Solar Dynamics Observatory

Activity Name	Grades	Suggested Activity Time	Prep Time*	Materials**
Electricity and Magnetism	5-8	35-45 min	20 min	*For each group:* one copy of SDO image (see page 7), two D batteries, one 2 "D" battery holder, one long nail (approx. 3"), 30 paper clips, 3-4 ft. insulated wire with alligator clips on each end

*Estimated prep time is 20 minutes once you have obtained all of the materials for the lesson.
**Most items can be purchased online at radioshack.com and other sites. Radio Shack catalog numbers are as follows: 2 "D" battery holder #270-386, insulated wire #278-503, alligator clips #270-380. Note: *Take out batteries from the battery packs when not in use to prevent them from draining quickly. Also, make sure to use insulated wire otherwise the experiment will not work.*

Objectives- Students will be able to:
- Perform an experiment using an electromagnet
- Explain how electricity and magnetism work together to make an electromagnet work
- Identify how the Sun is like an electromagnet

Description:
In small groups, students will build electromagnets, discover how electricity and magnetism are interrelated, and learn how these concepts relate to the Sun.

How to Prepare:
Cut the insulated wire into lengths of 3-4 ft so that there is one for each group. Attach an alligator clip to each end of the 3-4 ft long insulated wires (see pictures on right). Make sure that the batteries are not in the battery holders; they will drain more easily if left in the holders. If batteries are not new, test them to make sure they are not drained. Print out one copy per group of the image on page 7. Students are expected to have background knowledge about electricity and magnetism for this lesson (see Resources section for links to lessons on these topics). They should also be familiar with the basics of solar activity and the concept of the Sun having a magnetic field (see Resources section for link to the NASA SDO Educator page for the *Magnetic Fields of the Earth and Sun* lesson plan, which introduces these concepts).

Background Information:

Electromagnetism is an important concept that scientists need to understand when studying the Sun. Electromagnetic activity on the Sun can lead to solar activity (i.e. solar eruptions), which can cause Earth to be flooded by radiation from charged particles (see NASA SDO links in Resources section for footage of solar eruptions). Although this radiation is sometimes the cause of beautiful auroras, it is also a significant threat to our technological, navigation, and communication systems. For example, our power grids can be shut down, pilots can lose radio communication near the Earth's poles, satellites and astronauts can be harmed, and GPS signals can be interfered with (for more information, see the SolarStorms.org link under Resources). NASA scientists, such as those working on the Solar Dynamics Observatory (SDO) mission, study the Sun in hopes that they can better predict when solar events will occur and help prevent the problems they can cause.

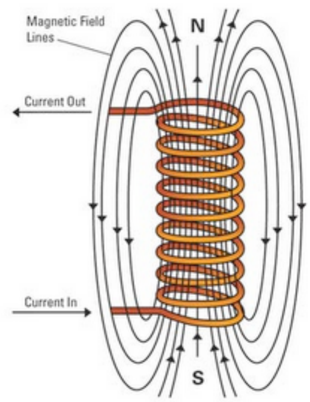


Image courtesy of the Los Alamos National Laboratory

In this activity, students will build and experiment with an electromagnet. When an electric current passes through a tightly coiled wire, it creates a magnetic field around the coil (see image on right). To create an electromagnet, a metal rod (i.e. a nail) is placed inside of the coiled wire. When the electricity flows through the wire around the metal rod, it becomes a magnet. The magnetic field inside the coil aligns the tiny magnetic fields in the metal rod in one direction (all the north poles point the same way), making it a magnet. When the electric current is turned off, the metal rod is not a magnet. An electromagnet differs from a permanent magnet (i.e. refrigerator magnet) in how it requires electricity to work.

Vocabulary:

1. Current
2. Electricity
3. Electromagnet
4. Electron
5. Magnetic Field
6. Magnetism
7. Magnetogram (see image on page 7)
8. Solar activity (i.e. solar eruptions)
9. Solar Dynamics Observatory (SDO)

Directions:

1. Do a warm-up activity to engage students and activate their prior knowledge. Write the first six vocabulary words on the board (see Vocabulary section above). Ask students to work individually and write down what they know about each word and/or how the concepts relate to their everyday lives. After a few minutes, have them pair up with a partner to add to their list. (Note: If they have not heard of the term electromagnet, you can suggest that they break the word into two parts—"electro" and "magnet"—and come up with an idea of what they think it means.)
2. After students have completed their lists, have groups take turns sharing what they wrote down with the entire class. If one group is unclear about a certain word, allow their classmates to explain what they mean. Allow students to collaborate and come up with the answers themselves. If they do not know what an electromagnet is, do not tell them. Instead, let them know they will be exploring the concept during the lesson.
3. Tell students that they will be building electromagnets, and learning about how electricity and magnetism cause intense activity that occurs on the Sun. To review what you mean by solar activity, show them footage of solar eruptions (see Resource section for NASA SDO videos). Explain that the NASA Solar Dynamics Observatory, which is constantly watching the Sun, took the videos and that this type of solar activity can effect us on Earth (for examples, see Background Information section).

Reinforce the concept that these eruptions are caused by the interaction of electricity and magnetism on the Sun.
4. Explain that they will be investigating the relationship of electricity and magnetism by building electromagnets. Tell them they will be expected to pick up paper clips with a nail by making it a magnet. Break students into groups of 3-4 people and hand out the materials.
5. In groups, have students work together to come up with a way to determine if the nail is a magnet or not. Have them prove their theories by showing you. (Sample answer: The nail is not a magnet because it does not attract metal objects, like the paper clips, as a magnet would do.)
6. Instruct students to wrap the insulated wire around the nail tightly. Have them count the number of coils they make if you plan to do step 14. (Note: In order for the electromagnet to work well, students must wrap the wire around the nail *tightly* at least 30 times. See **Step 6** image on page 6 for an example. If their electromagnet does not work well, ask them guiding questions to help them make this realization as outlined in step 11.)
7. Remind students that their objective is to build an electromagnet, which means they must turn the nail into a magnet and pick up the paper clips. Have students experiment with the materials in front of them to figure out a way to accomplish the objective (make sure they leave the wire coiled on the nail). If students need help, remind them to think of what two words make up the word electromagnet as in step 1—"electro" (electricity) and "magnet" (magnetism). If they need another hint, ask them to think about how they can get electricity flowing around the nail.
8. For students that have not yet figured out the procedure, instruct them to make sure their batteries are *not* in their battery packs yet. Leaving the wire coiled on the nail, have them clip one end of the coiled wire (using the alligator clip) to the wire protruding from one side of the battery pack. Have them clip the other end of the coiled wire to the wire protruding from the other side of the battery pack (see **Step 8a** image on page 6). Make sure the alligator clips are attached to the exposed metal wire and not its plastic covering (see **Step 8b** image on page 6).
9. With the batteries out of their battery packs, ask students if they think the nail will pick up the paper clips. Ask them if the presence of the coiled wire and battery pack make the nail a magnet. Have them support their answers. (Example: They can place the nail over the paper clips to show that the nail is still not a magnet.) Ask them to talk to their group members to determine a way to change their set up in order to magnetize the nail. Let them make changes and test them.
10. (Caution: When students add the batteries in this step, the alligator clips and battery pack may get hot.) If students have still not determined how to complete the construction of the electromagnet, ask them to predict what would happen if they put the batteries in the battery packs. Make sure they support their answers.
11. Have them test their predictions by loading the batteries into the battery packs. Have them place the nail over the paper clips. The nail should now be a magnet (see **Step 11** image on page 6). Ask students to explain what caused the nail to act as a magnet when the battery was added. (Note: If the electromagnet does not work well, ask them guiding questions about why that may be the case. For example, have them check to see if all wires are connected correctly, the batteries are in the battery pack, and the alligator clips are attached to the exposed wire as shown in the images on page 6. If that leaves the coil as the only part left for them to check, ask them to think of how they can change the coil to make it work better. If time is an issue or they struggle to find an answer, ask them what they think would happen if they added more coils and/or made the coils tighter on the nail and why. Then have them make a change and test it.)
12. Explain that the battery causes electrons to move through the wire, creating an electric current. Relate this to how they may use a battery to power a flashlight or cell phone; the battery creates the electric current (or electricity) that it needs to work. As the electric current passes through the coiled wire, it creates a magnetic field around the coil, thus causing the nail to act as a magnet (see Background Information section on page 2 for more information and diagram).
13. Give examples of electromagnets that are used in every day life including doorbells, electric can

openers, and junkyard cranes. (*Optional*: Using their electromagnets, you can have them demonstrate how a junkyard crane works. Have students imagine that the nail is the crane and is moving around scrap metal (the paper clips). Have them pick up the scrap metal (paper clips) with the crane (nail) by putting the batteries in their battery packs. The electricity flowing through the wire causes the crane (nail) to be magnetized. Have them then move the paper clips across the table. When they are ready to drop them, have them they take out the batteries to stop the flow of electricity. You can have them explain to you how a crane works like an electromagnet to check for understanding.)

