

## Finding the Magnetic Field of the Earth

The magnetic field in the vicinity of your lab station comes mainly from the earth, but it is sometimes significantly modified by the presence of steel or magnetic materials in the building construction. In this lab you will measure the strength  $B_E$  of this field. The basic idea is to compare the unknown  $B_E$  with another magnetic field whose strength is known. Suppose that a known magnetic field  $\mathbf{B}$  is perpendicular to  $B_E$  as shown in fig. 1. The two fields together produce a net field  $\mathbf{B}_{\text{net}}$  whose direction  $\theta$  relative to  $\mathbf{B}_E$  is given by

$$(1) \quad \tan \theta = B/B_E$$

If we know the strength of  $B$  and we can measure the angle  $\theta$  then the unknown  $B_E$  can be calculated. A compass needle at any location points in the direction of the net magnetic field, and can be used to measure  $\theta$ .

In order to generate a known and controllable magnetic field  $\mathbf{B}$ , we will use a circular loop of current carrying wire of radius  $R$ . The magnetic field generated by such a current is shown in fig. 2. At the center of the loop the magnetic field has a magnitude given by

$$(2) \quad B = \frac{\mu_0 NI}{2R}$$

where  $I$  is the current in the loop and  $N$  is the number of turns. The direction of the magnetic field at the center of the loop is perpendicular to the plane of the loop and follows the right hand rule.

### Preliminary

- a. Because the magnetic field at your lab station is mainly from the earth, you should expect that a compass needle points roughly north. Check that it does so. You may have to raise the compass a few inches above the surface of the table to avoid the effect of steel screws.
- b. Place the compass carefully at the center of the wire loop. A tiny gob of clay applied to the bottom of the compass will help hold it in place. Your instructor will describe how to align the wire loop and the compass. Note that the digital multi-meter is set to read current in mA. The 220 Ohm resistor in the circuit is intended to prevent the current from getting too large and burning out the fuse of the multi-meter. Try running a current through the circuit to see that the compass needle does indeed deflect.
- c. Now do things more carefully. Turn on the power supply and set the current so that the compass deflects through  $40^\circ$  and record the current. Do this as accurately as you can and then retry it from scratch. The difference between your two values for current is a measure of uncertainty. You should have a discussion with your lab partners about how best to measure angles accurately.

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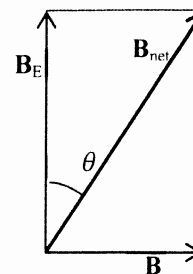


Fig. 1 Combining Magnetic Fields

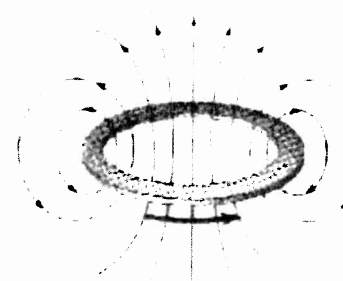


Fig. 2 Magnetic field of a circular current.

- d. Turn off the power supply and reverse the leads. Now repeat part c. Note that the compass deflects in the other direction. Are your currents different from those of part c. Defects in the manufacture of the compass can cause it to deflect differently in the two directions. This is also a source of uncertainty.
- e. You will be making several measurements of the kind that you just made. Here is a suitable method for handling measurement uncertainties. Take two measures of current on each side and find the average of the four measurements. Use the standard deviation of the mean (as calculated in Excel) to get the uncertainty in the current. [Your instructor can remind you how to calculate the standard deviation of the mean.] Make sure you write your final value for current with uncertainty in the correct format.
- f. Now that we know the current with uncertainty let's calculate the magnetic field generated by that current with uncertainty. Equation 2 above is the formula to use. But first, calculate the numerical value of the following constant

$$K = \frac{\mu_0 N}{2R}$$

Knowing this constant, the magnetic field generated by the current loop can be calculated as  $B = KI$  and the uncertainty in  $B$  can be calculated as  $\Delta B = K(\Delta I)$ . Calculate those values and record them in the correct format.

- g. Now that we have a value for  $B$ , we can find  $B_E$  from equation 1.

$$B_E = B / \tan \theta$$

and

$$\Delta B_E = \Delta B / \tan \theta$$

Calculate those values and record your measured value for the magnetic field of the earth with uncertainty in the correct format.

