VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
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Electromagnetism

Fall 2018

(Adapted from Student Guide for Electric Snap Circuits by Elenco Electronic Inc.)

Here are some Fun Facts for the lesson
Wind turbines generate electricity by using the wind to turn their blades. These drive magnets around inside coils of electric wire

Electromagnets are used in junk yards to pick up cars and other heavy metal objects

Electromagnetics are used in home circuit breakers, door bells, magnetic door locks, amplifiers, telephones, loudspeakers, PCs, medical imaging, tape recorders

Magnetic levitation trains use very strong electromagnets to carry the train on a cushion of magnetic repulsion. Floating reduces friction and allows the train to run more efficiently.

Materials
16 sets (of 2) D-batteries in holder
16 sets (of 2) nails wrapped with copper wire
  1 nail has 50 coils and the other 10 coils
16 cases Iron fillings (white paper glued beneath for better visibility)
16 paper clips attached to each other
16 bags of 10 paper clips
16 circuit boards with:
  4 # 2 snaps
  1 # 1snap
  1 # 3 snaps
  1 electromagnet
  1 switch
  1 red and 1 black lead
  1 voltmeter/ammeter
  1 motor
1 magnet
1 red spinner (blade)
1 iron rod and grommet
16 simple motors
16 Transparent generators
Observation sheet

Divide class into 16 pairs.

I. Introduction

Learning Goals: Students understand the main ideas about magnets and electromagnets.

A. What is a Magnet?

Ask students to tell you what they know about **magnets.** Make sure the following information is included:

All magnets have the same properties:

- All magnets have 2 magnetic poles.
  - The poles in the bar magnet are at the ends.
  - One pole is labeled **N**
  - The poles are the places where its magnetism is strongest.
- Same poles repel each other:
  - If the **N** pole is brought close to the **N** pole of a second magnet they will repel each other, the same is true for 2 **S** poles brought together.
- Opposite poles attract each other.
  - If the **N** pole of one magnet is brought close to the **S** pole of another magnet, they will attract each other.

All magnets have a magnetic field, which can be visualized using iron filings.

B. What is an electromagnet?

Ask students if they know what an electromagnet is and accept answers.

An electromagnet is made by wrapping copper (the metallic reddish-colored) wire around a coil. It generates a magnetic field when an electric current passes through it. An iron rod placed inside the coil will increase the magnetic force.

Explain that an electromagnet is a magnet that works only when an electric current passes through it (when it is connected to a battery). Electromagnets differ from permanents magnets in that they have an inducible or temporary magnetic field. Their magnetic field can be turned off by removing the electric current.

II. Making an Electromagnet Using Batteries, a Nail and Copper Wire.

Learning Goals: Students understand the components necessary for making an electromagnet and the steps needed to do so.

Materials

10 bags containing:

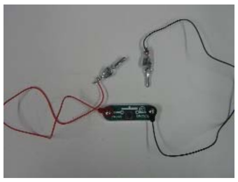
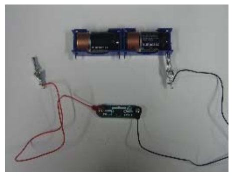
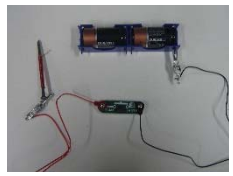
- 1 set of 2 nails wrapped with copper wire (1 nail has 50 coils and the other 10 coils)
- 1 bag of 10 paper clips
- 2 single alligator clips,
- 1 double alligator clip,
- 1 push switch

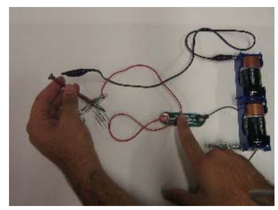
Your Notes:

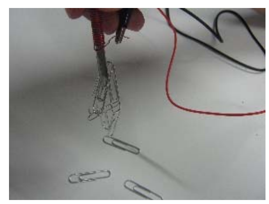
Tell students to:

1. Look at the 2 nails – one has 50 coils of copper wire, and the other has only 10. Tell students that they will be testing the strength of the 2 electromagnets by finding out how many paper clips each one can hold.
2. Take the nail with the 50 coils and test the nail to make sure it is not magnetic by attempting to pick up a paperclip with the nail. If the nail does pick up the paper clip, have the students carefully tap it on the table until it becomes demagnetized and no longer picks up the paper clip.
3. Have students look at the diagram on the Instruction Sheet and make the circuit by:

a. Snapping the 2 wires containing snaps onto the switch.
b. Clipping one of these wires to the metal bar protruding from the battery holder, using the alligator clip.
c. Clipping the other wire to one of the ends of the copper coil on the nail, using the alligator clip.





d. Take the 3rd wire (with alligator clips on **both** ends) and clip one end onto the other metal bar on the battery holder and the remaining end of the copper wire coil.
e. Ask students what they need to do to complete the circuit (press and hold the switch).
f. Tell students to press the switch and to try to pick up a paper clip with the tip of the nail.
g. **Warn students not to hold switch too long as the batteries can become very hot and drained.**
h. Tell students to see how many paper clips they can hang from the nail while the circuit is complete.
i. What happens when the circuit is broken?
j. Repeat the test with the nail with 50 coils.

Collect all battery holders, etc.

Your Notes:

III. Comparing Properties of Magnets and Electromagnets

Learning Goals:

- **Students understand the components necessary for making an electromagnet and the steps needed to do so.**
- **Students explore how electromagnets' magnetic properties can be modified**

Materials

16 paired paper clips

16 circuit boards with:

4 # 2 snaps

1 # 1snap

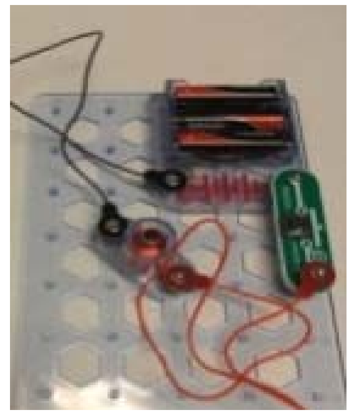
1 # 3 snaps

1 electromagnet

1 switch

1 red and 1 black lead

Iron rod



Divide students into pairs and give each pair one electromagnetism kit and one bar magnet. Have students connect battery holder, switch, and electromagnet using black and red jumper wires and insert iron core rod into the center of the electromagnet.

Explanation:
Tell students to examine the electromagnet from the kit and notice that this commercial electromagnet has copper wire that is coiled many more times compared with the nail used in the previous experiment.

The iron core rod replaces the nail in the previous experiment.
Ask students to predict if this electromagnet will be stronger or weaker than the one they made with the nail and wire? Why?

The snap circuit electromagnet should be stronger, since it has more coils.

A. Testing the Magnetic attractiveness of the magnet and electromagnet?

1. Move the **magnet** towards the paper clip. Is the paper clip attracted to the magnet? – yes
2. Testing the **electromagnet:**
   Hold the paper clip close to the top of the iron rod in the electromagnet. Is there any attraction? *No.*

Your Notes:

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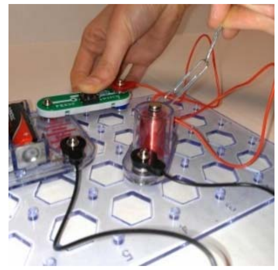

3. Press and hold the switch **down** and repeat step 3. Is there any magnetic attraction? *Yes, the paper clip is attracted to the electromagnet.*
4. Release the switch to **OFF** and notice what happens. *The paper clip is no longer attracted.*
5. Place the paper clip near the rod **under** the electromagnet and notice what happens
when the switch is turned **ON**.

Explanation:

Explain to students that all materials have tiny particles with magnetic charges, which are usually so well balanced that you do not notice them.

A **magnet** is a material that concentrates the magnetic charges at opposite ends (the poles).

In an **electromagnet**, the electric current that flows in the wire has a tiny magnetic field. By looping a long wire into a coil the tiny magnetic field is concentrated into a large one. The strength of the magnetic field depends on how much current is flowing in the wire and how many loops of wire are present.