14. (*Optional*) Allow groups to experiment with their electromagnets to see how many paper clips they can pick up. In a table on the board, have each group record the number of paper clips they picked up <u>and</u> the number of times they wrapped the wire around the nail. Ask them if they see a connection: Does the number of times you wrap the wire around the nail affect how many paper clips you can pick up? (Note: It should, but the strength of their batteries also affects it.) How could you modify the experiment to increase the number of paper clips you pick up? (Sample answers: wrap the wire more times around the nail or more tightly, add more battery power, etc.)

15. Have students put their electromagnet materials to the side. Tell them that the Sun is another example of an electromagnet. Make the connection that electrons do not only flow through wires, but many other things too—even the Sun! Electrons moving around in the Sun cause electric currents, which in turn create a magnetic field around the Sun (for more information, see the YPOP link under Resources). To check for understanding, ask students how the Sun is like the electromagnet they built earlier. Have them do a think-pair-share activity (they come up with ideas on their own, then they talk to a partner, then they share as a class).

16. Hand out a copy of the magnetogram on page 7 to each group. Explain that this is an image of the Sun taken by the Solar Dynamics Observatory; is it essentially a map of the magnetic activity on the Sun. The black and white areas indicate that there is a high level of magnetic activity, and the gray areas indicate there is no magnetic activity (for more information, see the Stanford Solar Center link under Resources). The white lines represent the complex magnetic field lines around the Sun.

17. To extend the lesson to solar activity, explain to students that the areas of intense magnetic activity on the Sun (point out the black and white areas on the magnetogram) are where intense solar activity often occurs, including the solar eruptions they saw at the beginning of the lesson. This is all caused when magnetic field lines (point out white lines on the magnetogram) get twisted together. After they get tangled enough for a large amount of energy to build up, they can violently unwind and cause an eruption, which can head in Earth's direction (for more information, please see the NOVA PBS link under Resources). When they head in Earth's direction that is when our technological, communication, and navigation systems can be affected.

18. To assess students, have them draw a diagram of their electromagnet (the materials should be disassembled at this point). Ask them to include a paragraph describing how electricity and magnetism played a role in making the electromagnet work. Encourage them to label their picture or give step-by-step instructions if this helps them to explain themselves. Then have them relate their knowledge of the electromagnet to the Sun. Ask them to write down at least two ways the Sun is like an electromagnet (sample answers: it has electrons running through it, it is magnetic).

Extension:

To further investigate electromagnetism on the Sun, you can link to the concept of auroras, which can be particularly interesting for students. Auroras are caused when electrons from the Sun travel to Earth and get caught in its magnetic field, also called its magnetosphere. (The concept of Earth's magnetosphere can be introduced using the *Magnetic Fields of the Earth and Sun* lesson. A link to it can be found in the Resources section under NASA SDO Educator page). When teaching about auroras, connections can be made to NASA's THEMIS mission, which is investigating what causes auroras in the Earth's atmosphere to dramatically change shape and color. You can find a link to the THEMIS mission website and other aurora-related resources in the Resources section below.

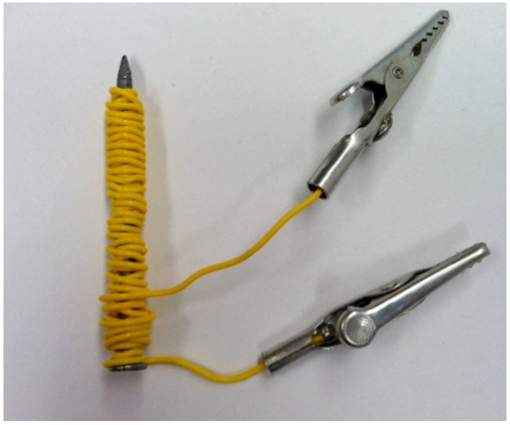
Resources:

