Physics 121 Lab 4: Measurement of the Earth's Magnetic Field

1 Introduction

The Earth's magnetic field is well known and heavily studied. It also is ever present and affects any experiments in which relatively small magnetic fields are involved. In this lab, we will use our knowledge of the magnetic field created by currents to measure the Earth's magnetic field in our lab.

At a given location on the Earth's surface in the northern hemisphere, the direction of the earth's magnetic field is generally toward the earth's north magnetic pole, but directed downward at an angle θ (called the "dip angle") below the horizontal. As shown in Figure 1 the total B field vector is related to the horizontal component $B_H$and the dip angle by

$$B = \frac{B_H}{\cos\theta}. \tag{1}$$

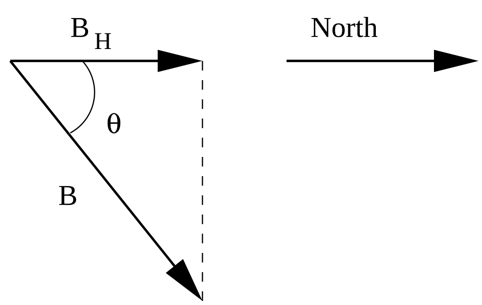

Figure 1: The relationship between the earth's magnetic field B and the horizontal component B_H at the earth's surface in the northern hemisphere.

2 Apparatus

We will measure the strength of the horizontal component of the earth's magnetic field using a simple device called a *tangent galvanometer*. This device consists of a small magnetic compass at the center of a circular coil of wire. A power supply provides an electric current that produces a magnetic field at the center of the coil where the compass is located.

The B field of the current is directed perpendicular to the plane of the coil and , as explained in class, its magnitude is given by

$$B_{coil} = \frac{\mu_0}{4\pi}\frac{2\pi NI}{R} \tag{2}$$

where N is the number of turns of wire in the coil, I is the conventional current, and R is the radius of the coil. With the plane of the coil aligned parallel to the Earth's magnetic field, the field of the coil B_{coil} will be perpendicular to the direction of B_H. The Earth's field B_H tries to align the compass needle toward magnetic north, while B_{coil} tries to align it along the east-west line. The resultant orientation of the needle lies somewhere between these directions depending on the relative strength of the two fields. The angle α, shown in Figure 3, through which the needle is deflected away from the direction of B_H gives a measure of the strength of the field B_{coil} relative to the strength of the horizontal component of the earth's magnetic field B_H. In fact,

$$B_H = \frac{B_{coil}}{\tan \alpha}. \tag{3}$$

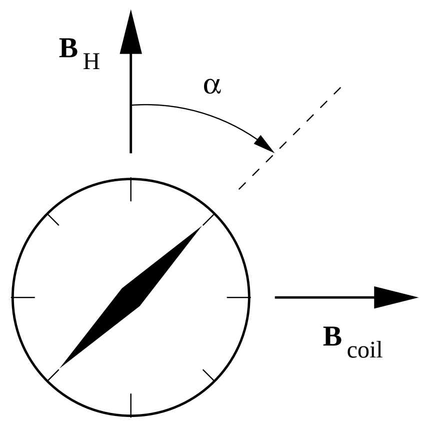

Figure 2: The deflection of the compass needle due to the magnetic field of the coil perpendicular to the horizontal component of the earth's magnetic field.

By calculating B_{coil} from the data and reading the deflection angle off the compass as illustrated in Figure 2, we obtain a value for B_H.

3 Procedure

1. Measure the radius, R, of the coil, and record the value with uncertainty on the data sheet.

2. Record the number of turns of wire N on the data sheet.

3. Place the compass at the center of the coil, let the needle settle, and align the plane of the coil parallel to the North-South direction.

4. Carefully rotate the compass until the ends of the compass needle are aligned with $0°$ and $180°$ on the compass scale.

5. Get three wires from the rack in the front of the room, and, connect the circuit as described below. IMPORTANT: do NOT turn on the power until your instructor has checked your circuit (or you can blow a fuse in the meter).

6. Connect the '+' socket in the power supply to the left-most socket in the coils. Connect the right-most socket in the coils to the 'Com' socket in the meter, and the 'mA' socket in the meter to the '-' socket in the supply.
7. Turn the dial on the meter to the milliamps setting.
8. HAVE YOUR INSTRUCTOR CHECK YOUR CIRCUIT. If OK, turn on the power supply, and adjust the current to a value around 15 mA. Record the current, with uncertainty, for trial 1 in Table 1 on the data sheet.
9. Read the deflection (in degrees) of each end of the compass needle. (Tap on the compass box lightly to make sure that the compass needle is not binding and moves freely.) Record the deflection of the north pole of the compass needle as α_{N-left} and the deflection of the south pole as α_{S-left} in Table 1. Include an estimated uncertainty in these values.
10. Repeat for four other values for the current between 5 and 25 mA.
11. Turn off the power supply and switch the leads into the power supply so that the current will run in the opposite direction. Turn the supply back on.
12. Obtain measurements of the deflection of the compass needle at the same currents as above.

4 Analysis

1. For each value of the current, average the four measured deflection angles and record the result as α in Table 1.
2. Calculate and record the horizontal component of the earth's magnetic field B_H for each trial as described in the Introduction. Also determine and record the uncertainty for each value.
3. Calculate the average of the values you obtained for B_H from the five trials and enter the result, *with uncertainty*, on the line provided on the data sheet.
4. Compare your value for B_H with accepted values (as can be found by Googling "Magnetic Field Earth Schenectady") and comment on the agreement.

5 Data

Radius of the coil R = ______________; Number of turns of wire N = ______________

Table 1: Measurements of current and deflection angle used to determine the horizontal component of the earth's magnetic field.

Trial	I (A)	α_{N-left} (degrees)	α_{S-left} (degrees)	$\alpha_{N-right}$ (degrees)	$\alpha_{S-right}$ (degrees)	α (degrees)	B_H (T)
1							
2							
3							
4							
5							

Average value for B_H = ______________________