2. Comparing the magnetic fields of magnets and electromagnets

Gently shake the **iron filings pack** so that the filings are spread evenly and thinly

Place the magnet underneath the pack and notice how the filings produce a distinct pattern. The pattern you see shows the magnetic field of the magnet. The field has areas of strong and weak magnetism.

How is the magnetic field around the electromagnet similar to that found around a magnet? Place the iron filings container above the electromagnet and turn the switch on. What happens to the filings?

A similar pattern is formed, but much weaker

IV. Making Electricity with Magnets

A. Using a meter to observe the current.

Show students the meter and tell them that it is capable of measuring both current (as an ammeter) and voltage (as a voltmeter).

Voltage is measured in volts (V).

Current is measured in amperes (A) or milliamps (mA, 1/1000 of an ampere).

Build the circuit shown in **figure 2** on the *Instruction sheet*. (Do not place the rod into the core yet.)

Your Notes:

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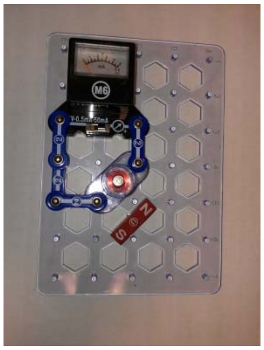


Figure 2

Figure 3

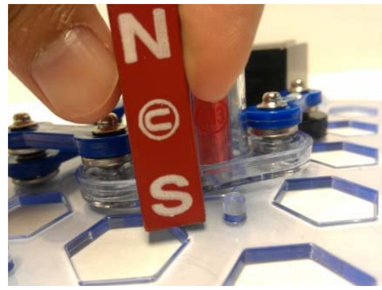


Figure 4

1. Set the meter to the **<u>middle setting</u>**, 0.5mA. (The current produced by the circuit you have built will be very small, and will not be detected with the 50mA setting.)
2. Place the board flat on the table surface (you are going to be looking for small movements in the meter needle, so the board needs to be stable).

3. Hold the bar magnet against the coil (vertically or horizontally) and move it up and down or across back and forth (see **figures 3 & 4** below). Observe the meter needle while moving the magnet. Very small movements will be detected.
4. Place the iron core rod into the coil and repeat. The meter needle movement will be larger.
5. Place the magnet on the top of the rod and use it to move the rod up and down.

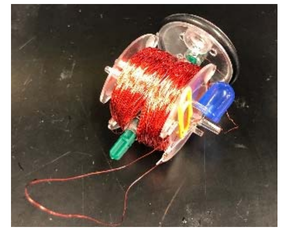
- The movement of the meter needle indicates that a small current is being produced.
- Remember that <u>NO</u> batteries are being used – the electric current has been induced by the movement of the bar magnet and copper wire coil.
    - This occurs because electric fields and magnetic fields <u>always</u> occur together, hence electromagnetic spectrum (EM spectrum).
    - Since electric and magnetic fields always occur together, altering or inducing one will cause a change in the other.
    - EM spectrum refers to the range of energy waves known to man, which range from Gamma to visible light to radio waves, just to name a few.
- Moving the bar magnet changes the magnetic field around the coil. This change produces an electric current. Alternatively, the coil could be moved instead of the magnet, and an electric current would still be produced.

B. Using an LED to observe a current

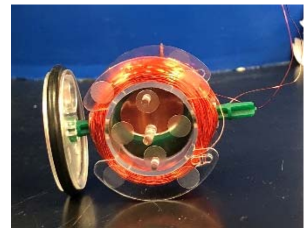
Learning Goals: Students know that an electric current can be induced by using a magnet and a wire.

Your Notes:

- Pass out a generator to each group
- Tell students to identify the different parts – a coil, a magnet (inside), a light bulb and moving spindle.



