

The Strength of an Electromagnet

Kit Contents

QTY	ITEM DESCRIPTION
1	Enamel-coated magnet wire, 30 gauge (75 feet)
2	Alligator clip leads
4	Iron bolts
1	1 Lantern battery, 6V

You will also need from home:

- 220 grit sandpaper
- Masking tape
- Box of steel paper clips (about 100 count)
- Scissors or wire cutters
- Optional: shallow plastic container, slightly longer and wider than the iron bolts

Summary

Prerequisites	None
Safety	The electromagnet can become hot during periods of extended use.

Frequently Asked Questions



http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p035.shtml#help

Abstract

You may be familiar with permanent magnets—the kind that hang on a refrigerator. But did you know that other magnets, called electromagnets, can be turned on and off? When turned on, electromagnets act just like permanent magnets, but if you turn them off, their magnetic properties disappear. Electromagnets are an important part of many electronic devices, like motors, loudspeakers, and hard drives. You can create an electromagnet with a simple coil of wire and a battery. In this science fair project idea, you will explore whether the strength of an electromagnet changes with the number of turns in the magnet's coil. You will measure the magnet's strength by counting the number of paper clips your electromagnet can lift.

Objective

In this science project, you will make an electromagnet by wrapping a coil of wire around an iron core. You will then investigate whether the number of coils changes the electromagnet's strength.

Introduction

Electromagnets, or magnets that use the magnetic field created by electrical current flowing through a wire, lie at the heart of many electrical devices, ranging from simple things like doorbells to complex machines, like particle accelerators.

The strength of electromagnets varies, but some electromagnets are strong enough to lift entire trains! So how does an electromagnet work? How does **electric current**—the movement of electric charges—make a magnet?

When electric current flows through a wire, it creates a magnetic field. You can prove this to yourself with a magnetic compass (see the Science Buddies Abbreviated Project Idea [Using a Magnet as an Electrical Current Detector](http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p044.shtml) (http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p044.shtml)). The magnetic field around a straight wire is not very strong. But if the wire is wrapped in a coil, the fields produced in each turn of the coil add up to create a stronger magnetic field. When the coil is wrapped in the shape of a cylinder, it is called a **solenoid**. (See Figure 1)

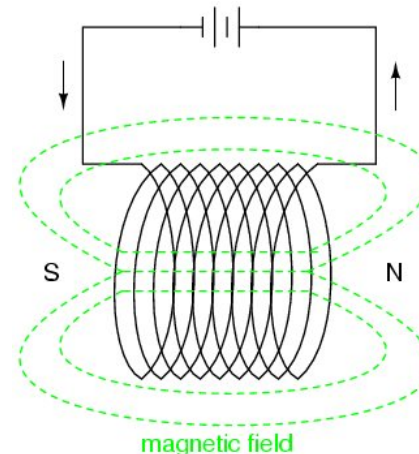


Figure 1. The green lines show the magnetic field surrounding a solenoid (or cylindrical coil) through which electric current is flowing. "N" and "S" indicate the north and south poles of the electromagnet.

If an electromagnet consists only of coiled wire (if it has nothing but air in its middle) then the magnet will not be very strong. But if you place a piece of iron in the middle of the coil—an iron bolt, for example—then the piece of iron, called the **magnetic core** or **iron core** of the electromagnet, will make the magnetic field much stronger (see Figure 2). This is because iron is **ferromagnetic**. It contains lots of tiny areas, called **magnetic domains**, that act like small magnets. As soon as the iron core is placed in the coil, the magnetic domains line up with the magnetic field made by the coiled wire solenoid. As a result, the strength of the magnetic field around the solenoid greatly increases.

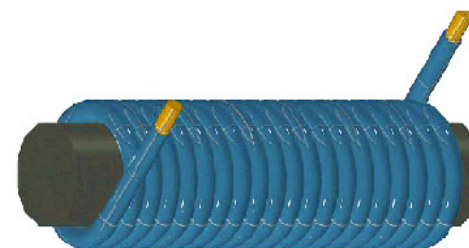


Figure 2. Insulated wire (blue) wrapped around an iron core (black). Electric current flowing through the wire creates a magnetic field, a field that is magnified by the iron core.

In this science project, you will investigate how the strength of the magnetic field produced by an electromagnet changes as the number of turns in the coil increases.

