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Experiment 2.07: Magnetic Field of the Earth

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I. EXPERIMENT 2.07: MAGNETIC FIELD OF THE EARTH

A. Abstract

The local horizontal magnetic field strength of the earth is measured using a tangent galvanometer.

B. Formulas

$$B_{\text{center coil}} = N\frac{\mu_0 I}{D} \tag{1}$$

$$B_H^{(\text{earth})} = \frac{B_{\text{coil}}}{\tan\theta} \tag{2}$$

where D in the first equation is the diameter of the coil, and the second equation is specific to the experiment described below.

C. Description and Background

As we have learned in class, the magnetic field of the Earth resembles the field of a bar magnet. Magnetic field lines originate at the magnetic north (near geographic south) pole, enter the magnetic south (near geographic north) pole, and then run through Earth and back to the magnetic north pole. Although the magnetic field of the Earth is a three-dimensional vector field, we normally measure the horizontal component (north, south, east, west) with a compass. The north pole of the compass needle follows the field by pointing to the south magnetic pole of the Earth (located close to the geographic north pole).

In this experiment, we will measure the horizontal component of Earth's magnetic field, $B_H^{(\text{earth})}$, by using the field generated by a tangent galvanometer. A tangent galvanometer (Fig. 1) consists of a circular coil of N turns, diameter D, and carries a current I. The magnetic field produced within the tangent galvanometer is not uniform but can be calculated at its center, using Eq. (1), where $\mu_0 = 4\pi \times 10^{-7}\ T \cdot m/A$ is the permeability of free space. We will measure the deflection in direction of the compass' needle, θ, as it is affected by both B_{coil} and $B_H^{(\text{earth})}$. The magnetic fields will add to yield a net magnetic field, such

FIG. 1. Tangent galvanometer.

that

$$\vec{B}_{net} = \vec{B}_{coil} + \vec{B}^{(\text{earth})}$$

Placing the compass at the center of the vertical coil, we can rotate it so that its north-

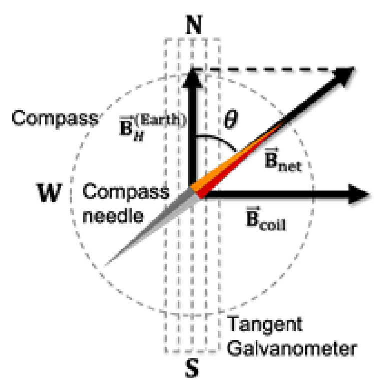


FIG. 2. Compass face.

south axis is aligned with the plane of the coil. Then we align the coil's plane with magnetic north, so that B_{coil} is perpendicular to $B_H^{(\text{earth})}$, and the net field will be aligned with the compass' needle as shown in Fig. 2. Thus, we can measure the local horizontal magnetic field strength of the earth by using B_{coil} and the angle of deflection of the compass needle, θ, by employing Eq. (2).

D. Procedure

1. When setting up the circuit for this experiment, make sure the ammeter is used in the Amp (*not* milli- or micro- Amp) scale; this involves the use of the COM and 10A sockets of the multimeter. The current in the circuit should be between 0.3 A and 0.5 A.

2. Measure the radius of the tangent galvanometer coil.

3. With the compass at the center of the vertical coil, align the coil plane with magnetic north.

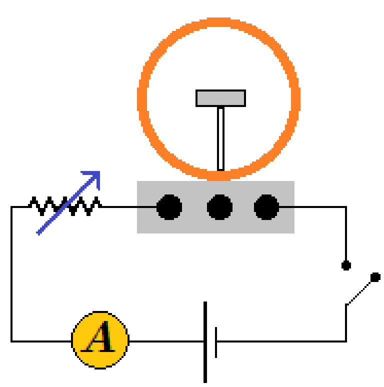
4. Rotate the compass casing so that its north-south axis is aligned with the plane of the coil as well.

5. Complete the circuit and record the number of turns in the coil (N), the current, and the angular deviation from north.

6. Repeat the measurement with the battery's terminal connections reversed. Both angles, $\theta^{(\pm)}$ (*i.e.*, east and west of north), are acute angular deviations from north.

7. Repeat the procedure for the three different values of the coil turns number, N $(= 5, 10, 15)$.

1. Figures



Circuit for this experiment.

E. Measurements

coil diameter D [cm]	

Trial	N	$\theta^{(+)}$	$I^{(+)}$ [Amp]	$\theta^{(-)}$	$I^{(-)}$ [Amp]
1	5				
2	10				
3	15				

F. Instructions

1. In the three cases, use the average of the two angles ($\bar{\theta} = \left(\theta^{(+)} + \theta^{(-)}\right)/2$), the average of the two currents ($\bar{I} = \left(I^{(+)} + I^{(-)}\right)/2$), and Eqs. (1) and (2), and calculate coil field and the earth's horizontal component of magnetic field, $B_H^{(\text{earth})}$ [$\mu Tesla$].

2. Based on the three previous calculations, what is your experimental determination of the horizontal component of the earth's magnetic field, $\bar{B}_H^{(\text{earth})}$ [$Gauss$]?

3. Take the accepted value of the earth's horizontal component of magnetic field in south Florida to be 0.25 $Gauss$ and calculate the percent error in your answer.

G. Calculations

Trial	$\bar{\theta} = \frac{1}{2}\left(\theta^{(+)} + \theta^{(-)}\right)$	$\bar{I} = \frac{1}{2}\left(I^{(+)} + I^{(-)}\right)$ [A]	B_{coil} [$\mu Tesla$]	$B_H^{(\text{earth})}$ [$\mu Tesla$]
1				
2				
3				

$\bar{B}_H^{(\text{earth})}$ [$Gauss$]	
$\delta\bar{B}_H^{(\text{earth})}$ [$Gauss$]	
%-Err $\left(\bar{B}_H^{(\text{earth})}\right)$	