Exercise 5: Magnetic field mapping

Purpose: to determine the magnetic fields surrounding bar magnets and the contours in the presence of Earth's magnetic field.

Introduction

A magnetic field exerts a torque on a compass needle such that the needle tends to align itself with the direction of the field. If the magnetic field is strong enough and additional non-magnetic forces (gravity, etc.) are negligible, then the compass needle points for all practical purposes in the direction of the field.

The end of your compass needle that points toward the magnetic pole of the Earth in the northern hemisphere (in the absence of all other sources of magnetic field) is by definition a N pole, or "north-seeking" pole. Therefore Earth's magnetic pole in northern Canada is actually an S pole, since the N pole of the compass points to it and unlike poles attract. The N pole of the compass needle points toward the S pole of your magnet. The magnetic poles of all magnets can thus be labeled by means of a compass and the definition of an N pole.

A bar magnet can be modeled (not the actual physical situation with all details, but a good approximation) by treating the N and S poles as individual magnetic poles with a flux from each pole exiting the bar magnet. The bar magnet will then be a dipole field with the sum of the magnetic fields from each pole, $\vec{B}_{\text{bar}} = \vec{B}_{\text{N}} + \vec{B}_{\text{S}}$. In terms of the magnitude of magnetic flux from the N and S poles Φ_{pole} leaving the bar magnet, the magnitude of the fields from each pole are given by

$$B_{\text{N}} = \frac{\Phi_{\text{pole}}}{4\pi r_N^2}$$

$$B_{\text{S}} = \frac{\Phi_{\text{pole}}}{4\pi r_S^2}$$

where the distances r_N and r_S are measured from the respective north and south poles on the bar magnet.

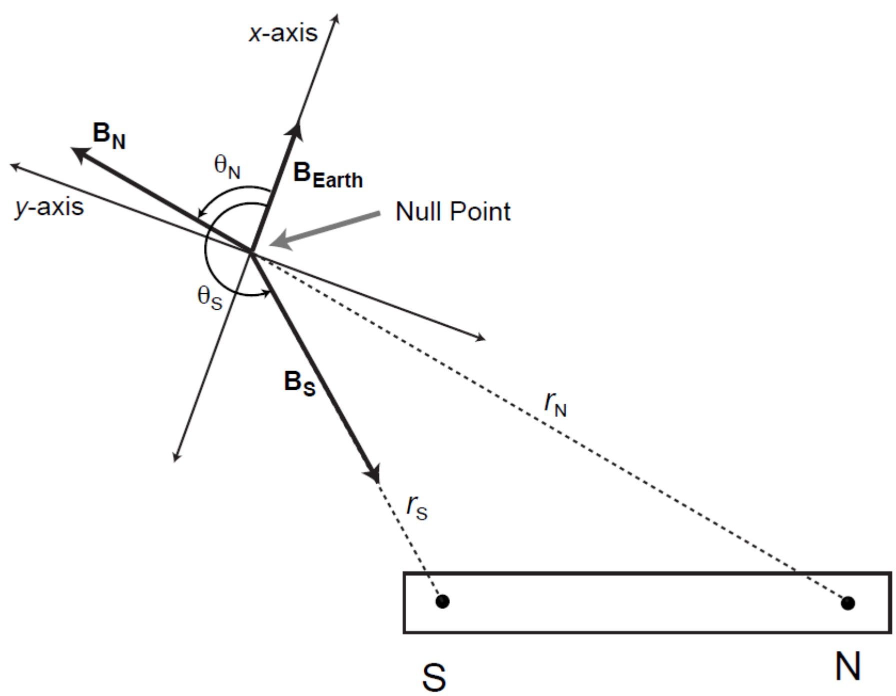
Laboratory assignment

1. Test your bar magnet with one of the compasses. If the poles are reversed on your bar magnet, or it is unusually weak, tell your instructor so that they may either remagnetize or replace it.
2. Tape a large sheet of paper to the table. Orient a bar magnet at the center of the sheet as directed by the instructor (different groups will be given different magnet alignments).
3. Carefully outline the bar magnet and mark the orientation of its magnetic poles on the sheet of paper with a nonmagnetic pencil.
4. You can start your map anywhere in principle, but try starting the first compass at a location about 10 cm from the center of the magnet. Other compasses can begin this process at the same time and at around the same distance, but in different directions from the center of the magnet.
5. Place the compass on your paper. Use a *nonmagnetic pencil* to put dots on the paper at the tip and tail of the arrow of the compass.

6. Move the compass (approximately one diameter) so that the tail of the arrow is at the point where the tip was previously. Put a dot at the location of the tip of the arrow. Repeat this procedure until you move off the edge of the paper or run into the magnet itself.
7. To complete the field line in the other direction go back to the initial position, but this time move the compass so that the tip of the arrow is where the tail was previously. This time put a dot at the location of the tail of the arrow and repeat.
8. Connect all the dots with a smooth curve, which constitutes one magnetic field line. Before proceeding put arrows on the line to indicate which way the magnetic field is pointing.
9. Place your magnet at a new location to begin another line, and follow steps 5-8 to create another magnetic field line. Continue making new magnetic field lines until the paper is filled in.

Analysis

10. (a) Are there any regions on the map that the field lines seem to avoid? (b) What is the magnetic field at these points? Explain your reasoning. (c) How many such points are there on your map?
11. Measure and record the distances from one null point to both poles to determine r_N and r_S.
12. Using your information about the magnetic fields from each pole and that the total field must be zero at the null point, $\vec{B}_N + \vec{B}_S + \vec{B}_{\text{Earth}} = 0$ with the Earth surface horizontal component in Hawaii being $B_{\text{Earth}} = 2.745 \times 10^{-5}\ \text{T}$, estimate the magnitude of the magnetic flux from one of the poles Φ_{pole}. (make sure you include information about the direction of each field as shown in the figure below when using this equation!)
13. Scan/photograph your electric field map.
14. Look at the magnetic field maps drawn by the other lab groups in your lab section. Each map has been made with the bar magnet in a different orientation. (a) Scan/photograph these other map configurations to include with your lab notes. (b) Do these other maps have any features in common with your map? (c) How do they differ from your map?



Equipment list: bar magnet, butcher paper, small compasses (4 per group).