Electromagnets

Strand	Force, Motion, and Energy	
Topic	Investigating electromagnets and magnetism	
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 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; l) models are constructed to clarify explanations, demonstrate relationships, and solve needs.

Background Information

Magnetism is a property of materials. If a material is said to be magnetic, that material responds to an applied magnetic field. Magnetism, simply put, is due to the motion of electric charges.

To ancient people, magnetism must have seemed like magic. Until about two hundred years ago, people made magnets by finding a lodestone and rubbing iron in the same direction many times on it. They didn't know why it made the iron magnetic, but now we know that rubbing it on the lodestone lines up the electrons of the iron so that all the electrons pull in the same direction. It's a little like you are "combing" the electrons.

By the 20th century, we realized that all materials are made up of atoms and it became clear that magnetism was caused by electrons. We know everything is made of atoms and that atoms have a nucleus in the center which is made up of protons and neutrons. Electrons move around the atom's nucleus in orbits, a bit like the planets in our solar system move around the sun. The planets not only travel around the sun, but they also spin on their axes at the same time (just like spinning tops). It is a little like the teacup ride at an amusement park. All the teacups move around the center of the ride, but each teacup can spin independently if you turn the center wheel inside the teacup. Most of the electrons in an atom exist in pairs that spin in opposite directions, so the magnetic effect of one electron in a pair cancels out the effect of its partner. However, atoms of ferromagnetic elements have several unpaired electrons that have the same spin. Iron is an example of a ferromagnetic element and its atoms have four unpaired electrons. When you run a magnet over a chunk of iron, the extra electrons all start spinning the way the magnet pulls them, and the chunk of iron becomes a magnet itself. The term ferromagnetic, means "magnetic like iron."

Some materials like iron and the rare-Earth metals become strongly magnetized when exposed to a magnetic field and usually stay magnetized even when the field is removed. However, a ferromagnetic material will still lose its magnetism if you heat it above a certain point, known as its Curie temperature. If you heat an iron magnet to 800°C (~1500°F), it stops being a magnet. You can also destroy or weaken ferromagnetism if you hit a magnet repeatedly.

Only a few substances are ferromagnetic. The common ones are iron, nickel, cobalt, and most of their alloys, some compounds of rare earth metals, and a few naturally-occurring minerals such as lodestone.

Most of the magnets we encounter on a daily basis today have been artificially magnetized. We can use electricity to make magnets which are called electromagnets. An electromagnet is a type of magnet in which the magnetic field is produced by the flow of electric current. The magnetic field disappears when the current is turned off. How much magnetism is applied can be controlled by increasing or decreasing the electricity.

Virtually all the electricity we use (with the exception of electricity produced from solar cells) is made by devices called generators. Generators use powerful electromagnets made with magnets and coils of wire to produce electricity with the help of turbines.

Many things around us work by magnetism or electromagnetism. Every electric appliance with an electric motor in it uses magnets to turn electricity into motion. There are magnets in a refrigerator holding the door closed. Magnets read and write data (digital information) on a computer's hard drive. If someone is sick with a serious internal illness, they might have a type of body scan called MRI (magnetic resonance image), which draws a digital image of what is below a patient's skin using patterns of magnetic fields. Magnets are used to recycle metal trash. Steel food cans are strongly magnetic but aluminum drink cans are not, so a magnet is an easy way to separate the two different metals.

Materials

- One clear glass jar with a metal lid (e.g., empty mayonnaise jar)
- Clear tape
- Small magnet that can be taped on the inside of the clear glass jar lid
- A piece of fishing line or thread about the length of the height of the jar
- Copies of attached Electromagnetic Challenges packet for each student
- Iron filings
- 6 volt battery

For each group, a box that includes:

- Bar magnets
- Plastic baggies
- 50 to 75 cm copper wire
- One iron nail
- Paperclips
- Scissors

Vocabulary

magnet, electromagnet, magnetic field, voltage, independent variable, dependent variable, constant

