General Physics II Lab (PHYS-2021)
Experiment MAGN-2:
Magnetic Fields of Coils

1 Equipment

Included:

1	Helmholtz Coil Base	EM-6715
2	Field Coil (500-Turn)	EM-6723
1	Primary and Secondary Coils	SE-8653A
1	Patch Cords (set of 5)	SE-9750
1	Patch Cords (set of 5)	SE-9751
1	60 cm Optics Bench	OS-8541
1	Dynamics Track Mount	CI-6692
1	20 g hooked mass (Hooked Mass Set)	SE-8759
1	Small Round Base (Set of 2)	ME-8974A
2	25 cm Steel Rod	ME-8988
1	Optics Bench Rod Clamps (Set of 2)	OS-8479
1	2-Axis Magnetic Field Sensor	PS-2162
1	Rotary Motion Sensor	PS-2120
1	850 Universal Interface	UI-5000
1	PASCO Capstone Software	

2 Introduction

The magnetic fields of a coil is plotted versus position as the Magnetic Field Sensor is passed through the coils, guided by a track. The position is recorded by a string attached to the Magnetic Field Sensor that passes over the Rotary Motion Sensor pulley to a hanging mass. This experiment requires a formal Lab Report as described in the "Lab Report Format" document.

3 Theory

Single Coil

For a coil of wire having radius R and N turns of wire, the magnetic field along the perpendicular axis through the center of the coil is given by

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

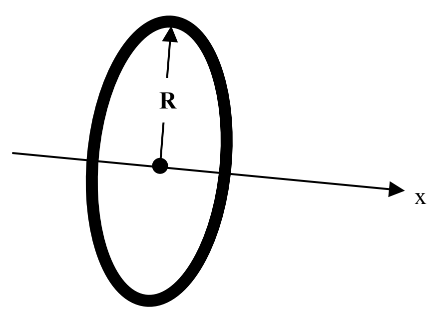

Figure 1: Single Coil

Figure 2: Single Coil Setup

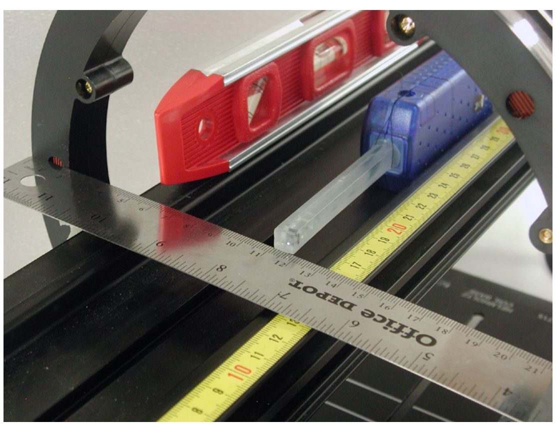

Figure 3: Finding the Coil Center

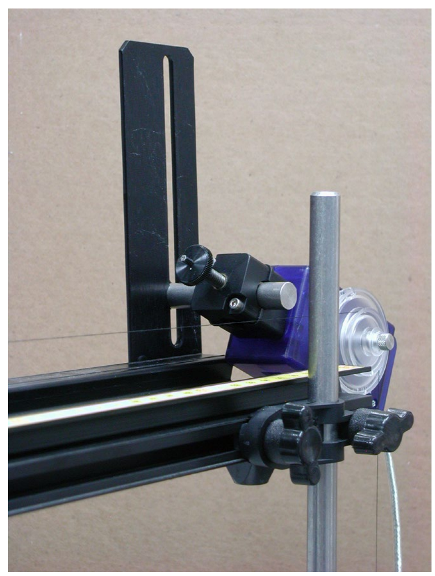

Figure 4: RMS Setup

4 Setup

1. Attach a single coil to the Helmholtz Base so it is aligned with the white rectangle on the base and thus perpendicular to the base. Connect Output #1 of the 850 Universal Interface directly across the coil as shown in Figure 2.

2. Pass the optics track through the coil and support the two ends of the track with the support rods. One end of the optics track should be close to the edge of the table so when you hang a mass over the Rotary Motion Sensor, it will hang freely over the edge of the table.

3. Level the track and adjust the height so the Magnetic Field Sensor probe will pass through the center of the coil when it is pushed along the surface of the track against the side with the yellow metric scale. An accurate way to do this is shown in Figure 3. The coil diameter is 23.4 cm. The height is adjusted (while maintaining level) so that a thin metric ruler lies just below the holes in the side of the coil holder and 0 cm is at the edge of the coil. The track is adjusted so that the white dot marking the axial sensor is at the 11.7 cm mark. The bottom of the sensor probe is even with the ruler. The coil base needs to be parallel with the optics track. Note that the coil is 2 cm wide, so the exact coil center is 1 cm from the edge of the ruler (at 17 cm in Figure 3). When the white dot on the side of the magnetic probe is at this point (17 cm on the yellow scale in Figure 3), the sensor is very close to the coil center.

