Laboratory 8: Currents and Magnetic Fields – Prelab

1 Adding magnetic fields

Figure 1 illustrates a situation in which two perpendicular magnetic fields, $\vec{\mathbf{B}}_1$ and $\vec{\mathbf{B}}_2$, combine to produce a net field, $\vec{\mathbf{B}}$. The magnitude of $\vec{\mathbf{B}}_1$ is 1.5×10^{-6} T. Determine the magnitude of $\vec{\mathbf{B}}_2$.

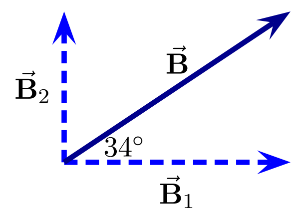

Figure 1: Adding magnetic fields.

2 Forces between parallel currents

Consider two parallel wires as illustrated in Fig. 2. The current in the lower wire points left. The current in the upper wire points left. Determine the direction of the magnetic field produced by the lower wire at the location of the upper wire. Then determine the direction of the force exerted by this magnetic field on the current in the upper wire.

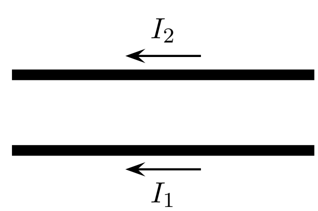

Figure 2: Parallel current carrying wires.

Laboratory 8: Currents and Magnetic Fields – Activity

Electric currents produce magnetic fields. These fields will exert forces and compasses and other currents. This laboratory explores the fields produced by currents. In one experiment these will be used to determine a component of Earth's magnetic field. In another experiment theses ideas will be used to investigate the force that one current exerts on another.

1 Field Produced by a Current Carrying Coil: Determining the Earth's Magnetic Field

In this experiment a circular coil will be oriented vertically so that the Earth's magnetic field lies in the plane of the coil. Figure 3 illustrates this as viewed from above. A current passes through the coil and this produces a magnetic field at the center of the coil that points along the axis of the coil (i.e. perpendicular to the coil). This will combine with the Earth's magnetic field to produce a net magnetic field. Determining the field produced by the coil and the direction of the net magnetic field will allow one to determine the field produced by Earth.

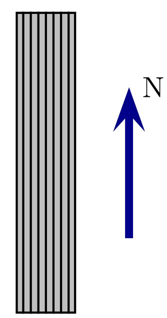

Figure 3: Coil in Earth's field.

a) Sketch one of the two possible directions of the field produced by the coil, $\vec{\mathbf{B}}_{\text{coil}}$. Sketch the field produced by Earth, $\vec{\mathbf{B}}_{\text{Earth}}$. Add these vectors graphically to illustrate the net magnetic field vector, $\vec{\mathbf{B}}_{\text{net}} = \vec{\mathbf{B}}_{\text{coil}} + \vec{\mathbf{B}}_{\text{Earth}}$.

b) Let θ be the angle between north and $\vec{\mathbf{B}}_{\text{net}}$. Indicate this angle on your sketch. You will be able to measure θ and also B_{coil}, the magnitude of $\vec{\mathbf{B}}_{\text{coil}}$. Describe *how* you could use this to determine the magnitude of $\vec{\mathbf{B}}_{\text{Earth}}$. You should arrive at a formula that relates B_{Earth} to B_{coil} and θ. Ensure that the instructor checks your result.

This experiment uses a circular current-carrying coil with N complete loops of wire. The magnetic field at the center of the loop points along the axis of the loop in a direction given by the right hand rule. The magnitude of the magnetic field at the center of the loop is given by

$$B_{\text{coil}} = N\,\frac{\mu_0 I}{2R} \tag{1}$$

where $\mu_0 = 4\pi \times 10^{-7}\,\text{N/A}^2$ is a constant called the permeability of free space, R is the radius of the loop and I the current through the loop. Eq. (1) is what you will use to determine the magnitude of the field produced by the coil.

c) Place the compass at the center of the loop and orient the loop so that the plane of the loop lies along the north-south direction. Then orient the compass base so that the 0° mark points north along the loop plane.

d) Adjust the current through the coil so that the compass needle deflects by about $\theta = 40^\circ$. Measure the current through the coil, determine B_{coil} and use this, θ, and your formula from 1 b) to determine B_{Earth}.

e) Repeat part 1 d) for compass needle deflections of $50^\circ, 60^\circ$, and 70°.

f) Determine an average value for the earth's magnetic field based on your measurements (this is actually the horizontal component of the earth's magnetic field).