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

Introduction

1. Before you begin this lesson, construct your “magic jar.” To make your “magic jar,” do the following:
    - Cut the string about the length of the jar from top to bottom.
    - Tie the paper clip to one end of the string.
    - Tape the other end of the string to the bottom (inside) of the jar.
    - Tape or glue the magnet to the inside of the lid.
    - Cut a circle the size of the inside of the lid and tape that over the magnet so that the magnet cannot be readily seen.
2. Bring the class together and show the students the jar with the paper clip lying at the bottom of the jar. Ask them to describe what they see.
3. Now place the lid on the jar and turn it upside down so that the paper clip is hanging from the string. Again, ask them to describe what they see.
4. Now carefully turn the jar right side up so that the paper clip is being pulled by the magnet. It will appear that the paper clip is suspended in the air. Ask the students what they see. Have them make inferences as to why they see this. Guide them to discuss what the paper clip is made of and what might make it stay suspended in the air. Again, guide them to discuss that a magnet might cause the paperclip to remain suspended.
5. Remove the circle of paper covering the magnet.
6. Review with the class what they can tell you about magnets.
7. Ask the students what they know about electricity. Ask the students, *“Has anyone heard of an electromagnet? What does an electromagnet do? How do we create an electromagnet?”* Share some of the background information about electromagnets with the class.
8. Tell the students that today they will use the magnetic field around a wire to create an electromagnet, using coils of wire and a battery. Ask them what they think will happen. Give them a few minutes to discuss this question in groups of three to four students and make a group prediction.

Procedure

1. Give each group the box of materials. Hand out the attached Electromagnetic Challenges packet to each student.
2. Assign each group their own number of turns to build the electromagnet (10, 25, 50) and have them fill it in on the first page, Challenge 2, of the packet.

3. Discuss attached Electromagnet Challenges packet with the students. Make sure to let them know to raise their hands at the end of each challenge so that you can check to make sure everyone in the group understands the directions for the next activity.
4. At the end of Challenge 2, students will need teacher assistance to hook up the wire to the battery. (*Note: When touching the wire to the battery, students should not touch the bare portion of the wire. The current being used is low and not dangerous, but the wire will heat up. It is also important that students not keep the circuit connected too long or it will become too hot to handle.)*
5. Continue to circulate and observe the experiment process to assist where needed.

Conclusion

1. Have students share their findings with two partners in the classroom who weren't in their group, filling in the chart under Challenge 2.
2. Ask students to offer any findings that were different between the partners. Discuss all these results from their experiments.

Assessment

- **Questions**
  - What are some similarities and differences between permanent magnets and electromagnets?
  - What can make an electromagnet stronger?
- **Journal/writing prompts**
  - A superhero has the power of electromagnetism and his villain has the power of permanent magnetism. In a battle, who would you think would win? Be sure to explain why!
  - What are some products in your home that use electromagnets? How do electromagnets help the products function?
- **Other**
  - Have students draw a diagram of an electromagnet labeling the parts carefully.
  - Grade students attached activity sheet.
  - Draw different sketches of functional and dysfunctional electromagnets and discuss with students which ones work. Ask students how to make dysfunctional electromagnets work.

Extensions and Connections (for all students)

- Have students complete an experiment to strengthen electromagnetism by raising the amount of voltage in an electromagnet.
- Take an older unused small appliance and have the students dissect it looking for electromagnets.
- Have students research Michael Faraday and his discoveries and how that has affected the uses of electromagnets today.
- Invite an electromagnet operator to visit the class. Ask the operator to describe the role of the electromagnet in the moving of materials (recycling, car parts business, factory, etc.).

Strategies for Differentiation

- Give students the option to draw a diagram to explain their answers on the Electromagnetic Challenges sheet.

Electromagnet Challenges

Names: ______________________________ Date: _________________

Directions: Work together as a team to complete the following challenges. After you finish each challenge, have each of your teammates quietly raise their hands to get the teacher's attention. Once she or he has asked you a few questions about your completed work, you may go to your next challenge.

