or should a new lesson be added?)

Summary table row displayed may look something like this (lessons B, C, & D shown also):

Activity	Observations	Learning	Connection
Exploring Magnets Question: What can magnets do? 	Pull: ▪ Magnets stick together ▪ Magnets pull even if there is plastic between them Push: ▪ Magnets push each other. ▪ Magnets stay in place on the string even if you hold it up by one end Poles: ▪ You can make two magnets pull or push if flip around the magnet that is touching the other magnet	Magnets can push and pull other objects that are magnets. Magnets have poles that will pull (attract) together or push (repel) apart. Magnets have north and south poles	The junkyard magnet has a magnet that can pull on the metal hubcaps to pick them up.
Testing Materials Question: Which materials are magnetic? 	Magnetic: Recording tape; Steel nail; Steel washer; Twist-tie (metal) Non-Magnetic: Aluminum foil, wire; Brass brad, washer; Copper wire; Golf tee (wood) Not all objects were magnetic. We thought more of the metals would be magnetic but they were not.	Some metals are magnetic but other metals are not magnetic. A magnet attracts and repels. Magnetic materials attract. Some metals are attracted to a magnet.	The junkyard magnet picks up metals that are attracted to a magnet and won't pick up other objects. (Maybe they use a crane with a claw to pick up non-magnetic scrap?)
Measuring Magnets Question: How can we make magnets stronger? (sketch activity here)	Adding more magnets makes them stronger – For example 1 magnet held __ washers but 4 magnets held __ washers. (tape graph from student here to remind students what they graphed – student graph sheet in TG pp 25)	The number of magnets affect the strength of the magnetic force. Magnets can be combined to form stronger magnets.	The junkyard magnet is effective at picking up heavy objects because it is a large magnet and the bigger the magnet, the stronger the magnet
Creating magnetism with electricity Question: How can you use electricity to make a magnet? (sketch activity here)	When we move a magnet near a compass, the compass needle moves. The compass needle moves when it is near an electric circuit. The compass needle is shows magnetism.	When a current flows through an electric circuit it causes magnetism. Before the circuit is closed it is not magnetic. Circuits cause a magnetic field when it is turned on.	The junkyard magnet is a temporary magnet. It can pick up and drop objects that are attracted to a magnet.

F: LESSON EIGHT: MAKING MAGNETS WITH ELECTRICITY (TG pp 49 – 55)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS*
How can you use electricity to make a magnet?	The electromagnet will pick up paper clips like a magnet. The compass shows the magnetic poles of the coiled wire. The magnetic poles reverse when the direction of the current being pushed through the coil is changed by reversing the battery.	When a current flows through an electric circuit it causes magnetism. When the circuit is open it is not magnetic.	The junkyard magnet is a temporary magnet. It can pick up and drop objects that are attracted to a magnet	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Next Generation Science Standards (NGSS)

Performance Standards

MS-PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Developing and Using Models - • Develop a model to describe unobservable mechanisms.	PS2.B: Types of Interactions • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-5)

INTRODUCING THE LESSON:

In today's lesson students will observe that an electric current induces a magnetic field as indicated by the motion of the needle on a compass AND they build two different kinds of electromagnets (open coil and a coil around a steel bolt). The purpose of these investigations is to show students that they relate to their own ideas and questions and can help us understand a part of the explanation for the phenomenon. Lessons E and F give students information to understand how the junkyard magnet can "turn on" and "turn off". Introduce this lesson using a student question about how the junkyard magnet can turn on/off and/or student model(s) that attempt to explain this unobservable mechanism.

OBSERVING:

Have students follow the task cards on pgs 52-55. These tasks may take 2 class periods. In this lesson students build on their experiences from the previous lesson and build an electromagnet. As students are exploring circulate among the groups and ask questions that assess and advance their thinking. Ask the students to write in their notebooks what they observed while working with the electromagnet. Notebook task: Draw a model of an electromagnet of your choice. Include things we can't see such as magnetic fields and explain how an electromagnet works using this model.

Questions to ask students as they explore magnets in partners/groups:

- What do you notice?
- What would happen if …?
- How do you know it is a magnet?
- What happens with the compass when it is moved to different ends of the coil? Why?
- What happens with the compass when you reverse the battery? Why?

LEARNING:

Think, Pair, Share – How can you use electricity to make a magnet? Ask the students to use the observations in their notebooks to summarize what they have learned about electromagnets. Record the students' learning on a class summary chart.

Engaging in one or both of the options below may add an additional day to the lesson to engage with the readings and/or video and make sense of them with the tasks students completed.

Optional: After completing observations and talking about tasks on pg 52-55, you may have students read one of the following articles from the readers that come with the kit:

"The Story of Electromagnets" pp 28-29

"The Case of the Coiled Wire" pp 30-32

Optional: After completing observations and some science talk about the tasks on pgs 52-55, you may want students to watch some related video clips.

- 30 second video clip describing how a circuit induces a magnetic field and moves a compass needle (similar to task 5/6 on pg 54) https://www.youtube.com/watch?v=AgZHqfIBkUI
- 1-minute video clip describing and showing an electromagnet that picks up paperclips (similar to task #7 on pg 55) https://www.youtube.com/watch?v=vrNvsDPJ98E
- 4 min 57 sec video about electromagnets https://www.youtube.com/watch?v=emlzh9XXWgQ

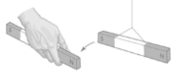
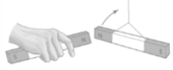
CONNECTING:

A/B Partners – How does our learning help us understand the junkyard magnet phenomena? Partner A shares their ideas and Partner B responds by agreeing disagreeing or adding on to their idea. Partner B shares their ideas and Partner B responds. Ask students to share their partner's thinking and record their connections on the class summary chart. You may wish to rewatch either of the junkyard magnet phenomena videos http://goo.gl/aXnN8P or http://goo.gl/qCUXAK.

Planning for Future Instruction:

This RSST will be more focused around student understanding of circuits and the relationship between electric current and magnetism. How are students' ideas changing? What ideas are they wrestling with? What are they surprised by? What questions do they have? What are you wondering about student understanding? What do you think students need more information about? (And will they get it in an upcoming lesson or should a new lesson be added?)

