

Making an Electromagnet

Grade 4

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Science Content Standards: Grade 4, 1c — *Students know* electric currents produce magnetic fields and know how to build a simple electromagnet.

Lesson Concept: Electricity and magnetism are related effects that have useful applications.

Conceptual Flow:

- ▶ Electric current produces a magnetic field.
 - When an electric current from a battery flows through a wire wrapped around a nail, the nail becomes magnetized.
 - Disconnecting the wire from the battery stops the flow of electricity and the nail is no longer magnetized.
- ▶ Electromagnets are used in many devices.
 - Electromagnets are important in the function of electric motors, generators, doorbells, and earphones.
 - Electromagnets use the interactions of two magnetic fields: one from a coil and the other from a permanent magnet.

Teacher Background:

All materials are made of atoms. The electrons in each of the atoms do not necessarily orbit in a circular motion. The best model that scientists have at the present is that electrons can be found in something called a “probability cloud” that surrounds the nucleus. Electrons can be described as having something called a “magnetic moment”. An atom acts like a magnet depending on how the “magnetic moments” of its electrons and protons and neutrons add together. If the “magnetic moments” of all the atoms in a material more or less line up, they reinforce one another and make the material as a whole magnetic.

The “magnetic moments” in a permanent magnet are lined up and they tend to stay that way. The more lined up the “magnetic moments” of the atoms, the stronger the magnet. Most

nonmetals have atoms with tiny or even almost nonexistent “magnetic moments.” Lining up the “magnetic moments” in these materials will not make a magnet.

When a coil of wire is wrapped around an iron nail and electricity is sent through that coil, a magnetic field is created around the nail. The “magnetic moments” of the atoms in the nail react to this magnetic field from the coil of wire and line up with it. By lining up with the magnetic field of the wire, these “magnetic moments” make for a stronger magnetic field. Thus, a coil of current-carrying wire with a nail inside is a stronger magnet than just the coil of wire alone.

When the coil of wire is removed from the nail, the nail will still be slightly magnetic because once the “magnetic moments” of the atoms in the nail are lined up, they don’t easily move back to randomness. To get those “magnetic moments” randomly oriented again, bang the nail hard several times; this shakes things up inside the nail and gets those “magnetic moments” into a more random orientation.

(Adapted and excerpted from *Stop Faking It! Electricity and Magnetism* by William C. Robertson.)

The strength of an electromagnet is related to the number of times the wire is coiled around the core and the distance the wire covers across the core. The more coils wrapped closer together, the stronger an electromagnet will be. The amount of voltage running through the wire also plays a role in an electromagnet’s strength. More voltage means more electrons moving through the wire and thus a stronger magnet.

Since an electromagnet will not work without electricity, a power source such as a battery is needed. The power source provides the electricity to charge an electromagnet into action. Power runs through the wire, around the coil, and back to the battery to produce the magnetic field.

Disconnect the battery and the electromagnet no longer functions. If the battery is reconnected with the positive and negative terminals reversed, current will flow through the wire in the opposite direction. This results in a switch of the magnetic poles in the electromagnet. Metal objects or other magnets can be moved back and forth (attracted and repelled) by repeatedly switching the poles of an electromagnet.

(Adapted and excerpted from www.essortment.com/hobbies/electronicsques_sbbr.htm)

The following information is from the *Science Framework for California Public Schools: Kindergarten Through Grade Twelve*):

Electric currents produce magnetic fields, and a simple electromagnet can be made by wrapping a half-meter length of insulated wire around a large iron nail or iron rod and connecting the ends of the wire to a battery. When an electric current from the battery flows through the wire, the iron bar is magnetized. Students can use a compass to prove that, like permanent magnets, their electromagnet has two poles. If the orientation of the battery is reversed, the poles of the magnet are reversed so that south becomes north and north becomes south. Students in grade

four are unlikely to have sufficient knowledge to predict that this would happen, but in high school they will have an opportunity to understand the principles at a much deeper level.

Electromagnets are important in the function of electric motors, generators, doorbells, and earphones. Electromagnets may be thought of as magnets that can be turned on and off. When an electromagnet is switched on, an adjacent iron magnet can be made to move; this type of electrically induced movement can be harnessed (e.g., to ring doorbells or vibrate a speaker element in a pair of head-phones). Constructing such a device helps students realize that they are using the interaction of two magnetic fields: one from a coil (an electromagnet) and the other from a permanent magnet (or, in some schemes, another electromagnet).

One way to understand a motor is that the alternating attraction and repulsion of the two magnetic fields converts electrical energy into the energy of motion. In high school, students will learn that charges (electrons) flowing in wires that cross magnetic fields experience a force that explains the rotation in the motor. An electric generator acts like an electric motor operating in reverse to change the energy of motion into electrical energy.

