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Science Posse

Fun With Electricity
Luke Dosiek

Lesson Plan: Electricity and Magnetism (~100 minutes)

Concepts

1. Electricity and magnetism are fundamentally related.
2. Just as electric charge produced an electric field, electric current produces a **magnetic field**.
3. Since whenever there is current there is charge, both electric and magnetic fields exist. They are lumped together and called an **electromagnetic field**.
4. A rotating magnetic field produces an electric current.
5. A rotating electric current produces a magnetic field.
6. The right hand rule is used to determine the direction of the produced current or field.
7. The **electromagnet** is a device that is used very often in everyday objects that exemplifies the relationship between electricity and magnetism.
8. The electromagnet is used in converting electromagnetic energy to mechanical energy and back.

Key Questions

1. How are electricity and magnetism related?
2. What effect does passing current through a coil of wire have?
3. How are electromagnets used in everyday objects?
4. How are electromagnets important for electric power generation?

Student Learning Objectives	Standards
Students will be able to explain how electric current can generate a magnetic field.	WYO 8.A.S.1.7, 11.A.S.1.7; Benchmarks 13 and 14
Students will be able to create an electromagnet.	
Students will be able to apply the concept of the electromagnet in the creation of a telegraph.	
Students will be able to explain how electricity and magnetism work together in electric motors and generators.	

Anticipatory Set

- Students have learned about electricity, electric circuits, voltage, and current.
- They are familiar with how to connect circuit elements.
- Electricity and magnetism are closely related.

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- The electromagnet is a widely used tool for converting electromagnetic energy into mechanical energy and back again.

Key Terms

Electricity	Magnetism	Electromagnet
Telegraph	Motor	Generator
Electric Field	Magnetic Field	Electromagnetic Field
Right Hand Rule		

Teaching Plan

General Plan

- Part 1: Introduce electromagnetism
- Part 2: The electromagnet (with activity)
- Part 3: The electric motor activity

The accompanying PowerPoint presentation, Electricity and Magnetism.ppt, closely follows the following teaching plan.

- Part 1: Introduce electromagnetism
  - Begin by asking the class how they think electricity and magnetism are related. **(5 min.)**
    - Can you create a magnet using electricity? How?
    - Can you create electricity using a magnet? How?
    - Ask the students to think about these answers as the lesson progresses.
    - The answer is that a moving electric or magnetic field produces the other type of field, i.e. a moving magnetic field produces an electric field, and thus electricity, and vice versa.
  - Ask for examples of objects where both electricity and magnetism are present. **(2 min.)**
    - Electric motors: microwave ovens, DVD players, electric cars
    - Electric generators: wind turbines, coal power plants, nuclear power plants
    - Microphones and speakers
    - Hard drives
  - Define **electromagnetism** as the fundamental relationship between electrical and magnetic fields. **(10 min.)**
  - A moving electric field produces a magnetic field that rotates around it.
  - A moving magnetic field produces an electric field that rotates around it.
  - The **Right Hand Rule** helps understand this. (Handout) **(10 min.)**

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- First define positive electric current as flowing from the positive terminal of a battery to the negative terminal.
- Define a magnetic field to move from the North pole to the South pole.
- Curl the fingers of your right hand in the direction of the rotating electric (or magnetic) field. Your thumb points in the direction of the resulting magnetic (or electric) field.