Summary table row displayed may look something like this (lessons B, C, D, & E shown also):

Activity	Observations	Learning	Connection
Exploring Magnets Question: What can magnets do?  unlike poles attract  like poles repel	Pull: ▪ Magnets stick together ▪ Magnets pull even if there is plastic between them Push: ▪ Magnets push each other. ▪ Magnets stay in place on the string even if you hold it up by one end Poles: ▪ You can make two magnets pull or push if flip around the magnet that is touching the other magnet	Magnets can push and pull other objects that are magnets. Magnets have poles that will pull (attract) together or push (repel) apart. Magnets have north and south poles	The junkyard magnet has a magnet that can pull on the metal hubcaps to pick them up.
Testing Materials Question: Which materials are magnetic? 	Magnetic: Recording tape; Steel nail; Steel washer; Twist-tie (metal) Non-Magnetic: Aluminum foil, wire; Brass brad, washer; Copper wire; Golf tee (wood) Not all objects were magnetic. We thought more of the metals would be magnetic but they were not.	Some metals are magnetic but other metals are not magnetic. A magnet attracts and repels. Magnetic materials attract. Some metals are attracted to a magnet.	The junkyard magnet picks up metals that are attracted to a magnet and won't pick up other objects. (Maybe they use a crane with a claw to pick up non-magnetic scrap?)
Measuring Magnets Question: How can we make magnets stronger? (sketch activity here)	Adding more magnets makes them stronger – For example 1 magnet held __ washers but 4 magnets held __ washers. (tape graph from student here to remind students what they graphed – student graph sheet in TG pp 25)	The number of magnets affect the strength of the magnetic force. Magnets can be combined to form stronger magnets.	The junkyard magnet is effective at picking up heavy objects because it is a large magnet and the bigger the magnet, the stronger the magnet
Creating magnetism with electricity Question: How can you use electricity to make a magnet? (sketch activity here)	When we move a magnet near a compass, the compass needle moves. The compass needle moves when it is near an electric circuit. The compass needle is shows magnetism.	When a current flows through an electric circuit it causes magnetism. Before the circuit is closed it is not magnetic. Circuits cause a magnetic field when it is turned on.	The junkyard magnet is a temporary magnet. It can pick up and drop objects that are attracted to a magnet.
Making magnets with electricity Question: How can you use electricity to make a magnet? (sketch activity here)	The electromagnet will pick up paper clips like a magnet. The compass shows the magnetic poles of the coiled wire. The magnetic poles reverse when the direction of the current being pushed through the coil is changed by reversing the battery.	When a current flows through an electric circuit it causes magnetism. When the circuit is open it is not magnetic. When the circuit is closed, the wire coil becomes a magnet.	The junkyard magnet is a temporary magnet. It can pick up and drop objects that are attracted to a magnet

G: LESSONS NINE/TEN/ELEVEN – PLANNING, CONDUCTING AND COMMUNICATING RESULTS OF AN EXPERIMENT TO TEST THE STRENGTH OF AN ELECTROMAGNET (TG pp 57 – 76)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS*
How can you change the strength of electromagnetic force?	Cores that contain iron make better magnets. The more turns of the wire around the core results in greater magnetic strength. The more batteries used results in a stronger electromagnet.	Factors that affect the strength of an electromagnet include the material making up the core, the length of the wire carrying the current and the amount of electricity powering the magnet.	The cranes have an electric generator connected to a wire coil in the large round lifting disc. When the power is on, its magnetic field attracts heavy iron and steel to it. When the scrap is positioned where they want it, they cut the power to the electromagnet and the scrap drops.	MS-PS2-3: Factors that affect the strength of magnetic forces

Next Generation Science Standards (NGSS)
Performance Standards
MS-PS2-3: Ask questions about data to determine factors that affect the strength of magnetic force

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Planning and Carrying Out Investigations • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.	PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3)

OBSERVING: Students will plan, conduct and communicate the results of a controlled experiment that will investigate how changes in some variables affect electromagnetic force. As groups plan, conduct and communicate the results of their investigation circulate among the groups and ask questions that advance and assess their thinking.

Planning Questions	*Conducting the Experiment Questions*	*Communicating Ideas*
• What variables do you think would change the strength of the electromagnetic force? Why? • What variable did you select to manipulate in your experiment? How do you think it will affect the strength of the electromagnetic force? Why? • How is your experiment fair?	• What are you noticing? • Are any of your results surprising? Why? • How can you make an electromagnet weaker? Stronger?	• How can you make an electromagnet weaker? Stronger? • If you conducted this experiment again how would you change it? Why?

LEARNING:

Consensus – What did you learn about how to change the strength of an electromagnetic force? Provide students with three to five minutes of private think and write time before working with their groups. Each group should record what they learned on one post-it note after discussing and coming to consensus on their ideas. Post their learning on the class summary chart.

CONNECTING:

Post the chart of student ideas about the junkyard magnet phenomena in front of the class. In pairs students should select one idea from the chart that they agree with and have evidence to support from the last three lessons and one idea they now disagree with supported by evidence. During the student discussions, listen to the students' thinking and select three to four productive ideas to bring forward in a large group discussion. Add these ideas to the class summary chart.

Planning for Future Instruction:

This RSST will be more focused around student understanding of circuits and the relationship between electric current and magnetism. How are students' ideas changing? What ideas are they wrestling with? What are they surprised by? What questions do they have? What are you wondering about student understanding? What do you think students need more information about? (And will they get it in an upcoming lesson or should a new lesson be added?

H. Model Revisions & Pressing for Evidence-based Explanations (added lesson, not in TG)

Focus Question		*NGSS*
How can we use evidence from activities to explain our phenomenon?	Use the summary table with information from each of the activities to find evidence to explain how a junkyard magnet works.	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact MS-PS2-3: Factors that affect the strength of magnetic forces

Teacher Background

For the explanation of the junkyard magnet, see the teacher explanation pages. Briefly, there are key science ideas students will develop an understanding of in this unit beginning today:

1. Forces, such as magnetism, act at a distance. These forces fields that extend from an object and can be mapped and represented.
2. Non-magnetic metals can temporarily become magnetic if an electric current is passed through them. When the current stops, the metal loses its temporary magnetic properties. This can be partially explained using the idea of energy transfer and the particulate nature of matter.

Next Generation Science Standards (NGSS)

Performance Standards

MS-PS2-5: Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact

MS-PS2-3: Determine the factors that affect the strength of magnetic force

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Developing and Using Models - • Develop a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.	PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)

Materials

- Junkyard magnet Video clip #1 https://www.youtube.com/watch?v=XBWy9gzGGd4 (found also at http://goo.gl/aXnN8P)
- Junkyard magnet video clip #2 https://www.youtube.com/watch?v=N9XoUGxM2h0 (found also at http://goo.gl/qCUXAK)
- Model scaffold sheet (1 copy per student or per partner pair)
- Pencils (colored pencils optional)
- Summary table with list of activities and what we learned and connection to phenomenon

Procedure – Day 1

1. Opening – Whole Group (5 minutes)
    a. Reintroduce/review the phenomenon: junkyard magnet video #2 to remind students what they will need to explain.

2. Developing Models (25 minutes)
    a. Pass out model scaffold sheets (1 per student or 1 per pair).
    b. Explain to students that their job is to show what they can observe from the video on their paper and label the parts they draw. More importantly, it's to somehow represent or draw what they can't see that they think is causing the magnet to work this way. How can the junkyard magnet pick up and drop off metal pieces with our little magnet could only pick them up?
    c. As students discuss and work in pairs, circulate and observe the different hypotheses students have, encouraging students to represent what they can't see but they think is happening AND relate it back to activities students have done so far this unit.
    d. Midway through this time, select 2 pairs or students to share one specific piece (not the whole thing) of their model with the class under the doc cam. Have a reason for the student(s) to share. For example, maybe two different students/pairs did clear representations of magnetism since it's not something we can directly observe and their representations are different. Another example could be how students are explaining causes in words and in their model. This sharing step mid-point during model development helps students see each other's' work and perhaps get some ideas or questions they have to add to their own models.

