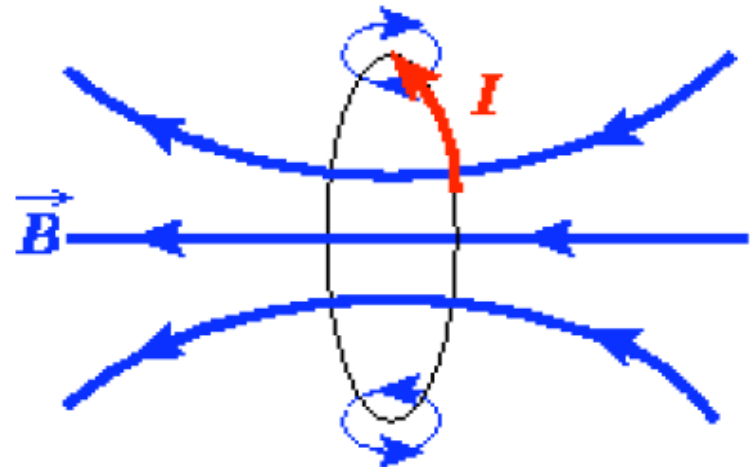
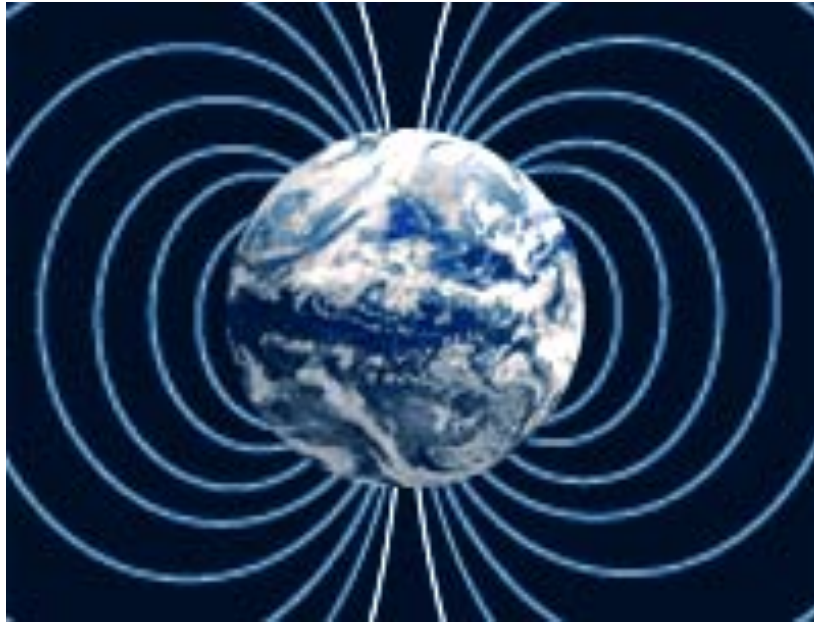


Vector Nature of Magnetic Fields



Introduction

A current through any conductor creates a circular magnetic field around the conductor due to Ampere's law. The direction of the magnetic field produced by a coil can be determined by the right hand rule.

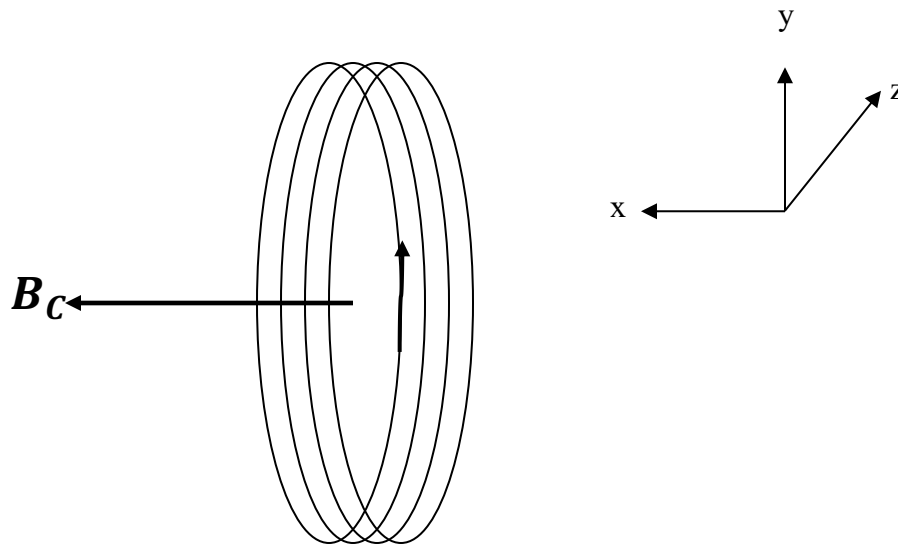
When a current I is carried in N coils of wire of radius R , a magnetic field is produced at the center which has a magnitude of

$$B_c = N \frac{\mu_0 I}{2R} \quad (1)$$

where the symbol for magnetic field is B and magnetic field has units of tesla (T), μ_0 is the permeability of free space and has the value $4\pi \times 10^{-7} Tm/A$.