4. Attach the Rotary Motion Sensor to the track using the bracket as in Figure 4. Cut a piece of thread long enough to reach from the floor to the track. Tie a loop in one end of the thread and slide the sensor probe of the Magnetic Field Sensor through it (see Figure 3). Pass the other end of the thread over the middle step of the Rotary Motion Sensor pulley and attach the 20-g mass. Place the Magnetic Field Sensor against the side of the track with the yellow scale and adjust the position of the Rotary Motion Sensor so the thread is aligned with the middle step pulley.

5. In PASCO Capstone, open the Hardware Setup and click on Signal Generator #1 and select the Output Voltage Current Sensor.

6. Plug the Magnetic Field Sensor and the Rotary Motion Sensor into any two of the PASPORT inputs on the 850 Universal Interface. Set the sample rate of all the sensors to 20 Hz.

7. Create a graph of Magnetic Field Strength (axial) vs. Position. Create a digits display with the Current.

NOTE: The string is threaded over the medium size (middle step) pulley, but the rotary motion sensor defaults to the large pulley. When you adjust the Zero sensor by clicking on the rotary motion sensor gear, don't forget to also select the medium size pulley. It will keep the peak in B from being too skinny.

5 Single Coil Procedure

1. Create a graph of the Perpendicular Magnetic Field Strength vs. Position.

2. Find the radius of the coil by measuring the diameter from the center of the windings on one side across to the center of the windings on the other side. Enter the value in the Coil Properties table in the Analysis section.

3. Slide the Magnetic Field Sensor along the track until the probe sensor is in the middle of the coil. Press the tare button on the Magnetic Field Sensor. Click on Data Summary at the left of the page. Open the properties of the Rotary Motion Sensor (RMS) by clicking on the gear

symbol to the right of the Rotary Motion Sensor label. De-select "Zero Sensor Measurement at Start". Click on "Zero Sensor Now". This will make zero on the x-axis be at the center of the coil. Click OK. Click Data Summary to close the panel.

4. Slide the Magnetic Field Sensor back away from the coil until it is about 15 cm from the coil.

5. Click on Signal Generator at the left of the screen. Verify that the DC voltage is set to 15 V and click On.

6. Click RECORD and slowly move the Magnetic Field Sensor along the track, keeping it against the side with the yellow scale, until the end of the sensor is about 15 cm past the coil. Then click STOP.

7. Click the DC current off in the Signal Generator. Click Data Summary. Double click Run #1 and re-label it "Single Coil".

8. Record the Coil Current (see below) in the Coil Properties table in the Analysis section.

6 Analysis: Single Coil

1. For each graph, click the black triangle by the Run Select icon and select "Single Coil". Click the Scale-to-Fit icon.

2. For the Axial Field graph, click on the black triangle by the Curve Fit icon and select User Defined. Click on the User Defined box that appears on the graph. The Curve Fit Editor will appear on the Tools bar at the left of the screen.

3. Click on the Curve Fit Editor and type in the theoretical equation for the magnetic field (Equation 1 from Theory) into the equation line where y = magnetic field strength (B) and the other symbol are as written in Equation 1 except let $m = \mu_0$. Click Apply. Enter $m = \mu_0 =$ 1.257e-6, the current, the coil radius, and number of turns in the coil and lock all parameters. Click Update Fit.

4. Discuss any differences between the experimental axial curve and the theoretical fit.

5. The perpendicular field should be zero everywhere on the axis. If it isn't, why not?

7 Magnetic Field across a Single Coil

1. Set up the single coil as before except instead of putting the track through the coil, set up the track so it is parallel to the face of the coil. Make sure the elevation of the track is set so the magnetic probe is at the height of the center of the coil.

2. Create a graph of the Axial Magnetic Field vs. Position and then add a second plot area for the Perpendicular Magnetic Field vs. Position.

3. With the DC power off, slide the magnetic field sensor along the track until the end of the Magnetic Field Sensor in the middle of the coil. Press the tare button. Also, open the properties of the Rotary Motion Sensor in the Data Summary and click on "Zero Sensor Now". This will make zero on the x-axis be at the center of the coil. Also uncheck "Zero on Start".

4. Slide the Magnetic Field Sensor back so it is about 15 cm away from the edge of the coil. Turn on Signal Generator #1. Start recording and slowly move the Magnetic Field Sensor along the center of the track, keeping the probe parallel to the track, until the end of the sensor is about 15 cm past the other edge of the coil. Then stop recording.

5. Explain the shape and magnitude of the plots of the parallel and perpendicular magnetic fields.