3. Review Public Records (Summary Table) (10 minutes)
    a. Close this science time by referring back to the summary table and encouraging students to take one activity and think about what evidence that has and how it connects to the phenomenon – Did they include that idea on their model?

Procedure – Day 2

Using their revised models and the summary table, students will write an evidence-based explanation of the junkyard magnet phenomenon. Sentence starters are provided to help students connect what they did in activities with parts of the phenomenon. OPTIONAL: Work with students to create a "gotta have" checklist of science ideas or relationships that students have to include in their writing.

Procedure – Day 3

Students peer conference in pairs with a short rubric or checklist to provide feedback about what to add or clarify in their partners' writing. Models and writing can be displayed. You can develop your own simple rubric or checklist or use the checklist of 4 ideas provided on the next page. OPTIONAL: Get students' feedback on how they think their thinking has changed over this unit so far (written or in pair-share).

CLAIMS:

The junkyard magnet can pick up scraps because…

The junkyard magnet can drop scraps because…

It is important that a junkyard magnet is really big because…

It is likely that the junkyard magnet is part of a circuit because…

EVIDENCE:

In the “Making Magnets with Electricity” investigation, we observed that….
This relates to the junkyard magnet because…

In the “Measuring Magnets” investigation, we found out that…
This is important to know because it explains why the junkyard magnet….

In the “What magnets do” activity, we noticed that magnets attract…
Therefore, we know that the junkyard magnet can only attract scraps made of…

CHECKLIST OF WHAT IDEAS TO INCLUDE:

- ✓ Describe the properties of magnets and the objects they attract
- ✓ What makes a magnet temporary
- ✓ Relationship between strength of magnet and size of magnet
- ✓ Relationship between electricity and magnetism

Unit Overview: Part 2

Lesson	Kit Curriculum	Lesson Title	Time*
I	ADDED	Eliciting Ideas: Developing initial models to explain how a shakelight flashlight works	2 x 45 mins
J	ADDED	What's a generator? How do generators work?	2 x 45 mins
K	ADDED	What's a capacitor? How do capacitors work?	2 x 45 mins
L	ADDED	Making a Sun Clock	2 x 45 mins

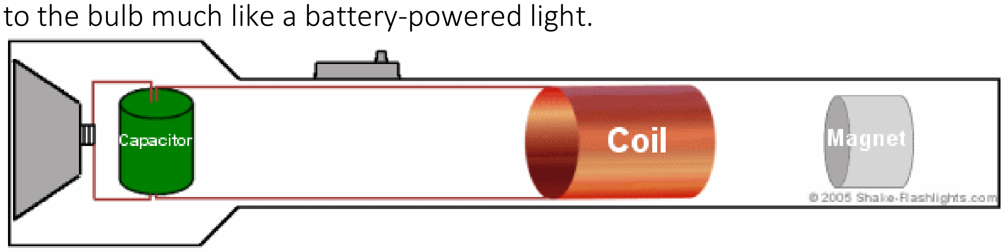
PART 2 - UNIT PHENOMENON – Why does the shake flashlight work?

TEACHER BACKGROUND KNOWLEDGE:

A shake flashlight (also known as a Faraday Flashlight) works without batteries because by shaking it a magnet slides back and forth inside a coil of copper wire inducing an electric current which lights an LED. This energy is stored in a capacitor in order to be used later. Through investigations in this unit, students will gather evidence about magnets, electromagnets, electrical circuits, energy transfer and transformation in order to explain how this flashlight works and apply it to a similar invention, a socket ball.

What is a shake flashlight?

In 1819 Hans Christian Oersted discovered that an electric current creates a magnetic field. Just over ten years later the English scientist Michael Faraday demonstrated the reverse effect. He showed how a magnetic field could be used to generate electricity. In the early 1830s, Faraday designed an experiment to observe that by passing a magnet through a coil of wire, a small electrical current is created. The same thing happens when a person charges a shake flashlight. A magnet passes back and forth through a coil of wire and creates an electrical current that is then stored in a capacitor. When the flashlight is turned on, the capacitor supplies the stored energy to the bulb much like a battery-powered light.



Components:

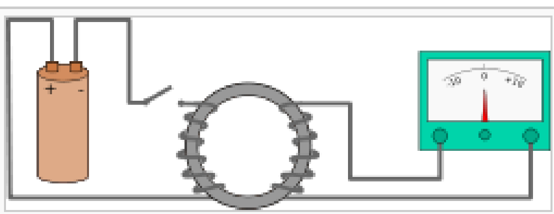
- **Magnet:** The magnet is what generates the power as it passes through the wire coil. The stronger the magnet, the more power is generated with each shake.
- **Coil:** The size of the wire coil (i.e. the number of windings) will also determine how much power is generated on each pass of the magnet.
- **Capacitor:** The capacitor stores the power that you generate while shaking the flashlight. The higher the quality and larger the size of the capacitor, the longer the light output.
- **Switch and body:** The primary considerations here are the sturdiness and waterproofness of the flashlight.
- **Bulb:** Generally this will be an LED due to their reduced power consumption and durability. Factors include the color of the light and its brightness.

How does it work?

How does passing a magnet through a copper coil induce an electrical current?

To use a typical Faraday flashlight, you first shake it for 30 to 60 seconds depending on the model (or up to 3 minutes if the capacitor is fully discharged). This builds up energy in the capacitor. Now turn the flashlight on and use it like a typical flashlight until its lighting power is diminished. Then simply shake it up again and repeat the process as often as needed. By how does this work?

Magnets can exert a force at a distance and opposite magnetic poles repel and like poles attract. *Electric charges* can also experience a magnetic force if the charge moves through a magnetic field. Current is induced in the coil of wire because of Faraday's Law of Induction. In Faraday's first experimental demonstration of electromagnetic induction (August 29, 1831), he wrapped two wires around opposite sides of an iron ring (see figure below, at left). Based on his assessment of recently discovered properties of electromagnets, he expected that when current started to flow in one wire, a sort of wave would travel through the ring and cause some electrical effect on the opposite side. Indeed, he saw a transient current (which he called a "wave of electricity") when he connected the wire to the battery, and another when he disconnected it.



A diagram of Faraday's iron ring apparatus. Change in the magnetic flux of the left coil induces a current in the right coil.[3]

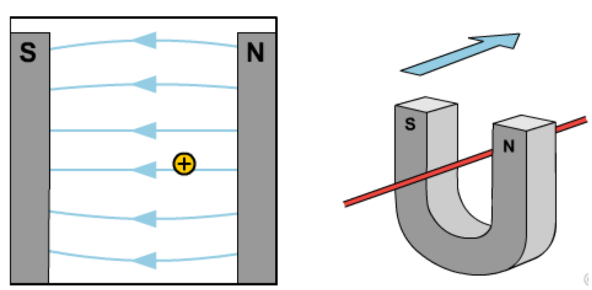


Figure 1. Moving a wire in a magnetic field. The arrow indicates the direction of current flow.