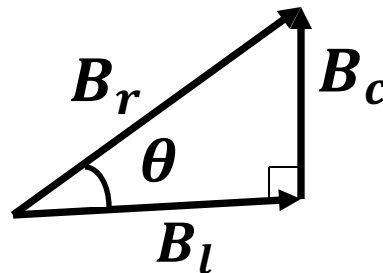
Introduction

The direction of the magnetic field at the center of the coil is **perpendicular** to the plane of the coil.



Introduction

A **resultant** magnetic field B_r is the vector sum of the local magnetic field B_l and the magnetic field produced by the coil B_c and these two fields will be set to be perpendicular. The vector sum may be sketched:



where θ is the angle which will be measured with the compass.

Introduction

Because the two magnetic field vectors are perpendicular, θ is given by

$$\tan \theta = \frac{B_c}{B_l} \quad (2)$$

and if we substitute the Equation (1) into Equation (2), we see that

$$\tan \theta = N \frac{\mu_0 I}{B_l 2R} \quad (3)$$

Objectives

In this experiment, you determine the magnetic field of the lab by observing the magnetic field produced by a current carrying wire as a function of current.

In this experiment, you will investigate the resultant vector magnetic field created by adding the magnetic field of the lab to a magnetic field produced by a coil of current carrying wire and these two fields are set to be perpendicular.

Predictions

Q

QUESTION 1: Use the equation $\tan \theta = N \frac{\mu_0 I}{B_l 2R}$ to derive the expression for the slope of the graph of $\tan \theta$ vs I .

!

You may want to refer to the introduction section on plotting and interpreting graphs in your Laboratory Workbook.

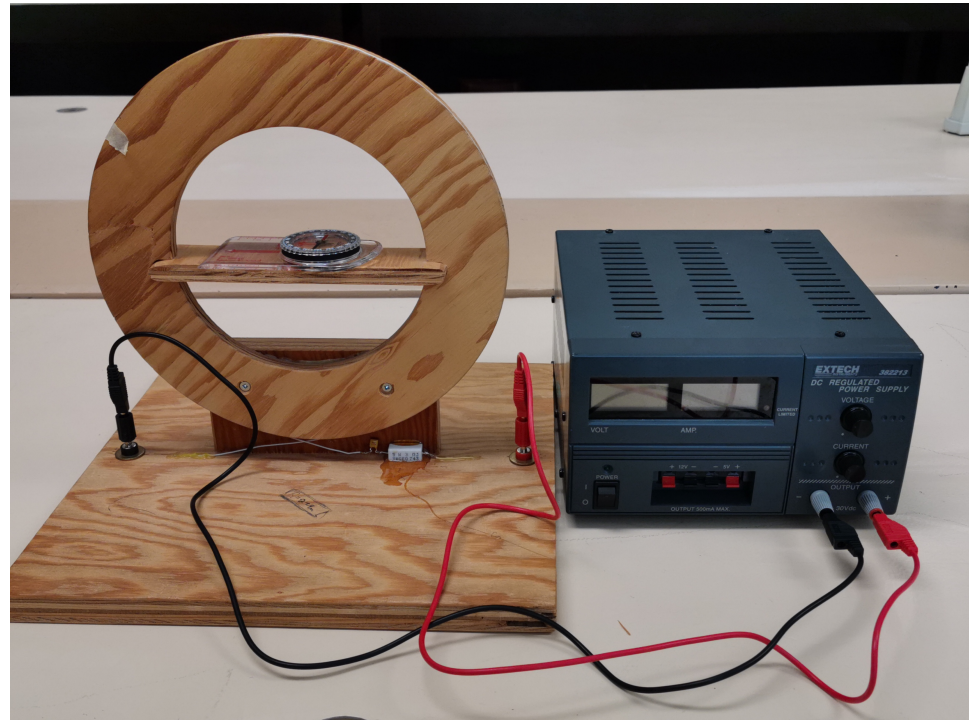
Q

QUESTION 2: How would you expect the graph of $\tan \theta$ vs I to look? Make a sketch of this graph.

Apparatus

We will use the following items for this experiment

- Wooden circular frame wound with 6 turns of wire
- Power supply
- Electrical leads
- Compass
- Metre stick



Deflection Angle vs Current

LW

Measure the outer diameter of your wooden frame and record it in **Table 1** of your Laboratory Workbook along with the experimental uncertainty.

