MAGNETIC FIELD OF A CURRENT THROUGH A COIL

OBJECTIVES

-To determine the <u>direction</u> and <u>magnitude</u> of the magnetic field due to the current flowing through the wire of a coil.
-To estimate the magnetic field of earth at college location.

Note: The magnetic field of EARTH (B_E) is ALWAYS present. <u>We cannot eliminate it.</u>

If $\vec{B}_I =$ Magnetic field of current (***I***) in coil

and $\vec{B}_E =$ Magnetic field of the EARTH — then we will always observe.

$$\vec{B} = \vec{B}_I + \vec{B}_E \tag{1}$$

And hence in order to find $\boldsymbol{B_I}$ we must first "know" $\boldsymbol{B_E}$ and work with their resultant $\boldsymbol{B}$ which is aligned along the direction shown by the compass.
(We can "know" $\mathbf{B_E}$ by simply calling it a unit "B_E". We don't need an actual value in Tesla for this.)

The procedure will be simple:
a) Find direction of $\boldsymbol{B_E}$ without any ***I*** in coil.
b) Set up coils so that their plane (vertical) contain the direction of $\boldsymbol{B_E}$**.** This way $\boldsymbol{B_I}$ will always be perpendicular to $\mathbf{B_E}$ and therefore

$$B_I = B_E * \tan\theta \tag{2}$$

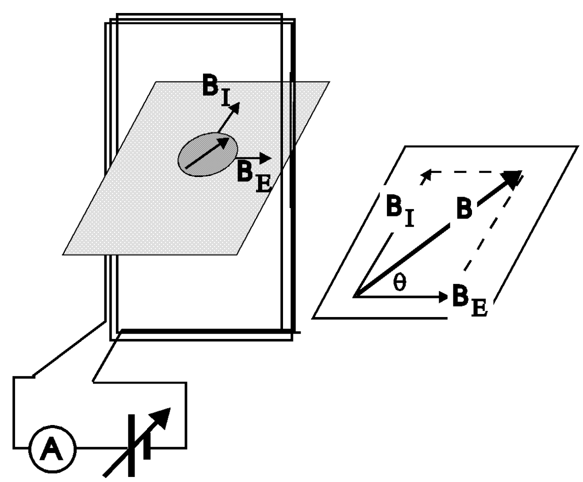

Figure 1

PART A. *MAGNETIC FIELD DUE TO A COIL*

EXPERIMENT _1

Verify the relation between the magnetic field and the magnitude of the current at its source.

Find the direction "***θ***" of the total "B" for a set of values of current through the coil. For each value of "***I***", measure the angle ***θ***, calculate ***tanθ*** and express $\boldsymbol{B_I}$ in $\boldsymbol{B_E}$ units. With ***4 turns*** of wire in the coil obtain **5** readings of ***I (****say 0.3, 0.6, 1.2, 2, 4****)*** and $\boldsymbol{B_I}$ and plot the graph ***B_I vs. I***.
What kind of relation do you find?

EXPERIMENT _2

Verify the relation between the magnetic field and the number of turns in the coil.

With a ***fixed I value***, change the number of turns ***N*** (1,2,3,4)and obtain ***4*** different readings of $\boldsymbol{B_I}$.
Plot a graph of **B_I vs. N** (the number of turns) with ***I*** constant. What kind of relation do you find?

Observe. Wrap 2 wires one way and 2 wires the opposite way. Change the current through coil and note B_I. What do you find out?

PART B ***CALCULATING THE MAGNITUDE OF B_E***

As shown in theory (*lect. 9*), the magnitude of magnetic field at a **point P** at distance R (fig.2) from a piece of wire with current ***I***, is

$$B = \frac{\mu_0 I}{4\pi R}(\sin\alpha_1 + \sin\alpha_2) \qquad (3)$$

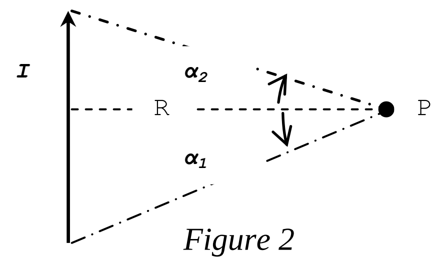

Figure 2

By applying this expression for the left side of rectangle in fig.3, after substituting R = a / 2 and $\sin\alpha_1 = \sin\alpha_2 = (b/2) / L$

one gets $$B_L = \frac{\mu_0 I}{4\pi(a/2)} 2*(b/2)/L = \frac{\mu_0 I}{2\pi a}(b/L) \qquad (4)$$

Next, as $L = [(a/2)^2+(b/2)^2]^{1/2} = 1/2* [a^2 + b^2]^{1/2}$, it comes out that

$$B_L = \frac{\mu_0 I}{2\pi a}[2b/(a^2+b^2)^{1/2}] = \frac{\mu_0 I}{\pi a} * \frac{b}{\left[a^2+b^2\right]^{1/2}} \qquad (5)$$

The magnetic field due to the current in the right side of rectangle has the same magnitude and same direction. So, the magnetic field due to left and right sides has magnitude

$$B_{L-R} = 2*B_L = \frac{2\mu_0 I}{\pi} * \frac{b}{a} * \frac{1}{\left[a^2+b^2\right]^{1/2}} \qquad (6)$$

A similar calculation for field due to the upper and lower side of rectangle shows that its magnitude is

$$B_{U-D} = \frac{2\mu_0 I}{\pi} * \frac{a}{b} * \frac{1}{\left[a^2+b^2\right]^{1/2}} \qquad (7)$$

As all these fields have the same direction, their magnitudes sum up and give at central point P a field

with magnitude $$B_P = \frac{2\mu_0 I}{\pi} * \frac{1}{\left[a^2+b^2\right]^{1/2}} * \left(\frac{a}{b} + \frac{b}{a}\right) \qquad (8)$$

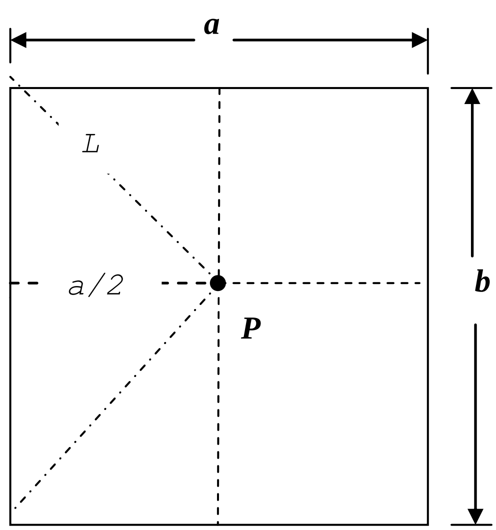

Figure 3

For a loop with N-turns

$$B_P = N\frac{2\mu_0 I}{\pi} * \frac{1}{\sqrt{a^2+b^2}}\left[\frac{a}{b} + \frac{b}{a}\right] \qquad (*)$$

You will use this expression and the results obtained above to calculate a value of the earth's magnetic field $\boldsymbol{B_E}$. For this you will need the geometry of your coil of wire(***a*** and ***b*** *in figure*). Based on expression (*) you can get the numerical value, in Tesla, for some of $\boldsymbol{B_I}$ used in exp _1. Next, from those values and the corresponding angle ***θ, you can*** determine the value of $\boldsymbol{B_E}$. An average value of these estimation should be reasonably close to the true value of $\boldsymbol{B_E}$ here at Vanier College location.