- Ask students to identify what happens when the spindle moves (it rotates the magnet). Students should twirl the spindle with a finger,. Do not let them run the wheel on the desk.
- What happens when you turned the spindle of the transparent generator SLOWLY? (nothing)
- What happens when you turned the spindle of the transparent generator FASTER? (the LED lights up)
- Explain that a generator uses a magnetic field to turn motion into electricity.
- What kind of energy are you using when you turn the spindle? (mechanical energy)
- What kind of energy is it being converted to (electrical).



- What devices use generators to convert energy to electricity? Windmills, steam/water turbines, alternator of a car

Generators are used to produce electric current by changing magnetic fields. They can be small to produce electricity for a single house, or large to create electricity for cities. Hydroelectric power plants use turbines (acts like a giant water-wheel) to turn coils, or magnets, in generators. Turbines are turned by flowing water (at dam sites), rising steam (at coal burning sites), wind (windmill farms), or other sources.
The electricity is produced by converting **mechanical energy** (water moving the turbines) into **electrical energy.** Generators also typically produce alternating current, or AC, which is the same form of electricity that an electrical outlet in a house provides.

Your Notes:

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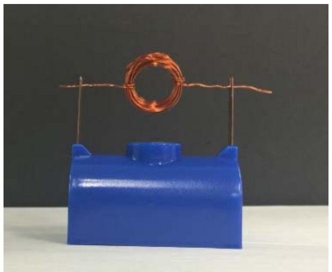
V . Applications of Electromagnets - Using Electricity and an Electromagnet to make a Motor

Learning Goals: In a motor, electric energy is converted to kinetic energy.



Pass out the assembled motors.
In an electric motor, a magnetic field turns electricity into motion.
Tell students to look at the motor and identify the following parts: a permanent magnet, an electromagnet. copper wire, and a battery.

Point out that the electrical current is produced by the battery

Point out the copper supports that connect the battery to the coil.

Point out that the copper wire is covered with an enamel coating for insulation. Tell students to look closely at the 2 straight ends of the copper coil. Both ends have had the enamel coating stripped from one side of the wire (it does not have the same shiny copper color as the other side). The coated side will not conduct electricity, whereas the stripped side will allow a current to flow through the coil.

Tell students to:

1. Place the straightened wires from the coil into the U of the copper supports. The shiny (insulated) side must be facing UP.
2. Give the coil a gentle tap. If it spins continuously, the student has succeeded in making a motor.
3. If the coil does not spin, have the student tap it in the other direction.
   Optional:
4. Flip the magnet over (a different pole will now be facing up). Repeat steps 1-3. What happens?

Explanation:
We know that an electromagnet has a magnetic field when an electrical current flows through it. Magnets also have permanent magnetic fields. The 2 magnetic fields can attract or repel each other.

The motor works because electricity flows through the coil and a magnetic field is formed. The magnetic fields from the magnet and electromagnet repel each other and the coil pushes away from the magnet with enough force to turn it around. As the coil rotates around, the coated side makes contact with the copper supports and breaks the electrical circuit. Momentum carries the coil around to its starting position, where the stripped wire now comes back into contact with the copper supports. The circuit is again completed, so the magnetic field in the electromagnet is created again, and the coil continues to spin.

VII. Using Electricity to Run a Motor

Motors are more commonly used to convert electricity to mechanical energy. Motors are the opposite of an electromagnet.
A motor has 3 parts.

1. A fixed magnet that cannot move (it is on the shell of the motor).

Your Notes:

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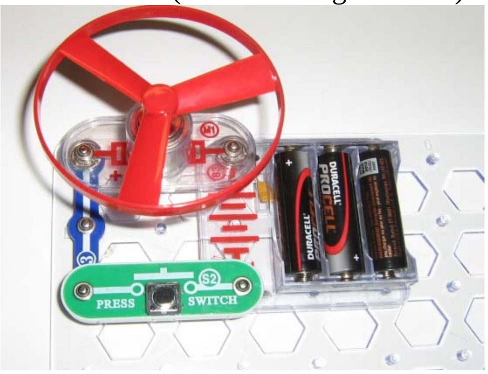
2. A coil of wire (an electromagnetic coil) attached to a moveable shaft.