See http://www.physics4kids.com/files/elec_magnets.html for additional information on electromagnets.

Materials Needed for the Lesson:

Teacher Materials

- Picture of a junkyard magnet moving junk metals (cars, etc.)
- Magnet
- Metal paper clips (5-10)
- One 5-inch nail
- 40 cm of insulated wire
- D-cell battery
- Battery holder

Teacher Preparation

Make a class chart (to use for debrief)

Average # of paper clips picked up	Number of wire wraps on nail

Student Hands-on Materials

For each set of partners

- One 5-inch nail
- 40 cm of insulated wire
- D-cell battery
- Battery holder
- Metal paper clips (about 30)
- Large (3" x 5") "stickie" note (self-stick removable notes)

Student Handouts

- Student Assessment: "Electromagnets"

5E Lesson: Title of Lesson

Teacher Does	Student Does	Concept
<p><u>ENGAGE:</u> Have students discuss with a partner or in groups: “What do you know about magnets?”</p> <p>Chart ideas.</p> <p>Show a picture of a “junkyard” magnet moving metal junk.</p> <ul style="list-style-type: none"> ▶ <i>What is this magnet used for?</i> ▶ <i>How do they get the metal to fall off?</i> <p>Show a magnet with paper clips stuck to it.</p> <ul style="list-style-type: none"> ▶ <i>How can I get this magnet to “let go” of these paper clips?</i> ▶ <i>How do you think you can make a magnet that you can turn on and off like the big magnet in the junkyard?</i> ▶ <i>Today we are going to explore making a magnet and see if we can turn the magnet on and off.</i> 	<p>Discuss magnets.</p> <p>Expected Student Responses (ESR): Magnets pick up metal things; some magnets are really strong; magnets stick to metal</p> <p>ESR: Moving the metal junk from one place to another.</p> <p>ESR: Turn the magnet off.</p> <p>ESR: You have to pull them off.</p>	<p>Magnetism is a force that attracts certain metals.</p>
<p><u>EXPLORE:</u> Hold up a nail and ask:</p> <ul style="list-style-type: none"> ▶ <i>Is this a magnet? If it is a magnet, what would happen if I put the nail into the paper clips? If it is not a magnet, what would happen if I put the nail into the paper clips?</i> ▶ <i>Dip the nail into the paper clips. Thumbs up if you think the paper clips will stick; thumbs down if you think the paper clips will not stick to the nail.</i> <p>Pull the nail out from the paper clips.</p> <ul style="list-style-type: none"> ▶ <i>Since paper clips are not stuck to the nail ... is the nail acting like a magnet? Might there be a way to turn this nail into a magnet?</i> <p>Model how to wrap a wire around a nail and attach the wire ends to a battery. (Make certain to leave 10 cm of wire available at both ends to attach the wire ends to the battery;</p>	<p>ESR: The paper clips would stick to the nail.</p> <p>ESR: The paper clips would not stick to the nail.</p> <p>ESR: Thumbs up or thumbs down</p> <p>ESR: No</p> <p>ESR: No, yes, maybe</p>	<p>Wrapping a wire around a metal bar and attaching the ends of the wire to a battery will create an electromagnet.</p>

Teacher Does	Student Does	Concept
<p>make the coils tight and close together.) Once the battery is attached, dip the nail into the paper clips.</p> <ul style="list-style-type: none"> ▶ <i>Did the nail pick up any paper clips?</i> <p>Distribute nails and wire to each set of partners.</p> <p>Ask students to wrap their nails with the wire.</p> <p>Distribute batteries and battery holders to each set of partners.</p> <p>Model connecting the wire ends to the battery.</p> <ul style="list-style-type: none"> ▶ <i>Now test your nail to see if it can pick up any paper clips.</i> ▶ <i>What did you just make with a nail, wire, and a battery?</i> ▶ <i>Did you use an electric current to make the magnet?</i> ▶ <i>Raise your hand if you know the term for this type of magnet.</i> ▶ <i>We are going to test how many paper clips your electromagnet can pick up.</i> <p>Distribute a large stickie note to each set of partners.</p> <ul style="list-style-type: none"> ▶ <i>Write your names on sticky note and the number of wraps of wire on your nail.</i> ▶ <i>Then do 5 trials, each time recording on your sticky note the number of paper clips picked up by your electromagnet.</i> ▶ <i>After the 5 trials calculate the average (add all the numbers of paper clips picked up by the electromagnet and divide by 5.) Write that number in the bottom right hand corner of the stickie note and circle it.</i> ▶ <i>Put a square box around the number of wraps on your nail.</i> <p>When pairs have completed their trials and calculations, collect the sticky notes.</p> <p>Chart results (the number of wraps and the average number of paper clips picked up, on a pre-made class chart – see “Teacher Preparation”).</p>	<p>ESR: Yes</p> <p>Wrap nails with the wire.</p> <p>Connect the wire ends to the battery.</p> <p>Dip nail into paper clips to see if the paper clips stick to the nail.</p> <p>ESR: A magnet.</p> <p>ESR: Yes</p> <p>ESR: An electromagnet</p> <p>Test to see how many paper clips the electromagnet can pick up.</p> <p>Record the 5 trials and find the average.</p>	

