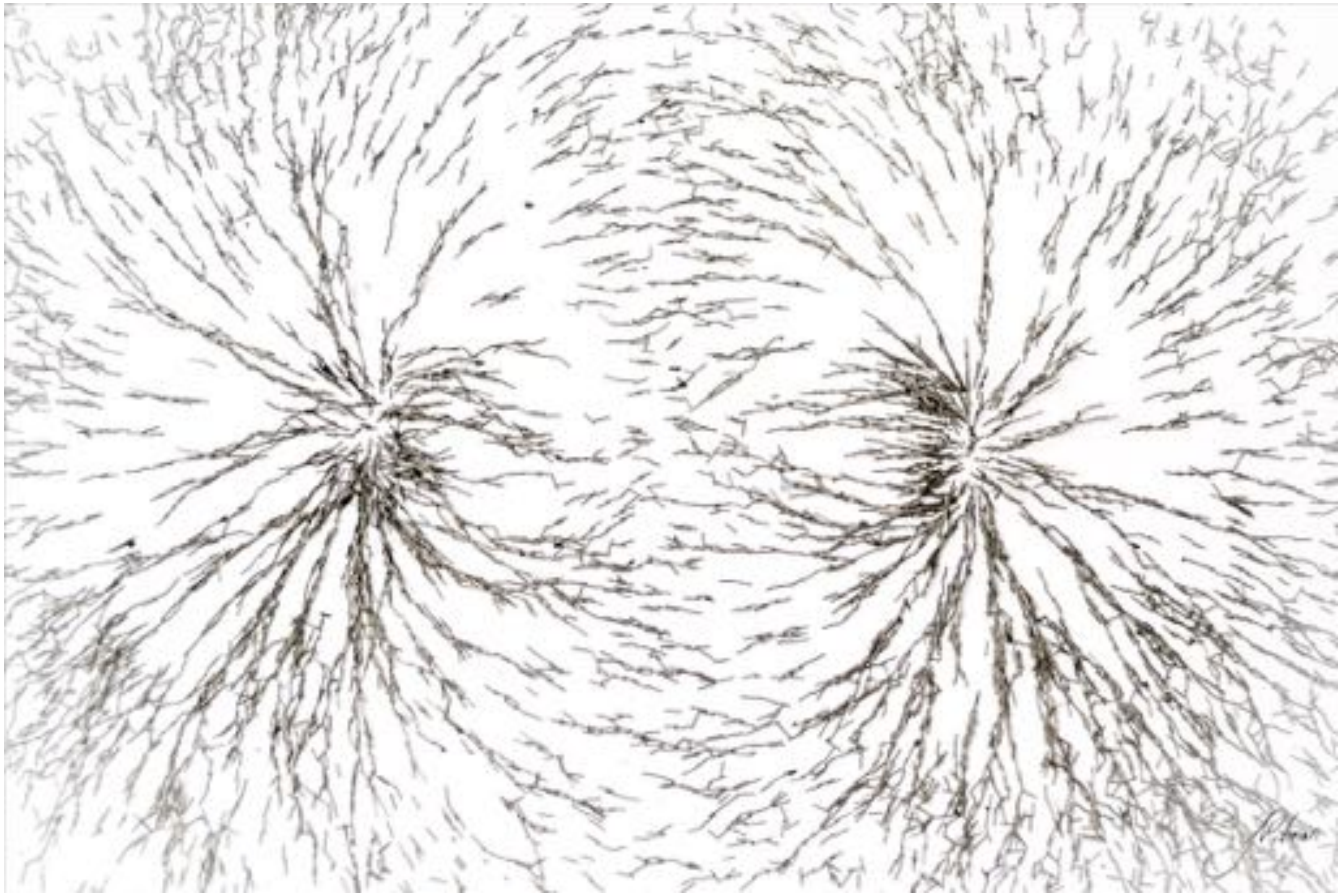
Vector Nature of Magnetic Fields



Prelab

LR Write experiment title, your name and student number at top of the page.

LR **Prelab 1:** Write the objective of this experiment.