When a current flows in the wire, we say that the current has been induced. A current is only induced in the wire when it cuts across the magnetic field lines (see above, right). In figure 1 above, as the wire is moved down between the magnetic poles, electric current flows through the wire perpendicular to the magnets (shown by the arrow). When the wire stops moving, there is no current. No current is induced when the wire moves along the magnetic field lines (left and right, rather than up and down, in the example in Figure 1). This is an effect called **electromagnetic induction**.

For figure 1 animation, visit:
http://www.absorblearning.com/physics/demo/units/DJFPh055.html#Amovingwire

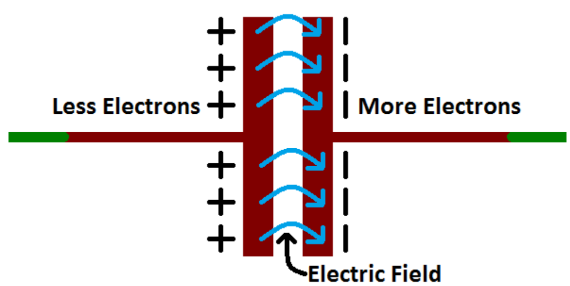
What does a capacitor do?

Capacitors generally are two metal plates with equal and opposite electric charges separated by a non-conductive substance. Basically, it can be thought of as a simple rechargeable battery; however, a rechargeable battery would be described as stored chemical energy, whereas a capacitor would be described as stored electrical energy.

A capacitor can discharge the stored voltage much faster (seconds) compared to a battery discharging (minutes or longer). So devices such as camera flash which need to discharge quickly are governed by a capacitor. So why does a shake light need a capacitor? It uses the capacitor to store electrical energy – since this energy is now stored, it can also be described as potential electrical energy, until the switch is turned on.

How a Capacitor Works

Electric current is the flow of electric charge, which is what electrical components harness to light up, or spin, or do whatever they do. When current flows into a capacitor, the charges get “stuck” on the plates because they can’t get past the insulating dielectric. Electrons – negatively charged particles – are sucked into one of the plates, and it becomes overall negatively charged. The large mass of negative charges on one plate pushes away like charges on the other plate, making it positively charged.



The positive and negative charges on each of these plates attract each other, because that’s what opposite charges do. But, with the dielectric (insulator) sitting between them, as much as they want to come together, the charges will forever be stuck on the plate (until they have somewhere else to go). The stationary charges on these plates create an electric field, which influence electric potential energy and voltage. When charges group together on a capacitor like this, the cap is storing electric energy just as a battery might store chemical energy.

Charging and Discharging - When positive and negative charges coalesce on the capacitor plates, the capacitor becomes charged. A capacitor can retain its electric field – hold its charge – because the positive and negative charges on each of the plates attract each other but never reach each other. At some point the capacitor plates will be so full of charges that they just can’t accept any more. There are enough negative charges on one plate that they can repel any others that try to join. This is where the capacitance (farads) of a capacitor comes into play, which tells you the maximum amount of charge the capacitor can store. If a path in the circuit is created, which allows the charges to find another path to each other, they'll leave the capacitor, and it will discharge.

Why does the bulb need to be an LED rather than a regular flashlight bulb?

A light emitting diode. They replace traditional incandescent bulbs and aren't actually bulbs at all, but rather a type of semiconductor diode that produces electroluminescence. LEDs are used in shake flashlights because they don't require as much voltage to work as regular flashlight bulbs. Since the user is creating the current by shaking, it makes sense to have a lightbulb that wouldn't need as much voltage (to save our muscles!).

What is the Energy Story?

Our muscles transfer motion (kinetic) energy from shaking our arm/hand holding the flashlight into motion (kinetic) energy inside the flashlight (where the magnet is moving back and forth within the coil). The motion of the magnet inside the coil is motion (kinetic) energy. This motion energy is transformed into electrical energy through the process of induction – whereby the moving magnet induces an electrical current. In the circuit wires, the electrical energy is transferred into the capacitor and stored (potential energy) until it is used and transformed into light energy when the switch is turned on.

Key Disciplinary Core Ideas about Energy:

- Definitions of Energy (PS3.A): A system of objects may contain stored (potential) energy.
- Relationship between Energy and Forces (PS3.C): When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

References

What is a shake-flashlight? *http://www.shake-flashlights.com/how-they-work.html*
Wikipedia
https://en.wikipedia.org/wiki/Mechanically_powered_flashlight
https://en.wikipedia.org/wiki/Faraday%27s_law_of_induction
http://en.wikipedia.org/wiki/Applications_of_capacitors

I: ELICITING IDEAS & INITIAL MODELS (added lesson, not in TG)

Focus Question	*What will students observe?*	*What will students*	*Connection to Phenomenon?*	*NGSS* (See below)*
How does this flashlight work without needing batteries?	▪ Shakelight must be shaken before it will turn on. ▪ If it doesn't work, shake it again and then it will work. ▪ It has a switch to turn it on/off. ▪ Inside it has a magnet and a coil of copper wire. ▪ It does not have batteries. ▪ It has a light bulb, tiny ones (LEDs)	Moving a magnet through a coil of wire makes the flashlight work	(Initial models & hypotheses about the causes of the phenomenon)	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact MS-PS2-3: Factors that affect the strength of magnetic forces

Teacher Background

For the explanation of the shakelight, see the teacher explanation pages. Briefly, there are key science ideas students will develop an understanding of in this unit beginning today:

1. Magnetic fields can induce an electric current by moving or spinning a magnet near a coil of wire. This principle is behind how all generators work.
2. This idea that magnetism can induce electric current is the inverse of the pattern observed in Part I of the unit that electric current can induce magnetism (electromagnets). This relationship works both ways.

Next Generation Science Standards (NGSS)

Performance Standards

MS-PS2-5: Fields exist bet. objects exerting forces on each other even though the objects are not in contact

MS-PS2-3: Factors that affect the strength of magnetic force

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Developing and Using Models - • Develop a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.	PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)

Materials

- Shakelight Video clip #1 https://www.youtube.com/watch?v=X9MYhChHBME found also at http://goo.gl/woinYp (Play on MUTE, music doesn't lend much to making observations)
- Shakelight video clip #2 https://www.youtube.com/watch?v=KxxgfkPhrmo found also at http://goo.gl/FGe9KA (Turn sound ON to hear the narration)
- Model scaffold sheet (1 copy per student or per partner pair)

- Pencils (colored pencils optional)
- Chart paper and markers (for recording initial observations and ideas)
- Shake flashlight
- OPTIONAL: a typical battery-powered flashlight, as a comparison

Procedure – Day 1

1. Opening – Whole Group (5 minutes)
   a. Introduce the new phenomenon using the flashlight and video clips explaining that in this next part of the unit we will be exploring and testing different ideas to explain how this flashlight works without needing batteries.
   b. Pass around the flashlight and have students make observations. OPTIONAL: Bring in a typical flashlight and have students do a quick sketch of each and identify the similarities and differences (the main difference being that the shakelight has no batteries).
   c. Play video clip and have students write down 2 things they observe in their notebook and any questions they have.