- h. Make a sketch of the apparatus and briefly describe the procedure for making measurements. From the notes you have taken here in lab, you should be able to write a paragraph describing the alignment of the apparatus and your technique for measuring angles.

#### Collect Data

For angles of 10, 20, 30, 40, 50 and 60 degrees collect the kind of data that you did for 40 degrees above. Equation 1 can be written as  $B = B_E \tan \theta$  so that a graph of  $B$  vs  $\tan \theta$  should give a straight line through the origin, and the slope of the graph should be  $B_E$ . Be sure you understand why! Considering all of your data record your value for  $B_E$  with uncertainty in the correct format. Print out your Excel results.

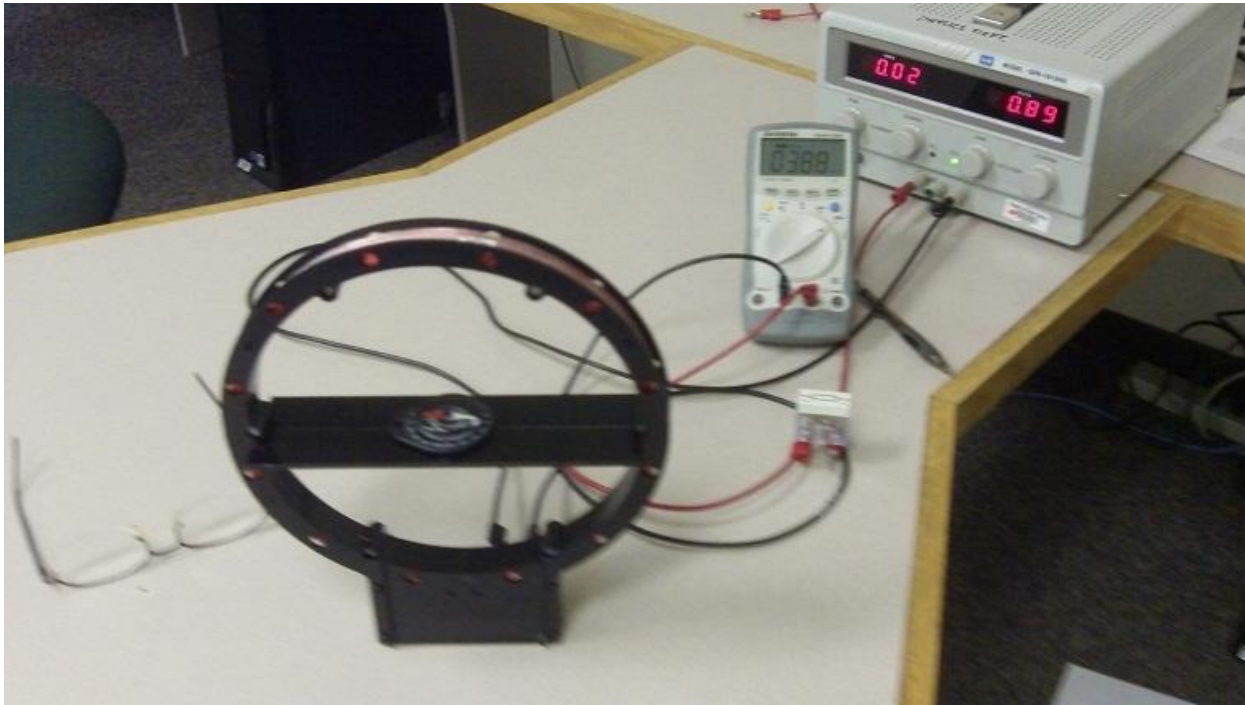
Students turn in completed data sheet (both sides). A typed Procedure as instructed. The graph and table from Excel.

