Abstract

Electric current flowing through a wire wound around an iron nail creates a magnetic field, which caused an iron nail to become a temporary magnet. The nail can then be used to pick up paper clips. When the electric current is cut off, the nail loses its magnetic property and the paper clips fall off. The students will make an electromagnet that will attract a paper clip. They will then increase the strength of an electromagnet (improve on their initial design) so that it will attract an increased number of paper clips. The participants will also compare the properties of magnets and electromagnets.
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### History & Process Standards

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I. OBJECTIVES

Students will:
- learn the difference between a magnet and an electromagnet.
- make their own electromagnets.
- learn how to make an electromagnet stronger.

II. SAFETY

Don’t connect the electromagnet for an extended period of time, because the terminals connection between the battery and electromagnet get hot. Don’t touch the connection.

Don’t let participants use the nails to damage property or other participants.

III. LEVEL, TIME REQUIRED AND NUMBER OF PARTICIPANTS

LEVEL
The activity is appropriate for grades 4-12.

TIME REQUIRED
The participants require about 20 minutes to complete this activity.

NUMBER OF PARTICIPANTS
If only one person is administering the activity, groups of 5 - 7 are ideal. With two people available, groups of 8 - 14 are fine.

IV. LIST OF MATERIALS

lots of batteries (6 volt) and/or power supply (batteries are expended quickly!)
paper clips
magnet
wire stripper

For each participant you need:
15 inch strips of insulated copper wire with one inch exposed wire on each end
1 iron nail, x” long
1 iron nail, y” long
one horseshoe shaped bolt
one S shaped piece of meta
V. INTRODUCTION

When current is made to flow in a piece of wire it generates a circulating magnetic field about the wire. (See Figure 1)

![Figure 1: Wire with current flowing in it](image)

The direction of the circulating magnetic field depends on the direction of the flow of current through the wire. The electric current direction depends on the applied voltage’s polarity. Figure 2 shows that when the current moves towards you (imagine that you are looking at the piece of wire at its cross section) the magnetic lines of force are circulating in a counterclockwise direction (Figure 2 - left hand drawing). However if the current is flowing away from you, the magnetic lines of force are flowing in a clockwise direction.

![Figure 2: Direction of current flow in a wire](image)

When a current-carrying wire is wound around a metal that can be magnetized, the magnetic field generated by the current magnetizes the metal. This is called an electromagnet.
So, when we take a wire which induces a magnetic field around it and curl the wire into loops, we get a straight magnetic field. Notice the north and south poles on figure 3.

![Figure 3: current through curled wire inducing a straight magnetic field](image)

Putting a conducting material, such as a nail, through the center of the curled wire increases the magnetic field.

**A simple electromagnet:**

![Battery and curled wire](image)

An electromagnet can be made by wrapping insulated copper wire around a nail. Attach a volt battery or power supply to the ends of the wire (be sure to strip the insulation away first) and note the nail’s ability to act like a magnet (i.e., pick up paper clips, etc.) and to react to another magnet brought close to it. Note what happens when you:

- Increase the voltage (2 or more batteries in series; be careful that you don't get burnt by the wire or start a fire)
- Reverse the battery connections.
VI. EXECUTION

THE DIFFERENCE BETWEEN A MAGNET AND A NAIL

Start by asking the participants what the difference between a magnet and a nail is. Show them that the primary difference is that the magnet can pick up paper clips, and the nail cannot. Make sure the nail is not magnetized.

WE CAN MAKE A MAGNET OUT OF A NAIL!

Explain the concept of electromagnetism: if we have current flowing in a wire, it generates a magnetic field. If we wrap wire around a nail, and a current flows in wire, the nail acts like a magnet. This is called an electromagnet. Demonstrate the concept by making a simple electromagnet. Don’t use too many windings of copper wire. Connect the electromagnet to a battery, and show that it picks up paper clips.

NOW MAKE YOUR OWN

Give each student a variety iron nails and other shaped metal objects and 20" copper wire, and tell them make their own electromagnet. The aim is to make the strongest electromagnet that will hold the most paper clips.

When the participants have finished their design of an electromagnet, have them bring it to you to be tested. Attach one end of the wire to the negative pole of the battery, and then touch the other end of the wire to the positive pole of the battery while they use the electromagnet to pick up paper clips. Then release the wire from the positive pole of the battery. Record the number of paper clips picked up by the magnetized nail by each participant.

Ask the participants for ideas and suggestions on how they can make the nail pick up more paper clips.

Possible ideas are to:
(a) use more wire;
(b) use more batteries;
(c) use more nails.

Allow them to improve on their designs and come back to retest their electromagnet. Reconnect the circuit and pick up as many nails as possible. Record the results of each participant.

The strength of an electromagnet can be increased by using more batteries and/or more coils of wire. Using more nails will increase the electromagnet’s capacity to hold more paper clips, without necessarily increasing the magnetic force.
Questions:

(a) Name 3 ways in which magnets and electromagnets are alike. 
(Have poles, attract metals, have field lines)

(b) Name 3 ways electromagnets differ from magnets. 
(Electromagnets need electricity to work, the poles of electromagnets can be 
reversed, the strength of electromagnets can be increased)

(c) List 2 ways to increase the strength of electromagnets. 
(more batteries, more coils of wire)

CLEANUP
Make sure that you get all the nails back. Pack everything away neatly. Mark expended batteries.

VII. FREQUENTLY ASKED QUESTIONS

VIII. TROUBLESHOOTING
If the electromagnet doesn’t work at all the battery is dead. Switch to a new battery or try the 
power source. Mark the old battery as dead, so that it can be disposed.

IX. HANDOUT MASTERS

X. REFERENCES
Physics: algebra/trig by Eugene Hecht

FOOTNOTE
1. Image found at http://library.thinkquest.org