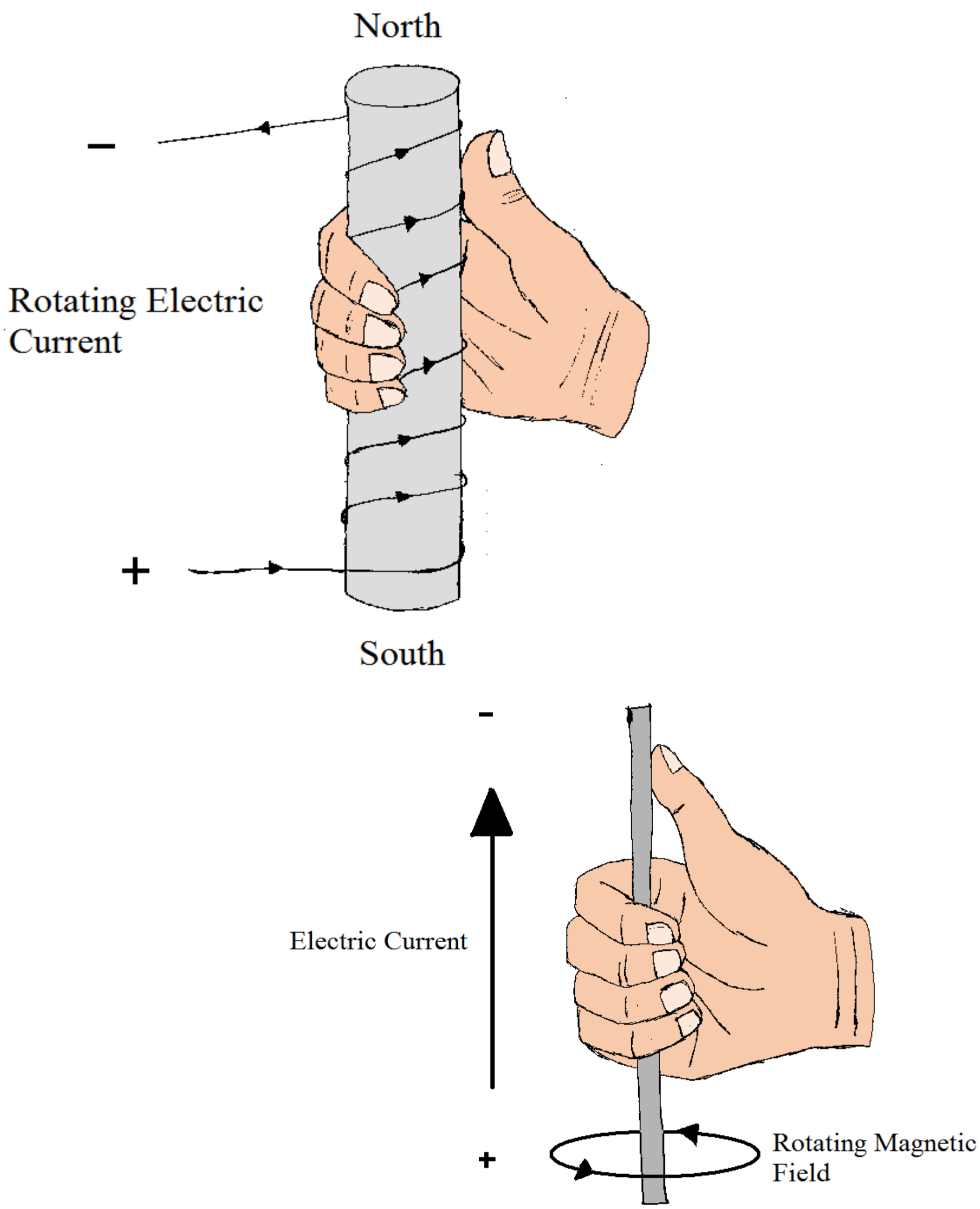

Fig. 1 - The Right Hand Rule

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- Part 2: The electromagnet
    - Explain that, by the right hand rule, a coil of current carrying wire will create a magnetic field. **(10 min.)**
    - The strength of the magnetic field is based on 3 things:
        - The amount of current in the wire: the more current, the stronger the magnetic field.
        - The number of turns in the coil: the more turns, the stronger the magnetic field.
        - The material in the coil.
            - Having a magnetic material such as iron or steel as the core of the coil works to magnify the effects of the coil, thus creating a stronger magnetic field.
            - Having nothing in the coil will still produce a magnetic field, though it will be very weak.
    - Ask the class for some examples of what materials would be good for the core of the electromagnet. **(2 min.)**
        - Steel, iron, anything that is attracted to a common refrigerator magnet
    - Give several examples of where electromagnets are used. **(5 min.)**
        - Motors and generators
        - Doorbells
        - Speakers
        - Hard drives
        - VHS and Audio tapes (do the students remember these?!)
        - Telephones
    - Ask the class to come up with other examples of electromagnets around them. **(5 min.)**
    - Break the class into groups and begin the Electromagnet Activity. **(20 min.)**
    - Remember to reinforce the above concepts during the activity.
        - Ask the students to use the right hand rule to describe what's going on with their nails and coils of wire.
        - Ask them if they think a pencil will work as an electromagnet's core and why/why not.
        - Ask them if they've seen electromagnets like this before and where.
    - Optional Telegraph activity.
        - This is used as a practical example of how electromagnets are (were) used in communications technology.
        - This can be a demo if time is an issue.

- Part 3: The Electric motor **(30 min.)**
    - By utilizing electromagnets that rotate, an electric motor or generator can be built.
    - An electric motor converts electromagnetic energy into mechanical energy.

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    - It takes electric current into a series of specially wound coils to create North and South magnetic poles that spin in a circle. These poles pull along magnets on a rotor, which then spins.
- An electric generator converts mechanical energy into electromagnetic energy.
    - As mechanical energy spins a rotor with magnets on it, these rotating magnets pass by a series of coils of wire. An electric current is produced in these coils via the right hand rule.
- Electric motor Demo or Activity
- Depending on the level of the students, this can either be a demo or an activity in which they actually build a simple motor. Either way, its goal is to produce a hands-on experience with an electric motor converting electricity into mechanical energy.
- The motor in this activity works as follows:
    - The electricity from the batteries flows through the coil of wire creating an electromagnet and thus a magnetic field
        - This only happens when the coil is in a position where the exposed copper touches the copper wire supports
    - The magnetic field from the electromagnet is attracted to or repelled from the permanent magnets sitting on the desk. This spins the coil to align the two magnetic fields
    - This is where the proper sanding of the coils comes into play
    - As the magnetic fields are drawn into alignment, the coil moves into a position such that the copper support wires are now touching the insulated side of the coil, thus turning off the electromagnet.
    - Since the coil has momentum, it continues to spin past the aligned position and back into the position where copper touches copper and the permanent magnet can draw the coil back down.
    - This cycle continues creating a rapid spinning motion!
    - If we had sanded the entire wire ends of our coil, the moment it saw electricity it would simply move into alignment with the magnet on the desk and stay there!
    - By sanding one half of the wire (and specifically the way we did it) we create this cycle of first magnetic attraction and then momentum to get the coil to spin.

