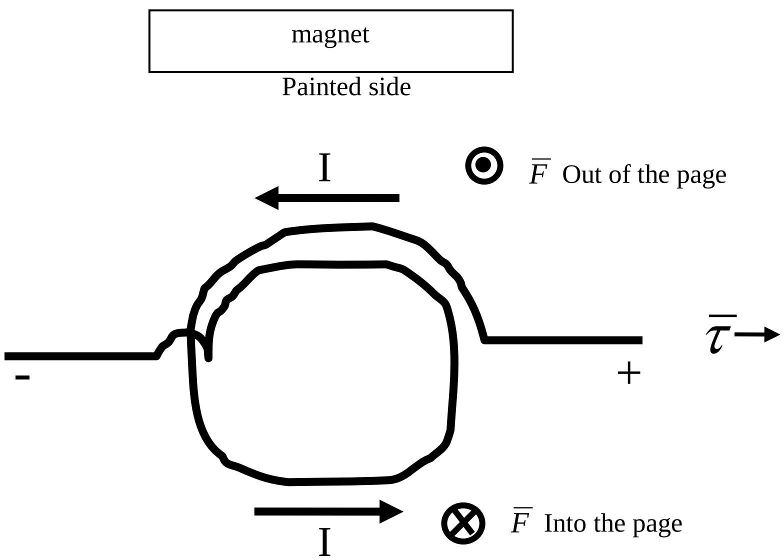
<u>Simple Motor Activity</u>

<u>Purpose:</u>

To build a simple motor, and analyze the relationship between current flow in a conductor in the form of a coil, the permanent and induced magnetic fields, and the resulting torque that turns the motor.

<u>Introduction:</u>

The force a charged particle experiences while moving in a magnetic field is given by $\overline{F} = q\overline{v} \times \overline{B}$. If charges are confined to a length of wire, L, the wire will experience a force of $\overline{F} = I\overline{L} \times \overline{B}$, where $\overline{L}$ is in the direction of the current and $\left|\overline{L}\right| = L$. If the wire is configured in the shape of a loop with an axle and the current is turned on and off appropriately, the loop of wire will spin due to a torque defined as $\overline{\tau} = \overline{r} \times \overline{F}$. As a motor spins, a back emf is induced due to the changing currents. The magnitude of the back emf is proportional to how fast the motor spins, and it will reduce the effective voltage available to deliver current to the motor. These are the fundamental principles of an electric motor.



From this diagram you should be able to determine that the top of the coil is coming out of the page, and the bottom of the coil is going into the page. Applying $\overline{F} = I\overline{L} \times \overline{B}$ at the very top and very bottom of the coil, it can be determined that the magnetic field, $\overline{B}$, supplied by the magnet is pointing down; therefore, the painted side of the magnet is the North Pole of the magnet.

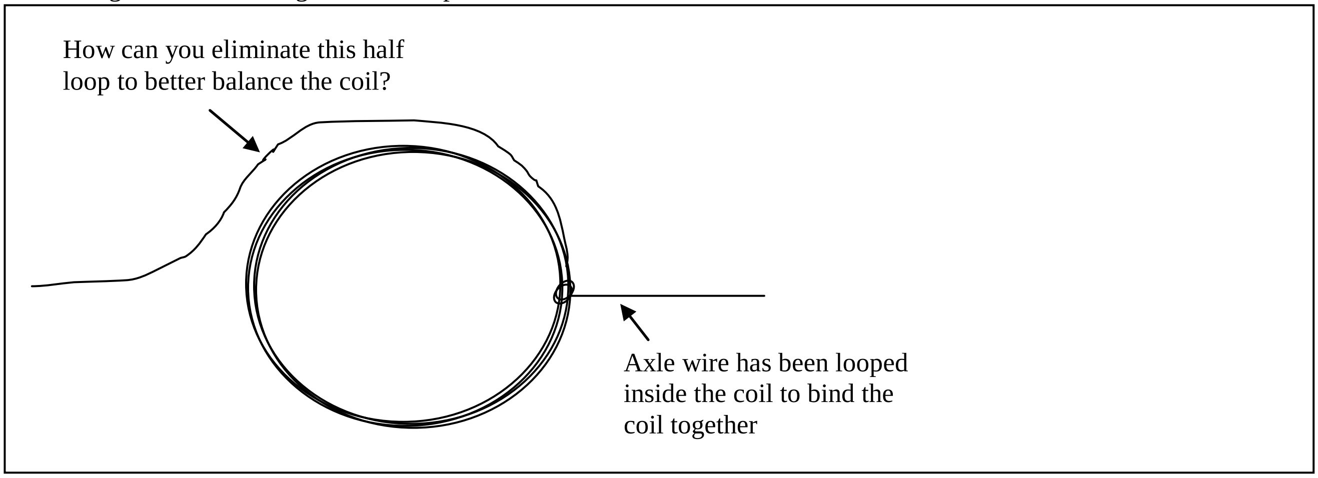
Procedure

<u>During this lab you will be working in groups of three or less. There is a strong possibility that you will work in a group of two. In addition, you will need your student ID to check out a battery and magnet</u>. Returning a damaged battery or magnet will result in point reductions.

