MAGNETIC FIELD OF A COIL

OBJECTIVE

To verify the formula for the magnetic field generated at the center of a coiled wire

EQUIPMENT

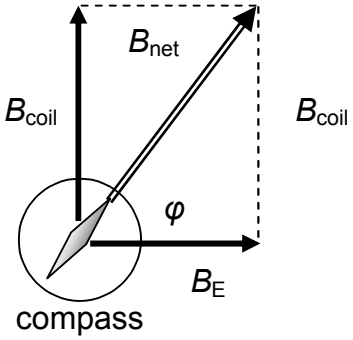
Glass jar, wooden support, compass, insulated wire, power supply, ammeter, terminal spacer, clamp, 3 patch cords, tape

THEORY

A few well-known facts:

- Compass needles always point in the direction of the net magnetic field.
- Currents produce magnetic fields.
- The Earth produces a magnetic field B_E of magnitude in the range 20 μT to 80 μT.
- The magnetic field B_{coil} at the center of a coil of N circular turns of wire is given by the formula $B_{coil} = \frac{2\pi \times 10^{-7} NI}{R}$, where I is the current in amperes and R is the radius in meters.

In this experiment, your compass with be exposed to two perpendicular magnetic fields: one from the coil and the other from the Earth:



Deflection angle φ:

$$\tan\varphi = \frac{B_{coil}}{B_E} = \frac{2\pi \times 10^{-7}}{B_E R} \cdot NI \qquad \textbf{Equation 1}$$

When I is fixed, $\tan\varphi \propto N$

When N is fixed, $\tan\varphi \propto I$

SET-UP

1) Turn the knobs fully counterclockwise on the power supply and set the slide switch to “volts.”
2) Use extra long patch cords so that the power supply is as far as possible from the spacer and the coil.
3) Twist the cords and wires together to reduce the effect of their magnetic fields on the compass.
4) Keep the turns of wire close together and flat on the glass jar. Tape them in place.
5) Be sure that the compass needle is always at the center of the coil. Gently tap the compass whenever the needle sticks in position.

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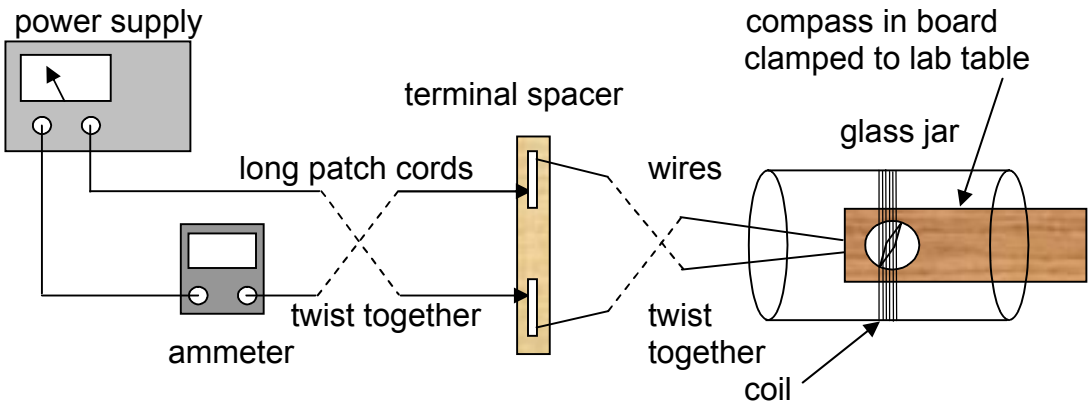

PROCEDURE

We will be testing Equation 1 is two ways: first, by fixing N and varying I; and by fixing I and varying N. The data obtained in each case will be plotted (tan φ vs. I and tan φ vs. N) using Excel and will be fitted to straight lines. The slope of the trend line will allow us to compute the local value for B_E.

Part A:

1) Measure the outer diameter of the jar and divide it in half to find the radius.
2) Find north on your compass and adjust the axis of the jar until it is perpendicular to north (i.e. the jar faces east or west). Clamp down the wooden support.

Part B:

1) Fix N = 5 turns.
2) Turn on the power supply on and slowly increase the voltage (using either the coarse or fine control knobs) until the needle begins to deflect away from north.
3) Record the angle φ (as shown on your compass) and the current I (as shown on your ammeter.)
4) Repeat Steps 2-3 to obtain four different angles under 30°. Turn the voltage knobs down to zero and turn off the power supply when you have all five measurements.

