

Electromagnets & Magnetism

Strand	Force, Motion, and Energy
Topic	Constructing circuits
Primary SOL	4.3 The student will investigate and understand the characteristics of electricity. Key concepts include e) simple electromagnets and magnetism.
Related SOL	4.1 the student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) distinctions are made among observations, conclusions, inferences, and predictions; e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources; i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs; j) numerical data that are contradictory or unusual in experimental results are recognized; k) data are communicated with simple graphs, pictures, written statements, and numbers; m) Current applications are used to reinforce science concepts.

Background Information

Just like electricity, magnets rely on electrons for their force. Magnets are composed of billions of atoms, and at the heart of each atom is a group of protons which form a nucleus. Around the nucleus swirls a group of electrons which orbit much like a miniature solar system. Within the atom, the protons and electrons each have charges. Protons have a positive charge, and electrons a negative charge.

A magnet is made when most of the electrons in a material all point in the same direction. Each atom exerts a magnetic pull as its electrons exert negative forces in whichever direction they are pointing. The electrons in most materials point in so many different directions that all the magnetic forces counteract each other, and the material is left with no overall magnetic force. However the majority of the electrons in some materials like magnetite, iron, and nickel tend to point in the same direction. Since all the electrons are pointing in the same direction, they work together to create a strong negative force which we call magnetism.

Every magnet has a north and south pole. The south pole contains the negative force which the electrons exert, and the north pole contains the positive force of the protons. Because magnetism relies on the movement of electrons, the negative forces in two south poles will never be attracted to each other. In the same way, the positive forces of two north poles will never be attracted to each other. Instead, the opposite poles will attract. A north and south pole will adhere to each other, while like poles will repel each other. When a magnet is broken, each piece will still have both a north and a south



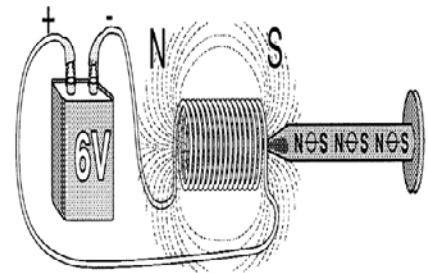
pole because the electrons in each half will still point in the same direction as before. Rather than creating two magnets – one positive and the other negative – you will simply have two smaller magnets, each with one north and one south pole.

The electromagnet is a special type of magnet. Electromagnets only exert a magnetic force when they have an electric current running through them. An electric current is simply the movement of electrons from one atom to the next. When electricity travels through a piece of iron, the current pushes all the electrons to point in the same direction, and the result is a magnet. However, when the electric current turns off, the electrons are no longer forced to align, and the material loses its magnetism. In order to make a very strong magnet, engineers wrap hundreds, or even thousands, of feet of copper wire around a larger piece of iron, and send an electric charge through the coil of wire. As the electric charge repeatedly moves around the iron rod through the coil, it exerts a much stronger force on the electrons in the iron, and as a result, creates an extremely strong magnet.

Just as electricity can be used to make magnets, so magnets can be used to make electricity. When a magnet is repeatedly moved through a metal coil, the magnetic forces propel the electrons in the coil to move. As the magnet spins, the electrons in the wire move through the coil, forming an electric current which can be harnessed to power machines and appliances. This is how electricity is produced in most generators. Mechanical energy such as steam, wind, or hydropower turns huge turbines which are attached to numerous magnets. The magnets are surrounded by coils of wire, and as they turn, they exert a magnetic force on the electrons in the coil. As these electrons move, they form an electric current which is then sent to power the appliances in our schools and homes.

Materials

- One iron nail for each student
- Magnets with labeled north and south poles (one for each student)
- Paper clips
- Staples
- One spool of copper wire for each group of students
- One AA battery for each group of students
- Tape (masking or electrical tape works better than scotch tape)
- Scissors



Vocabulary

magnet, electromagnet, magnetic field, magnetic poles, magnetism, electron, voltage

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

1. Ask students, “Have you ever moved something without even touching it? It seems impossible, but it sounds like what a magnet does.”