Part I. Building the Motor

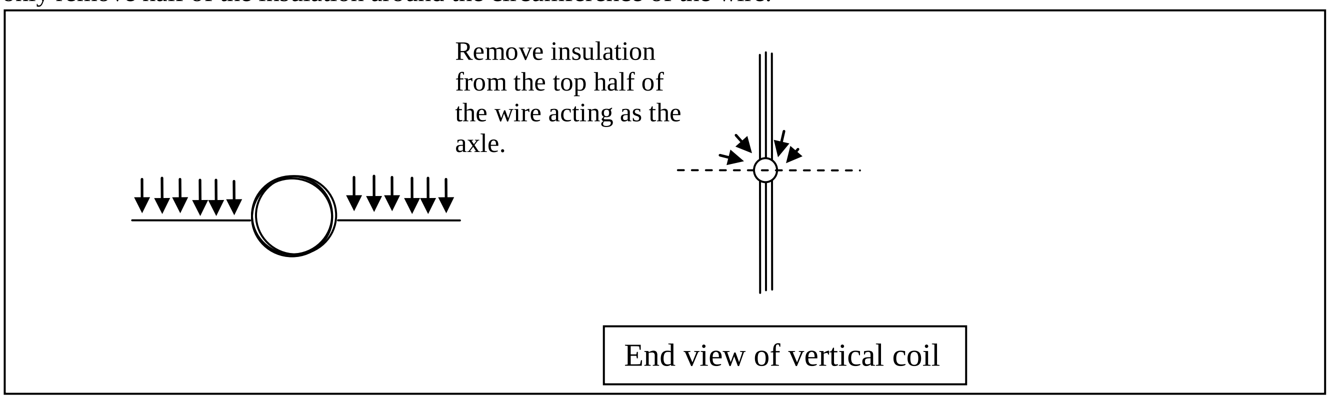
1. Starting with approximately 18" of 22ga wire, make a coil using the D battery as a form. Wrap at least two complete turns around the battery to form a coil; however, you will need approximately 2" of wire on opposite sides of the coil to use as axles so do not wind all of your wire around the D battery. Wrap the coil as neatly as possible. Later you will need to be able to identify how the coil is wrapped to determine the direction of current flow.
2. Carefully remove the coil from the D battery.

3. Your coil will need to be secured by looping the wires that will be the axles through the coil one or two times thus binding the coil together and holding the axles in place.



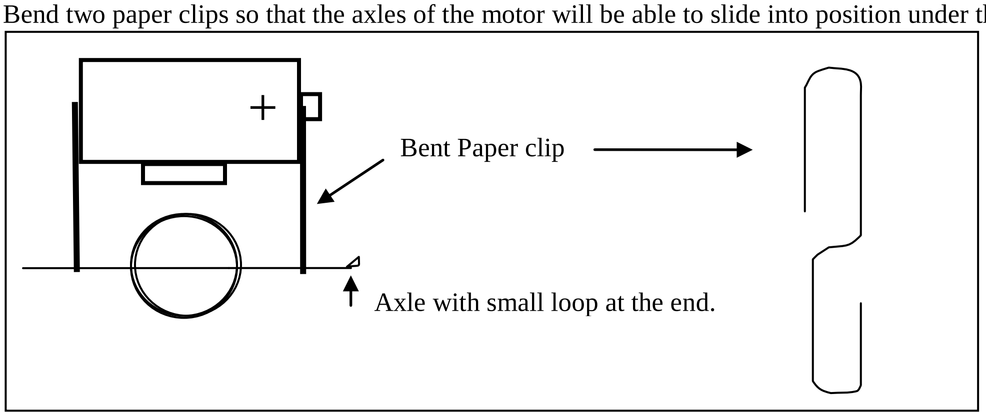
However it is important to balance the coil as much as possible. The loose length of wire shown in the diagram above will form a half loop and cause the coil to be unbalanced. Can you think of a way to re-route the length of wire that will result in a more balanced coil? As, you bind the coil, do it carefully and neatly such that you will be able to trace the direction the current will flow.

4. Once your coil is secure, you will need to remove some of the reddish insulation that is coating the wire. It is important to only remove half of the insulation around the circumference of the wire.



