Course and Section_______ Names ___________________________

Date___________ _________________________________

AMPERE'S LAW EXPERIMENT

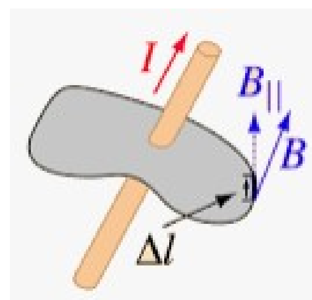
Introduction

The purpose of this experiment is to verify Ampere's law. You will measure the magnetic field due to a current-carrying coil of wire on a path enclosing a portion of the coil.

Equipment: GMR sensor and 12.0V transformer, multimeter, 1500 turn circular coil, power supply, two cables, ruler.

Theory

Ampere's Law provides a relationship between the current I in a wire and the magnetic field it generates in the surroundings.



Given an arbitrary closed the path around the current I, this path can be approximated as made up of short segments each of length Δl. Consider the product ($B_{||} \cdot \Delta l$) where $B_{||}$ is the projection of B on Δl, the sum of all these products along the closed path is equal to $\mu_0 I_{enc}$.

$$\sum_{i=1}^{n} (B_{||i} \cdot \Delta l_i) = \mu_0 I_{enc} \qquad (1)$$

We want to verify Ampere Law using a coil with N turns, i.e. $I_{enc} = NI$.

The magnetic field at the center of a coil of N turns carrying a current I is

$$B = \frac{\mu_0 N}{2a} I \qquad (2)$$

where a is the radius of the circular loop and $\mu_0 = 4\,\pi \times 10^{-7}$ T m/A.

Preliminary Questions

1. If $\sum_{i=1}^{n} (B_{||i} \cdot \Delta l_i) = 0$ does this always imply the magnetic field is zero?

2. Draw below an example of a path such that $\sum_{i=1}^{n} (B_{||i} \cdot \Delta l_i) = 0$ and the current I in the wire is not zero.

PART I – Calibration of the GMR sensor

Procedure

3. Measure the resistance R of your coil with the multimeter. If R = 50 Ω then your coil has N = 1200 turns, if R = 20 Ω then N = 600.

R = ____________ Ω N = ______________

4. Measure the inner and outer radius of the coil and find their average.

Inner radius = ______________ m
Outer radius = ______________ m
Average radius a = ______________ m

5. Calculated the expected values of the right hand side of equation (2).

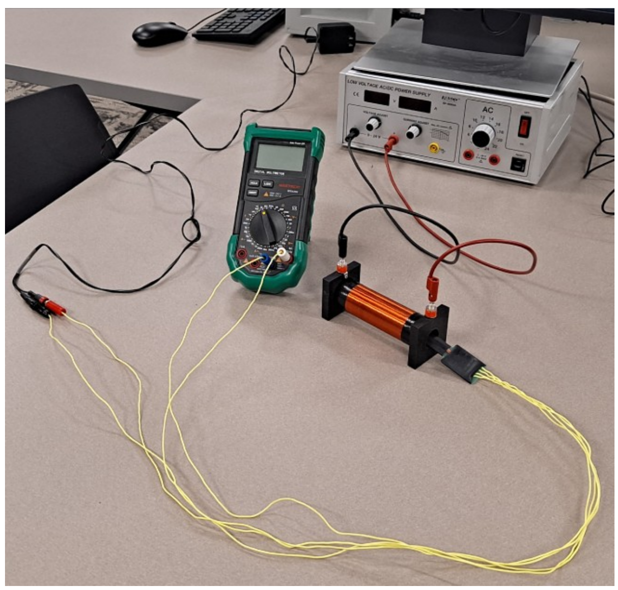
$$\frac{\mu_0 N}{2a} = \_\_\_\_\_\_\_\_\_\_\_\_ T/A \quad \text{(expected value)}$$

Calibration of the GMR sensor

A Giant Magneto Resistive sensor (GMR) is used measure $B_{||}$. When supplied with a source voltage, the sensor has an output voltage V_{GMR} proportional to $B_{||}$.

$$B_{||} = k V_{GMR} \qquad (3)$$

The first thing to do is to calibrate the GMR sensor by finding its value of k. To do so use the red solenoid. The magnetic field inside the solenoid is $B_{SOL} = \mu\, n\, I_{SOL}$, where $n = 2.65 \times 10^4$ is the number of turns/unit length.



Step 1. Connect the solenoid to the power supply and set the DC output such that V_{SOL} = 5.0 V.

