HALL EFFECT EXPERIMENT

Purpose

In this laboratory exercise you will use a Hall effect sensor to study magnetic fields. After completing this lab, you should have a good understanding of what the Hall effect, how Hall effect sensors operate, and how to calibrate and use a Hall effect sensor to quantify magnetic fields.

E.H. Hall first witnessed this effect in 1879. He found that when he placed a metal strip carrying a current into a magnetic field, a voltage was produced across the strip. It was the magnetic portion of the Lorentz force, $F = qv \times B + qE$, that was responsible for creating this voltage. We know that a current is composed of charges q moving at a velocity v. If this current is placed in a magnetic field, B, each one of the charges that compose the current will experience a force, and will consequently be pushed to one side or the other of the medium in which the current is flowing. Thus, charge will pile up on one side and an opposite charge will be induced on the other. The result is a potential difference, i.e. a Hall voltage. The sensors used in our probe are composed of semiconductor materials that carry a small constant current, and produce a small Hall voltage in the presence of a magnetic field. This voltage is amplified and output to terminals on the control box. Part of this lab exercise is to calibrate the instrument using a known field.

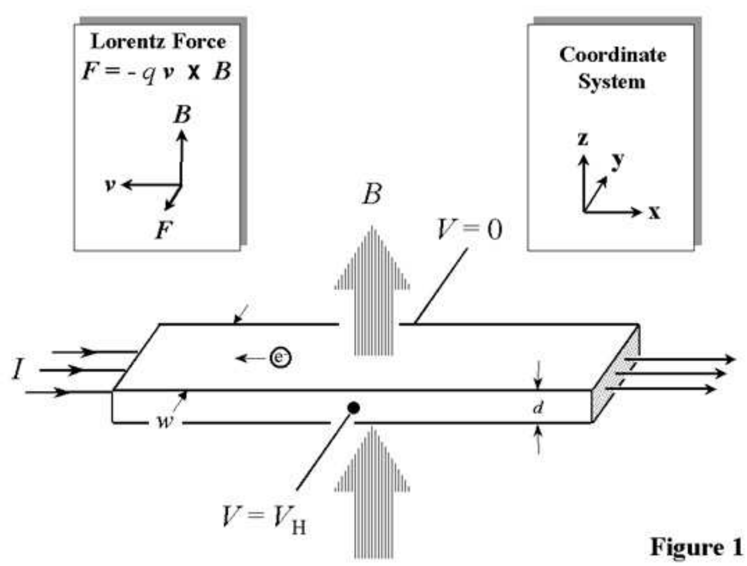

Figure 1

Equipment

We will use a TeachSpin HE1-A two-axis Hall effect unit, digital voltmeter, high current power supply, shunt resistor and handheld voltmeter, various calibration forms and wire, and a small permanent magnet. Read the Introduction, Operation, and Calibration sections from the TeachSpin manual before starting on this experiment.

Procedure

1. Prepare a small Helmholtz coil using the materials provided (PVC forms and winding wire). You will probably want to use 15-20 turns of wire on each side. Carefully measure the dimensions of the coil and verify that the two loops will satisfy the Helmholtz condition (nearly uniform field, first and second derivatives vanish along the coil axis) so that B_z is given by

$$B_z = \frac{\mu_o N I}{r} \frac{8}{5^{3/2}}$$

Calculate the expected field from your Helmholtz coil as a function of current I.

Now calibrate both the radial and transverse sensors in the probe rod using the procedures in this handout. Measure the output voltage as a function of coil current (B-field). Be sure to zero each sensor first! Also, note that the transverse sensor orientation is unknown; you will have to determine this during the calibration by rotating the probe to obtain maximum signal. You can also use the mounted, 900 G magnet and a compass to check the direction. (You can also check the magnitude of your calibration, but obtain you final calibration numbers using your Helmholtz coil.) Plot V vs. B and find the calibration constants from the slope. Do this for both the 1X and 10X sensitivity setting. How linear are the sensors?

2. Field from a long straight wire: Set up a length of wire ($\tilde{1}$ m) carrying a 5 A current (or as high as you can get using the power supply), and use the calibrated Hall probe to measure the magnitude of the field at radial distances from 2 cm to 14 cm from the wire, in steps of 2 cm (the transverse sensor would probably be the most convenient to use here). Plot your results (B vs. 1/r) and compare with the expected relationship from the Biot-Savart law.

3. Measure the axial field of a permanent magnet. Plot B vs. $1/z^3$, where z is the axial distance from the magnet. How does this compare to the theoretical, $1/z^3$ dependence of a magnetic dipole? Can you determine the dipole moment of this magnet?