Terms and Concepts

To do this project, you should do research that enables you to understand the following terms and concepts:

- Electromagnet

- Electric current
- Solenoid
- Iron core
- Ferromagnetic
- Magnetic domains

Questions

- How does an electromagnet work?
- Why does an electromagnet have magnetic properties only when energized?
- Does increasing the current flowing through a coil of wire increase or decrease the strength of the magnetic field?
- What does adding an iron core to an electromagnet do to the magnetic field created by the electromagnet?

Bibliography

- Brain, M. and Looper, L. (2006). *How electromagnets work*. HowStuffWorks. Retrieved May 30, 2012, from <http://www.howstuffworks.com/electromagnet.htm> (<http://www.howstuffworks.com/electromagnet.htm>).
- Thomas Jefferson National Accelerator Facility - Office of Science Education. (n.d.). *What is an electromagnet?* Retrieved May 30, 2012, from http://education.jlab.org/qa/electromagnet_is.html (http://education.jlab.org/qa/electromagnet_is.html).
- Nave, C.R. (2006). *Magnets and electromagnets*. HyperPhysics, Department of Physics and Astronomy, Georgia State University. Retrieved May 30, 2012, from <http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/elemag.html> (<http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/elemag.html>).

Experimental Procedure

Note Before Beginning: This science fair project requires you to hook up one or more devices in an electrical circuit. Basic help can be found in the [Electronics Primer](http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_primer-intro.shtml) (http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_primer-intro.shtml). However, if you do not have experience in putting together electrical circuits you may find it helpful to have someone who can answer questions and help you troubleshoot if your project is not working. A science teacher or parent may be a good resource. If you need to find another mentor, try asking a local electrician, electrical engineer, or person whose hobbies involve building things like model airplanes, trains, or cars. You may also need to work your way up to this project by starting with an electronics project that has a lower level of difficulty.

1. Make four different electromagnets, using four identical iron or galvanized steel bolts. The first electromagnet will have 50 turns in its coil, the second will have 100 turns, the third will have 150 turns, and the fourth will have 200 turns. It is important to wrap the magnet wire neatly around the bolts. Here are some tips to make wrapping easier.
 - a. Leave a tail of wire (5-6 centimeters [cm] long) at each end of the coil. You will use these wire tails to connect the coil to the battery.
 - b. Make a holder for the spool of magnet wire, so you can roll the wire right off the spool. For example, you can stick a pen or pencil through the spool, and tape the pencil to a couple of small boxes.
 - c. Use a small piece of masking tape to attach the wire to the iron bolt, near where the head of the bolt connects to the shaft of the bolt.
 - d. Turn the iron bolt to unwind the magnet wire from the spool. Use your fingers to keep the wire tight against the bolt. Wrap each successive turn so that the wire lines up neatly.
 - i. **Note:** How neatly you coil the wire will affect the strength of your electromagnet, so take the time to coil the wire neatly. See Figure 2 above for an example of what neatly coiled wire should look like: the turns of wire are tight against the iron bolt, and the turns lie next to each other, with no empty space between them.
 - e. Keep track of how many turns you make (or how many times you wrap the wire around the bolt). A turn happens each time the tape that holds the wire in place comes around. Counting turns is easier if you can recruit a helper to make tally marks for you.
 - i. **Troubleshooting Tip:** If you are having trouble keeping track of how many turns you have made, here are two tips.
 - First, draw a line straight down the iron core using a permanent marker. Count one turn each time you pass that line.
 - Second, if you know the gauge of your magnet wire, you can look up the diameter of the wire

in a table, like this one for [American wire gauge](http://en.wikipedia.org/w/index.php?title=American_wire_gauge&oldid=495948718) (http://en.wikipedia.org/w/index.php?title=American_wire_gauge&oldid=495948718).

Once you know the wire's diameter, you can calculate how much of the bolt should be covered by a given number of coils. For example, the wire in the Science Buddies kit is 30 gauge wire and has a 0.01 inch diameter. That means that 100 turns cover 1 inch of the bolt (0.01 inches x 100 = 1 inch), if the turns are right next to each other and do not overlap. So, if you wrap your coil very neatly, you can get a rough idea of how many turns are in your coil by measuring how much of the bolt is covered by the coil.

Note that this method does not work if your coil has more than one layer of wire or if there are spaces between turns.

