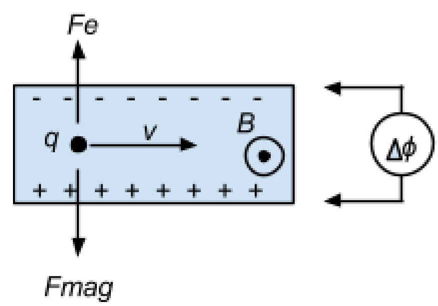
E&M Lab 5: Magnetic Fields

Experiment Overview

In this experiment, you'll measure the magnetic field created by a long straight wire, a circular coil, and the Earth itself. Since this lab is pretty straightforward, I've deliberately described the experiments in only general terms: you'll have to figure out how to implement it on your own. Decide on a technique, and make sure to explain it in your lab writeup.

The magnetic field sensor we will be using operates by the "Hall Effect". A Hall effect sensor consists of a small conducting strip through which a constant current flows. If a magnetic field is present with a component perpendicular to the surface of the strip, it will push charges vertically toward the edges of the strip: the buildup of charge on the edges creates an electric force which is equal and opposite to the magnetic force, allowing the charges to flow freely along the strip with no net force on them. The device measures the potential change across the strip.



$$F_{mag} = q\,v\,B$$
$$F_e = q\,E = -q\,\Delta\phi/L$$
$$q\,\Delta\phi/L = q\,v\,B$$
$$\Delta\phi = v\,B\,L$$

Thus, the electric potential (voltage) across the strip is proportional to the magnetic field perpendicular to its face.

The tip of your sensor is marked with a white circular ring, indicating the point where the sensor is located, and a small white arrow, indicating the direction along which the field is measured. A slider switch on the handle allows you to choose high sensitivity (0-0.3 millitesla) or low sensitivity and greater range (0-6.4 millitesla).

Equipment

Low-voltage power supply
100-turn coil
Labpro sensor controller
Meter stick
Long straight wire
Magnetic field sensor
Laptop

Experiment 5.1: Earth's Magnetic Field

Assemble the Labpro and laptop, and connect the magnetic field sensor. It should give you a real-time readout of the current magnetic field in a direction pointing toward the tip of the sensor. Set the switch on the sensor to the high-sensitivity (0.3 mT) range.

Hold the sensor in the air, away from any iron or steel objects. Measure three components of the Earth's magnetic field: B_x – the eastward component, B_y – the northward component, and B_z – the upward component. (From the old Science Center, north is toward Balfour-Hood. East is toward the athletic fields and Pine Street.)

Analysis: Calculate the magnitude of the measured magnetic field. Describe what direction the field points in three dimensions: give the angle in the horizontal plane with respect to north (azimuth), and the angle of deflection from horizontal (altitude).

Experiment 5.2: Field from a Straight Wire

Connect your long straight wire to the low-voltage power supply, and set the supply to deliver 3.0 amps of current through the wire.

Measure the magnetic field of the wire as a function of distance. Measure the field in two directions: one parallel to the wire, one perpendicular to the wire (in the direction that the field should point by the right-hand rule.) Perform measurements at 1, 2, 3, 4, 5, 6, 8, 10, 15, 20, and 30 cm from the wire.

A warning: the field you're measuring is small compared to Earth's magnetic field, so you'll have to subtract out the Earth's field! I'll let you figure out how to do that. Be aware that the Earth's field is strongly influenced by ferrous metal objects in the room, including the legs of your lab table, so it can vary even over just a few cm -- you can't just use your single result from experiment 5.1!

Analysis: Plot the magnetic field you measured and the theoretically predicted field from a straight wire on the same graph. Do they match up?

Experiment 5.3: Field from a circular coil

Connect the circular coil to the low-voltage power supply, and set the supply to deliver 0.5 amps through the wire. (NOT 3 AMPS LIKE LAST TIME!) Set the field sensor to its low-sensitivity setting (6.4 mT).

Measure the axial component of the magnetic field along the axis of the ring, at various distances from the center: 0, 2, 4, 6, 8, 10, 12, 14, 16, 20, and 30 cm. Before you start, think about how to make sure the sensor and ring stay in exactly the right position. Once again, the Earth's field is a significant factor, so you'll have to subtract it out!

Analysis: One of the examples in your textbook calculates the magnetic field from a single circular loop at any distance along the axis. Use this to calculate the theoretical magnetic field from your coil, and plot it on the same graph as your measured field. Do they match?