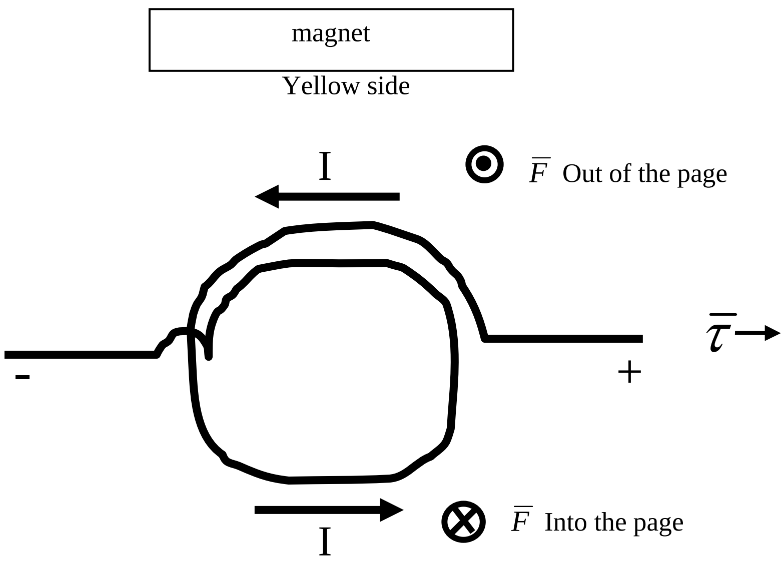
Simple Motor

Purpose:

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.

Introduction:

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.



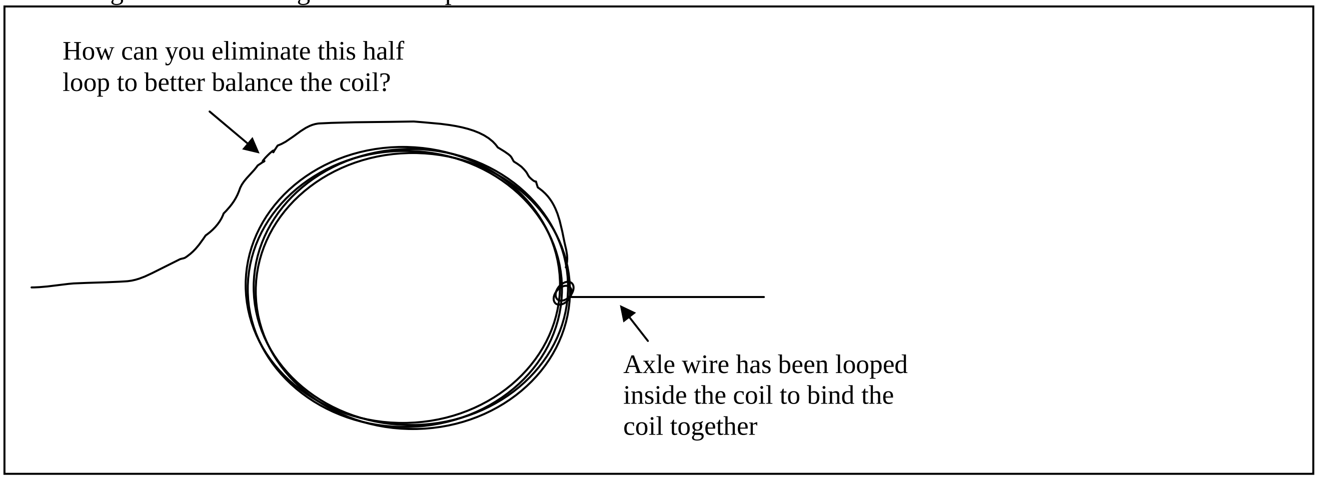
From this diagram you should be able to determine that the top of the coil is coming out of the page, and the bottom of the coil is going into the page. Applying $\overline{F} = I\overline{L} \times \overline{B}$ at the very top and very bottom of the coil, it can be determined that the magnetic field,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

Procedure

Part I. Building the Motor

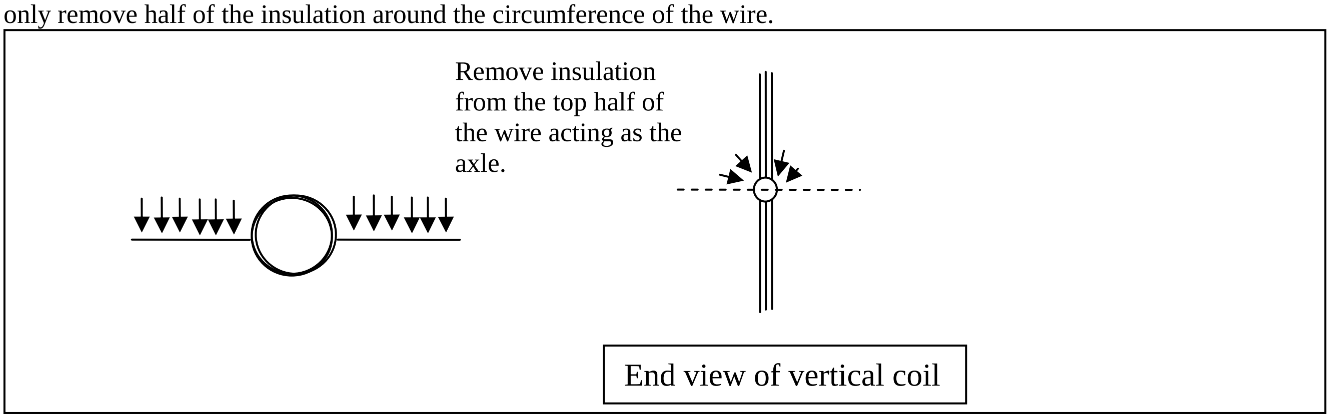
1. Starting with approximately 18” of 22ga wire, make a coil using the D battery as a form. Wrap at least two complete turns around the battery to form a coil; however, you will need approximately 2” of wire on opposite sides of the coil to use as axles so do not wind all of your wire around the D battery. 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.