Resources

Electricity and Magnetism.ppt Power Point Presentation
Right Hand Rule Handout
Electromagnet Activity and Related Materials
(Optional) Telegraph Activity
(Optional) Electric Motor Activity and Related Materials

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The Right Hand Rule

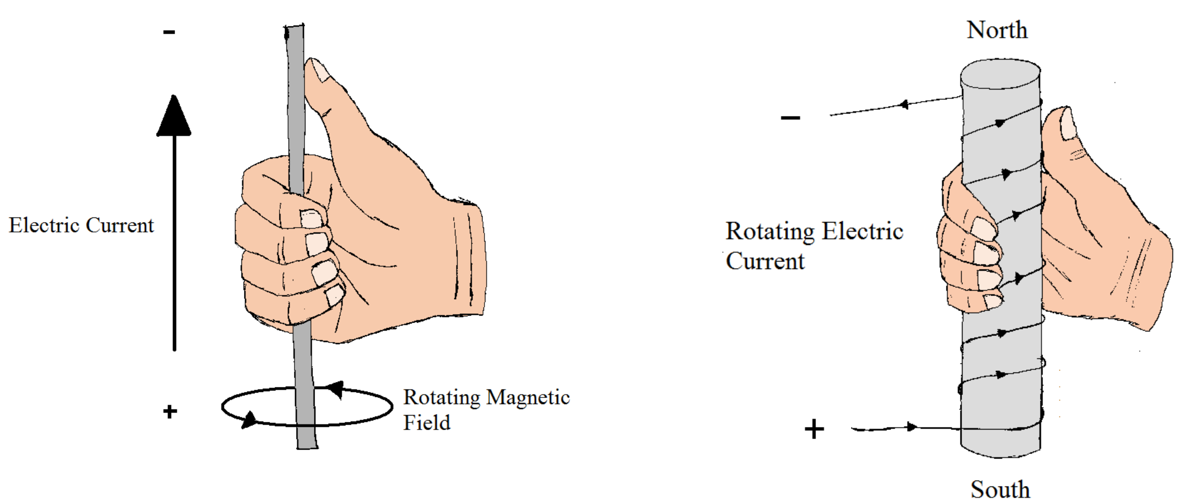
1. Examine the system. Is the magnetic field or the electric field rotating?

2. If it is the magnetic field that is rotating you probably have a straight wire. Point your thumb in the direction of the electric current. Remember, positive electric current goes out the positive end of the battery, through the wires, and back into the negative end!

3. With your thumb pointing in the correct direction, curl your fingers as in the left side of the figure below. This is the direction of the rotating magnetic field (clockwise or counterclockwise).

4. If it is the electric field that is rotating, you probably have a coil of wire. Figure out which way the electric current is rotating, again remembering that the current flows from the positive terminal of the battery to the negative.

5. Notice where your thumb is pointing. This is towards the North Pole of the resulting magnetic field, as in the right side of the figure.



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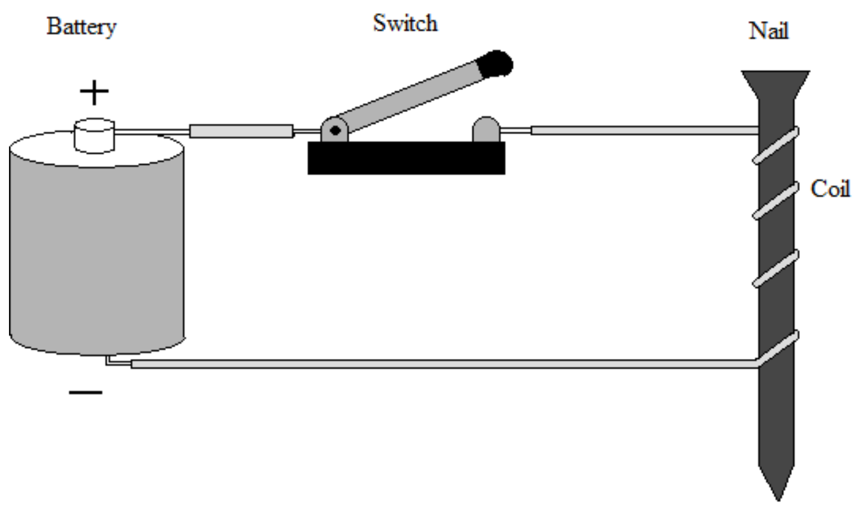
Lesson 2 Unshifted Activity: The Electromagnet

Purpose
The electromagnet is one of the most common electrical devices in use. They can be found in stereo speakers, headphones, DVD players, video recorders, wind turbines, and anything with an electric motor. The electromagnet is a great example of how electricity and magnetism are related. It also shows how this relation can convert electrical energy into mechanical energy.

Materials
- Battery with holder
- Switch
- Steel nail
- Pencil
- Several paper clips
- Compass
- 2 feet of wire, insulated with exposed ends

Procedure
1. Form groups and gather your materials as instructed by your teacher.
2. Make an electromagnet like the one shown in the figure.



3. Begin by wrapping your wire around your nail 10 times.
4. Turn on your electromagnet.
5. How many paper clips can you lift with the nail? ________________
6. Turn off your electromagnet.
7. Now try wrapping your wire around the nail as many times as possible, while still leaving room to connect to the battery.
8. How many turns were you able to get? ________________
9. Turn on the electromagnet and try to lift the paperclips.
10. How many paperclips can you lift with the nail now? ________________
11. Turn it off and replace the nail with a pencil, then turn it back on.
12. How many paperclips can you lift with the pencil? ________________

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13. Turn it off, and replace the pencil with your nail.
14. Using the right hand rule, predict which end of your nail is the North Pole.
15. Turn on your electromagnet and bring your compass near the point of the nail.
16. Is the point a North or South pole? ___________________
17. Turn off your electromagnet and switch your battery around, so the electric current will flow in the opposite direction.
18. Turn on your electromagnet and again bring the compass near the point of the nail.
19. Is the point North or South?