2. Ask students to tell you what a magnet is. Ask if anyone knows how magnets work.

Procedure

1. Give each student two magnets.
2. Explain that magnets are composed of atoms in which all the electrons point in the same direction. Explain how these electrons align their negative charges in the same direction, and exert a force called magnetism. Explain how a magnet has a negative and a positive pole, because of the positive and negative charges of the protons and electrons in the magnet.
3. Divide students into groups. Have students experiment with their magnets to see which ends attract or repel each other. Have one volunteer from each group record the group's findings. Ask students to work together to come up with a hypothesis for which poles attract. Have a second volunteer from each group write down the hypothesis. Have a third volunteer share the group's hypothesis with the rest of the class. Provide feedback and guidance and confirm when students have an accurate hypothesis. Students may word hypotheses how they wish, but a correct hypothesis will state that opposite magnetic poles attract, and/or that similar poles repel each other. **5-10 minutes**

minutes

4. Explain how magnetic poles are created by the combined force of many electrons (reference the Background Information).
5. Have students work individually to build their own magnets. Give each student a nail, a magnet, and a pile of paper clips and/or staples. By repeatedly stroking the nail in the same direction across the magnet, students will be able to magnetize their nails. After 50-100 strokes, the magnetic force of the nails will be strong enough to pick up a few staples or paper clips. **10 minutes**

Optional learning extension: Using the accompanying Make Your Own Magnet sheet, have students fill out the graph as they experiment with how many pieces they can pick up after different numbers of strokes. Let students observe that the nails lose their magnetism after a few minutes. 5 minutes

6. Ask students to explain how they are able to magnetize their nails, hinting that it has something to do with the force of the electrons in the magnet.

As the two materials rub across each other, the electrons in the magnet exert their force on the electrons in the nail, pulling them in one direction. When the magnet repeatedly rubs across the nail, it “combs” the electrons in the nail so they all lay in the same direction. As the electrons in the nail line up, their magnetic forces align and work together to create a magnet. Once you stop rubbing the magnet on the nail, the nail loses its magnetism because the electrons begin moving freely, and the magnetic forces of the electrons point in different directions and counteract each other.



7. Ask students to think back to what they learned about circuits and electricity. Ask them to define electricity.

Electricity is a kind of energy that makes heat, light, and movement.

8. Ask students to remember how electrical currents are generated when electrons are pushed from one atom to the next. Have them compare the similarities between electricity and magnetism.
9. Ask students if they have ever heard of an electromagnet. If so, ask them to define one.

An electromagnet is a material that turns into a temporary magnet when electricity runs through it.

10. Explain the difference between a temporary and a permanent magnet.

In a permanent magnet, the electrons in the substance remain aligned and exert a magnetic force without the help of another force. The magnet the students have been using are permanent magnets. A temporary magnet is a material which is only magnetized when a force is applied to align its electrons. The nails students magnetized were temporary magnets, as are electromagnets.

11. Divide students into groups and give each group a spool of copper wire and a battery. Have students follow the Build an Electromagnet instruction sheet to create their own electromagnets. See what the nail does to paper clips or staples. It should be magnetized and easily pick them up. Have student remove the battery and check if the nail is still magnetic. The nail will not be magnetic and will no longer attract paper clips or staples. **10 minutes**

Optional learning extension: Have students experiment with wrapping varying amounts of wire around the nail and see how this changes the magnetic force, or have students trade their AA battery for a AAA or a D battery, and see how this affects the nail's magnetism. Have students create a graph to chart their findings. Prompt them to think about the best format to represent the data they have collected, and to create their graph accordingly. For example, one good format will have one axis representing the number of coils on the nail or the voltage of the battery, and the other axis representing the number of paper clips picked up. 10 minutes

12. Explain to students: When electricity is pushed through a wire, the current pushes all of the electrons to point in the same direction. As the electrons move around the nail, they push the electrons in the nail to align in the same direction, as well. As a result, the magnetic charges of the nail's electrons line up, and work together to make a strong magnetic force. However, when the electric current is turned off, the electrons are no longer forced to align, and the material loses its magnetism.

Conclusion



1. Have students review and define the following vocabulary words: magnet, electromagnet, magnetic field, magnetic poles, magnetism, electron, permanent magnet, and temporary magnet.

Assessment

- **Questions**

- What do temporary and permanent magnets have in common? What differences do they have?

Temporary and permanent magnets both exert magnetic forces. A permanent magnet exerts a magnetic force independent of any force applied to it. A temporary magnet must have some other force acting on it (usually electricity) in order to be magnetic.

- What two ways can you make an electromagnet stronger?

You can strengthen the force of an electromagnet by sending a stronger current of electricity through the coil or by wrapping more coils of wire around the nail.

- When a metal is heated, the protons, and electrons begin to move around very quickly. As a result, the metal melts and becomes a liquid. What do you think would happen to a magnet if it was exposed to extreme heat?