Part C:

1) Turn on the power supply and slowly increase the voltage until the ammeter reads I = 0.2 A.
2) Record the angle φ (as shown on your compass) for N = 5 turns.
3) Unwind one turn of coil and record the angle φ for N = 4 turns.
4) Repeat until N = 1 turn. If you fail to see an appreciable deflection, set the current level to a slightly higher value, such as I = 0.5 A, and redo your measurements.

Part D:

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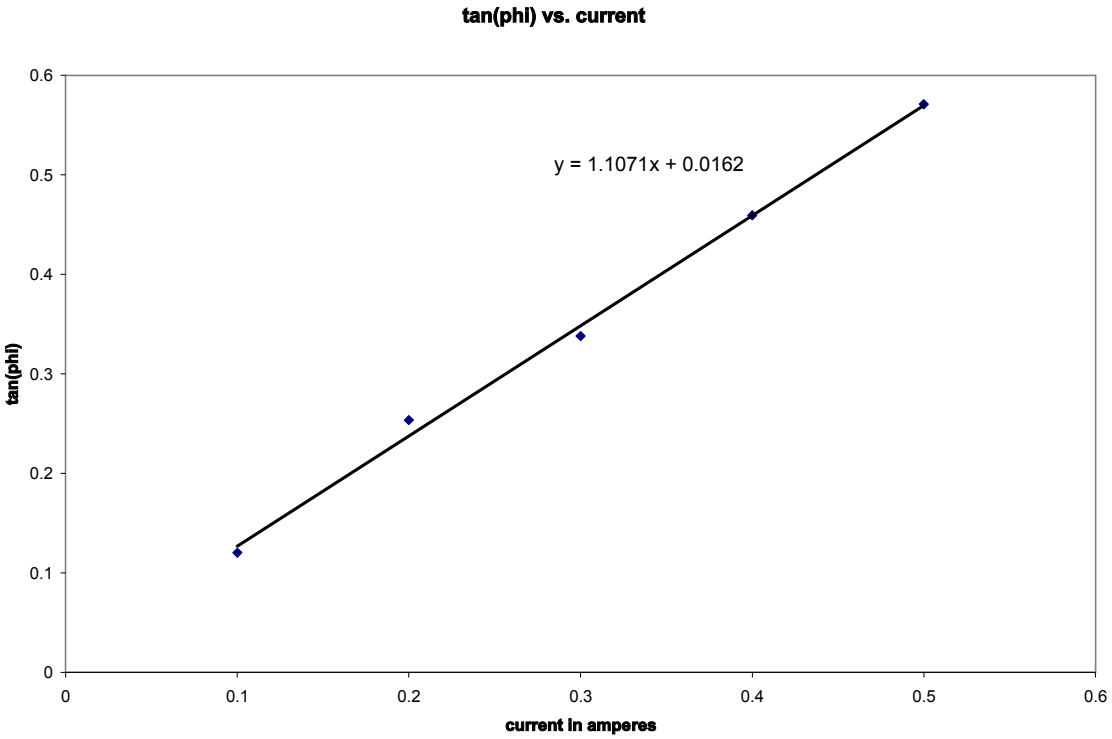
1) Graph tan φ vs. I using Excel. Fit to a straight line and record the slope.
2) Set the slope equal to $\frac{2\pi \times 10^{-7} N}{B_E R}$ and solve for B_E.
3) Now graph tan φ vs. N. Fit to a straight line and record the slope.
4) Set the slope equal to $\frac{2\pi \times 10^{-7} I}{B_E R}$ and solve for B_E.

Note that each graph must have a title, a label for each axis, and the equation for the trend line. A good example is shown below.



ASSIGNMENT: due by the end of the lab period
Each student must submit a completed data sheet with the two graphs stapled to it.

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Name _____ **Date** _____

Partners _____

_____

B FIELD OF A COIL DATA SHEET

Part A: Outer diameter of jar = _____ m

Radius of jar R = _____ m

Part B: Fixed N = 5 turns

Current I [A]	φ [degrees]	tanφ [no unit]

Part C: Fixed current I = _____ A

Turns N [A]	φ [degrees]	tanφ [no unit]
5		
4		
3		
2		
1		

Part D: For the graph of tanφ vs. I:

Slope of trend line = _____ A^{-1}

Earth's field B_E = _____ T

For the graph of tanφ vs. N:

Slope of trend line = _____ $turn^{-1}$

Earth's field B_E = _____ T

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