Discussion Questions

1. Explain how the number of turns in your coil affects the strength of your electromagnet.

   ____
   ____
   ____

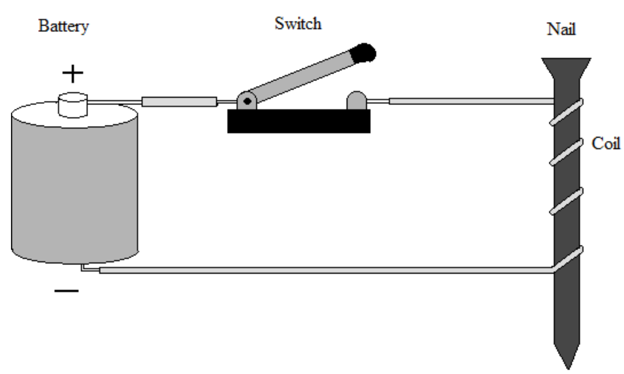
2. Was the electromagnet stronger with the nail or the pencil in its core? Why?

   ____
   ____
   ____

3. Did reversing the battery change the electromagnet? How?

   ____
   ____
   ____

4. In the figure, label the North and South Poles of the electromagnet. Also draw an arrow showing which direction the positive electric current is flowing.



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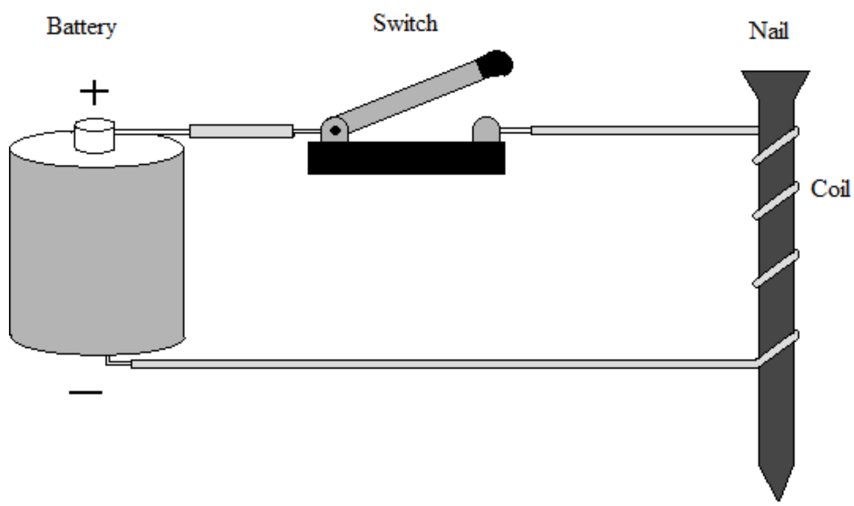
Lesson 2 Shifted Activity: The Electromagnet

Purpose
The electromagnet is one of the most common electrical devices in use. They can be found in stereo speakers, headphones, DVD players, video recorders, wind turbines, and anything with an electric motor. The electromagnet is a great example of how electricity and magnetism are related. It also shows how this relation can convert electrical energy into mechanical energy.

Materials
- Battery with holder
- Switch
- Steel nail
- Pencil
- Several paper clips
- Compass
- 2 feet of wire, insulated with exposed ends

Directed Experiment
1. Form groups and gather your materials as instructed by your teacher.
2. Make an electromagnet like the one shown in the figure.



3. Note that the figure shows the wire wrapped around the nail 4 times. Continue wrapping your wire so there are 20 turns in your coil.
4. Use the switch so we don't drain our batteries!
5. Connect your wires to the red positive terminal and the 1.5V negative terminal.
6. With the switch OPEN, determine how many paperclips your nail can lift (using magnetism)
7. With the switch CLOSED, determine how many paperclips you can lift with the nail.

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Observations and Explorations

1. Base on what you saw in the above experiment, list things that you think could affect the strength of your electromagnet, and how they would affect the strength. (Use a separate sheet of paper if needed.)

2. Think of a way to reverse the polarity of your electromagnet. How could you measure the polarity of your electromagnet?

3. Attempt to implement your predictions above, one at a time, and record your observations. You may use the number of paper clips that you can pick up as a measure of the electromagnet's strength. (Or you could try to determine how strong the paperclips bind to the nail by feel). If you have a magnetic field meter available, use that!

Further Thoughts

Using your recently gained knowledge of electromagnetism, describe how you think you could use an electromagnet to make an electric motor. That is, how can you use an electromagnet (and possibly other materials) to convert electrical energy into mechanical energy (motion)?