2 Magnetic Field Produced by a Helmholtz Coil

Standard electromagnetic theory predicts that the field at the center of a pair of Helmholtz coils is

$$B = \frac{\mu_0 8NI}{5\sqrt{5}R} \tag{2}$$

where N is the number of coils and R is the radius of the coil. The aim of this experiment is to check this relationship.

a) Align the Helmholtz coils so that they are parallel to the north-south direction. Adjust the current in the coils so that the compass deflection is about 45°. Measure deflection of the compass needle and the current in the coils.

b) Based on the measurement of the earth's magnetic field and the compass deflection, calculate the magnetic field produced by the Helmholtz coils.

c) Based on the measured value for I and Eq. (2), calculate the magnetic field produced by the Helmholtz coils.

d) Determine the percentage difference between the two values for the magnetic field produced by the Helmholtz coils.

e) Repeat for two more situations where the current through the coils is adjusted to produce deflections through angles other than 45°.

3 Forces between Two Parallel Currents

Since any current produces a magnetic field, and a magnetic field exerts a force on any other current, it must be possible for one current to exert a force on another current. Consider two parallel current carrying wires as illustrated in Fig. 4. The current in the lower wire points right. The current in the upper wire could point either left or right.

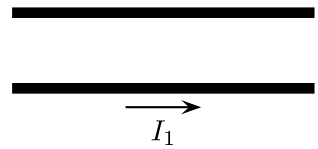

Figure 4: Parallel current carrying wires.

a) Determine the direction of the magnetic field produced by the lower wire at the location of the upper wire.

b) Suppose that the current in the upper wire points right. Use the magnetic field produced by the lower wire to determine the direction of the force that it exerts on the current in the upper wire.

c) Suppose that the current in the upper wire points left. Use the magnetic field produced by the lower wire to determine the direction of the force that it exerts on the current in the upper wire.

d) Do parallel currents attract or repel? Do opposite currents attract or repel? Explain your answers.

This rules can be investigated using a current balance, whose essential working parts are two rigid parallel wires through which the same current is passed. The current balance is designed so that the upper wire is free to pivot and the lower wire is fixed.

e) Set up the current balance with no additional mass in the pan. Let it come to rest and note the position of the reflected laser beam on the wall.

f) Trace the direction of the current through the lower wire and the upper wire. Use this to predict the direction of the force on the upper wire.

g) Turn the currents on and observe and record the motion of the wire. Does this agree with your prediction?

h) Repeat the previous parts for the case where the upper current direction is reversed.

4 Report

The lab exercise that you have done was broken down into many small steps, whose relationship to one another may not be obvious. In order to make sense of the entire exercise, compile a brief, informal report describing the aims, methods and results (for parts 1 and 2); excluding the data, a page should be enough. This may be written in *bullet point form.* A *guideline* of what this might contain is:

- *Introduction*
  - Describe the aim of the experiment. What is the question that it addresses?
- *Set up and Theory*
  - Briefly describe/sketch the set up that can be used to meet the aim of the experiment.
  - Briefly describe what theory is useful for understanding the situation and what it eventually predicts (include equations that form predictions). Include derivations that were essential.
- *Experiment*
  - Provide details of the experimental set up.
  - Provide the experimental data and associated calculated quantities.
  - Provide the data analysis.
- *Conclusion and discussion*
  - Describe what the experiment showed. Did it verify something? If so, what? Did it answer a question that was posed earlier? If so, how?
  - Describe possible sources of error in this experiment. Be specific (stating that "human error" is an issue without describing what human error and how it entered is not acceptable). Describe, if possible, how such errors may be reduced.
  - Describe the main conclusion of this experiment. What answer does it give?