Step 2. DO NOT USE the power supply to power the GMR sensor. Instead connect the red/black plugs of the GMR sensors to the 12.0 V black transformer: match the red and black inputs of the transformer (see picture). The voltage output V_{GMR} is measured with the multimeter: connect the blue/white plugs to the multimeter, either one inputs.

Step 3. Place the GMR sensor inside the solenoid and take a reading of the voltage.

6. V_{GMR} = ________ V

If you read a constant voltage regardless if the sensor is inside or outside the solenoid, or if the voltage reading decrease as you move the sensor closer to the solenoid, then the sensor is broken. Check with the TA.

7. Measure the resistance of the solenoid with the multimeter: it should be in the 70-80 Ohm range; if not check with the TA. Then use V_{SOL} to find the current through it.

R_{SOL} = ________ Ω $\qquad$ I_{SOL} = _________ A

8. Calculate the expected value of B_{SOL}.

B_{SOL} = ________ T

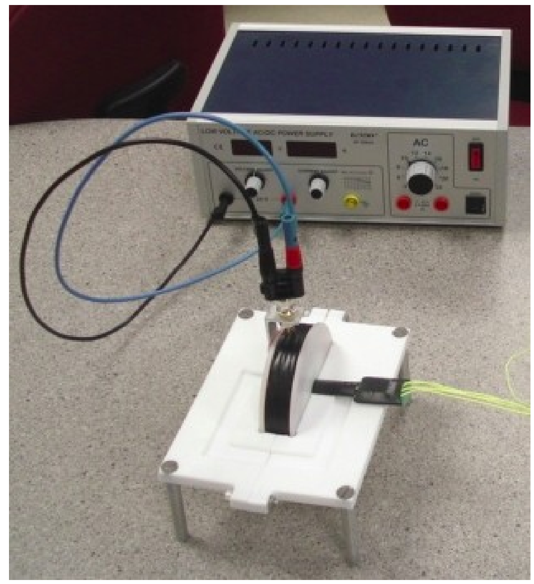
9. Determine k from equation (3). k = ________ T/V

Now your GMR sensor is calibrated and you can use it to find B|| with a measurement of V_{GMR}.

Step 4. Connect the circular coil to the Pasco DC power supply. Place the GMR sensor inside the coil with the microchip precisely in the center (see picture).

Step 5. Select different voltages in the range $0 < V_c < 5$ V.
Use Ohm law to find the corresponding current I through the coil.

From the readings of V_{GMR} calculate the B field corresponding to the different currents.



Analysis

10. Collect your data in the table below

V_{COIL} (V)	I_{COIL}(A)	V_{GMR} (V)	$B = k\,V_{GMR}$ (T)

11. Make a plot of B *vs* I_{COIL}. From the slope, see equation (2) calculate the quantity

$$\frac{\mu_0 N}{2a} = \_\_\_\_\_\_ \quad \text{(measured value)}$$

Print a copy of your plot.

12. Calculate the percentage error between the measured and the expected values of $\frac{\mu_0 N}{2a}$

%Error = | measured – expected | / | expected | x 100 = __________________

If your error is greater than 20% you won't be able to do PART II correctly, check with the TA.

PART II - Test Ampere's Law.

Step 1. Set the coil voltage V_{COIL} = 3.0 V and measure the magnetic field at each of the alignment marks on the coil support.

Step 2. Start with the sensor close to the center of the coil (index mark 1). Place the sensor in the groove and take the reading of the V_{GMR}. Try to keep the GMR sensor parallel to the plastic white support as much as possible while taking the measurement.

Step 3. Repeat, as 'walk' the sensor around the groove without changing its orientation along the path, and take measurements of V_{GMR} along the entire loop divided in 24 marks. Use the table below to collect your data.

Analysis

13. What is the distance between the marks?

Δl = ______ m

14. What is the current through the coil?

I_{COIL} = ________ A

15. Collect your data here.

Index i	V_{GMR} (V)	$B_{\parallel i}$ (T)
1		
2		
3		
4		
5		
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11		
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Since the Δl_i are equal they can be taken out of the summation $\sum_{i=1}^{n}(B_{||i} \cdot \Delta l_i) = \Delta l \cdot \sum_{i}^{n} B_{||i}$

16. Calculate left had side of equation (1)

$\Delta l \cdot \sum B_{||i} =$ _____________ Tm (measured value)

17. Calculate the right hand side of equation (1)

$\mu_0 \cdot N \cdot I_{COIL} =$ ____________ Tm (expected value)

18. Calculate the percentage error between the measured and the expected value assuming the right hand side of (1) to be the expected value.

%Error = | measured – expected | / | expected | x 100 = _____________

You would need an error less than 30% to get full credit for this question. For assistance check with the TA.

19. List the possible sources of error.