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Activity: Simple Electric Motor

Purpose

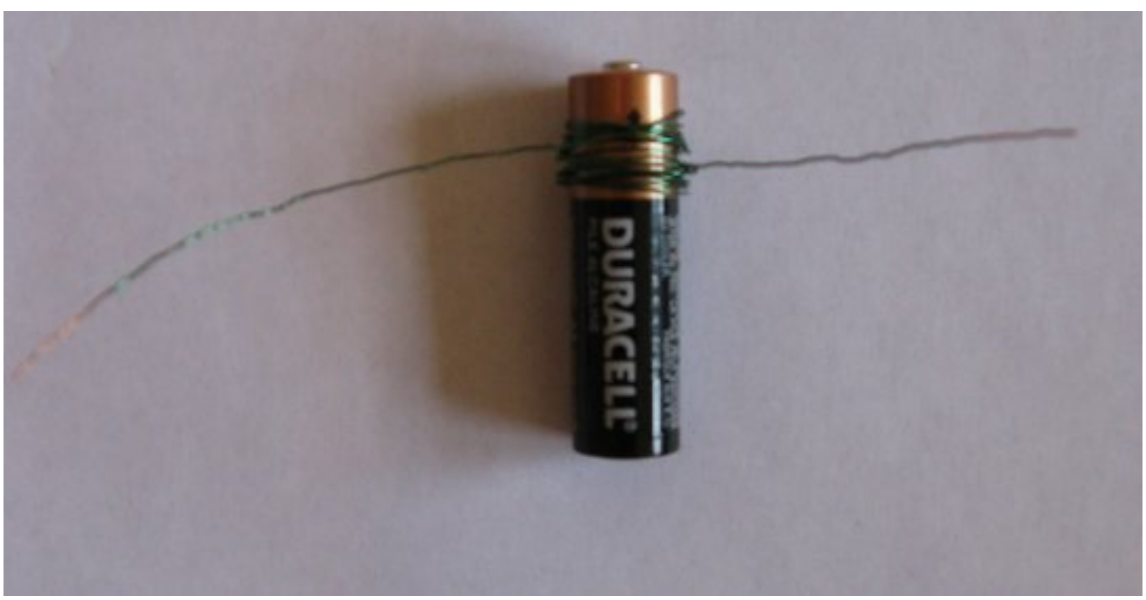
The electric motor is an important device because it converts electromagnet energy into mechanical energy. They can be found in DVD drives, microwave ovens, blenders, power tools, vehicles, and toys. The electric motor works by creating electromagnets with then push or pull other magnets, causing motion!

Materials

- D-cell battery pack
- AA Battery
- 3 Feet of enamel coated wire
- Magnets
- 2 Lengths of heavy wire, 6 inches each
- Sandpaper

Procedure

1. Form groups and gather your materials as instructed by your teacher.
2. Begin by wrapping the 3 foot length of wire around the AA battery. Leave about 3 or 4 inches of wire unwrapped at each end.



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3. Carefully pull the coil off of the battery, holding the wire so it keeps its circular shape.
4. To keep the coil in a circle, wrap the loose ends of wire around the coil a few times:

5. You should now have a small coil of wire with a few inches of extra wire sticking out of each side.
6. Now hold the coil at the edge of your desk so it NOT lying flat on your desk, it is instead standing up. Place it so only one of the free wires is lying on the desk. With your sandpaper, remove the insulation on the half of the wire that is visible.
7. Make sure you sand until the shiny copper is visible.
8. Do the same with the other free wire end, making sure that the shiny copper side is facing up on both wire ends.

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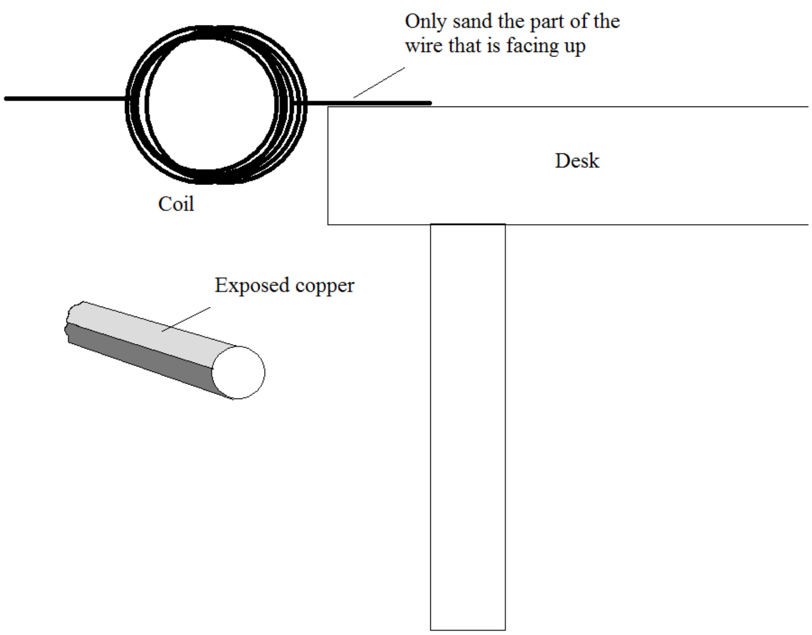
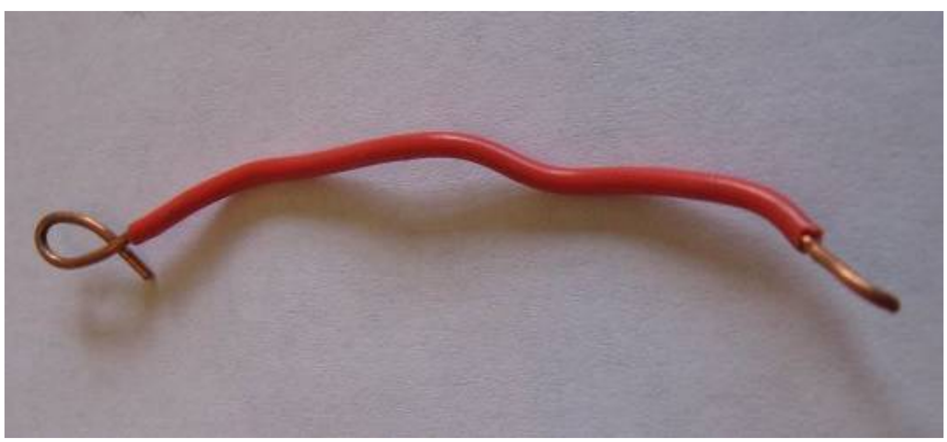


