Laboratory 5
Activity: Magnetic Field and Current

In this lab we will investigate the phenomena related to the interaction between an electrical current and a magnetic field. A static charge does not feel any force in the presence of a static magnetic field. However, a static magnetic field produces a force on moving charges (electrical current), called Lorentz force. The direction of Lorentz force is quite unusual but can be easily determined using a right-hand rule as shown in the figure below. The strength of Lorentz force is simply the multiplication of magnetic field strength, current, and length of the wire: $F_L = BIL$.

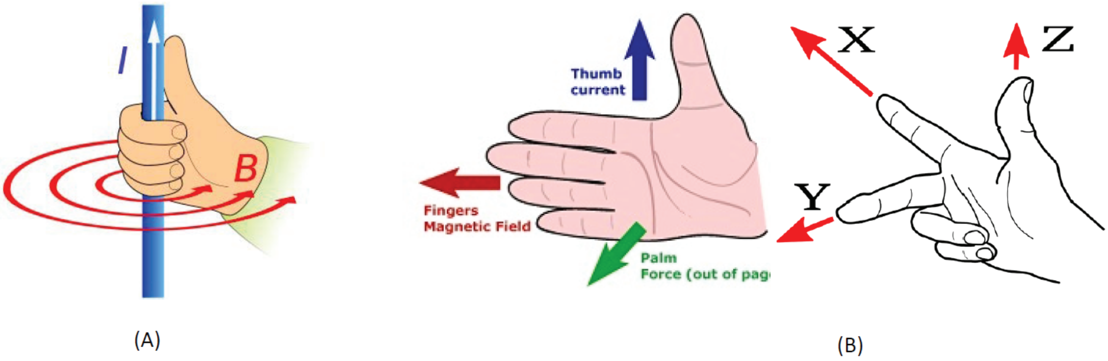

FIG. 1: Two right-hand rules.

Since a moving charge or current produces magnetic fields, it is not surprising that there is an interaction between a static magnetic field and a current. However, the direction of the force is indeed not so easy to understand. A current carrying wire produces a circular magnetic field winding in the direction represented by another right-hand rule (see Fig. 1). Suppose that a static magnetic field is somehow present along the direction of the wire. You can imagine that the interaction between two magnetic fields would be minimal. Why? because you know that two magnets aligned in one direction repel or attract most strongly. Therefore, you can project that a favorable direction of a static magnetic field to produce a force would be in the direction perpendicular to the current. Lorentz force involves the directions of three physical quantities. The structure of the right-hand rule for Lorentz force is that you cannot flip only one direction. If you do that there is no way you can use the right-hand to fulfill the rule, in other words, you have to switch your hand to left-hand. However, if you flip the direction of two quantities, everything is fine but just rotate you right-hand to realign the directions. For example, turn the hand around the thumb (Z force) so that the index finger (X current) points to the opposite direction in Fig. 1. This naturally turns the direction of the middle finger (Y magnetic field) in the opposite direction. What this means physically is when you flip the directions of the magnetic field and current simultaneously, the direction of the force does not change.

With this physics in mind, let us proceed to do some interesting experiments. You have a button magnet, a AA battery, a nail, and a piece of copper wire. A few things to know:

• The button magnet is magnetized so that the flat faces have N and S poles. You do not know which side is N, yet.

• When you establish a conducting path between the (+) and (-) electrodes of a battery, a current will flow from (+) to (-).

• The surface of the magnet is coated with a metal so that a current can pass through the magnet.

1. Please mark on the flat surfaces so that you can tell the faces. Mark also on the rim of the magnet so that you can clearly tell the direction of motion if it spins around the cylindrical axis.

2. Stick the head of your nail to the center of the magnet of any face and stick the tip of the nail to the bottom of your battery in a vertical position as shown in Fig. 2. The nail/magnet will hang freely from the bottom of the battery. Try to spin the nail/magnet.

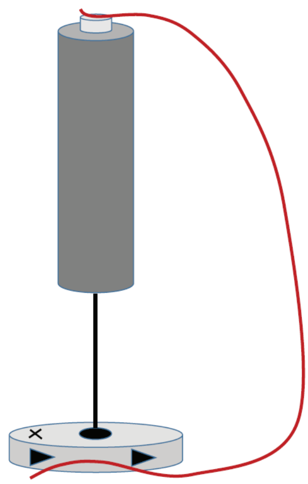

FIG. 2: Homo-polar motor.

3. Now you are ready to connect a wire. Hold down one end of wire on the (+) tip with your finger and touch the other end of the wire to the side rim of your magnet. You will have a better result when you touch the wire in a brushing manner rather than using the sharp tip. Do you see the magnet/nail starting or trying to spin? Which direction is it spinning? You just made a simple motor, homo-polar motor. Record the configuration in particular the orientation of the magnet, the current, and the spin.

4. You will feel the wire gets hot after the magnet spins for a while. Can you put your thought on what you are observing in the context of energy conservation?

5. There are actually four different configurations: reversing the directions of the current and/or the magnet. Record for all configurations.

6. Based on your observation and the right-hand rule, can you determine the actual pole of your magnet? Write down your conclusion on the pole of the magnet. *The current flows through the magnet radially along the direction connecting the contact point of the wire on the rim of the magnet and the head of the nail. Then the current flows through the nail.*

7. Now you can check the pole of the magnet using a compass. If your conclusion is correct, congratulations! If not, please explain what went wrong in applying the righ-hand rule.