Course and Section_______ Names ___________________________

Date___________ _________________________________

EARTH'S MAGNETIC FIELD EXPERIMENT

Introduction

The magnetic field at the center of a circular coil B_{COIL} is added to the Earth's magnetic field B_{EARTH}. Measurements of the deflection of a compass needle as a function of coil current are used to determine the intensity of B_{EARTH}.

Equipment

Earth magnetic field apparatus with compass, power supply, multimeter, ruler, four cables, two 470 Ω resistors.

Theory

Magnetic fields can be produced by permanent magnets or by currents in wires.

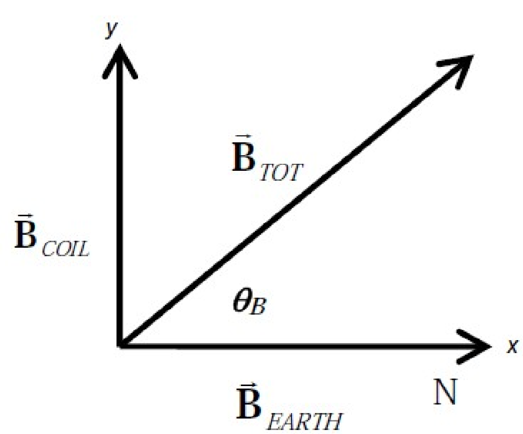
The total magnetic field of a coil and the Earth is the vector sum of the two fields.

$$\vec{B}_{TOT} = \vec{B}_{COIL} + \vec{B}_{EARTH} \qquad (1)$$

Define a coordinate system such that B_{EARTH} is in the x-direction, then $\vec{B}_{EARTH} = B_{EARTH}\,\hat{x}$.
Orient the coil such that B_{COIL} at the center of the coil is in y-direction, then $\vec{B}_{COIL} = B_{COIL}\,\hat{y}$.

The total magnetic field is then

$$\vec{B}_{TOT} = B_{EARTH}\,\hat{x} + B_{COIL}\,\hat{y} \qquad (2)$$



with B_{COIL} perpendicular to B_{EARTH},
From the figure it follows that

$$B_{COIL} = B_{EARTH}\,\tan(\theta_B) \qquad (3)$$

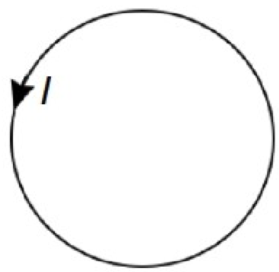
The magnitude of B_{COIL} at the center of a circular coil of radius a and carrying a current I is

$$B_{COIL} = N\frac{\mu_0 I}{2a} \qquad (4)$$

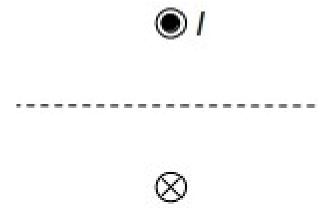
where $\mu_0 = 4\pi \times 10^{-7}$ T m/A and N is the number of turns of the coil.

Preliminary Questions

1. The two figures below give two views of the circular coil. Make a sketch of the magnetic field lines for each case.



facing the coil



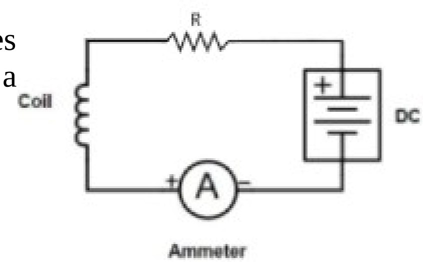
from the side of the coil

2. Add in the figures above the vector representing B_{COIL} at the center of the coil.

3. Given that θ_B is the angle of the compass needle from North, what value of θ_B results in $\vec{B}_{COIL}$ and $\vec{B}_{EARTH}$ having same magnitude?

Procedure

Step 1. Construct the circuit shown in figure to the right: a series combination of the galvanometer (coil), the multimeter and a resistor. When connecting the cables to the galvanometer select $N = 50$ (first and third yellow inputs). DC power supply off.