1. Build the circuit shown in picture #6 in the *Instruction sheet*.
    a. Do not add the fan yet.
    b. Make sure the positive side of the motor is on the correct side.
2. Turn the switch **ON,** and note that the blade of the motor is turning.
3. Attach the blade to the motor and repeat. Turn the switch **OFF** when the motor reaches full speed.

Why does the blade float off in the air?

Lesson written by Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Leandra Fernandez, VSVS Lab Worker, Vanderbilt University

Your Notes:

Electromagnetism Observation Sheet **Name**___________________________________

1. How many paper clips can you pick up with the nail plus 50 coils? _________________________

2. What happens when the circuit is broken (the switch no longer pressed)?

   ____

3. How many paper clips can you pick up with the nail plus 10 coils? _________________________

4. What makes an electromagnet stronger?

   ____

5. Is the magnetic field around the electromagnet similar or different to that around a magnet? How?

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   ____

6. What happens to the current reading on the meter when you move the magnet past the coil plus the iron rod?

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7. What does the movement of the meter needle tell us?

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8. What happens to the meter needle when you gently turn the motor with your finger?

   ____

9. By turning the motor, what are you doing?

   ____

10. With the motor hooked up to the batteries, what happens when you press the switch?

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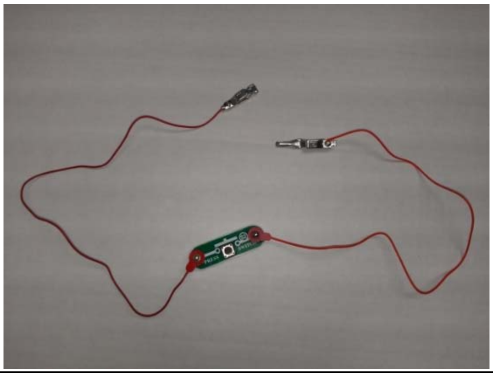
Electromagnetism Instruction Sheet

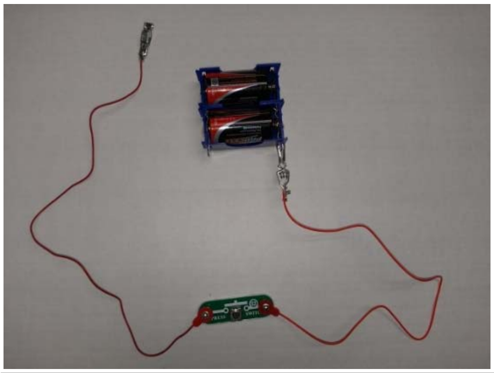
I. Introduction

II. Making an Electromagnet Using Batteries, a Nail and Copper Wire

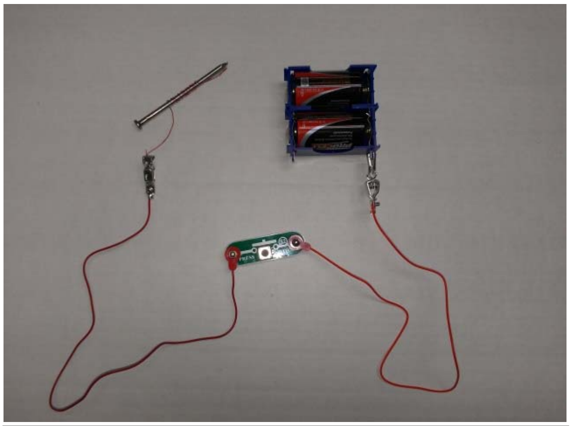
1. Build the circuit shown in **figure 1** below



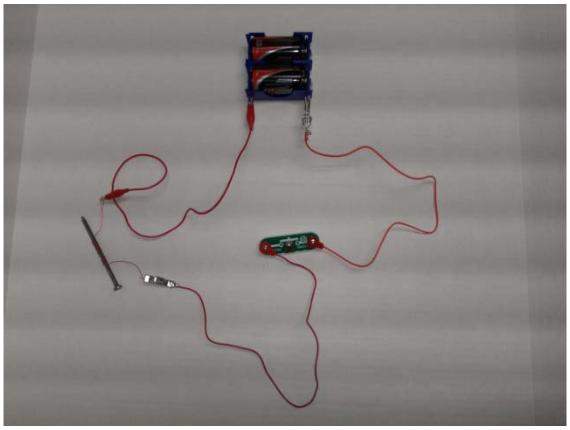
Snap the 2 wires containing snaps onto the switch



