Experiment 9: Biot-Savart Law with Helmholtz Coil

Introduction

In this lab we will study the magnetic fields of circular current loops using the Biot-Savart law. The Biot-Savart Law states the magnetic field B from a wire segment length ds, carrying a steady current I is given by

$$B = \frac{\mu_0}{4\pi} \int \frac{I\, ds \times r}{r^2} \tag{1}$$

where μ_0 is the permeability of free space and r is the displacement vector from the current element ds to a point P where we wish to evaluate the magnetic field. This equation allows us to calculate the magnetic

Figure 2: Magnetic field lines for a current loop and a bar magnet. Here the z-axis is along the North-South line.

We can create a stronger and more uniform magnetic field by aligning two identical current loops. A particular configuration that we will be using is known as a Helmholtz coil. This consists of two current loops, each with N turns and radius R. The two loops are aligned along their axis and are separated by a distance R, identical to the radius, each carrying equal steady currents in the same direction (see Figure 3). We can use the Biot-Savart law to find the magnetic field at any point along along the axis of the Helmholtz coil by summing the individual magnetic fields of the coils via the superposition principle. It can be shown that the magnetic field at the center of this configuration when z=0 (point O on Fig. 3) is given by

$$B(z=0) = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 I N}{R} \tag{4}$$

where the variables have the same definitions as before.

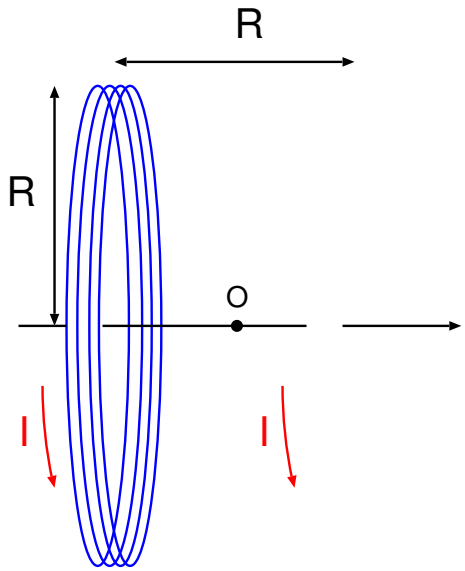
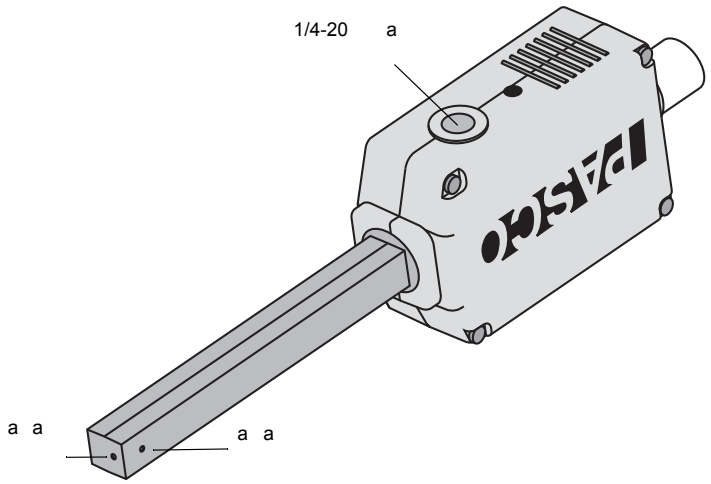


Figure 3: Helmholtz coil separated by a distance R equal to the radius of the coils.



(a) (b)

Figure 5: (a) Magnetic eld sensor. (b) Top view of probe with setting options.

at identical distances in front and behind the coil, then nd the average value of B at that distance.

Part 2 Procedure - Magnetic Field at the Center of a Helmholtz Coil:

Measure the radius of the Helmholtz coil and record the number of turns. Connect the Helmholtz coil

PHYS 221, Lab 9 Questions

Name: CWID:

Write your answers on a separate sheet and attach your signed datasheet when turning it in. You must show all of your work for full credit. Make it clear to me you understand what you're doing. Any graphs or tables should be made via computer software and attached to this handout.

1. Answer the following questions using the data you acquired from Part 1 of this lab:

   (a) Add to your data table(s) a column consisting the value of $1=(R^2 + z^2)^{3=2}$.

   (b) Plot a graph of B(z) versus $1=(R^2 + z^2)^{3=2}$.

   (c) What is the eld value at the center of the loop? Compare this value with Equation 3.

   (d) Find the slope of the best- t line from your graph. From Equation 2, this slope should correspond theoretically to $_0IR^2N=$