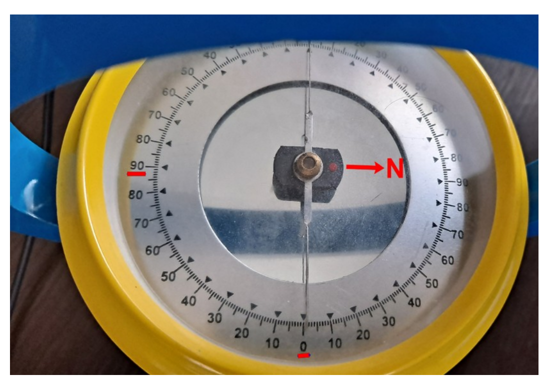


Step 2. In order to use the multimeter to measure current (A), connect the cables to the two inputs in center of the multimeter. Switch set on 200mA.

The resistor R is built as the parallel combination of two 470 Ω resistors, which is then connected in series with coil.

Step 3. Check that the compass is mounted correctly on the galvanometer: the mark for the angle 90° must be right below the coil (the outer blue circle).
If not, rotate the compass (the yellow circle) but not the galvanometer.

Step 4. The red dot on the compass points in the North direction. Rotate and orient the galvanometer so the compass needle to point to 0°.



PART 1 – Equal Magnitudes

Step 1. Turn on the power supply. Sightly increase the voltage.

4. What happen to the compass needle?

5. Is the rotation clockwise or counter-clockwise?

Step 2. Set the voltage back to zero, reverse the two cables at the DC output of the power supply. Again, sightly increase the voltage.

6. Is the rotation clockwise or counter-clockwise?

Step 3. Set the voltage back to zero, then sightly increase and adjust the voltage such that the compass needle points to 45º. Try to be as much precise as possible.

Analysis

7. For which value of the current does the compass needle point to 45º?

I =________

8. Measure and record a, the radius of the coil.

a =__________

9. Using equation (4) calculate $B_{EARTH.}$.

$B_{EARTH.}$ = __________ μT

Compare the measured value of $B_{EARTH.}$ with the expected value given by NOAA website (http://www.ngdc.noaa.gov/geomag-web) or google "NOAA Magnetic Field Calculators". Select the 'Magnetic Field" tab and input the latitude and longitude of Tuscaloosa. Click 'Calculate'.

10. This web site gives the horizontal and the vertical components of the total magnetic field of the Earth. Which component is relevant to the experiment?

11. Does the vertical component tend to rotate the magnet left or right, or would it tilt it up or down?

12. Use the value of the component of question 10 for the magnetic field of the Earth

$B_{EARTH\,(NOAA)}$ = _________μT

13. Calculate the percentage error assuming $B_{EARTH\,(NOAA)}$ as the exact value.

% error = ___________

PART 2 – Linear Plot

To obtain a more precise value of B_{EARTH} you will take several measurements of the angle θ_B corresponding to different values of the coil current I.

Step 1. Make sure the set up is ready: power supply off, compass needle pointing at 0º so that, when the current I passes through the coil, B_{COIL} is perpendicular to $B_{EARTH.}$.

Step 2. Increase and adjust the voltage at the power supply so that the angle θ_B assume values in the range of $5^\circ < \theta_B < 75^\circ$. To obtain angles above 45º ~ 50º you might need to use a voltage above 12 V which cannot be input if you are using the 12 V power supply: in this case select on the galvanometer N = 500 (first and forth yellow inputs) *or* use three 470 Ω resistors in parallel instead of two.

Step 3. Read and record the corresponding currents in the table below.

Analysis

14. When $I \neq 0$, in which direction does the compass needle of the galvanometer point to?

___ in the direction of B_{COIL}
___ in the direction of $B_{EARTH.}$
___ in the direction of B_{TOT}
___ in the direction perpendicular to B_{TOT}

15. Use the table below to collect your data.

I_{COIL} (A)	B_{COIL} (μT)	θ_B	tan θ_B

16. Plot B_{COIL} vs tan $\theta_{B.}$ (y-axis*:* B_{COIL} , x-axis*: tan* θ_B). Use equation (3) to determine $B_{EARTH.}$.

$B_{EARTH.}$ = __________ μT

17. Print a copy of your plot.

18. Calculate the percentage error assuming $B_{EARTH\,(NOAA)}$ as the exact value.

% error = ___________

19. Calculate the percentage difference of the two B_{EARTH} obtained experimentally.

% difference = ___________