When magnets are exposed to extreme heat, they lose their magnetism because the forces of the moving electrons no longer align with one another.

- **Other**

- Have students research machines or appliances that use electromagnets (i.e. doorbells, speakers, cranes, MRI machines, maglev trains). Then have them design a new machine that requires an electromagnet.
- Have students produce a slideshow of home products that use permanent and temporary magnets, including explanation for their uses in each product.

Extensions and Connections (for all students)

- Sprinkle iron filings on a paper and place the paper on top of a magnet. Have students create illustrations of the filing patterns using a medium of their choice. Possible options include drawing the patterns, gluing pebbles in the same arrangement as the iron filings, and snipping paper out of a sheet to leave holes in the shape of the magnetic pattern.
- Have students research and draw diagrams of how magnets work in a generator.

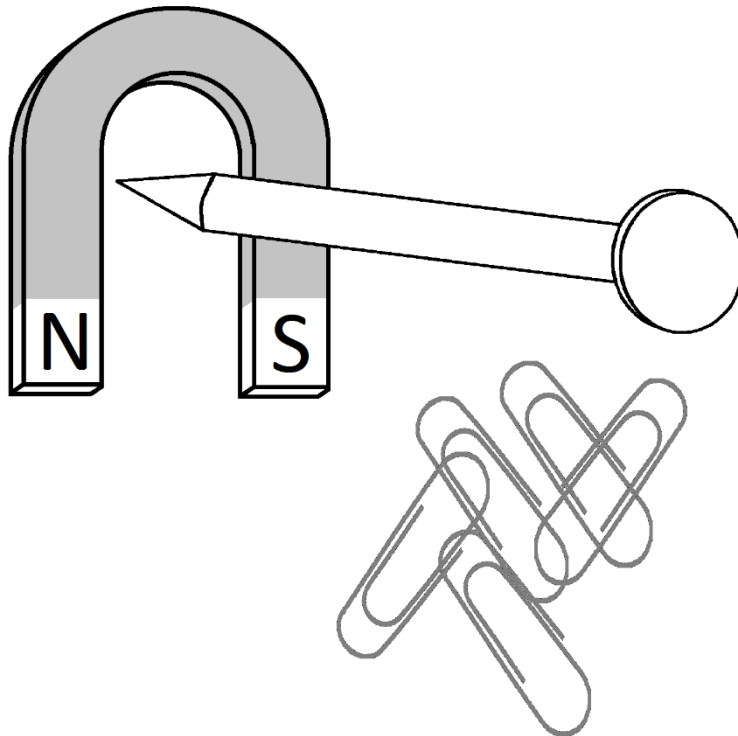
Strategies for Differentiation

- Place struggling students in groups with gifted or excelling students and have them work together.
- Work with struggling students in small groups to provide extra guidance as they build their magnets and electromagnets.
- Give clues to struggling students that point them in the right direction in creating their magnets, magnets, and electromagnets.