2. Observations – Whole Group (10 mins)
   a. Both video clips and allow students to make observations using the flashlight or photograph of the flashlight. Give students time to make specific observations. Pair-share observations in partners before sharing out to create a list.
   b. On chart paper, create a class list of observations from the video and manipulating/observing the shakelight itself (things students can directly see or hear). Also, note any student questions. *Option: Have students come up and write on the chart (instead of the teacher leading the writing). A student recorder can write the whole list or students can take turns.*

Shakelight Observations

- Shakelight must be shaken before it will turn on.
- If it doesn't work, shake it again and then it will work.
- It has a switch to turn it on/off.
- Inside it has a magnet and a coil of copper wire.
- It does not have batteries.

It has a light bulb, tiny ones (LEDs)

Questions

- How can it work without a battery?
- Why does it flicker if the switch is on when we shake it?
- Is the magnet like a battery?

3. Recording Initial Hypotheses – Whole Group (15 mins)
   a. Think-Pair-Share: Why can the shakelight work without batteries? What's happening that we can't see that could cause this? Set a timer for 3 or 4 minutes and have the video replaying during this time. Students watch, think, and partner share about this question.
   b. Listen in as students share to hear the different kinds of ideas or hypotheses. Think about who you want to call on to share out in whole group – look for a variety of ideas even if they are opposing or different.
   c. Have students share ideas and create a list. Students can refer to this list as they get to work on their models in the next step.

Our Initial Ideas
How does a shakelight work?

- The shaking gives the magnet energy.
- The magnet energy powers the light.
- If you shake it and don't turn it on, the energy would not have anywhere to go.
- If there were more coils it would be a brighter light, kind of like the electromagnet we made where it was stronger.
- The magnet is a battery, like the + and – is like N and S which would make a circuit attract or repel electrons.

4. Individual Ideas – Science Notebook Entry (10 minutes)
    c. Students write about what they observed today. Many students may be beginning their personal theories of how the shakelight works and how it can work without a battery and why shaking it is important.
    d. Encourage students to make a sketch and complete a few sentences about today's introduction to the unit in their science notebook. Sentence starters for notebook entry:
        i. The shakelight has a magnet and a coil of wire because….
        ii. You have to shake the shakelight so that…
        iii. I know the metal cylinder inside the shakelight is a magnet because…
        iv. I think that the shakelight can work without batteries because….

Procedure – Day 2

5. Opening – Whole Group (5 minutes)
    a. Reintroduce shakelight video clip and have students read over their notebook entry from part 1 of this lesson. Refer to the list of observations and hypotheses from previous day.

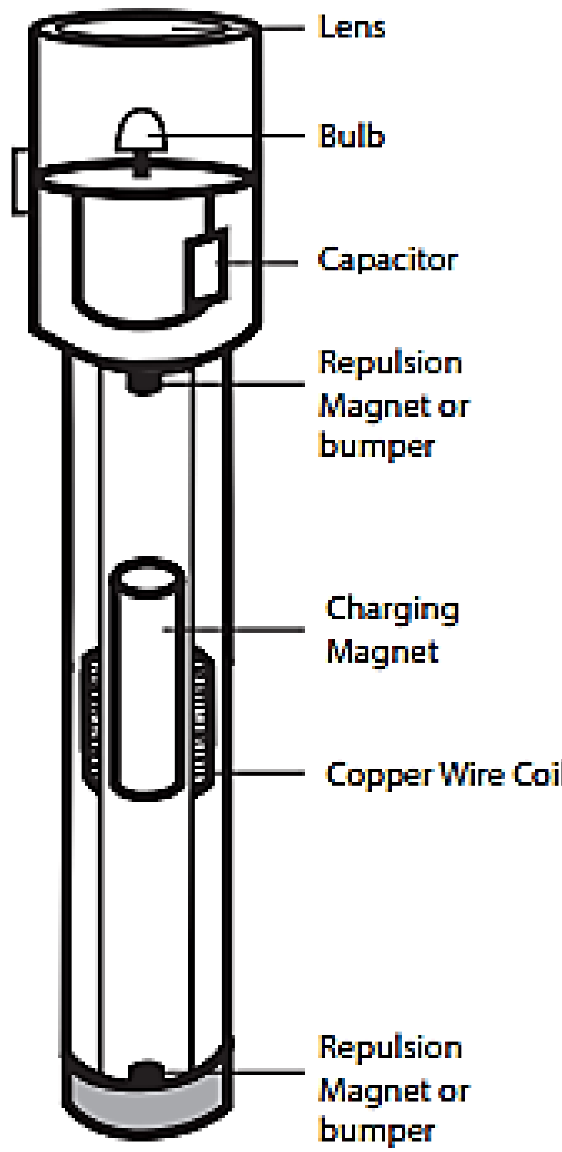
6. Developing Models (30 minutes)
    a. Pass out model scaffold sheets (1 per student or 1 per pair, teacher's choice).
    b. Explain to students that their job is to show what they can observe from the video on their paper and label the parts they draw. More importantly, it's to somehow represent or draw what they can't see that they think is causing the flashlight to work this way. How can the shakelight work without batteries? Why is the magnet important?
    c. As students work, circulate and observe the different hypotheses students have, encouraging students to represent what they can't see but think is happening.
    d. Midway through this time, select 2-3 pairs or students to share one specific piece (not the whole thing) of their model with the class under the doc cam. Have a reason for the student(s) to share. For example, maybe two different students/pairs did clear representations of magnetism or electromagnetism since it's not something we can directly observe and their representations are different. Another example could be how students are explaining causes in words and in their model. Another pair/individual could have made connections to prior activities from Part 1 of the unit. This sharing step mid-point during model development helps students see each other's' work and perhaps get some ideas or questions they have to add to their own models.

7. Review and Complete Public Records
    e. Ask for any final ideas to add to the list of initial ideas now that students have talked in a pairs/groups, written and drawn then ideas, and heard from their peers
    f. Add to the list of questions students have about this shakelight device. Students can put up sticky notes with their questions on a question chart or they can come up and write the question. This list of question can serve as a place to frame future activities as they find evidence and answers to their questions.

Planning for Future Instruction

After this lesson, use student work and what you remember from student talk during the lesson to fill out a Rapid Survey of Student Thinking (RSST). This tool helps teachers keep track of the partial ideas, alternative understanding, everyday language, and experiences that students have and which can be used in future lesson s to help students make changes to their understanding over time.

Photo and Diagram of Shake Flashlight



Rapid Survey of Student Thinking (RSST)

Directions: Complete the RSST either during class or right after a class.