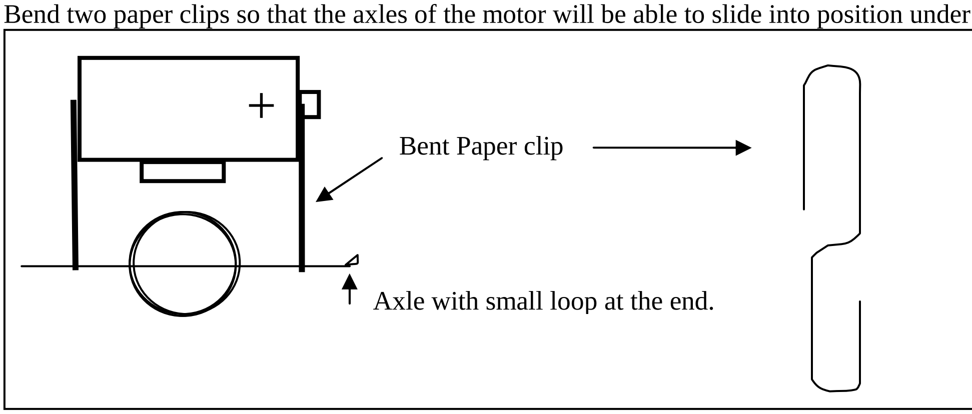
However it is important to balance the coil as much as possible. The loose length of wire shown in the diagram above will form a half loop and cause the coil to be unbalanced. Can you think of a way to re-route the length of wire that will result in a more balanced coil? As, you bind the coil, do it 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. Excessive pressure will cause the axle to curve and wind around the sanding drum. It is important to remove the insulation from the same 'top' side on both axles. Otherwise, current will not flow.

5. Now 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 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.
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

1. Orient the battery such that the positive end is to the right as you are looking at it. Place the coil in the paper clips such that the axle with the small loop at the end is in contact with the positive side of the battery.
2. Draw a snap shot of your simple motor when the coil is vertical and *current is flowing*. Your drawing should look similar to the drawing displayed in the Introduction. You will need to carefully determine the directions of your windings. Label the + and – contacts, the directions the top and bottom of the coil are moving, the yellow side of the magnet, and the directions the current is flowing at the top and bottom of the coil.
    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. With the positive side of the battery still oriented to the right as you look at it, flip your coil around such that the axle with the loop is now at the negative end of the battery. Draw a snapshot of your simple motor as before.
    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 force at the top of the coil and the bottom of the coil.
        i. Indicate the direction of the torque on your drawing.
    d. Did the coil spin in a different direction?
    e. Comment on why the direction of spin should remain the same or change.
4. Now flip the magnet, and draw a snapshot of your simple motor as before.
    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 force at the top of the coil and the bottom of the coil.
        i. Indicate the direction of the torque on your drawing.
    d. Did the coil spin in a different direction as compared to the previous trials?
    e. Comment on why the direction of spin should remain the same or change.
5. 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 *current* is flowing.
    b. Use your diagram to intuitively explain which direction the motor should spin.
6. Ask you TA to confirm the polarity of the magnet at your station.
7. 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.

Part III. What happens if the current is not turned on and off? Before performing this step, make sure you have identified the polarity of the magnet at the TA station.

1. Explain what would happen if the insulation was completely removed from both axles?
    a. Draw diagrams to explain the problem.
    b. Remove all of the insulation from both the axles of your coil and explain how your motor responds.

Simple Motor

Data Sheet

Part II

Step 2

Sketch

What side of the magnet is the north pole?

Is the resulting torque from both forces in the same direction? Explain.

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

Step 3

Sketch

What side of the magnet is the north pole?

Did the coil spin in a different direction?

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

Step 4

Sketch

What side of the magnet is the north pole?

Did the coil spin in a different direction as compared to the previous trials?

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

Step 5

Sketch

Use your diagram to intuitively explain which direction the motor should spin.

Part III.

Using diagrams, explain what would happen if all of the insulation was removed from both axles.

How does your motor respond when all of the insulation is removed 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?

2. How does your simple motor spin when the current is only flowing during half of the cycle?

Name: ____________________________ Name: ____________________________

Name: ____________________________ Name: ____________________________

Scoring

Attendance and Participation:

/30

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

/30

Identification of North Pole at Station:

/10

Identification of North Pole at TA Station (with Explanation):

/30

Total

/100