Clip one of these wires to the metal bar protruding from the battery holder using the alligator clip



Clip the other wire to one of the ends of the copper coil on the nail, using the alligator clip (notice that this nail has 50 coils)



Take the 3rd wire (with alligator clips on both ends) and clip one end to the other metal bar on the battery holder and the other end of the copper wire coil

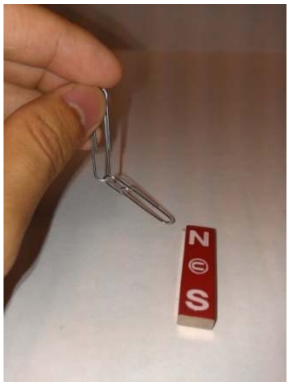
Figure 1

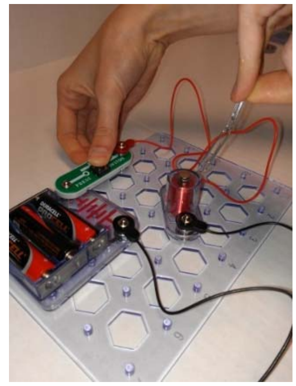
2. Make sure the button is not pressed. Hold the paper clip close to the tip of the nail in the electromagnet. Is there any magnetic attraction?
3. Hold down the button and repeat step 2. Is there any magnetic attraction?
4. Let go of the switch and notice what happens.
5. Replace the nail with 50 coils with the nail with 10 coils
6. Repeat steps 2 – 4 with the second nail

III. Comparing Properties of Magnets and Electromagnets

A. Testing the magnetic attractiveness of the magnet and electromagnet

1. Take two paperclips and loop them together. Next, move them close to the magnet. Observe how the paperclips react.



2. Construct the circuit as shown above. Be aware that there is a 1 connector beneath the switch to make it even with the battery pack. Test the electromagnet by holding the paperclip close to the top of the iron rod in the electromagnet.
3. Press and hold the switch down and repeat step 2.
4. Place the paper clip near the rod under the electromagnet and notice what happens when the switch is turned ON.

B. Comparing the magnetic fields of magnets and electromagnets

1. Gently shake the iron filings pack so the filings are spread
2. Place the magnet underneath the pack and notice how the filings produce a distinct pattern.
3. Repeat step 1 and place the pack over the electromagnet and turn the switch on. Notice what happens to the filings.


IVA. Making Electricity with Magnets

Figure 2

Note: The 5 V setting measures voltage, and the 0.5 mA and 50 mA settings measure current.

Voltage is measured in volts (V).

Current is measured in amperes (A) or milliamps (mA, 1/1000 of an ampere).

Build the circuit shown in **figure**. (Do not place the rod into the core yet.)

1. Set the meter to the **middle setting**, 0.5mA. (The current produced by the circuit you have built will be very small, and will not be detected with the 1A setting.)
2. Place the board flat on the table surface (you are going to be looking for small movements in the meter needle, so the board needs to be stable).
   a. Hold the bar magnet against the coil (vertically or horizontally) and move it up and down or across back and forth (see **figures 3 & 4** below). Observe the meter needle while moving the magnet.
   b. Place the iron core rod into the coil and repeat. Is the meter needle movement larger?
   c. Place the magnet on the top of the rod and use it to move the rod up and down.