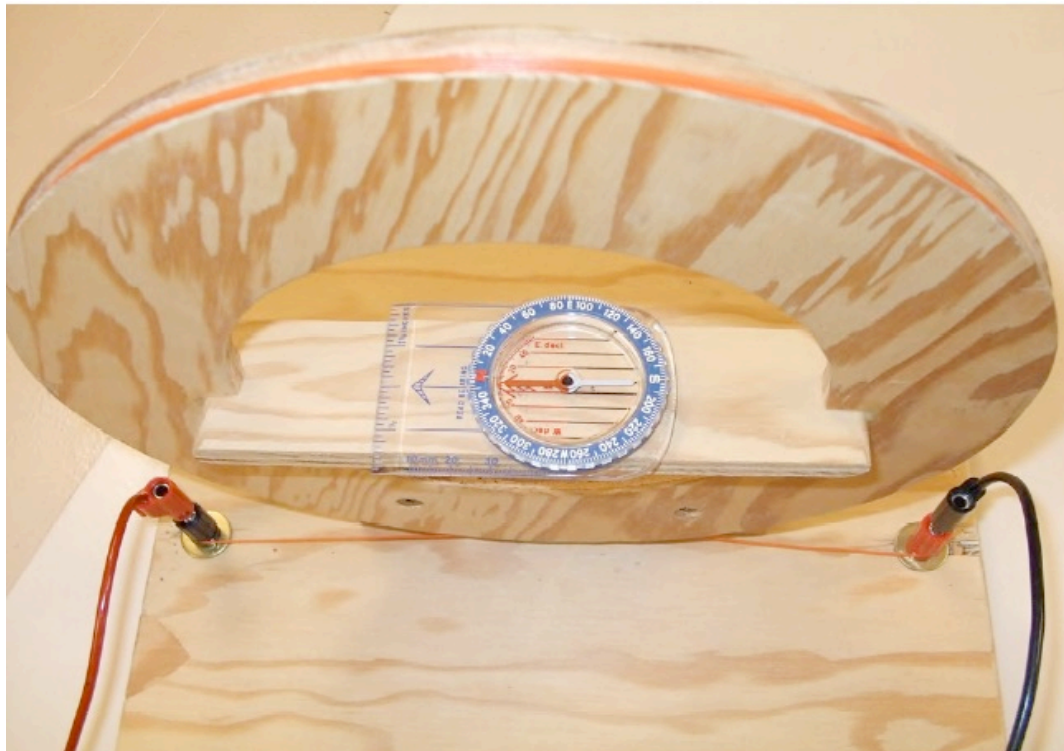
Connect the circuit as follows (see photo previous page):

1. Plug in the power supply but keep the main switch OFF while assembling your circuit.
2. Connect the (+) 0-30VDC output on the power supply to one terminal of the wooden frame.
3. Complete the circuit by connecting the other terminal of the wooden frame to the (-) 0-30VDC output on the power supply.



Alignment

Place the compass on the platform at the centre of the wooden frame, so that North lies along the diameter as shown.



Alignment

Rotate the frame so that the compass needle points along the diameter of the frame.

You have now oriented your apparatus so that the compass is directed along the local magnetic field.



This alignment is very important! Once the frame is positioned make sure it does not move.



Vector Diagram

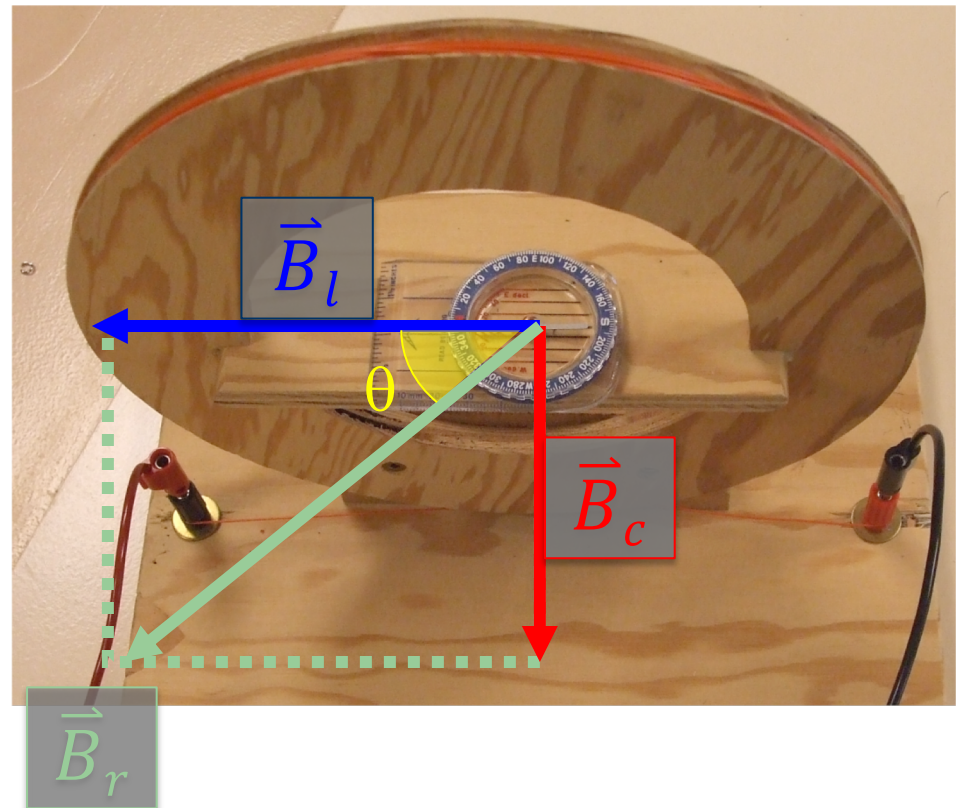
The local magnetic field \vec{B}_l is indicated with the blue arrow.