Categories	Trends in student understandings, language, experiences [sample sentence starters included below]	Instructional decisions based on the trends of student understanding
Partial understandings What facets/ fragments of understanding do students already have?	List partial understandings: What approximate % of your students have these partial understandings?	★ Star the ideas on the list that need action. Instructional options: • Do further eliciting of initial hypotheses to clarify your understanding of students' partial understandings • Do 10-minute whole class whole class conversation of 2-3 key points elicited • Write multiple hypotheses on board and/or develop an initial consensus model
Alternative understandings What ideas do students have that are inconsistent with the scientific explanation?	List alternative understandings: What, if any, experiences or knowledge bases are they using to justify these explanations?	★ Star the ideas on the list that you *really* need to pay attention to based on the following criteria… 1. Which alt. conceptions seem deeply rooted (kids seem sure about)? 2. What % of kids think this? 3. Which are directly related to final explanation (not just a "side-story") Instructional options: • Do further eliciting about what experiences/frames of reference students are drawing on • Pose "what if" scenario to create conceptual conflict about validity of alt. ideas • Challenge students to think further/give them a piece of evidence to reason with • Target a lesson using "Teaching Practice 3" to address this alt. conception
Everyday language What terms did you hear students use that you can connect to academic language in upcoming lessons?	Cite examples: What approximate % of your students use these terms and phrases?	★ Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: • Use this language to reframe your essential question in students' terms • Use as label in initial models that you make public. Work in academic versions of these words into public models and discussions later.
Experiences students have had that you can leverage What familiar experiences did students describe during the elicitation activity?	What was the most common everyday or familiar experience that kids related to the essential question or task? What were the less common experiences students cited?	★ Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: • Re-write the essential question to be about this experience • Make their prior experiences a central part of the next set of classroom activities • If kids cannot connect science idea to familiar experiences they've had, then provide a shared experience all kids can relate to (through lab, video, etc.)

J: ALL ABOUT GENERATORS (added lesson, not in TG)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS* (See below)*
Can electricity be made using magnets?	Spinning a magnet in a coil of wire can create an electric current. The electric current is stronger (i.e. bulb brighter) if there are more coils, more magnets, and/or the magnet is moved more quickly.	Generators contain a magnet & coil of wire. A force spins the magnet inside the coil of wire. A magnet moving in and out of a coil of wire will generate electricity	The shake flashlight doesn't need a battery because the magnet moving through the coils of wire generates electricity	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Next Generation Science Standards (NGSS)

Performance Standards

MS-PS2-5: Fields exist bet. objects exerting forces on each other even though the objects are not in contact

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Obtain, Evaluate, and Communicate Information • Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings	PS2.B: Types of Interactions • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems.(MS-PS2-5)

Lesson Objective

In this lesson students will observe that moving magnets can create an electric current – this is an opposite idea to the one they observed using electric current to create magnetic fields by creating their own electromagnets in earlier lessons. Students will make observations using 2 video clips and one homemade demonstration generator made by the teacher. (Optional: Students could create their own generator in pairs given enough materials).

Materials

For learning about generators:

- Video of how a generator works: https://www.youtube.com/watch?v=BKXw2OjuPpY
- Student Readings (1 copy per student)
- Video of hydroelectric generator: https://www.youtube.com/watch?v=rnPEtwQtmGQ

For creating demonstration generator:

- Spool of magnet wire
- Cardboard piece about 8cm x 30 cm
- xacto knife (for scoring cardboard to make the box)
- 2-4 rectangular magnets
- 4" or longer nail
- Small light bulb (1.5v/25mA)
- Volt meter (optional, but will register small changes in current if not strong enough to light bulb)
- Video of how to make a generator: http://www.amasci.com/amateur/coilgen.html
- Written directions: http://www.discoverthis.com/project-simple-electric-generator.html

Procedure

Day 1

1. Orientation to the concepts (5 minutes)
    a. Select a student's question or idea from the initial charts that relates to "Why doesn't the flashlight need batteries?" or "The magnet is like a battery" or similar idea that can be an entry point into today's lesson where students will learn about the power source for this shake flashlight.
    b. Today's question we will try to answer is: Can electricity be made using magnets? And how does this help us understand out shake flashlight? Remind students (or ask students to describe) the parts inside the shakelight (i.e. magnet, coil of wire).

2. Making Observations (10 minutes)
    a. Use the homemade demonstration generator to show students that by spinning the nail (with magnets stuck to the nail inside the box) that the lightbulb lights or flickers. Have students make observations or turn-and-talk to a partner about what they see happening. (If homemade generator is unavailable, use video clip: http://www.amasci.com/amateur/coilgen.html
    b. Begin to fill in "observations" box on the summary table row with what students observe about what key parts are moving and what happens.
    c. Introduce the word "generator" – create a class definition using what they know so far from the demo generator.

3. Making Connections (30 minutes)
    a. Play the video clip https://www.youtube.com/watch?v=BKXw2OjuPpY. As students watch, ask them to try to answer the following two questions:
        i. What parts are needed in a *generator* to make the bulb light up?
        ii. What is the energy story that makes the lightbulb light up? Where does the energy come from?
    b. Replay video as needed to find answers to these questions. Record responses in science notebooks to the two questions above along with labeled sketch of a generator (either the demo generator or the one in the video).
    c. Read one or more of the articles about electric generators. Read to find out what a generator is, how it works, and what parts it needs.
    d. As students to work in partners to come up with a connection between what we've seen and learned about generators today and our shakelight. Have pairs write one connection on a sticky-note and post it on the summary table in the "connections" box.

    If students are going to create their own homemade generators in partners or groups, do this here and push steps 4 and 5 until day 2 of the lesson.

> Questions to ask students as they explore and learn about generators:
>
> - What are you noticing?
> - What happens if we spin the magnets slower?
> - What happens if we spin the magnets faster?
> - Why is the coil of wire important?
> - How is our homemade generator similar or different to the one shown in the video?
> - What would happen if …?

Day 2

4. Whole class coordination of ideas (15 mins)
    a. Use the sticky notes to help the whole class come up with a summary statement to put in the "connections" box. There are multiple ways to coordinate this conversation. One

way could be to begin with one sticky note and read it aloud (also post it under the doc cam if convenient) and ask other pairs to publicly agree, disagree, or add on with their idea on their sticky note.

b. Come to a consensus about what to write as a connection from this lesson.

5. **Creating or revising a public record (15 mins)**
   a. Check in on the observation, learning, and connection boxes of the summary table row for this activity and ask students if they would like to nominate anything to be added.
   b. Revisit the list of initial hypotheses and/or questions and see if this lesson helps answer a question or revise an idea. Also, what additional question do students have? (Use these questions to decide to add in a lesson before moving to lesson K).

Extension

Play the video clip about how hydroelectric generators work and look for similarities between the shakelight, homemade demo generator, and hydroelectric generator
https://www.youtube.com/watch?v=rnPEtwQtmGQ

Planning for Future Instruction

After this lesson, use student work and what you remember from student talk during the lesson to fill out a Rapid Survey of Student Thinking (RSST). This tool helps teachers keep track of the partial ideas, alternative understanding, everyday language, and experiences that students have and which can be used in future lesson s to help students make changes to their understanding over time.