LR **Prelab 2:** Write the relevant theory of this experiment.

LR **Prelab 3:** List the apparatus and sketch the setup.

! Have these ready to be checked by lab staff at the door on the day of your lab.

Introduction

Magnetic fields are vector fields that are produced by the movement of electric charges, or by magnetic materials like permanent magnets. These fields can exert forces or torques on moving electric charges or nearby magnetic materials.

Any moving charge will produce a magnetic field. This is an important ramification in that as electric current passing through a wire, a magnetic field is produced.

Using a simple vector relationship, we'll use the deflection angle of a compass due to the magnetic field produced by a coil, and determine an estimate of the local magnetic field.

Biot-Savart Law

The magnetic field of a coil can be determined by applying the Biot-Savart Law

$$d\vec{B} = \frac{\mu_0 I}{4\pi r^2} d\vec{s} \times \hat{r} \ .$$

Where $\vec{B}$ is the magnetic field, $\mu_0 = 4\pi \times 10^{-7} Tm/A$ is the permeability of free space, I the current, r the radial distance, $d\vec{s}$ the length element along the current path, and finally, $\hat{r}$ the radial direction to the point of measure.

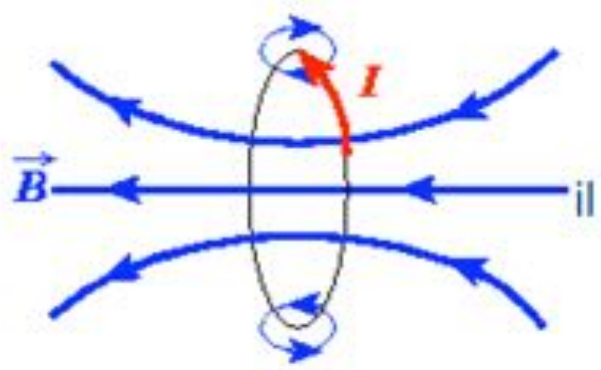
The Biot-Savart law tends to cause some confusion, mostly related to the outcome of $d\vec{s} \times \hat{r}$. A firm understanding of the right hand rule for cross products is essential to understanding this relation and determining the correct field direction.

Biot-Savart Law

When a **current** I is carried through N **number of coils** of wire of **diameter** D, a magnetic field is produced at the center which has a magnitude of

$$B_c = N\frac{\mu_0 I}{D}$$

where B_C is measured at the center of the coil and points perpendicular to the plane of the coil.



Note that at the center of the coil, the direction of the magnetic field is perpendicular to the plane of the coil.

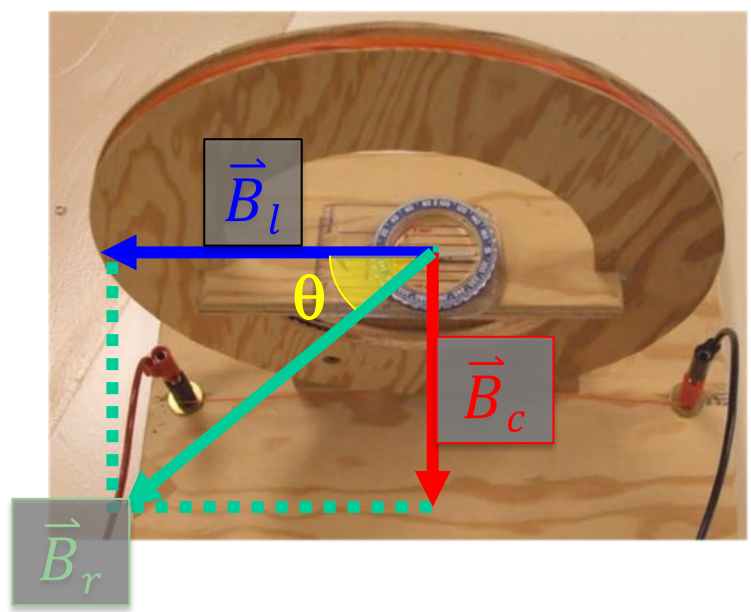
We'll use this property to help understand how these vectors sum.