- f. When you reach the desired number of turns, tape the wire to the bolt to hold the coil in place. Cut the wire, leaving a 5-6 cm long "tail" for making the connection to the battery.
 - g. Particularly for larger coils, you may need to wrap multiple layers of wire, one layer on the other, to get the desired number of turns.
2. Use the 220 grit sandpaper to sand off 1 cm of the enamel insulation from the end of each magnet wire tail. You will need to do this for all four of your electromagnets.
 - a. Fold a small piece of sandpaper (about the size of two postage stamps, use scissors to cut a small piece of necessary) in half, with the rough sides facing each other, to make a "sandpaper sandwich".
 - b. Put the end of the magnet wire to be stripped inside the sandpaper sandwich.
 - c. While softly pressing the sandpaper sandwich together, gently pull the wire through the sandpaper sandwich, turning the wire as you pull so that you remove the insulation from all sides of the wire. Or, you can rub the wire back and forth inside the sandpaper sandwich.
 - d. The wire is stripped when you can see the shiny copper wire underneath.
 - i. **Troubleshooting Tip:** It is a good idea to practice stripping the enamel insulation off a practice piece of wire. You may need some practice to get the pressure right so that the wire does not break while you sand it.
 3. Place the paper clips in a shallow container (slightly longer and wider than the electromagnet). If you do not have a shallow container, put the paperclips in a pile on a flat surface.
 4. Starting with the 50-turn coil, use the electromagnet to pick up paper clips from the shallow container.
 - a. Use the alligator clip leads to connect the coil to the battery. When current flows through the coil, the coil is *energized* and will behave as a magnet. When no current flows through the coil, the magnetic characteristics of the electromagnet disappear.
 - i. **Troubleshooting Tip:** After connecting the coil to the battery, you can check that the electromagnet works by touching a paper clip to the coil. If the paper clip sticks, then the electromagnet is working. If the paper clip does not stick, then the electromagnet is not working. If this is the case, make sure that the alligator clips are connected to both the battery and the wire. One end of each lead should be clipped to one of the terminals of the battery (one lead to each terminal), and the other end of each of lead should be clipped to the stripped part of the magnet wire (one lead to each end of the wire). If the clip leads are connected correctly to the coil and battery but the electromagnet is still not working, then the problem may be that the magnet wire was not completely stripped. Try re-sanding the ends of the magnet wire until all of the reddish insulation is gone, then reconnect and retest the electromagnet.
 - b. Touch the energized coil (lengthwise) to the paper clips, and then pull the coil away from the tray. See Figures 3 and 4.



Figure 3. After connecting the alligator clip leads to the battery and wire on the coil, the electromagnet will be energized. Lower the electromagnet into the container of paper clips so that the long part of the electromagnet touches the paper clips.



Figure 4. Once you have touched the electromagnet to the paper clips, lift the electromagnet up. Some of the paper clips will stick to the electromagnet. Move the electromagnet away from the container (so that the paper clips will not fall back into the container) and then disconnect the coil from the battery.

- c. Once the coil is no longer over the container, disconnect the coil from the battery, and count how many paper clips the coil picked up. Record the number in your lab notebook. Organize your data in a table like Table 1.
- d. Repeat steps 4a to 4c four more times, for a total of five trials.
5. Repeat step 4 for the 100-, 150-, and 200-turn coils.
6. Calculate the average number of paper clips lifted by each coil (see Table 1).

Number of Turns on Coils	Number of Paper Clips Picked Up					
	1	2	3	4	5	Average
50						
100						
150						
200						

Table 1. Record the number of paper clips each coil picked up in each of the five trials and then calculate the average for the five trials.

Analyzing the Data

1. Make a graph of the results. Plot the number of turns in the coil (x-axis) versus the number of paper clips picked up (y-axis).
2. Does the number of paper clips picked up by the coil increase or decrease as you increase the number of turns in the electromagnet?

Variations

- Try using different metals as core materials inside the coil, such as steel, copper, aluminum, etc. You can use nails, bolts, pipe, tubing, etc. For making comparisons, it would be ideal to have core materials that are the same diameter and weight. You can wrap the coils directly around the core materials as described above, or you can make a single coil (for each number of turns that you want to test) and test it with different core materials inside. Here is a procedure for making coils so that you can swap the core material:
 - Make a coil form by wrapping several layers of paper (or a piece of thin cardboard) around a sample of your core material.
 - Use enough layers of paper or cardboard so that the coil form will hold its shape.
 - Tape the paper or cardboard so that it will hold its shape, and then slide it off the cylinder form.
 - Test the coil form with each of the core materials to make sure that they all fit.
 - Wrap your coil around the coil form, as described above.
 - Now you will be able to slide different core materials in and out of the coil. You can leave the paper form in place.
 - You could also try another experiment to see if removing the paper makes any difference in the strength of the electromagnet. Test the coils both with and without the paper form inside.