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## B of Earth Equipment

1 Low Volt Power Supply	GW GPR-1810HD
1 Digital Multimeter	GW GDM-396
1 Resistor	220 Ohm - 2 W
1 200-turn Field Coil	Pasco EM-6711
1 field Coil platform	
1 Compass	Brumpton



## Finding Magnetic Field of the Earth

Angle	tan(40)
40	0.839098626

Current (mA)	
East	1 18.33
	2 17.82
West	1 17.61
	2 17.60

Avg current (mA)	17.84
std dev	.3421
std dev of mean	.1710

Current for 40° deflection w/ unc	Current	17.8 ± .2 mA

Calculation of B

K	$1.197 \times 10^{-6}$	
B	$2.130 \times 10^{-5}$	T
$\Delta B$	$2.394 \times 10^{-7}$	T

B from coil

B for 40° deflection w/ unc	$(2.13 \pm .02) \times 10^{-5}$	T
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Calculation of  $B_E$

$B_E$	$2.539 \times 10^{-5}$	T
unc	$2.853 \times 10^{-7}$	T

$B_E$ w/ unc	$(2.54 \pm .03) \times 10^{-5}$	T
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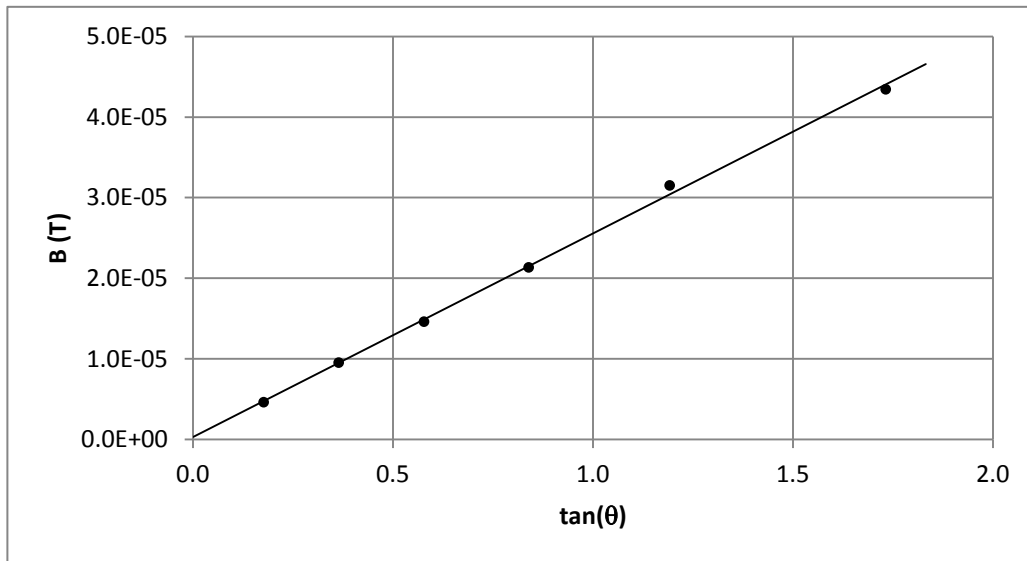
Procedure with Sketch

Final value of BE  
w/ unc

# Finding Earth's Magnetic Field

			Deflection						Field from Coil		Field from Earth	
$\theta$ (deg)	$\theta$ (rad)	$\tan(\theta)$	East		West		Avg I (mA)	Std Dev	B (T)	unc	$B_E$ (T)	unc
10	0.175	0.176	4.14	4.19	3.47	3.67	3.87	0.177	4.629E-06	2.117E-07	2.625E-05	1.200E-06
20	0.349	0.364	8.96	8.31	7.06	7.55	7.97	0.418	9.538E-06	5.008E-07	2.621E-05	1.376E-06
30	0.524	0.577	12.77	12.85	11.95	11.29	12.22	0.369	1.462E-05	4.421E-07	2.532E-05	7.658E-07
40	0.698	0.839	18.33	17.82	17.61	17.60	17.84	0.171	2.135E-05	2.047E-07	2.545E-05	2.440E-07
50	0.873	1.192	27.92	27.73	25.40	24.30	26.34	0.889	3.152E-05	1.064E-06	2.645E-05	8.924E-07
60	1.047	1.732	35.40	37.05	35.75	37.00	36.30	0.425	4.344E-05	5.084E-07	2.508E-05	2.935E-07

Average      Std dev  
 2.579E-05      2.352E-07



Graph	
	int
value	3.12E-07
unc	4.95E-07