Make Your Own Magnet

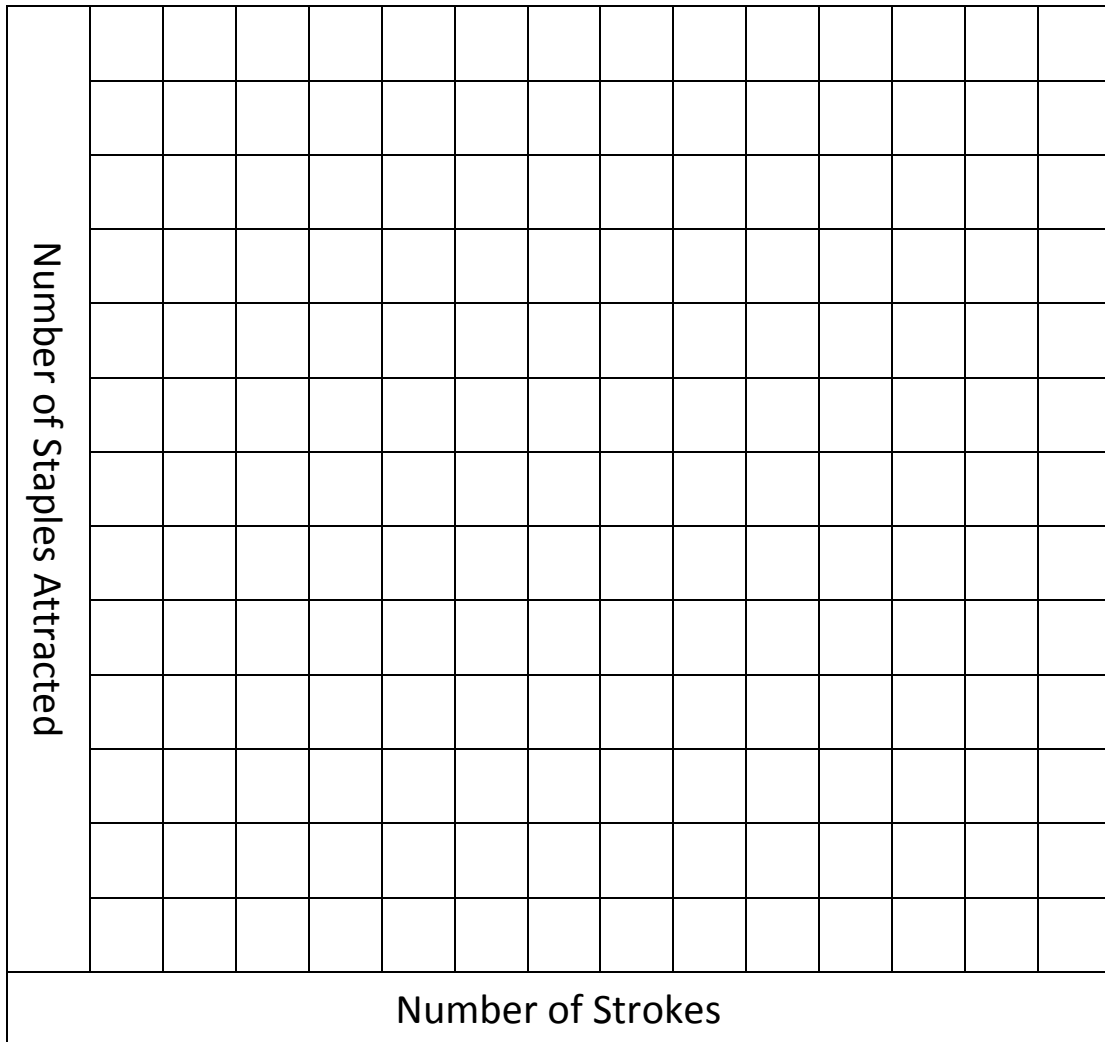
1. Collect your materials.
 - One iron nail
 - Paper clips
 - One magnet
2. Stroke the nail across the magnet 50 times. Make sure to stroke across the magnet in the same direction each time.
3. Touch the nail on the pile of staples and count how many staples the nail attracts.



Learning Extension:

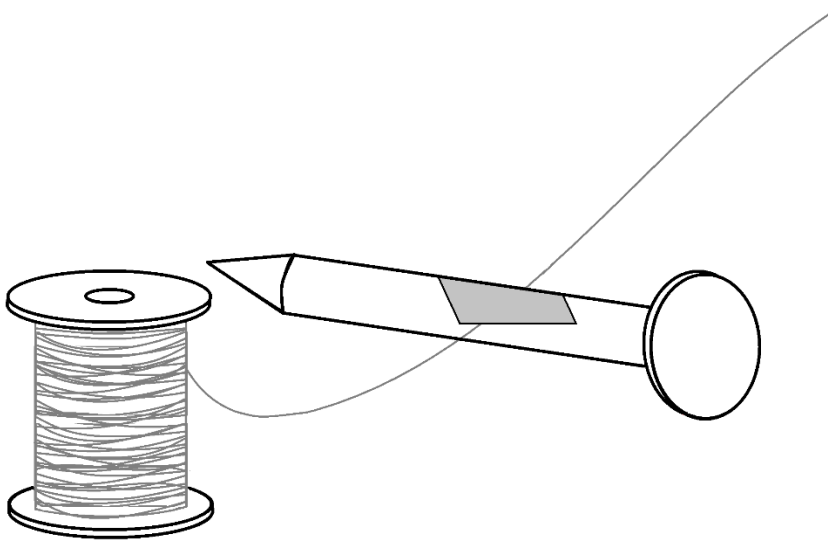
1. Try rubbing the nail across the magnet a varying number of times, and count how many staples the nail picks up after each try.
2. Graph the results in the chart below.

