Laboratory 5: Currents and Magnetic Fields – Prelab

1 Adding magnetic fields I

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 2.0×10^{-3} T and the magnitude of $\vec{\mathbf{B}}_2$ is 3.0×10^{-3} T. Determine the magnitude and direction of $\vec{\mathbf{B}} = \vec{\mathbf{B}}_1 + \vec{\mathbf{B}}_2$. Sketch this vector.

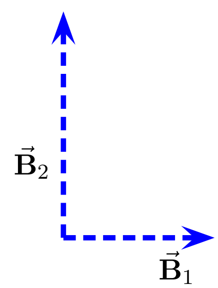

Figure 1: Adding magnetic fields.

2 Adding magnetic fields II

Figure 2 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 $\vec{\mathbf{B}}_2$.

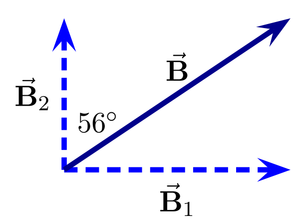

Figure 2: Adding magnetic fields.

Laboratory 5: 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.

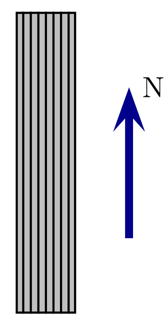

Figure 3: Coil in Earth's field.

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 $50°, 60°$, 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 Field Produced by a Coil: Dependence on Number of Coils and Location

The coil has a variable number of loops and the magnetic field produced by the coil should be proportional to the number of loops.

a) Align the coil so that it is parallel to the north-south direction. Connect the coil so that it uses 10 loops. Adjust the current in the coils so that the compass deflection is about $30°$ and record the current. Using the value of the Earth's magnetic field that you determined earlier determine the magnetic field produced by the coil.

b) Using the current through the coil, determine the magnetic field predicted by Eq. (1). How does it compare to the field as determined in the previous part?

c) The coil produces a magnetic field at all points and it is possible to predict the magnitude of the field along the axis of the coil. As the distance, along the coil axis, from the coil increases what do you expect happens to the magnetic field strength? How would this affect the angle between the Earth's magnetic field and the net magnetic field? Explain your answer.

d) Drag the compass along the axis of the loop in a direction away from the loop. Does the behavior of the compass deflection match your prediction?

3 Forces between Two Parallel Currents

Any current produces a magnetic field and we can explore the effects of magnetic fields produced on a current using the 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.

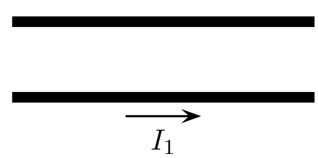

Figure 4: Parallel current carrying wires.

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

b) Set up the current balance so that the current in the upper wire points right. In what direction is the force on the upper wire?

c) Note that the force on the upper wire is exactly the force exerted by the magnetic field (produced by the lower wire) on the upper wire. Is the force along the same direction as the magnetic field or along the opposite direction or neither?

d) Set up the current balance so that the current in the upper wire points left. In what direction is the force on the upper wire?

e) Note that the force on the upper wire is exactly the force exerted by the magnetic field (produced by the lower wire) on the upper wire. Is the force along the same direction as the magnetic field or along the opposite direction or neither?

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