

Measurement of Earth's Magnetic Field

Purpose: To measure the horizontal component of the earth's magnetic field.

Equipment: Tangent galvanometer, 6 volts power supply, milliammeter, reversing switch, connecting wires.

Introduction: The magnetic field, \vec{dB} , at a point due to a current, I , of length \vec{dl} (see figure 1) is given by the Biot-Savart law:

$$\vec{dB} = \frac{\mu_0}{4\pi} I \frac{\vec{dl} \times \hat{r}}{r^2} \dots\dots\dots (1)$$

Where r is a unit vector in the direction of the vector \vec{r} which connects \vec{dl} and P , μ_0 is the magnetic permeability of free space ($\mu_0 = 4\pi \times 10^{-7}$ w/amp-m).

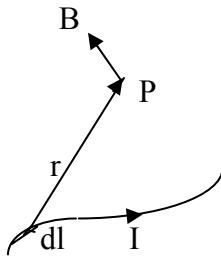


Figure 1

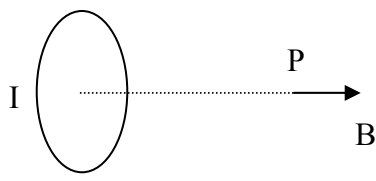


Figure 2

We can use equation 1 to calculate the magnetic field due to a circular loop of wire. If we restrict ourselves to finding \vec{B} for points along the axis of the loop (see Figure 2), the resultant field can be shown to be

$$\vec{B} = \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}} \dots\dots\dots (2)$$

Where R is the radius of the loop and x is the distance from the center of the loop along the axis of the loop. The direction of \vec{B} is given by the right hand rule.

On the surface of the earth, the magnetic field at the center of such a current loop is the resultant field due to two fields: that due to the current in the loop and the magnetic field due to the earth. By determining the direction of the resultant magnetic field we can, using equation 2 and vector addition, determine the horizontal component of the earth's magnetic field.

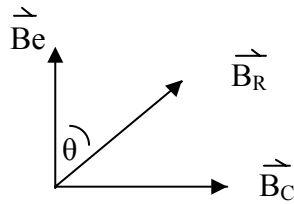


Figure 3

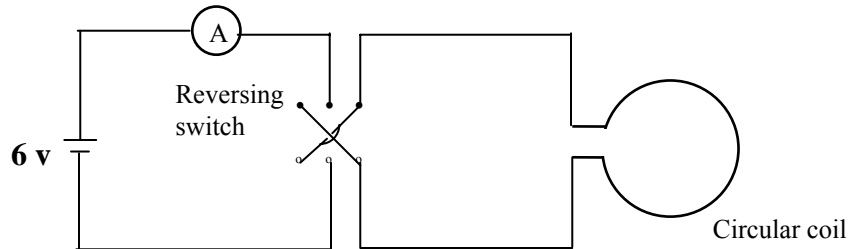


Figure 4

Procedure:

1. Starting with the Biot-Savart law set up the integral necessary to determine the magnetic field at points along the axis of a current loop. Perform the integral and show that your result agrees with equation 2. Using the binomial expansion, show that the series expansion in R/x for B when $x \gg R$ is given by

$$B = \frac{\mu_0 \mu}{2\pi x^3} \left[1 - \frac{3}{2} \left(\frac{R}{x} \right)^2 + \frac{15}{8} \left(\frac{R}{x} \right)^4 + \dots \right]$$

where μ = magnetic dipole moment.

2. Choose a location in the room as far as possible from any magnetic materials (iron pipes, etc). Align the plane of the current coil of the tangent galvanometer as closely as possible with direction of the earth's magnetic field as shown by the compass at the center of the coil.
3. Set up the circuit shown in figure 4 and carefully increases the voltage on the power supply until the current through the coil causes a deflection of approximately 35° . Record the value of the current. Read the deflection angle, θ_1 , as closely as possible, then throw the reversing switch to reverse the direction of the current and carefully measure the new angle, θ_2 . By measuring the deflection for both current directions the error introduced by inexact alignment of the coil with the earth's magnetic field is reduced.
4. From figure 3 the horizontal component of the earth's magnetic field is

$$B_e = B_c / \tan \theta$$

Where B_c is the magnetic field due to the current in the coil and θ is the angle of deflection. Find the average B_e (from forward and reverse currents) for approximate deflection angles of 35° , 40° , 45° , 50° , and 55° . Find the percent difference from the mean for each of the five values obtained for B_e . If possible, obtain a local value for B_e and compare with your results.