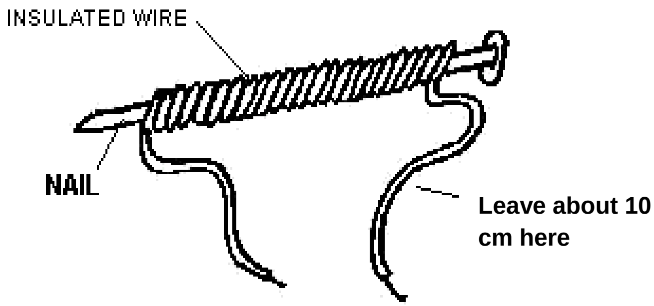
Challenge 1

Your challenge is to find out what a magnetic field looks like. Place the ***bar magnet in a plastic baggie*** on your desk**.** Place ***one sheet of white cardstock*** on top of the bar magnet. Carefully sprinkle ***iron filings*** on the white cardstock to see the shape of a magnetic field.

1. Draw the shape you see below showing a magnetic field.

Challenge 2

1. Your next challenge is to make an electromagnet. Your teacher will give you the number of times you wrap your wire around your nail. Write that number here: ________.
2. Wrap your wire tightly around your nail the number of times your teacher gave you starting at the nail point and making sure about 8 cm of wire is left free at the end.



3. After your group has wrapped the wire around the length of the nail, cut the wire so that about 10 cm are left free. Now, use scissors to strip the insulation from the last 2 cm of the wire.
4. Predict how many paperclips you think your electromagnet will pick up. ________
5. Raise your hand and wait patiently for your teacher to help you hook up the battery.
6. Now, fill in the following table with how many paperclips you were able to pick up. As you can see in the table, you should complete 5 trials with your electromagnet. After completing all five trials, add the number of paperclips attracted for all five trials and then divide the sum by five. This will give you the average for all the trials.

NOTE: Only fill in the first row of this table for your team's experiment. The other rows will be filled in later with data from the other teams.

Turns of wire	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average

Conclusion

1. Before graphing, discuss any unusual experimental results. List the unusual results, or outliers, below and what may have caused them.

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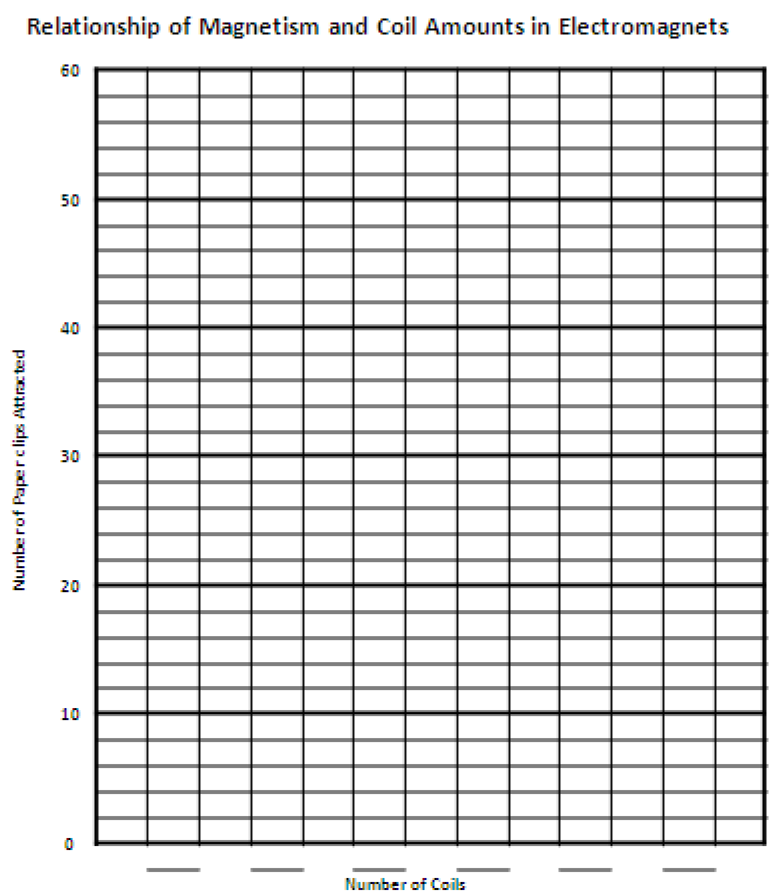
2. After all the class data have been analyzed and recorded, make a bar graph of the results below.



3. Looking at the data on the bar graph, what conclusions can you make from the findings?

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Connections

1. What are some things electromagnets might be used for today? How would you use an electromagnet in your life? Answer in complete sentences.