Magnetic Field in a Current-Carrying Coil

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Abstract

We used a magnetic field sensor to measure the axial and radial components of the magnetic field generated by a current-carrying coil. We calculate that the magnetic field strength of our solenoid is between 22.016 and 26.420 mT. In gathering our data, the magnetic field sensor was not kept exactly in line with the vertical axis of the coil, introducing the radial component of the field vector into our axial field data and causing discrepancies in the data.

Introduction

In this lab, we will move a magnetic field sensor through a current-carrying coil and record data about the magnetic field in order to compare changes in axial and radial components of the field. We will attach the magnetic field sensor to a rotary motion sensor in order to record the position of the magnetic field sensor relative to the coil.

When referring to the magnetic field created by a solenoid, we call the component that runs parallel to the vertical axis of the solenoid the **axial component** of the field; likewise, we call the component that runs perpendicular to the vertical axis of the solenoid the **radial component** of the field. The direction of each field component, as measured by the sensor, is relative to the orientation of the sensor. This direction is shown with positive and negative values.

The general equation for finding the magnetic field along the perpendicular axis through the center of a coil of wire with negligible length, radius R, and N turns of wire (**Equation 1**) is

$$B = \frac{\mu_0 N I R^2}{2(x^2 + R^2)^{3/2}} \tag{1}$$

where $\mu_0 = 4\pi \times 10^{-7}\ T \cdot \frac{m}{A}$ is the permittivity of free space, I is the current through the coil, and x is the distance from the center of the coil. To find the magnetic field of a long solenoid with n turns per unit length, we use **Equation 2**:

$$B = \mu_0 n I \tag{2}$$

where μ_0 is again the permittivity of free space, shown above. Equation 2 fails when approaching the ends of the solenoid, where the magnetic field strength begins to decrease.

To be considered a *long* solenoid, the length of the coil inside the solenoid must be significantly longer than the diameter of the coil. Solenoids that do not fit this description are referred to as *short* solenoids. For short solenoids, we are not able to use either Equation 1 because the length of the coil is too long, and we are not able to use Equation 2 because the length of the coil is too short. Instead, the two equations provide bounds on the value of the magnetic field.

Specifications for the Solenoid

N	600 turns
R	0.015 m
L	0.025 m

Apparatus

- AC/DC Electronics Laboratory
- Rotary Motion Sensor
- 2-Axis Magnetic Field Sensor
- Short Patch Cord (x8)
- Large Rod Base
- 90-cm Rod
- Mass and Hanger Set
- Thread
- 850 Universal Interface
- PASCO Capstone

Experimental Procedure

We first zeroed the magnetic field sensor and the rotary motion sensor without any current running through the solenoid. We ran 5V of DC current through the coil, inserted the magnetic field sensor as far as possible into the coil (while centered about the vertical axis of the coil), and recorded the data from the magnetic sensor probe as we slowly pulled the sensor out of the coil with the handle facing north. We labeled this data set **Center**. We measured and recorded the peak amplitude.

We repeated this process with the probe held against the **East** wall of the coil, and again with the probe held against the **West** wall of the coil. We switched the patch cords, reversing the direction of the current through the coil and repeated the process with the probe held against the east wall of the coil. We labeled this data set **East, rev**.

We then calculated the bound values for our solenoid using Equations 1 and 2.

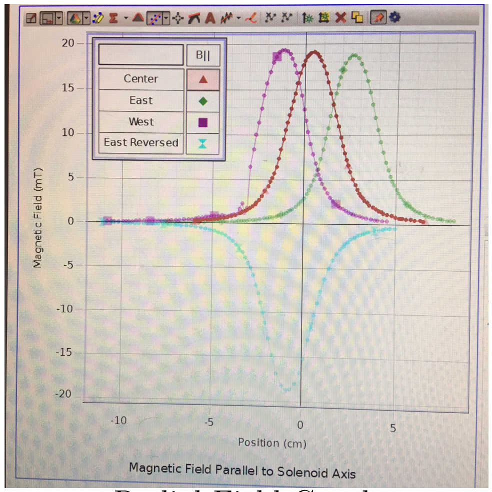
Data

Current through Coil

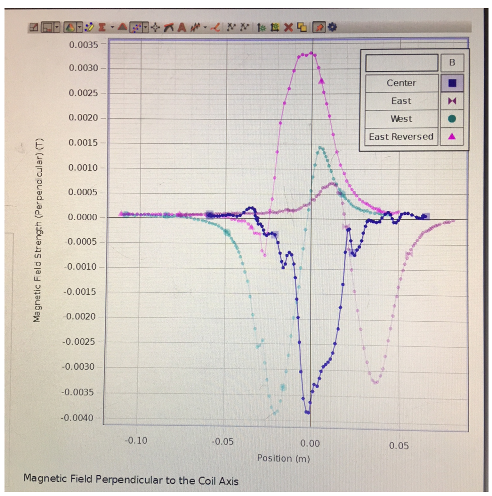
Trial	Current (A)	Axial Peak Ampl. (mT)
Center	0.876	19.154
East	0.854	18.736
West	0.855	19.377
East, rev.	0.849	-18.774

Calculations and Graphs

Axial Field Graph



Radial Field Graph



Discussion of Results and Error Analysis

Conclusion