9. Set aside your coil.
10. Bend your two thick wires into the shape shown below.



11. Take the straight ends of your thick wires and connect them to the battery pack's 3V and DC terminals.
12. Bend the thick wires so that your coil will balance in their looped ends, about 2 inches off of your work surface

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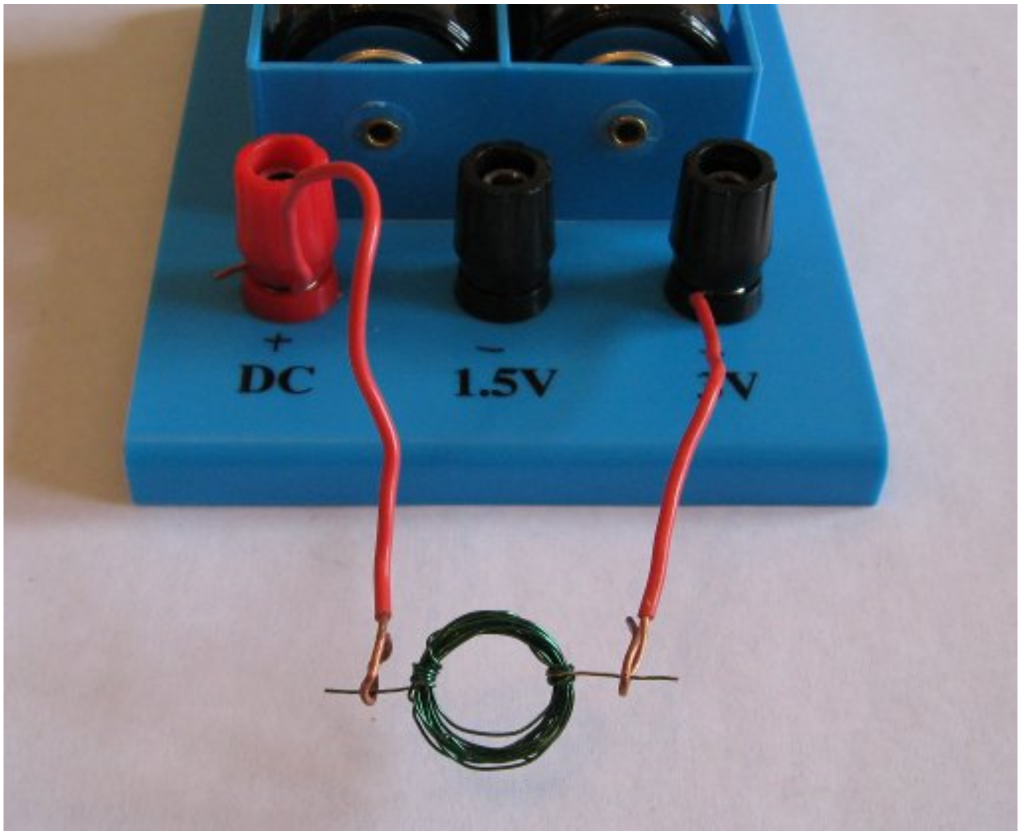

13. Place your magnets directly underneath the coil on your work surface.
14. If the coil isn't already spinning, give it a nudge!

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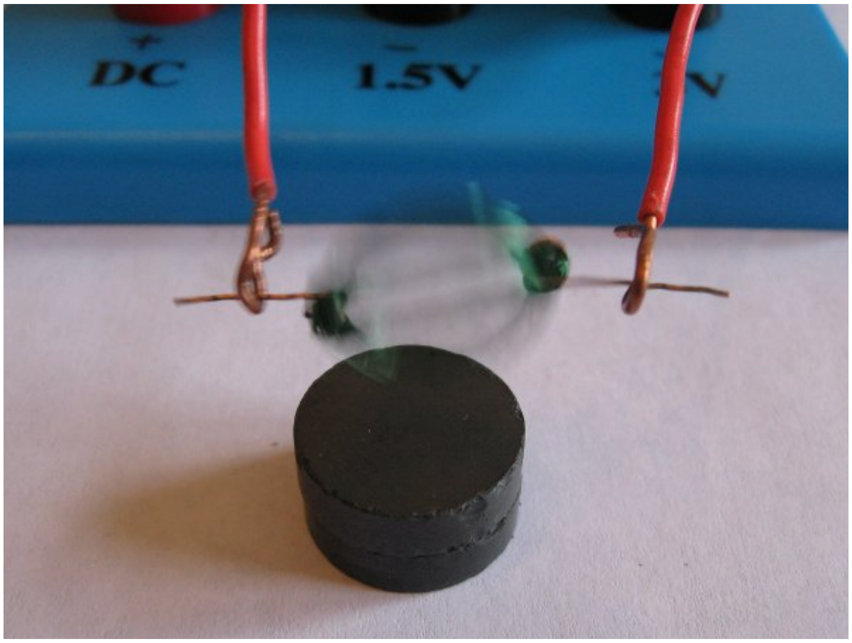

Observations and Explorations

5. Base on what you saw in the above experiment, list things that you think could affect the speed of your motor, and how they would affect the speed. (Use a separate sheet of paper if needed.)

