LAB 8
Magnetic Forces and the Right-Hand Rule

OBJECTIVES

1. Observe the forces of magnetism and develop the concept of the magnetic field.
2. Qualitatively test the right-hand rule that describes the effect of a magnetic field on moving electric charges.
3. Observe that the magnetic field strength varies as an inverse-square law.

EQUIPMENT

Magnets, compasses, magnaprobes, Plexiglas, iron filings, coils, motors, light bulbs, power supplies, demo oscilloscope, hand-held generators, demonstration galvanometer, e/m apparatus, meter stick, DataStudio, Magnetic Field Sensor.

PROCEDURE

This is an "Exploratorium" type lab. Experiment with all of the equipment and make diagrams that show what you observed. Check at each station to see that your observations are consistent with the concept of the magnetic field and with the right-hand rule as developed in class. *Please turn off the currents when you stop using them.*

Part 1: Magnetic Fields

Use the small compasses, magnaprobes, and/or iron filings to map the magnetic fields due to bar magnets, disk magnets, a solenoid (coil), and a long straight wire. Compare to the pictures in the text. Use the convention to put arrowheads in the correct direction on the magnetic field lines that you sketch in your notes.

Part 2: Force on a Conductor in a Magnetic Field

(a) Observe the current-carrying wire in the strong magnetic field. *Predict the direction of the force, using* $\vec{F}_B = i\vec{L} \times \vec{B}$. *How should the direction of the force change if you reverse the direction of the current?* Try it and see.

(b) Bring a magnet near the filament of a gooseneck lamp and watch the filament shake due to the alternating current. Be gentle – don't break the filament. *Why does the filament shake when the lamp is on but not when it is off? Why does the filament oscillate back and forth?*

Part 3: Ribbon Microphone

Closely observe the ribbon microphone. Try to visualize how the magnetic forces, $\vec{F}_B = q\vec{v} \times \vec{B}$, affect the electrons in the aluminum foil as it oscillates up and down. *Explain how the ribbon microphone works.*

Part 4: Electron beam from an Oscilloscope and TV in a Magnetic Field

(a) Observe the effects of a magnet on the electron beam in the old oscilloscope. *Predict the direction of the force, using* $\vec{F}_B = q\vec{v} \times \vec{B}$. This is tricky; it makes a great check question!

(b) Observe the effect of magnets on the small black/white TV. *Explain what you see.*

Part 5: Electron beam in a Magnetic Field

Observe the bending of the beam of electrons in the glass globe of the e/m Apparatus when they are influenced by magnetic fields. Observe the following:

(a) the helical (or circular) paths obtained when the magnetic field is uniform (the big coils produce a nearly uniform field),

(b) the magnetic mirror effect of a non-uniform field of a bar magnet, and

(c) the trapping of the electrons in the non-uniform field of a magnetic bottle made by two bar magnets.

Part 6A: Generators

Operate the model generator with the light bulb. *Explain how it works in terms of* $\vec{F}_B = q\vec{v} \times \vec{B}$. *Notice, if you can, that it is easier to turn the crank when the bulb is unscrewed. Why?*

Part 6B: Hand-Held Generators

(a) Predict which hand-held generator will be easier to turn, the one connected to 2 light bulbs in series or the one connected to 2 light bulbs in parallel. *After you have made your prediction, test it. Try and estimate approximately how much harder it is to turn the hand-held generator.*

(b) Calculate how much power (in terms of V and R) is generated by two light bulbs of resistance R connected in series to a power supply of voltage V. Do a similar calculation for two light bulbs connected in parallel. *Use the results of these calculations to explain your observation from part (a).*

(c) For the circuit consisting of 4 light bulbs connected in parallel to the hand-held generator, unscrew all of the light bulbs but one. While one person is turning the hand-held generator, have another person screw in the remaining light bulbs one at a time. *How does the effort needed to turn the generator (and hence the energy needed to light the light bulbs) change as the more light bulbs are connected in parallel?*

Part 7: Magnetic Field versus Distance

Use the Magnetic Field Sensor to measure the magnetic field strength of a small neodymium magnet as the distance between the sensor and the magnet changes. Determine a relationship between the measured strength of the magnetic field and the distance from the magnet.

- Place the meter stick on a flat surface away from the computer. Place the Magnetic Field Sensor so the end of the rod is even with the zero end of the meter stick.

- Setup Capstone to read the magnetic field strength in the Digits display. Select AXIAL by pressing the Field Selector Switch on the top of the sensor box. Move the magnet away from the sensor. Zero the Magnetic Field Sensor by pressing the TARE button on the top of the sensor box.

- Keeping the magnet away from the computer, place the magnet next to the 3-cm mark on the meter stick. Move the magnet in 2-cm increment and record both the distance and the magnetic field strength in a data table until the magnet is about 20 cm from the sensor.

- *Use EXCEL to plot the magnetic field strength versus the inverse of the distance cubed, that is,* B vs. $1/r^3$. *Is the relationship between the two linear? Explain.*