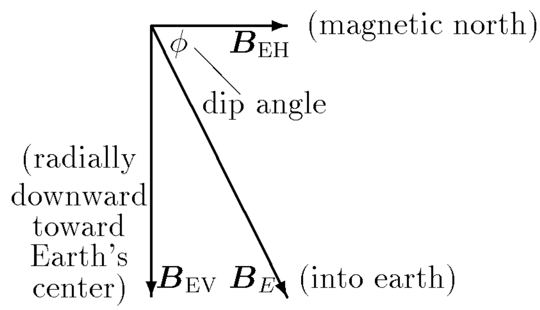
PHSX 222L Magnetic Field of the Earth Name:______________________

Object: To measure the magnetic field of the Earth.

Theory: The Earth's magnetic field resembles that of a huge bar magnet; however, the interior temperature of the Earth is above the Curie temperature for ferromagnetic materials and a bar magnet would lose its magnetism. The Earth's magnetic field must be related to motion or currents within its core.

Navigators have used the Earth's field for centuries. Compass needles are light bar magnets which align themselves with the Earth's field when they are free to rotate. By long tradition, the end of the compass needle which points north is called the north pole. But since opposite poles attract, it must be a magnetic south pole that is closest to the Earth's geographic north pole (the magnetic poles of the Earth do not coincide exactly with the geographic poles). The Earth's field varies from place to place and therefore must be determined experimentally. In general, the magnetic field lines $\boldsymbol{B}_{\mathrm{E}}$ enter the Earth's surface at an angle and so can be resolved into horizontal ($\boldsymbol{B}_{\mathrm{EH}}$) and vertical ($\boldsymbol{B}_{\mathrm{EV}}$) components, as shown in the following figure drawn in a vertical plane. The dip angle (ϕ) can be measured with a compass in such a vertical plane.

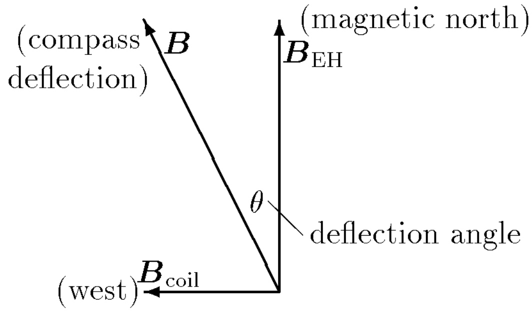


A tangent galvanometer can be used to measure small uniform magnetic fields such as the Earth's. It consists of N turns of wire around a ring of radius R in a vertical plane. If a current I is passed through the coil then a horizontal magnetic field is created at the center of the ring with magnitude

$$B_{\mathrm{coil}} = \frac{\mu_o N I}{2R}. \tag{1}$$

If the tangent galvanometer is oriented so the Earth's magnetic field vector is in the plane of the coil then the field created by the coil will be perpendicular to the Earth's field vector $\boldsymbol{B}_{\mathrm{E}}$ (and, obviously, its two components $\boldsymbol{B}_{\mathrm{EH}}$ and $\boldsymbol{B}_{\mathrm{EV}}$). Then the compass will point in the direction of the vector sum of $\boldsymbol{B}_{\mathrm{EH}}$ and $\boldsymbol{B}_{\mathrm{coil}}$, as shown in the following diagram which is drawn in a horizontal plane. From the diagram it is easy to see how the tangent galvanometer got its name.

$$B_{EH} = \frac{B_{\mathrm{coil}}}{\tan\theta}. \tag{2}$$



Experimental Apparatus: Draw the circuit including some details of the tangent galvanometer.

Procedure:

1. Hook up the tangent galvanometer (and an ammeter in series) to a low voltage, high current power supply. Also adjust the tangent galvanometer so the compass platform is level.
2. Orient the tangent galvanometer so the Earth's magnetic field vector is in the plane of the coil; then rotate the compass dial until the needle indicates north.
3. Note the compass needle deflection θ for various values of N and I, including an equal number of readings with the leads switched so I is negative (but remember not to go above the rated current of the supply or 6 A, whichever is less, in either direction).
4. Use a dip needle to measure ϕ.

Results and Data Plots:

1. Make a plot of $\tan\theta$ versus NI and determine B_{EH} from the least squares slope.
2. Use ϕ and B_{EH} to compute B_E.
3. How close did you come to accepted values for Ephraim? See the web for accepted values; try `<http://www.ngdc.noaa.gov/cgi-bin/seg/gmag/igrfpg.pl>` for pictures and a FAQ and `<http://www.ngdc.noaa.gov/cgi-bin/seg/gmag/fldsnth2.pl>` for the value of the field (and its components) at any location.

Questions:

1. Did the magnitude of the Earth's field surprise you?
2. How would this expermient vary at different latitudes?
3. What other ways could you measure the Earth's field?

Conclusions: What clever techniques did you use to reduce error?