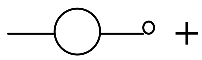
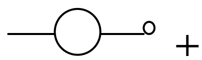
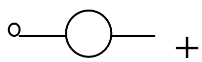
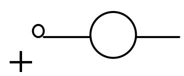
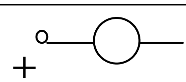
With the axles horizontal and the coil held in a vertical position, carefully remove the top half of the insulation from each axle using the rotary tool with a sanding drum attachment. Carefully guide the rotary tool to remove the insulation around half of the circumference. By only removing half of the insulation around the circumference, the current will effectively be turned on and off. It is important to remove the insulation from the same 'top' side on both axles. Otherwise, current will never flow. Take care not to allow the wire to wrap around the sanding drum.

5. After sanding, form a small loop or fold a small piece of the axle over at the end of only one of the axles. This small loop will be used to help keep track of the coil orientation.
6. Attach a round magnet to the D battery. Note: If the D battery is not an alkaline battery, the magnet may not stick because the case of the battery may not be made of steel.
7. Bend two paper clips so that the axles of the motor will be able to slide into position under the magnet.



8. While holding the paper clips in place with your thumb and finger, slide the coil into position under the battery/magnet. Do not tape or otherwise force the paperclips to stay on the batteries. Hold the paperclips in place with your finger and thumb. ***<u>If your battery is returned damaged either by pealing the label or in any way exposing the end of the terminals, your grade will be reduced by 25 points. If you do not turn in your magnet, you will also lose 25 points.</u>***
9. Flick the coil with your finger if the coil does not begin to turn.
10. If your coil will not turn, check to make sure that the insulation was removed in the proper locations and that a sufficient amount of insulation was removed.

Part II. Determine the North Pole of the Magnet

Condition	Coil Position under Battery (As you are looking at it)	Magnet position (side with dot)
1		Down (Away from Battery)
2		Up (Against Battery)
3		Up (Against Battery)
4		Down (Away from Battery)
5		Up (Against Battery)

1. Orient the coil under the battery based on the conditions above, and observe how your coil spins.
2. For each of the conditions above, draw a snap shot of your simple motor when the coil is vertical and *<u>current is flowing</u>*. Remember that current is only flowing approximately half of the time in your winding. You will need to carefully determine when current is flowing in your winding and the direction of your winding to determine which direction current is flowing. Label the + and – contacts, the directions the top and bottom of the coil are moving, the painted side of the magnet, and the directions the current is flowing at the top and bottom of the coil. Your drawing should look similar to the drawing displayed in the Introduction.
    a. Draw the direction of the magnetic field of the permanent magnet on you diagram.
    b. What side of the magnet is the north pole?
    c. Determine the direction of the torque based on the directions of the force at the top of the coil and the bottom of the coil.
        i. Indicate the direction of the torque on your drawing.
        ii. Is the resulting torque from both forces in the same direction? Explain.
        iii. Approximately how much torque is being supplied by any straight horizontal lengths of wire such as the axles?
3. Another way to describe the motion of a motor is to think about the magnetic field that is created when current is flowing in the coil.
    a. Draw a simple diagram that shows the magnetic fields of the permanent magnet and the induced magnetic field of the coil when the coil is vertical and *<u>current</u>* is flowing.
    b. Use your diagram to intuitively explain which direction the motor should spin.
4. Ask you TA to confirm the polarity of the magnet at your station.
5. Identify the polarity of the magnet at the TA station.
    a. You will need to verbally explain how you determined the polarity of the magnet to the TA.

Simple Motor

Worksheet – The following three pages do not need to be turned in; however, it is highly recommended that they are completed.

Condition #1 -- Sketch

What side of the magnet is the north pole? (Circle One) Painted Side Unpainted Side

Is the resulting torque from the forces acting on the top of the loop and the bottom of the loop in the same direction? Remember, $\tau = r \times F$ or $\tau = rF\sin\theta$ Explain and draw the direction of the torque on the sketch above.

Approximately how much torque is being supplied by any straight horizontal lengths of wire such as the axles? Explain.

Condition #2 -- Sketch

What side of the magnet is the north pole? (Circle One) Painted Side Unpainted Side

As compared to Condition #1, what direction did the coil spin as you are looking at the coil?

Comment on why the direction of spin should remain the same or change.

Condition #3 -- Sketch

What side of the magnet is the north pole? (Circle One) Painted Side Unpainted Side

As compared to Condition #1, what direction did the coil spin as you are looking at the coil?

Comment on why the direction of spin should remain the same or change.

Condition #4 -- Sketch

What side of the magnet is the north pole? (Circle One) Painted Side Unpainted Side

As compared to Condition #1, what direction did the coil spin as you are looking at the coil?

