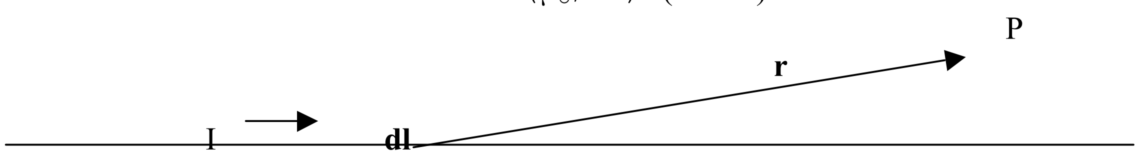
TANGENT GALVANOMETER

Apparatus: DC power supply, ammeter, tangent galvanometer coil, compass, magnetic dip needle, wires, and ruler.

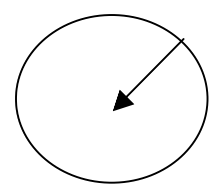
When a straight wire carries a current of magnitude I, there is a magnetic field set up in a circular fashion about the wire. The direction of the magnetic field is such that if one were to place the thumb to the right hand along the wire so the thumb is pointing in the direction of the positive current, the fingers of the right hand would curl about the wire in the same direction as the magnetic field. The strength of the magnetic field depends on the size of the current and on the distance from the wire to where the field is measured. The larger the current in the wire, the larger is the magnetic field. The greater the distance from the wire, the smaller will be the field. The Biot-Savart Law expresses the magnetic field contribution at a point P, located at a displacement **r**, from the section of wire **dl** carrying current I.

$$dB = (\mu_\circ/4\pi)\quad (I\mathbf{dl} \times \mathbf{r})/r^3$$



If the magnetic field of a wire coil of radius R is to be determined at the center of the coil and there is a current I, in the coil, then dl and r are at right angles to each other. The magnitude of dB is then determined as

$$\mathbf{dB} = (1 \times 10^{-7})\ (I\ dL/R^2)$$



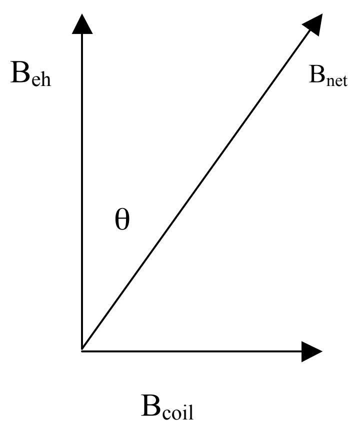
For each coil of wire the magnetic field at the center of the coil is given as

$$\mathbf{B} = 2\pi \times 10^{-7}\ I/R$$

The direction of the field is perpendicular to the plane of the coil and can be determined by use of the right hand rule indicated above.

The magnetic field of the earth has a magnitude and direction just as the field of a coil of wire carrying a current has a magnitude and direction. The purpose of this experiment is to determine the magnitude and direction of the magnetic field of the earth by knowing the magnitude and direction of a field produced by a current in a coil of wire. If the two magnetic fields are located in a region of space, they will add as vectors to produce the resultant field. This resultant field can be detected by means of a compass; its direction of point being the direction of the resultant magnetic field. If the horizontal component of the magnetic field is parallel to the plane of the vertical coil carrying a current the compass will deflect in the direction of the vector sum of the fields.

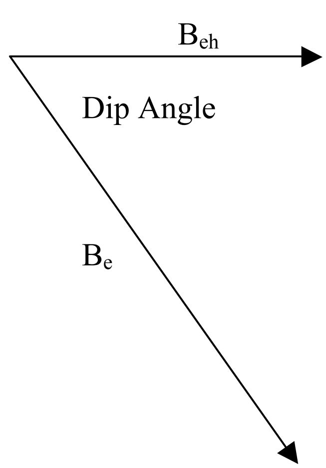
Placing the compass at the exact center of the coil and aligning the plane of the coil with the direction of point of the compass when no current is present will ensure the coil field is perpendicular to the earth field. When a current exists in the coil, the compass will be deflected through an angle θ, from the direction of the earth field. The ratio of the coil field to the horizontal component of the earth field will be the tangent of the angle of deflection. If the tangent is determined and the coil field is known, the horizontal component of the earth field may be calculated. Since varying the number of turns or the size of the current can vary the size of the coil field, the angle through which the compass is deflected will vary as well. If what has been explained here is valid, a plot of the current Vs the tangent of the angle will result in a straight line, the slope of which is $B_e R/(2\pi \times 10^{-7} N)$ where N is the number of coils which the current passes through and B_e is the horizontal component of the earth field.



$$\tan\theta = B_{coil}/B_{eh}$$

Once the tangent relation has been verified, the total magnetic field of the earth may be determined using a magnetic dip needle. This is nothing more than a compass that is free to turn in a vertical circle. Moving the dip needle to a region where only the earth field exists will mean that any deflection of the needle from horizontal will be due to the earth field. Aligning the plane of the compass in the direction of the horizontal component of the earth, the angle that the needle drops below the horizontal will indicate the direction of the total earth magnetic field. The total earth field may then be calculated from

$$B_E = B_{eh}/\cos(\text{Dip Angle})$$



PROCEDURE

1. Place the coil at the center of the table and as far as possible from any ferrous or other magnetic materials and electronic devices. Align the coil parallel to the earth's magnetic field by placing a compass at the exact center of the coil and then rotating the coil until the plane of the coil is parallel to the compass needle. Be as precise as you can. View the compass closely enough from directly above that your eyes see past the coil.

2. As in all of our experiments, set the Voltage control to ZERO on the power supply before connecting to anything or turning it on. Connect the DC power supply to the coil and use an ammeter to precisely measure the current passing through the coil. (DO NOT EXCEED 1 AMP!) For each value of current passing through the coil, measure the angle through which the compass has been deflected. Repeat the experiment three times recording three separate sets of data respectively for 5, 10, and finally all 15 turns of wire on the coil.

3. For each set of data, plot I vs tan θ graphically and establish a best fit line through the points. Determine the slope and intercept with linear least squares fit calculations as well as the regression coefficient. Display the linear equation and r on your graphs.

4. Using the slope of each best fit line (see discussion), determine the horizontal component of the earth's magnetic field. Average the three results and calculate the range of uncertainty due to random error alone.

5. Determine the angle (dip needle) that the full resultant earth field vector makes with its horizontal component, and use to determine the full magnitude of the resultant earth field at your location.

6. Assess the accuracy and precision of your result. (Refer to texts or online sources if necessary.) Does the numeric evidence support the existence of error sources that you might guess would be present?

DATA AND CALCULATIONS

		N=5			N=10			N=15	
Nominal Coil Current	Precise Coil Current	θ (Deg)	$\tan\theta$	Precise Coil Current	θ (Deg)	$\tan\theta$	Precise Coil Current	θ (Deg)	$\tan\theta$
0.1									
0.2									
0.3									
0.4									
0.5									
0.6									
0.7									
0.8									
0.9									
1									

NOTE: Do NOT exceed 1A in current nor 85° in angle θ. Stop taking data at 85°.

N=5: Slope of I versus $\tan\theta$ plot = _________ B_E (Horiz) = ___________

N=10: Slope of I versus $\tan\theta$ plot = _________ B_E (Horiz) = ___________

N=15: Slope of I versus $\tan\theta$ plot = _________ B_E (Horiz) = ___________

Ave B_E (Horiz) = ____________ +/-________

Magnetic Dip angle at apparatus = ___________

B_E (Total) for this area = ___________