As in the procedure above, you can compare the number of paper clips that electromagnets with different core materials can lift.

- What happens when you change the distance between the coil of wire and a metal core material? For example, increase the diameter of your core forms (described in variation 1, above) by 2, 5, 10, and 20 mm.
- For an interesting addition to your display board, you can map the shape of the magnetic field produced by your electromagnets. Here's how: [Mapping Magnetic Fields](http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p043.shtml) (http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p043.shtml).
- What happens when you change the voltage applied across the coil? You can connect two or three lantern batteries in a series, or use increasing numbers of D-cell batteries in a series. As above, measure how many paper clips you can lift with a coil at each voltage.

Related Links

- [Science Fair Project Guide](http://www.sciencebuddies.org/science-fair-projects/project_guide_index.shtml) (http://www.sciencebuddies.org/science-fair-projects/project_guide_index.shtml)
- [Other Ideas Like This](http://www.sciencebuddies.org/science-fair-projects/search.shtml?v=solt&pi=Elec_p035) (http://www.sciencebuddies.org/science-fair-projects/search.shtml?v=solt&pi=Elec_p035)
- [Electricity & Electronics Project Ideas](http://www.sciencebuddies.org/science-fair-projects/recommender_interest_area.php?ia=Elec) (http://www.sciencebuddies.org/science-fair-projects/recommender_interest_area.php?ia=Elec)
- [My Favorites](http://www.sciencebuddies.org/science-fair-projects/recommender_show_favorites.php) (http://www.sciencebuddies.org/science-fair-projects/recommender_show_favorites.php)

If you like this project, you might enjoy exploring these related careers:



Electrical & Electronics Engineer

Just as a potter forms clay, or a steel worker molds molten steel, electrical and electronics engineers gather and shape electricity and use it to make products that transmit power or transmit information. Electrical and electronics engineers may specialize in one of the millions of products that make or use electricity, like cell phones, electric motors, microwaves, medical instruments, an airline navigation system, or handheld games. [Read more](http://www.sciencebuddies.org/science-engineering-careers/engineering/electrical-electronics-engineer) (http://www.sciencebuddies.org/science-engineering-careers/engineering/electrical-electronics-engineer)



Physicist

Physicists have a big goal in mind—to understand the nature of the entire universe *and* everything in it! To reach that goal, they observe and measure natural events seen on Earth and in the universe, and then develop theories, using mathematics, to explain why those phenomena occur. Physicists take on the challenge of explaining events that happen on the grandest scale imaginable to those that happen at the level of the smallest atomic particles. Their theories are then applied to human-scale projects to bring people new technologies, like computers, lasers, and fusion energy. [Read more](http://www.sciencebuddies.org/science-engineering-careers/earth-physical-sciences/physicist) (http://www.sciencebuddies.org/science-engineering-careers/earth-physical-sciences/physicist)



Electrical Engineering Technician

Electrical engineering technicians help design, test, and manufacture electrical and electronic equipment. These people are part of the team of engineers and research scientists that keep our high-tech world going and moving forward. [Read more](http://www.sciencebuddies.org/science-engineering-careers/engineering/electrical-engineering-technician) (http://www.sciencebuddies.org/science-engineering-careers/engineering/electrical-engineering-technician)

Credits

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Contact Us

If you have purchased a kit for this project from Science Buddies, we are pleased to answer any question not addressed by the FAQs on our site. Please email us at help@sciencebuddies.org (mailto:help@sciencebuddies.org?subject=The%20Strength%20of%20an%20Electromagnet) after you have checked the Frequently Asked Questions for this PI at http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p035.shtml#help

In your email, please follow these instructions:

1. What is your Science Buddies kit order number?
2. Please describe how you need help as thoroughly as possible:

Examples

Good Question *I'm trying to do Experimental Procedure step #5, "Scrape the insulation from the wire. . ." How do I know when I've scraped enough?*

Good Question *I'm at Experimental Procedure step #7, "Move the magnet back and forth . . ." and the LED is not lighting up.*

Bad Question *I don't understand the instructions. Help!*