Comment on why the direction of spin should remain the same or change.

Condition #5 -- Sketch

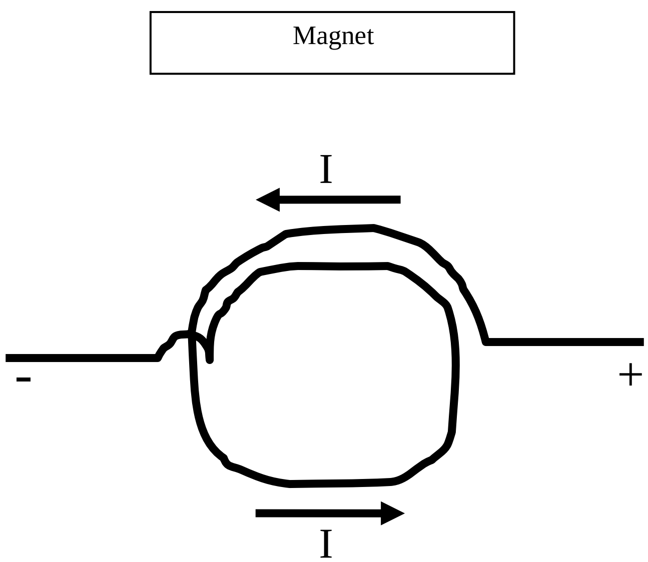
What side of the magnet is the north pole? (Circle One) Painted Side Unpainted Side

As compared to Condition #1, what direction did the coil spin as you are looking at the coil?

Comment on why the direction of spin should remain the same or change.

On the drawing below, assume that the north pole of the magnet is pointing down. Based on the direction current is flowing, indicate what direction the B Field generated by the coil is pointing on the drawing.

Use your diagram to intuitively explain which direction the motor should spin based on the directions of the two different magnetic fields.



TA Check of the polarity of your magnet.

What side of the magnet is the north pole (Circle One)? Painted Side Unpainted Side

Name: ____________________________ **Banner ID:** ____________________________

Lab Group ID: _____________________ **Number of Lab Partners:** ________________

Simple Motor Scoring

Working Motor (neatness, wobble, spin rate, etc):

20 or 15 or 10 or 5

Identification of North Pole and current Direction at Work Station:

10	or	0	Position of coil when current is flowing
10	or	0	Identification of North Pole

Identification of the North Pole at TA Test Station

(With Explanation):

Identify the position of the coil when current is flowing:	10	or	5	or	0
Direction of current on top of the coil when current is flowing	10	or	5	or	0
Application of right hand rule:	10	or	5	or	0
Polarity of the magnet	10	or	5	or	0

Removal of all insulation from both axles and Questions (20 points)

Returned Battery in Good Condition: 0 or -25

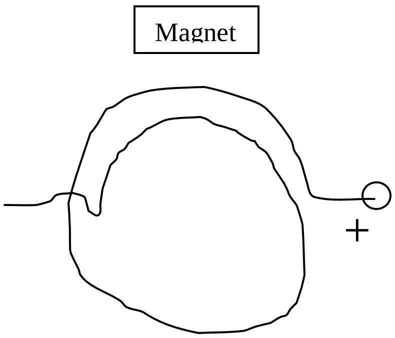
Returned Magnet in Good Condition: 0 or -25

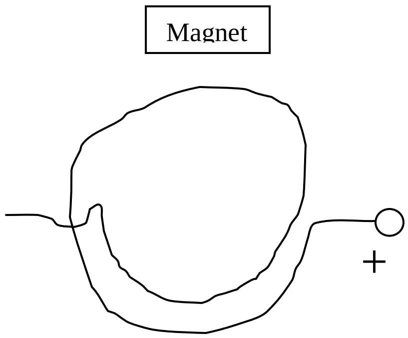
Total /100

Simple Motor

Removal of all Insulation from Axles

Complete the sketches below to help explain what would happen if all of the insulation was removed from both axles. The sketch on the right indicates the starting point of the coil; the sketch on the right is of the same coil after it has spun 180 degrees. The magnet is pointing in the same direction in both sketches. Since all of the insulation has been removed, current is flowing all of the time.





Explain what should happen to the coil if all of the insulation is removed from both axles.

After you have been tested at the TA Test Station, you may remove all of the insulation from both axles. Do your observations match what you predicted with your diagrams? Explain any differences between your predictions and your actual observation.

Questions

1. Why is it important to have the coil vertical when the insulation is removed from half the circumference of the axles?
   Hint: Use the right hand rule to determine the direction of the force acting on the coil when the coil is in a horizontal position.

2. What causes the coil to continue spinning when current is not flowing?