Vector Diagram

There are predominantly three magnetic fields at work in this experiment: the local field, $\vec{B}_l$, the field due to the coil $\vec{B}_C$, and the resultant field $\vec{B}_r$. These fields are indicated in the diagram below.

The compass indicates the direction of the ***resultant magnetic field***, illustrated by the green arrow in the figure. We should note that

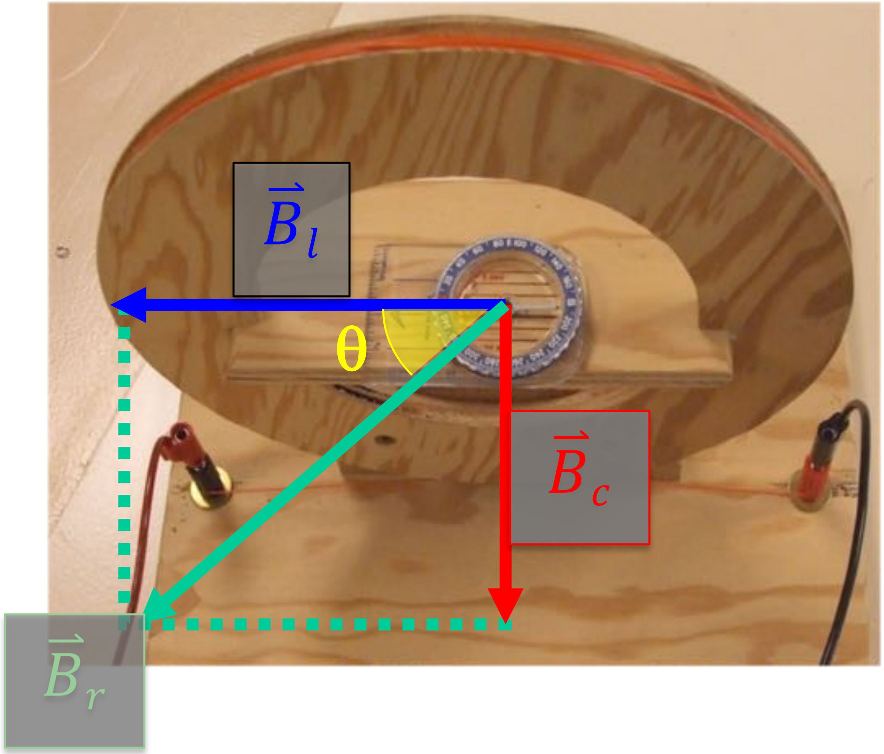
$$\vec{B}_r = \vec{B}_l + \vec{B}_C \,.$$



Meaning, if we measure the angle θ of the resultant magnetic field, and calculate the field produced by the coil, <u>we can determine an estimate of the local magnetic field</u>, which is mostly due to the earth.

Vector Relationship

Lab Report 1: Use a trigonometric identity to relate $\vec{B}_C$ to $\vec{B}_{\boldsymbol{l}}$ using the angle θ. Derive an expression for $\vec{B}_{\boldsymbol{l}}$ in terms of $\theta, I, N, D,$ and μ_0.



Apparatus

We will use the following items for this experiment

- Wooden circular frame wound with **6 coils of wire**
- Power supply
- Electrical leads
- Compass
- Meter stick

