Vector Nature of Magnetic Fields
Introduction

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

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

$$B_c = N \frac{\mu_0 I}{2R}$$

where $\mu_0$ is a constant.

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

**QUESTION 1**: How would you expect the graph of $\tan \theta$ vs $I$ to look? Make a sketch of this graph.

Hint: Do not use data! You may want to refer to Equation (3) of the introduction and the section on plotting and interpreting graphs in your Laboratory Workbook.

**QUESTION 2**: Using Equation (3) from the introduction, derive the equation for the slope of a graph of $\tan \theta$ vs $I$. 
Apparatus

We will use the following items for this experiment
- Wooden circular frame wound with 6 turns of wire
- Multimeter
- Power supply
- Electrical leads
- Compass
- Metre stick
Deflection Angle vs Current

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 the 10ADC terminal on the multimeter.
3. Connect the COM- terminal of the multimeter to one terminal of the wooden frame.
4. 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 $\theta$ 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. The multimeter dial should be set to the 10ADC position. Turn up the current and voltage on the power supply until you read a current of about 0.05 A.
- Record the current displayed on the multimeter in Table 2.
- Measure the deflection angle $\theta$ of the compass and record it in Table 2.
- Calculate and record $\tan \theta$ (with 3 significant digits) in Table 2.

The deflection angle, $\theta$, is the angle of the resultant magnetic field with the plane of the coil.

- Increase the current slightly, up to a maximum of 0.5 A. You will take 10 readings in all and they should be approximately evenly spaced.
- Record the current, $\theta$, 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 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 $B_i$

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

**QUESTION 4:** The average local magnetic field is $(1.6 \pm 0.5) \times 10^{-5} \ T$. Comment on your agreement with this value within the uncertainty.
Direction of Magnetic Field

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

- Set the current using the current knob to about 0.5 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).

**QUESTION 5:** How did the two deflection angles differ? Why was this difference produced?

Hint: You may wish to draw the vector diagram for each case!
Summary

QUESTION 6: Graphing $I$ vs $\tan \theta$, what would we obtain for our slope and intercept?

QUESTION 7: On the sketch of the frame with the wire coils, indicate the direction of the magnetic field due to the current carrying wire. Also sketch the local magnetic field and the direction of the resultant magnetic field.

QUESTION 8: Based on your results, which of the following statements is correct and why:

1. $B_C + B_l = B_r$
2. $\vec{B}_C + \vec{B}_l = \vec{B}_r$

QUESTION 9: Why was it important to align the coil with the local magnetic field?

QUESTION 10: Give at least two sources of uncertainty in this experiment and classify them as random or systematic.
Wrap it up!

✓ Check that you have completed all the tables of your Laboratory workbook.

✓ Make sure you have answered all the questions completely.

✓ Attached to your Laboratory workbook should be the following graph: $\tan \theta$ vs $I$