Experiment 22
The Earth's Magnetic Field

Advanced Reading:
(Serway) Chapter 30,
section 30-1 & 30-9

Equipment:
1 Tangent Galvanometer
1 Kelvin DMM
1 current limiting resistor
1 dip needle
1 power supply
3 banana plug wires

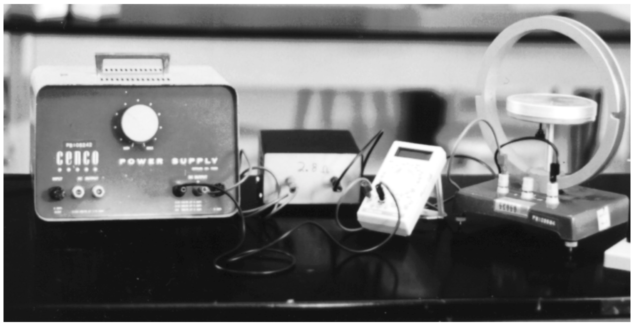

fig. 22-1 Earth's Magnetic Field

Objective:
The object of this lab is to measure the magnitude of the earth's total magnetic field in Oxford, MS.

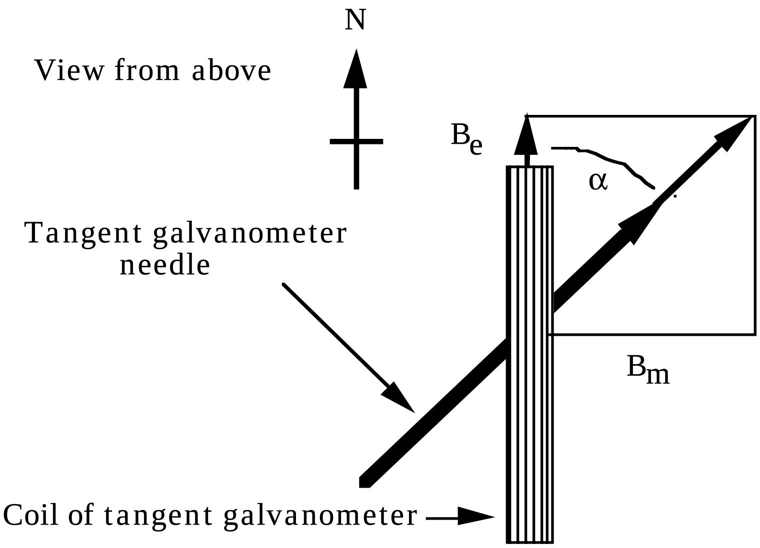

figure 22-2 Schematic of tangent galvanometer

Theory:
The magnetic field produced by a circular loop of wire is given by:

$$B_L = \frac{\mu_o i N}{2r}$$

where B_L is the magnetic field, μ_o is the permeability constant ($\mu_o = 4\pi \cdot 10^{-7}$ T·m/A), i is the current, N is the number of turns, and r is the radius of the circle. The direction of this field is given by the right-hand rule. If the thumb of the right hand points in the direction of the current flow (from positive to negative) then the fingers curl in the direction of the magnetic field around the wire. This field can be used to measure an unknown magnetic field by the following manner. If the coil of the tangent galvanometer is aligned with an unknown field and the current is on, the two magnetic fields will add to give a resultant field. The needle of the tangent galvanometer will line-up with this resultant field. The deflection angle α can be measured and the magnetic field B_m calculated from

$$\frac{B_L}{B_{eh}} = \tan\alpha \quad \text{or} \quad B_{eh} = \frac{B_L}{\tan\alpha}$$

eq. 22-1

where B_{eh} is the horizontal component of the Earth's magnetic field. From figure 22-2 we see that the dip needle points in the direction of the total field. By measuring the horizontal component and the direction of the total field, the total field can be calculated. (see figure 22-3).

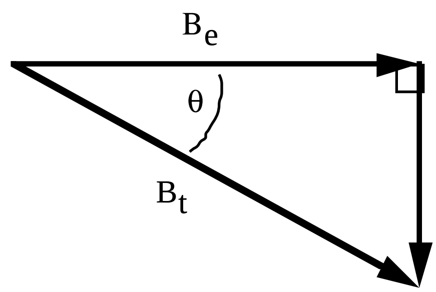

figure 22-3

Procedure:

1. Wire the tangent galvanometer, the current limiting resistor, the Kelvin DMM , and the power supply together in a series circuit. (see fig. 22-1) The tangent galvanometer has three places to connect wires. Where the wires are connected determines how many loops the current must pass through. Wire the circuit so that the current passes through 5 loops. **Have your lab instructor approve your circuit before plugging in the power supply.**

2. Align the tangent galvanometer coil so that it is parallel to the to the earth's magnetic field. (as shown in figure 22-2) Do this by rotating the dip needle so that it is horizontal and can act as a compass. The coil of the tangent galvanometer should be in line with the "compass" needle which points north-south.

3. Measure three different values for α by varying the current input. The values for α will be more accurate if they fall between 20^0 and 70^0.

4. Repeat step three using 10 loops and again for 15 loops of current carrying wire, for a total of nine trials. Calculate the average horizontal field from these data.

5. Measure the dip angle of the total field with the dip needle. Make sure that the power supply to the tangent galvanometer is off. From this angle, calculate the total field.

Questions/Conclusions:

1. Compare the value of the total field found in this experiment to a sample value of 43 μT. This is the magnetic field in Tucson Arizona.

2. Calculate the total resistance of 15 loops of copper wire on the galvanometer if the wire is 1 mm in diameter and the loops are 20 cm in diameter. (The resistivity of copper $\rho = 1.69 \times 10^{-8}\ \Omega\cdot m$)

3. Why was the current limiting resistor needed in the circuit? (See previous question)