Teacher Does	Student Does	Concept
<p>Note to teacher: Remember to get large and small number of wraps; the data should show that the more wraps, the more paper clips are picked up (i.e., the more wraps, the stronger the electromagnet).</p> <ul style="list-style-type: none"> ▶ <i>What do you notice about the data?</i> ▶ <i>What do you notice about the number of wraps on a nail and the number of paper clips the nail can pick up?</i> <p>Note to Teacher: If the student data is “skewed” (not giving the information of more wraps/ more paper clips picked up) then review the student’s electromagnets and how they are picking up the paper clips. Sometimes students scoop the paperclips onto the nail. “Sloppy” science can be the culprit for unreliable data.</p> <p>Collect an electromagnet that has a few wraps and only picked up a few paper clips; one with many wraps and picked up many paper clips; and one that is right in between. If one is available, put under the “Elmo” to compare. Otherwise, allow students to move to get a closer view of the three electromagnets.</p> <ul style="list-style-type: none"> ▶ <i>Which electromagnet will pick up the most paper clips?</i> <p>Compare a group that had many paper clips and the group who had the least number of paper clips. Have these groups bring their electromagnet to the front of the room to compare.</p> <ul style="list-style-type: none"> ▶ <i>How are they similar how and how are they different?</i> <p>Hold up the wrapped nail.</p> <ul style="list-style-type: none"> ▶ <i>This is a temporary magnet. What does “temporary” mean?</i> ▶ <i>What is the opposite of temporary?</i> ▶ <i>What does permanent mean?</i> <p>Write temporary and permanent on the board.</p> <ul style="list-style-type: none"> ▶ <i>What might be a way to turn off this magnet?</i> 	<p>ESR: Some electromagnets picked up more paper clips than others.</p> <p>ESR: The nails with more wraps pick up more paper clips than the ones with less wraps.</p> <p>ESR: The one with the most wraps.</p> <p>ESR: One has more wire wraps and the other has only a few.</p> <p>ESR: Temporary means sometimes, not always.</p> <p>ESR: Permanent</p> <p>ESR: It means all the time.</p> <p>ESR: Disconnect one or both wires; Take the wire off the nail.</p>	

Teacher Does	Student Does	Concept
<p>Unhook one wire from the battery and show that the electromagnet is severely weakened.</p> <ul style="list-style-type: none"> ▶ <i>An electromagnet is a temporary magnet. It becomes a magnet when it has electricity flowing through the coils and it is no longer a magnet when it is disconnected from the power source.</i> ▶ <i>Let's look at our data again. How might you make a stronger electromagnet?</i> 	<p>ESR: Add more wire wraps.</p>	
<p>EXPLAIN:</p> <p>Hand out assessment sheet, "Electromagnet" to each student and ask them to complete it.</p> <p>Once students have completed their assessments, discuss as a class:</p> <ol style="list-style-type: none"> 1. <i>How can you build an electromagnet?</i> 2. <i>How can you turn an electromagnet on and off?</i> 3. <i>Explain how to make an electromagnet stronger.</i> 	<p>Complete assessment</p> <p>ESR: Wrap wire around a nail and hook it up to a battery.</p> <p>ESR: Connect the electromagnet to a battery and it is on. Disconnect it from the battery and it is off.</p> <p>ESR: Put more wire wraps around the nail. More wraps makes an electromagnet stronger.</p>	<p>Electric current passing through a loop of wire creates a simple electromagnet.</p> <p>An electromagnet is a temporary magnet (the magnet can be turned on and off).</p>
<p>EXTEND:</p> <p><i>Using what you have learned about electromagnets, how can an electromagnet (a very large one) be useful at a landfill?</i></p> <p>See http://seplessons.ucsf.edu/node/21 for teaching students about variables when making an electromagnet.</p> <p>A more advanced lesson is described on: www.eduref.org/Virtual/Lessons/Science/Physics/PHS0070.html</p>	<p>ESR: A large electromagnet could be lowered into a pile of trash and all the metal would stick to it. Then the crane could move all the metal to another area and release the metal by disconnecting the electromagnet from the electric source.</p>	<p>Large electromagnets can be used to do work.</p>

Input Question: What do you know about magnets? (Engage); What does “permanent” mean? (Explore)

Process Question: How might you make a stronger electromagnet? (Explore)

Output Question: How can an electromagnet (a very large one) be useful at a landfill? (Extend)

