Name ______________________________ Date ___________________ Period _______

Turning Electricity and Magnetism into Mechanical Work: Simple Motor[1]

Background:

All matter is made of atoms; an atom is the smallest particle of an element and these atoms are made of even smaller particles called protons, neutrons and electrons. Protons and neutrons are located in the center of the atom in the nucleus. Electrons are located in the area outside of the nucleus called the electron cloud. Both protons and electrons have a basic property called **electric charge**. Charge is a physical property that cannot be seen. However, the effects of charge and how charge affects the behavior of particles can be measured.

Protons have a positive charge (+) and electrons have a negative charge (-). The difference between the two charges determines the forces the charges exert. **Forces** are the push or a pull on an object. When you throw a ball, your body exerts a force on the ball. Charged particles exert similar forces when they come in contact. When two like charged particles come in contact (positive and positive or negative and negative), these charged particles will have a force of repulsion. When charged particles with an opposite charge come in contact (positive and negative), these particles will have a force of attraction.

Electric **current** is the flow of charged particles and a measure of how fast the particles are flowing. Current is what runs from the outlets on your walls through the cords and wires connected to all your electronic devices. It provides the energy that enables these things (everything from your computer to your toaster) to run. In order for the charged particles to flow, they need a closed path through which to travel. An **electric circuit** provides a complete, closed path for an electric current.

Electricity and magnetism are important and deeply related topics. **Magnetism** refers to the attractive and repulsive forces that certain materials produce on other materials. Some common magnetic materials include nickel, cobalt, and iron. These forces are due to the **magnetic field** surrounding a magnetic material. If you hold two magnets close to each other, you will find that depending on the direction you are holding them, they will either pull toward each other or push away from each other. This is due to the direction of the magnetic field. A magnet has a north and south pole. The direction of the magnetic field flows out of the north pole and into the south pole as is depicted in the diagram below:

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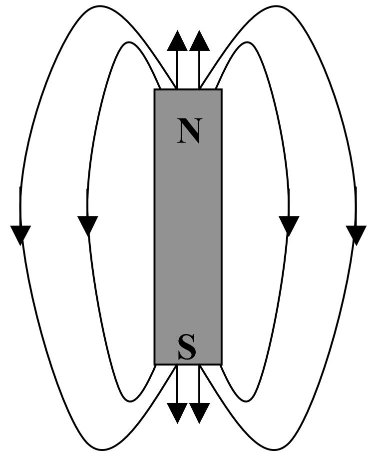
[1] This laboratory is based on one developed by Prof. Krishna Chowdary for the introductory physics labs at Bucknell University. We are grateful for his willingness to share the lab description.



When two magnets are repelling each other, their magnetic fields are pointing towards each other. Therefore, a north pole of one magnet will push away from the north pole of another magnet. Similarly, two magnets are attracted to each other when their magnetic fields are pointing in the same direction, i.e. a north pole of one magnet is attracted to the south pole of another magnet.

The interaction between electric charges and magnetic fields creates forces. A **force** is a push or a pull. Now that you understand some of the basic concepts, let's apply what you've read to create a force from interacting electricity and magnetism.

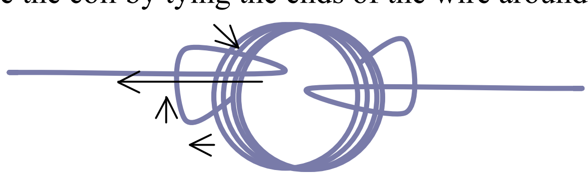
Equipment:

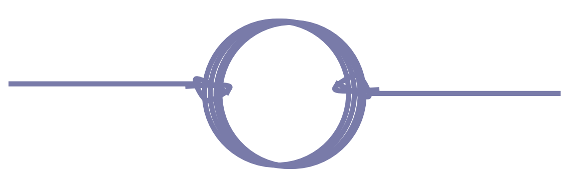
For this lab you will need the following materials:

- Magnetic wire
- Pencil or pen
- Paper cup
- 2 safety pins
- Tape
- Two small magnets
- Wire, preferably with alligator clips
- Battery

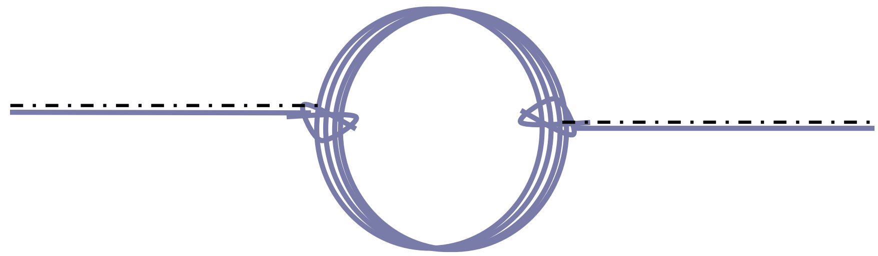
Procedure:

1. Cut a piece of the magnetic wire about 2 feet long.
2. Wrap the wire around a pen or pencil as many times as possible while still leaving about 2 inches of wire on each side of the coil. Slide the coiled wire off the pencil and secure the coil by tying the ends of the wire around the coil as shown below

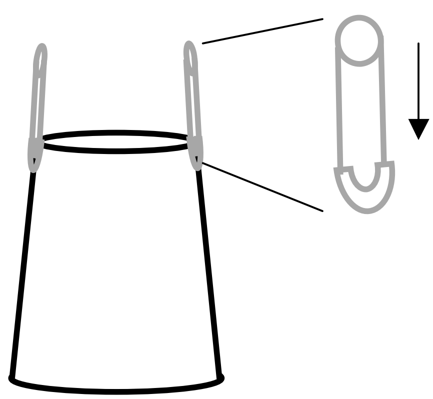




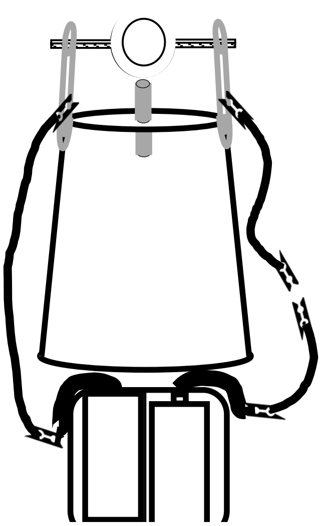
3. Sand the enamel off the top halves of the straight ends of the magnetic wire with coil kept vertical (the dashed areas in the figure below). **It is very important not to strip the enamel entirely off the wire but just on this top half.**



4. Now that your motor is built, you need to build the base for your motor. Take a paper cup and turn it upside down. Tape two safety pins on the cup, across from each other, with the pin part facing down.



5. Next you have to combine your motor and base for the final product. Attach your two magnets on either side of the bottom of the cup. Slide the straight ends of your loop of wires into the top holes of the safety pins. Connect the wires with alligator clips to the safety pins and to the battery. Configuration shown below.



6. Once connected to the battery, the coil should start to spin. (You might have to give it a little flick to get it started.) If it does not, there are a few things you can try. First, make sure that you have sanded the correct side of both ends of the coil; if you have not, you may need to make a completely new coil. Ensure that the straight ends of the coil are at 180° from each other and as straight as possible. Also, you can try to adjust your safety pins to lower the coil closer to the magnets without bumping into the magnets. After these adjustments, your simple motor should be fully operational.

Conclusions and Questions:

A current flowing through a wire creates a magnetic field. The reason that the coil spins is due to the force created from the interaction between the electric current flowing through the coil and the magnetic field of the magnets. Answer the following questions to ensure your understanding of the motor.

1. Name two different ways you could get your motor to spin in the other direction. Try them to see if you're right!

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2. Explain what you think would happen if instead of sanding only half the enamel off the ends of the coil, you sanded all of it. (Hint: When the enamel is making contact with the safety pins, there is no current running through the coil. In other words, the current is only flowing through the coil when the bare wire is making contact with the safety pins.)

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3. Can you think of anything you could change about the motor that would cause the coil to spin faster?

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4. If you had to make any of the adjustments listed in step 6 of the procedure, can you explain why they helped your motor to run?

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<u>Teacher's Answer Sheet:</u>

1. One way to make the coil spin the other way would be to reverse the battery leads, so that the current from the battery flows in the opposite direction (and as a result applies a force in the opposite direction). A second way would be to flip the magnets around, so that the poles are reversed (and again, the result is a force in the opposite direction). If both of these things are done, the coil will spin in the same direction as originally, because the force is identical to the force before.

2. The force placed on the coil can get it to spin about a half a turn – when it gets to that position, the force on it is reversed, making it spin in the opposite direction. If it wasn't for the enamel preventing the electric flow in the wire at the half-turn position, the coil would indeed reverse its spin and either spin back and forth in half-turn rotations, or simply get stuck (at an equilibrium force). The enamel prevents the electricity from flowing when it reaches the half-turn position, allowing the momentum of the turning wire to carry it over to the full rotation, so that it can continue spinning in the same direction.

3. There are a few valid options including increasing the strength of the batteries (thus increasing the current in the wire), increasing the strength of the magnets (thus increasing the force acting on the wire), and bringing the wire loop closer to the magnet (thus exposing it to more of the magnetic field).

4. The enamel adjustment is explained in answer #2, and bringing the wire closer to the magnet is explained in #3. Making sure that the wire is straight is important because it makes the turning easier. If the wire is bent, it is harder to bring the bent down portion upwards then it would be if the wire were straight.