- How Stuff Works—Electromagnets: http://science.howstuffworks.com/electromagnet.htm
- NASA SDO—"Burst Around the Corner" solar eruption image and videos: http://sdo.gsfc.nasa.gov/gallery/main.php?v=item&id=122
- NASA SDO—"Magnificent Eruption" solar eruption images and videos: http://sdo.gsfc.nasa.gov/gallery/main.php?v=item&id=158
- NASA SDO—Educator page (with *Magnetic Fields of the Sun and Earth* lesson plan): http://sdo.gsfc.nasa.gov/epo/activities.php
- NASA THEMIS—Mission Website: http://www.nasa.gov/mission_pages/themis
- NOVA PBS—Sun Lab: http://www.pbs.org/wgbh/nova/labs/boot-camp/1/3/
- SolarStroms.org—Space Weather Effects: http://www.solarstorms.org
- Stanford Solar Center—Solar Magnetograms: http://solar-center.stanford.edu/solar-images/magnetograms.html
- UC Berkeley Space Sciences Laboratory—*Auroras!* Book (printable PDF and Flash animation): http://ds9.ssl.berkeley.edu/auroras
- UC Berkeley Space Sciences Laboratory—Exploring Magnetism Teacher Guides: http://cse.ssl.berkeley.edu/SEGwayed/lessons/exploring_magnetism
- Utah Education Network—Flowing Electrons lesson plan: http://www.uen.org/Lessonplan/preview.cgi?LPid=11347
- Yohkoh Public Outreach Project (YPOP), Montana State University—The Magnetic Sun: http://solar.physics.montana.edu/ypop/Spotlight/Magnetic

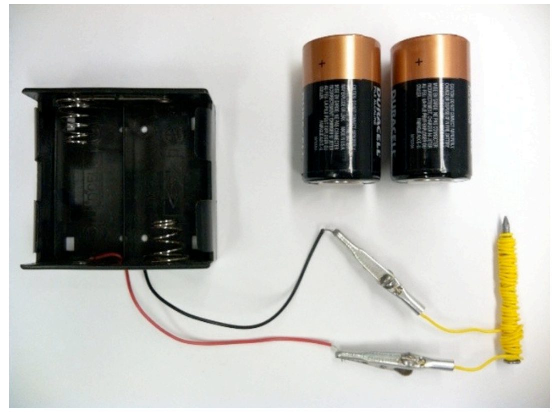
Standards addressed:

National Science Education Standards addressed:
K-4: *Content Standard B:* As a result of their activities in grades K-4, all students should develop an understanding of light, heat, electricity, and magnetism, 3: Electricity in circuits can produce light, heat, sound, and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass.

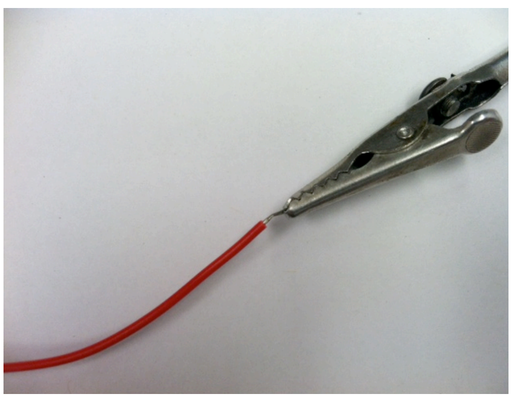
5-8: *Content Standard B:* As a result of their activities in grades 5 – 8, all students should develop an understanding of transfer of energy, 4: Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.



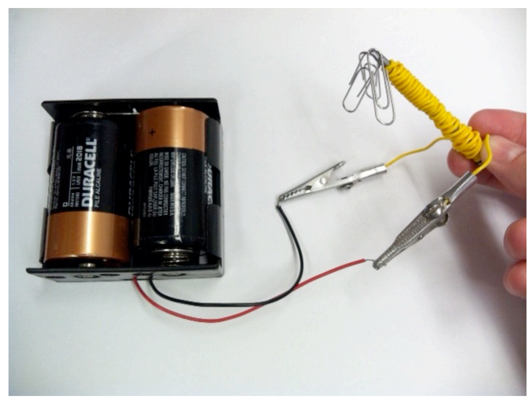
Step 6



Step 8a



Step 8b



Step 11

Magnetic Map of the Sun

Magnetogram image from 10/11/2011