Graph of Magnetic Force

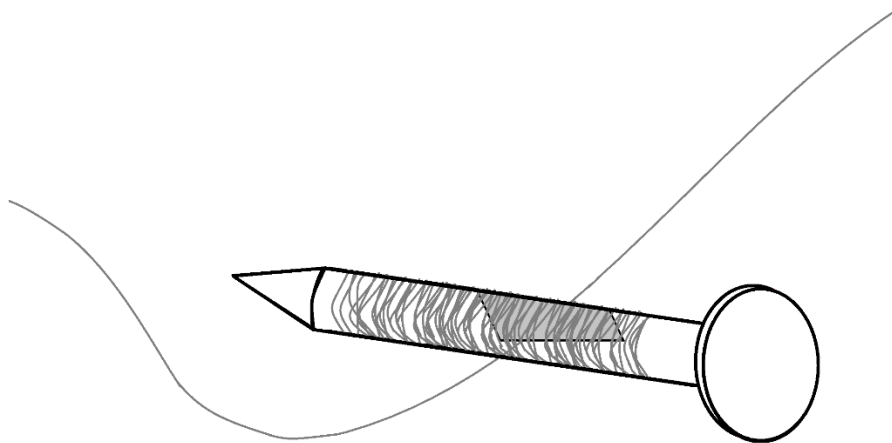


Build an Electromagnet

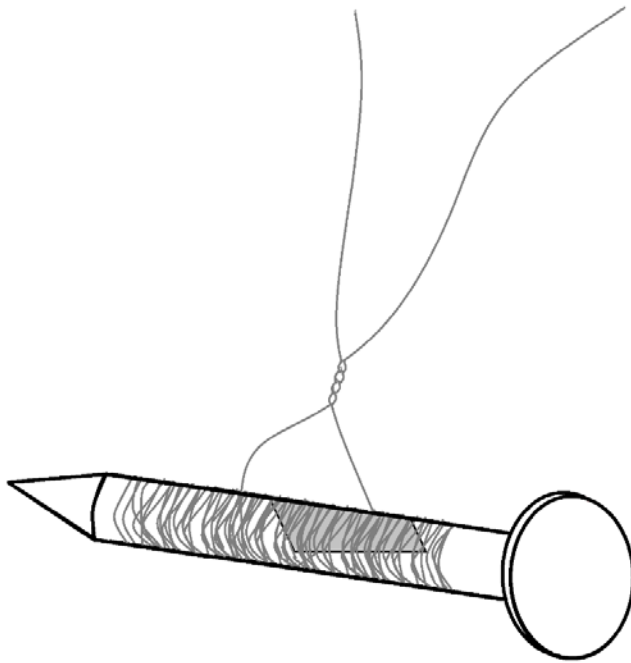
1. Collect your materials.
 - One iron nail
 - Paper clips
 - Staples
 - One spool of copper
 - One AA battery
 - Tape (masking or electrical tape works better than scotch tape)
 - Scissors
2. Tape the wire to the nail, leaving a four-inch wire tail.



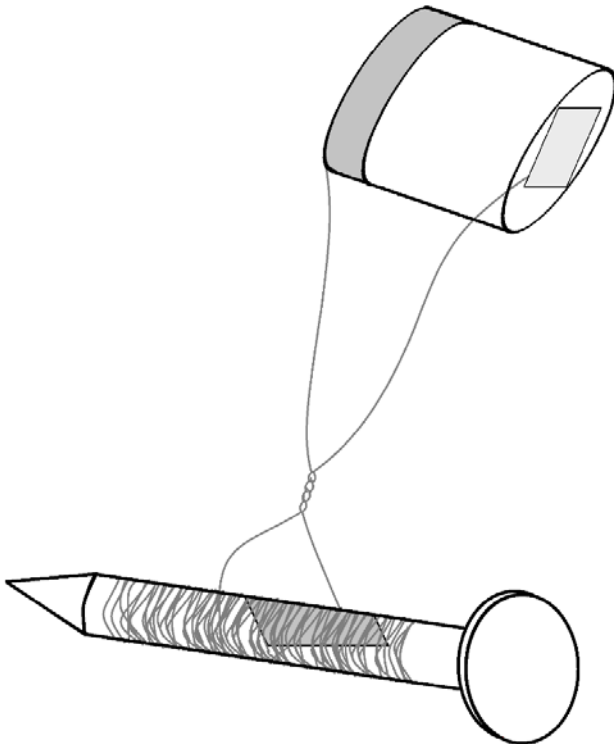
3. Wrap the other end of the wire around the nail 40-50 times.
4. Cut the wire four inches from the nail.



- Twist the two ends of the wire together near the nail, so that each end still has at least three inches of wire extending from it after the twist.



- Tape each end of the wire to opposite ends of the battery.



- See what the nail does to paper clips or staples.
- Remove the battery, and check if the nail is still magnetic.