Use the list of questions and/or ideas you heard students begin to discuss in today's lesson to decide if additional lessons about generators and how they work should be added.

How does a generator work?

Most metals have electrons that can move around freely. These electrons allow electricity to move through the metal, transmitting electrical energy from one place to another. These metals are called electrical conductors. A generator is a device that is used to move electrons through a conductor to give electric power. It does this by using a magnet that forces electrons to move along a wire at a steady rate while putting pressure on them.

With the help of a generator, the electrons can transmit electric energy from one point to another. The difference in the number of electrons and the pressure that the generator applies is what creates the different electric currents. The generator spins at a certain number of rotations per minute. The number of electrons that move is measured in amps. The pressure is measured in volts. In the United States, the electric current in the power outlets is 120 volts.

Source: http://discoverykids.com/articles/how-does-a-generator-work/

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Science of Electricity: Atoms & Electricity

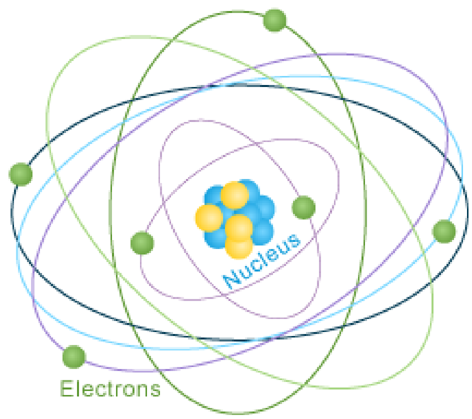
Everything is made of atoms

To understand electricity, it's important to know something about atoms. Atoms are the building blocks of the universe. Everything in the universe is made of atoms—every star, every tree, every animal. The human body is made of atoms. Air and water are made of atoms too. Atoms are so small that millions of them would fit on the head of a pin.

Atoms are made of even smaller particles

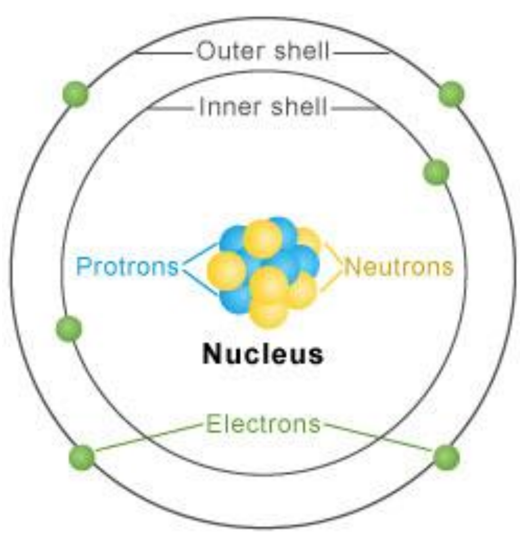
The center of an atom is called the nucleus. It is made of particles called protons and neutrons. Electrons spin around the nucleus in shells a great distance from the nucleus. Electrons are held in their shells by an electrical force.

The protons and electrons of an atom are attracted to each other. They both carry an electrical charge. Protons have a positive charge (+) and electrons have a negative charge (-). The positive charge of the protons is equal to the negative charge of the electrons. Opposite charges attract each other. An atom is in balance when it has an equal number of protons and electrons. The neutrons carry no charge and their number can vary.



Electricity is the movement of electrons between atoms

Electrons usually remain a constant distance from the nucleus in precise shells. The shell closest to the nucleus can hold two electrons. The next shell can hold up to eight. The outer shells can hold even more. Some atoms with many protons can have as many as seven shells with electrons in them.



The electrons in the shells closest to the nucleus have a strong force of attraction to the protons. Sometimes, the electrons in an atom's outermost shells do not. These electrons can be pushed out of their orbits. Applying a force can make them move from one atom to another. These moving electrons are electricity.

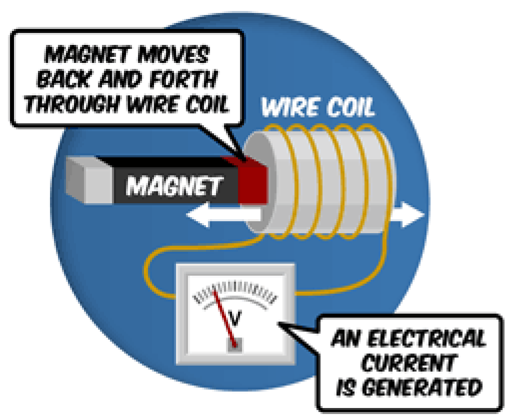
Science of Electricity: Magnetism & Electricity

Magnets and Electricity

Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the same poles together, they repel each other. But if you put different poles together, the magnets will stick together because the north and south poles are attracted to each other. Just like protons and electrons—opposites attract with magnets. The spinning of the electrons around the nucleus of an atom creates a tiny magnetic field. The electrons in most objects spin in random directions, and their magnetic forces cancel out each other. Magnets are different because the molecules in magnets are arranged so that their electrons spin in the same direction. This arrangement and movement creates a magnetic force that flows from a north-seeking pole and a south-seeking pole. The magnetic force creates a magnetic field around a magnet.

Magnetic fields can be used to make electricity

The properties of magnets can be used to make electricity. Moving magnetic fields can pull and push electrons. Metals such as copper have electrons that are loosely held, so the electrons in copper wires can easily be pushed from their shells by moving magnets. By using moving magnets and copper wire together, electric generators create electricity. Electric generators essentially convert kinetic energy (the energy of motion) into electrical energy.



FARADAY'S EXPERIMENT

How Electricity is Generated

A generator can be broadly defined as a device that changes a form of energy into electricity. Generators operate because of the relationship between magnetism and electricity. In 1831, scientist Michael Faraday discovered that when a magnet is moved inside a coil of wire, an electric current flows in the wire.

The most widely used method of producing electricity uses generators with an electromagnet—a magnet produced by electricity—not a traditional magnet. The generator has a series of coils of wire. This wire surrounds an electromagnet that rotates. As it spins, it induces an electric current in the wire. An electric power plant uses a turbine or other similar machine to drive these types of generators.

K: WHAT ARE CAPACITORS? (added lesson, not in TG)

Focus Question	*What will students observe?*	*What will students learn?*	*Connection to Phenomenon?*	*NGSS* (See below)*
What are capacitors? How are they used?	The light flickers with each shake or motion of the magnets.	Capacitors store electric charge/energy temporarily and can discharge or release the energy quickly	The shakelight has a capacitor in it near the switch. This stores the charge/energy	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact

Next Generation Science Standards (NGSS)

Performance Standards

MS-PS2-5: Fields exist bet. objects exerting forces on each other even though the objects are not in contact

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Obtain, Evaluate, and Communicate Information • Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.	PS2.B: Types of Interactions • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems.(MS-PS2-5)

Lesson Objective

In this lesson, students learn some information about what capacitors are and their function in a circuit. In the generator lesson, students observed that in the homemade generator the electricity flickered with each spin. With the shakelight, if shaken with the switch in the "on" position, the light will flicker. But how do we get a steady beam of light? For this we need a special part called a capacitor.