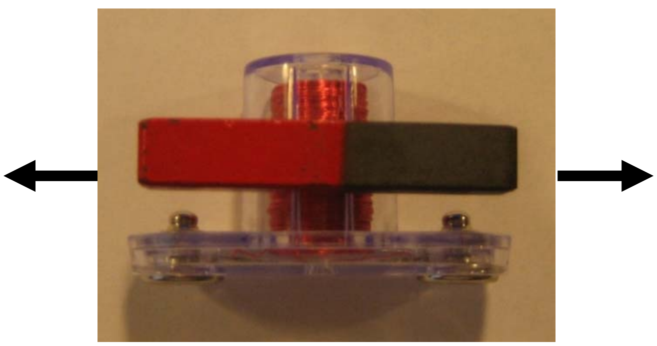


Figure 3

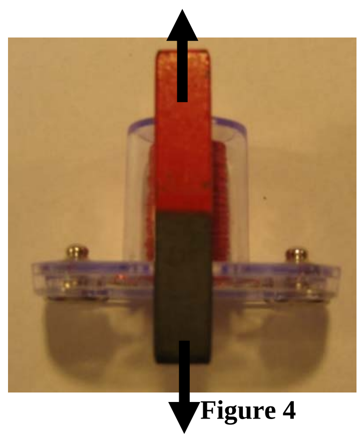
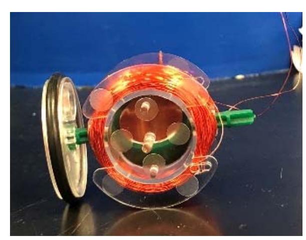


Figure 4

.IV B Making Electricity with Magnets and Coil



1. Identify the different parts of the generator (coil, magnet, spindle. LED)
2. Twirl the spindle with a **<u>finger.</u>**
   What happens when you turned the spindle SLOWLY?
   What happens when you turned the spindle FASTER?

V. Using a Motor to Make a Generator

a. Build the circuit shown in **figure 5** below.
   Note how the positive and negative sides of the motor are oriented.
b. Set the meter to 50 mA (you will be detecting small currents).
c. Turn the motor (gently) clockwise with the tip of a finger and observe the movement of the meter needle.
d. Now spin in the opposite direction, and note the movement of the needle.

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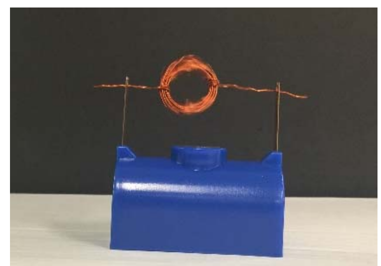
VI. Using Electricity and an Electromagnet to make a Motor.

Look at the motor and identify the following parts: a permanent magnet, an electromagnet (copper wire coil and a battery), and copper supports that connect the battery to the coil.
Note that the copper wire is covered with an enamel coating for insulation. Look closely at the 2 straight ends of the copper coil - both ends have had the enamel coating stripped from one side of the wire (it does not have the same shiny copper color as the other side).



1. Place the straightened wires from the coil into the U of the copper supports. The shiny (insulated) side must be facing UP.
2. Give the coil a gentle tap – it should spin
3. If the coil does not spin, tap it in the other direction
4. **Optional:** Flip the magnet over (a different pole will now be facing up). Repeat steps 1-3. What happens?

Figure 5

VI. Using Electricity to Run a Motor

4. Build the circuit shown in figure #6 below
   Do not add the fan yet. Make sure the positive side of the motor is on the correct side.
5. Turn the switch **ON,** and note that the blade of the motor is turning.

Attach the blade to the motor and repeat. Turn the switch **OFF** when the motor reaches full speed
Why does the blade float off in the air?

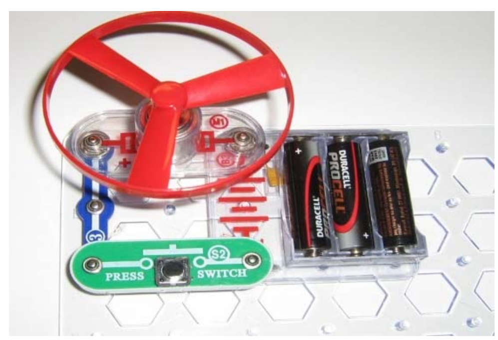


Figure 6