Connecting the Circuit

LR

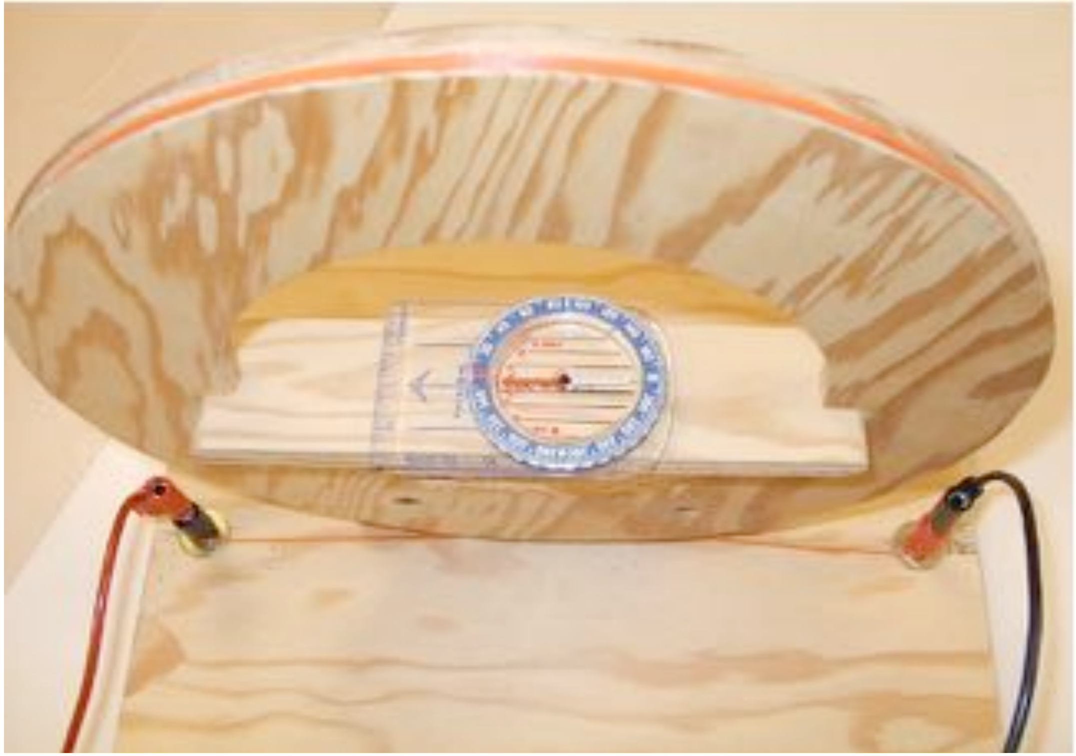
Lab Report 2: Measure the diameter of your wire coil and record it with the experimental uncertainty.

Connect the circuit as follows

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 wooden frame so that the compass needle points North along the diameter of the frame. Your apparatus must be aligned 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.

Data Acquisition

Be sure that your <u>frame does not move</u> 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.

<u>**Turn power OFF when not in use.**</u>

Data Acquisition

With the circuit connected, switch on the power supply. We wish to collect data to see the relationship between the current through the coil and the resulting deflection of the compass needle. Furthermore, to determine an estimate for the local magnetic field.

The current should never exceed $0.5\ A$.

Collect data of current $I = 0.5 \rightarrow {\sim}0\ A$ and the resulting deflection angle θ and assemble your data into a table. Include units for each quantity.

The deflection angle, θ, is the angle of the resultant magnetic field with the plane of the coil. It may be easiest to start near he maximum current and decrease as you measure angle.

Graphing your results

Use your data and your relation for $\vec{B}_l$ to **create a plot to estimate the local magnetic field and its uncertainty.**

Click the icon to launch Graphical Analysis

LR **Lab Report 3:** Record the value $\vec{B}_l \pm \delta\vec{B}_l$ as determined from your plot and any supporting workings and explain reasoning.

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

P Print your graph and include with your report.

Summary

LR

Lab Report 4: The average local magnetic field is $(1.6 \pm 0.5)\times10^{-5}\ T$. Comment on your agreement with this value.

Next, we observe the effect of the current direction on the direction of the magnetic field produced by the coil. Set the current to about 0.5 A.

LR

Lab Report 5: Noting the deflection angle of the compass needle, exchange the leads from the power supply.

a) When reversing the current direction, how do the two deflection angles differ?

b) Why was this difference produced?

LR

Lab Report 6: Why was it important to align the coil with the local magnetic field?

Summary & Conclusion

LR **Lab Report 7**: Briefly summarize your experiment, in a paragraph or two, and include any experimental results.

LR **Lab Report 8**: List any sources of experimental uncertainty and classify them as random or systematic.

! **Include your prelab, printed data, and all analysis with your report.**

Complete the following questions and submit your solution(s) with your lab report.