The flowing current in the coil creates a magnetic field perpendicular to the coil \vec{B}_c as indicated with the red arrow.

The two vectors are added tip-to-tail to create the **resultant magnetic field** indicated by the green arrow:

$$\vec{B}_r = \vec{B}_l + \vec{B}_c.$$

You will measure the angle θ of the resultant magnetic field.



Data Acquisition

Be sure that your frame does not move as you take your measurements! Periodically check the alignment by turning off the power supply and ensuring the compass needle points to 0° , along the diameter of the frame.



With power off.



With power on.

Turn power OFF when not in use.

Data Acquisition

- Switch on the power supply. Turn up the current and voltage on the power supply until you read a current of about 0.50 A.
- Record the current displayed on the power supply in **Table 2**.
- Measure the deflection angle θ of the compass and record it in **Table 2**.
- Turn off the power supply. Check the alignment. If it has changed realign and repeat the measurement.
- Calculate and record $\tan \theta$ (with **3** significant digits) in **Table 2**.
- Include units for each quantity.

LW

LW

LW

Data Acquisition (cont'd.)



The deflection angle, θ , is the angle of the resultant magnetic field with the plane of the coil.

- Turn on the power supply and decrease the current slightly. Record the new angle and continue, taking 10 readings in all, approximately evenly spaced.
- Record the current, θ , and $\tan \theta$ in **Table 2** at each increment.

Graphing your results

Launch **Graphical Analysis** by clicking on the icon below



- Use Graphical Analysis to plot a graph of $\tan \theta$ vs I .
- Obtain a linear fit by clicking **Analyze** then **Linear Fit**.
- Double click on the box which appears on the graph and check the box to show the uncertainties.
- Print the graph and include it with your Laboratory workbook.
- Record the value of slope in **Table 3** of your Laboratory workbook.

Have an instructor check your work and initial your lab report.

Determining B_l

Q

QUESTION 3: Using the slope of your graph, determine your experimental value for the local magnetic field and the associated uncertainty.

Q

QUESTION 4: The average local magnetic field is $(1.6 \pm 0.5) \times 10^{-5} T$. Calculate the range for your experimental value and comment on the agreement between your value and the given value.

Direction of Magnetic Field

We next observe the effect of the current direction on the direction of the magnetic field produced in the coil.

- Set the current using the current knob to about 0.50 A.
- Record the angle of deflection of the compass needle in **Table 4**. Include direction of deflection using E (east) or W (west).
- Reverse the direction of current by switching the leads at the power supply (with the power **OFF**). Turn the power supply back on.
- Record the new angle of deflection in **Table 4** of your Laboratory workbook. Indicate direction using E (east) or W (west).

LW

LW

Summary

Q

QUESTION 5: a) When reversing the current direction, how do the two deflection angles differ?
b) Why was this difference produced?

Q

QUESTION 6: If we were to plot graph I vs. $\tan\theta$, what would we obtain for the expression for the slope?

Q

QUESTION 7: Based on your results, which of the following statements is correct and why:

1. $B_C + B_l = B_r$

2. $\vec{B}_C + \vec{B}_l = \vec{B}_r$

Include a diagram showing this result.

Summary

Q

QUESTION 8: Why was it important to align the coil with the local magnetic field?

Q

QUESTION 9: Give at least two sources of uncertainty in this experiment and classify them as random or systematic.

- Staple **prelab and graph** printout to appropriate pages.
- Log out of computer
- Submit lab workbook
- Don't forget to sign out