Materials

- Shakelight
- Shakelight photo with diagram
- Video clips:
  - What is a capacitor? https://www.youtube.com/watch?v=B-m78bU-xxc (2 m 26 s)
  - How Capacitors work https://www.youtube.com/watch?v=SvqvRNt4fBU (3 minutes)

Procedure

1. **Orientation to the concepts & Making Observations (10 minutes)**
   a. Show students the shakelight but this time turn the switch "on" when shaking. Observe and share what happens.
   b. Remind students what they saw with the homemade generator and how the light flickered with each motion. This is like how the shakelight flickers with each shake.
   c. Today's question is: How can the flashlight make a steady beam of light when we aren't shaking it? Record observations about flickering shakelight in "observation" box.

2. Information from Videos (15 mins)
    a. Introduce the videos by using the color photo with diagram of the shakelight. Point out the part of the shakelight by the switch called the "Capacitor".
    b. Watch each video clip, pausing for questions and to highlight key information. By watching these clips students should be able to answer "What does a capacitor do?"
        i. What is a capacitor? https://www.youtube.com/watch?v=B-m78bU-xxc (2 m 26 s)
        ii. How Capacitors work https://www.youtube.com/watch?v=SvqvRNt4fBU (3 minutes)
    c. Fill in the "Learning box" on the summary table row.

3. Making Connections (10 minutes)
    a. Ask students to work in partners to come up with a connection between what we've seen and learned about capacitors today and our shakelight. Why do they think a shakelight or other generator needs a capacitor? Have pairs write one connection on a sticky-note and post it on the summary table in the "connections" box.

> Questions to ask students as they explore and learn about generators:
>
> - What are you noticing?
> - What does a capacitor do?
> - Why do you think the shake flashlight needs a capacitor?

4. Whole class coordination of ideas (5 mins)
    a. Use the sticky notes to help the whole class come up with a summary statement to put in the "connections" box. There are multiple ways to coordinate this conversation. One way could be to begin with one sticky note and read it aloud (also post it under the doc cam if convenient) and ask other pairs to publicly agree, disagree, or add on with their idea on their sticky note.
    b. Come to a consensus about what to write as a connection from this lesson.

5. Creating or revising a public record (5 mins)
    a. Check in on the observation, learning, and connection boxes of the summary table row for this activity and ask students if they would like to nominate anything to be added.
    b. Revisit the list of initial hypotheses and/or questions and see if this lesson helps answer a question or revise an idea. Also, what additional question do students have? (Use these questions to decide to add in a lesson before moving to lesson L).

Planning for Future Instruction

After this lesson, use student work and what you remember from student talk during the lesson to fill out a Rapid Survey of Student Thinking (RSST). This tool helps teachers keep track of the partial ideas, alternative understanding, everyday language, and experiences that students have and which can be used in future lesson s to help students make changes to their understanding over time.

Use the list of questions and/or ideas you heard students begin to discuss in today's lesson to decide if additional lessons about capacitors and how they work should be added. That being said, the capacitor is a relatively small part of the shakelight system. Its purpose is to store the electric current created by shaking the light so that the user doesn't have to continually shake it to use the flashlight.

L. Model Revisions & Pressing for Evidence-based Explanations (added lesson, not in TG)

Focus Question		*NGSS*
How can we use evidence from activities to explain our phenomenon?	Use the summary table with information from each of the activities to find evidence to explain how a shake flashlight works.	MS – PS2-5: Fields exist between objects exerting forces on each other even though the objects are not in contact MS-PS2-3: Factors that affect the strength of magnetic forces

Next Generation Science Standards (NGSS)

Performance Standards

MS-PS2-5: Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact

MS-PS2-3: Determine the factors that affect the strength of magnetic force

Science & Engineering practices:	Disciplinary Core Ideas:	Cross-cutting concepts:
Constructing Explanations • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)	• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)

Materials

- Shakelight
- Pencils (colored pencils optional)
- Summary table with list of activities and what we learned and connection to phenomenon

Procedure – Day 1

1. **Opening – Whole Group (5 minutes)**
   a. Reintroduce/review the phenomenon: Show the shakelight and/or shakelight videos to remind students what they will need to explain. Point out resources that will help students such as the summary table and notes/readings in their notebooks.

2. **Writing an explanation (40 minutes)**
   a. Explain to students that their job is to explain how the shake flashlight works and why it doesn't need batteries. More importantly, it's to somehow represent or draw what they can't see that they think is causing the flashlight to work this way.
   b. Before sending students to write, generate a list of key ideas they think they should include in their explanation.

c. Show students the sentence starters they can use and what resources they have in the room to help them write about the shake flashlight. Students should include a diagram with their writing if it helps them clarify their ideas. (Optional: Have students do a model revision).

d. Circulate as students get started writing. If needed, pause the class to clarify directions or make changes in scaffolding to make sure all students can participate in this task and show what they have learned.

Procedure – Day 2

1. Students peer conference in pairs with a short rubric or checklist to provide feedback about what to add or clarify in their partners' writing. Models and writing can be displayed. You can develop your own simple rubric or checklist or use the checklist of 4 items provided on the next page.

2. Get students' reactions on how they think their thinking has changed over this unit so far (written or in pair-share). Students could answer the following prompts in their science notebook:
    a. What do you know now about magnets that you didn't know before this unit?
    b. What is the most interesting thing you learned about magnets and electricity?

Multi-day Extension (Optional)

1. Show students this video of a Socket ball.
    a. Soccket ball video: https://www.youtube.com/watch?v=oeb2fyHKirQ

2. This invention operates on the same principles as the shake flashlight. When watching the video, have students answer the following questions:
    a. What does the socket ball do?
    b. How do they think the socket ball works? (What's likely inside it?)
    c. What need does this invention fill? Why is it an important invention?

3. Task: Design an invention that relies on the principles of electricity and magnetism we've learned about this unit AND serves a particular need. Students must…
    a. Name and describe the purpose of their invention. What does it do? What need does it fill? Who would likely use it?
    b. Draw a diagram of the invention interior and exterior views and briefly describe how it works using ideas about electromagnets, generators, capacitors, magnets, circuits etc.
    c. Draw a picture of the invention being used by likely consumers.

CLAIMS:

The shake flashlight does not need batteries because…

The shake flashlight has a magnet and a coil of wire because…

A capacitor in the shake flashlight is helpful because…

To make the shake flashlight brighter or more powerful, the manufacturer should…

EVIDENCE:

In the “All about Generators” lesson, we learned that….
This relates to the shake flashlight because…

In the “What are capacitors?” lesson, we found out that…
This is important to know because it explains why the shake flashlight….

From the homemade generator demonstration we observed that magnets …
Therefore, we know that the shake flashlight…

CHECKLIST OF WHAT TO INCLUDE or EXPLAIN:

- ✓ How a generator works
- ✓ The role of the capacitor
- ✓ Relationship between electricity and magnetism
- ✓ Evidence from activities and lessons