6. Think of a way to reverse the direction of the spin of your motor. Write it down.

7. Attempt to implement your predictions above, one at a time, and record your observations on a data sheet that you can create on a separate sheet of paper.

8. If there are any other aspects you would like to explore feel free to do so. Write down what is you are investigating, what your predictions are, and finally, what you observed and concluded.

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Further Thoughts

Using your recently gained knowledge of electric motors, describe how you think an electric generator works.

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Activity: The Telegraph

Purpose

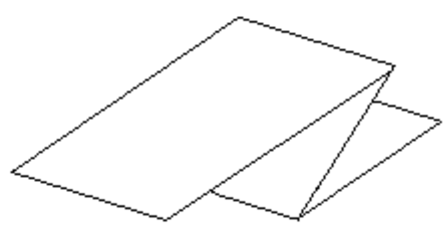
The electromagnet has been used for over a hundred years in such things as electric motors, generators, video cameras, stereo speakers, and in communication technologies such as the telephone, or previously, the telegraph. The telegraph was the first method of using electricity to communicate over great distances. Using Morse code, people would send a series of “dots and dashes” created by turning a switch on and off. A dot was created by holding the switch ON for a brief time, where a dash was created by holding the switch down for a longer time. In this activity you will build a simple telegraph system and send a message in Morse code.

Materials

- Battery
- Switch
- Long length of wire
- 2 Large nails (steel)
- 2 small nails
- Hammer
- Wood block
- Strip of metal

Procedure

15. Form groups and gather your materials as instructed by your teacher.
16. Begin by bending your strip of metal into a “Z” as shown below. Be careful, the metal may be sharp!!



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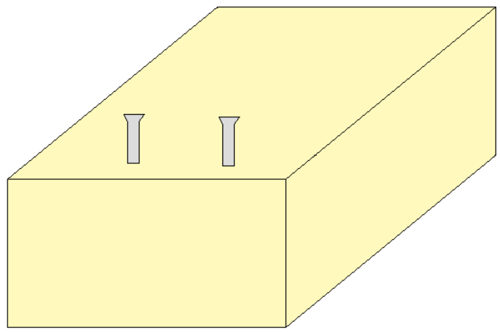
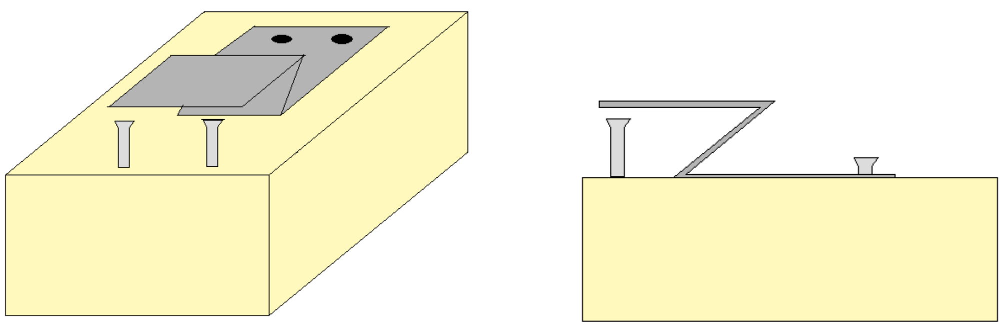
17. Set the metal piece aside.
18. Take your two large nails and hammer them into the top of your wooden block as shown. Make sure they are 1 inch apart.



19. Use the two small nails to attach the metal piece to the wood block. Make sure the top of the "Z" shape hangs over the top of the nails. The nails should not be touching the metal, but should be very close.



20. Take your wire and wind it around one of the large nails, **starting from the top** and working down toward the wooden base. Leave about a foot of wire sticking out from the top of the nail, and the rest of the wire sticking out of the bottom.

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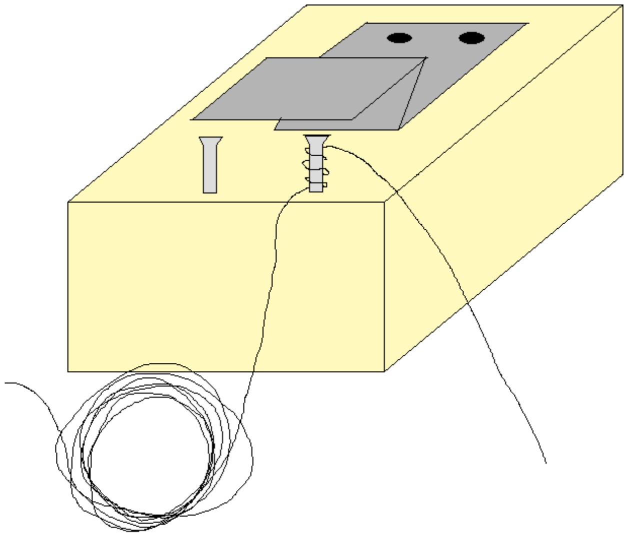
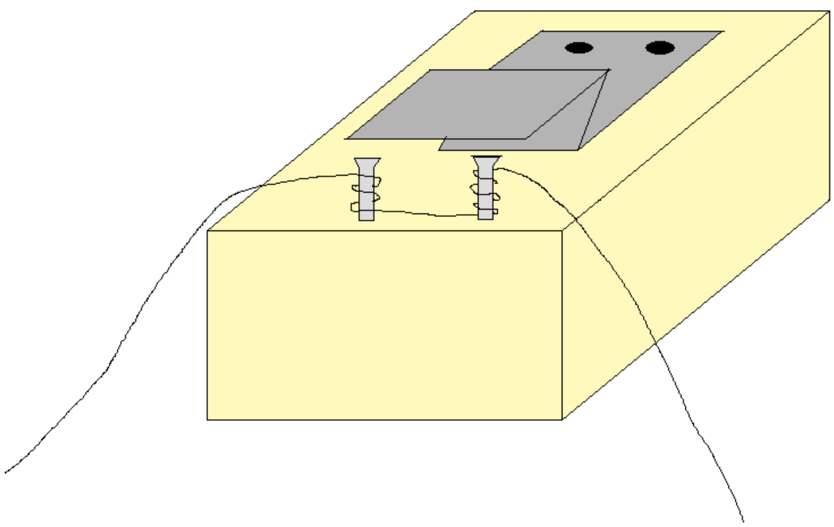


21. Now wrap the other nail with wire, now working from the **bottom to the top.**
22. To figure out which way to wrap the second nail, figure out if the first nail was wrapped clockwise or counterclockwise. Whichever the case, the second nail must be wound the **opposite**.



23. Now connect one of the wire ends to your one of your battery terminals. The other should be connected to a switch and then to the other battery terminal.

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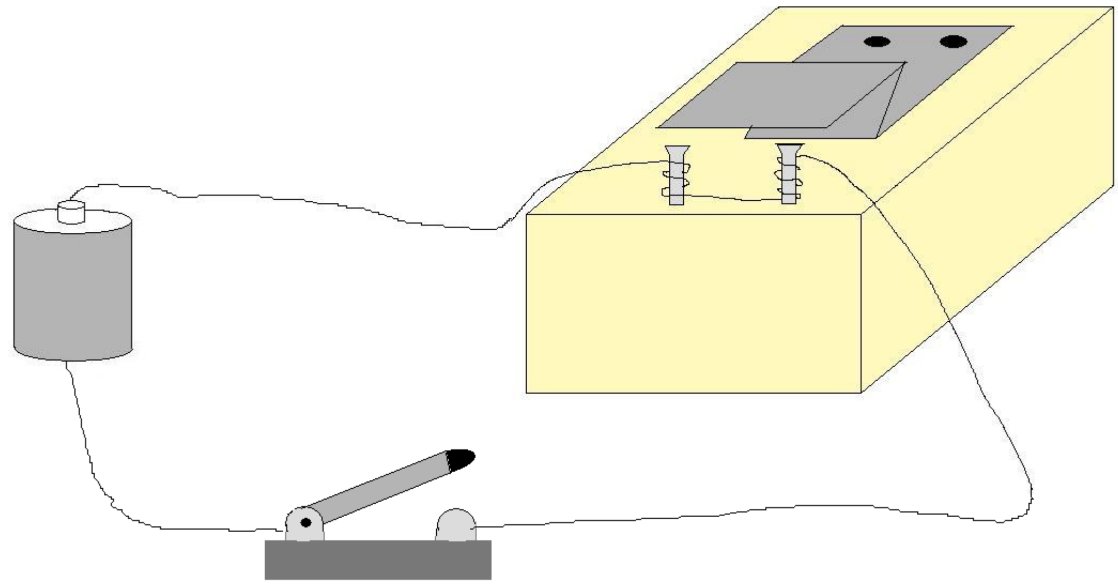

24. When the switch is closed, the nails, now electromagnets should energize, pulling the metal “Z” shape to them. When the switch is opened, the metal should spring back into its original position.
25. For best results, the head of one nail should be a North pole, and the other should be a South pole. Verify this with your knowledge of the Right Hand Rule, and rewind the second nail if the nails don’t have opposite poles.
26. You may experiment with Morse code. By holding the switch shut for a split second, you are sending a “dot”. Holding it down for about full second, you send a “dash.” Send messages across your desk and see if your partners can decode them.

A	.-	M	--	Y	-.--	.	.-.-.-
B	-...	N	-.	Z	--..	,	--..--
C	-.-.	O	---	0	-----	?	..--..
D	-..	P	.--.	1	.----	!	..--.
E	.	Q	--.-	2	..---	:	---...
F	..-.	R	.-.	3	...--	“	.-..-.
G	--.	S	...	4	....-	‘	.----.
H	....	T	-	5	.....	=	-...-

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I	..	U	..-	6	-....		
J	.---	V	...-	7	--...		
K	-.-	W	.--	8	---..		
L	.-..	X	-..-	9	----.		

Fig. 2 - List of Morse code characters

Discussion Questions

1. Describe in your own words how the telegraph works.

____
____
____
____
____
____
____

2. What would you add to your device so it could automatically write the received dots and dashes on a piece of paper? (Hint: start with a moving piece of paper!)

____
____
____
____
____
____

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