Online laboratory assignment 5 – Magnetic field

Purpose: to study the magnetic field from a dipole magnet source.

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

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

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

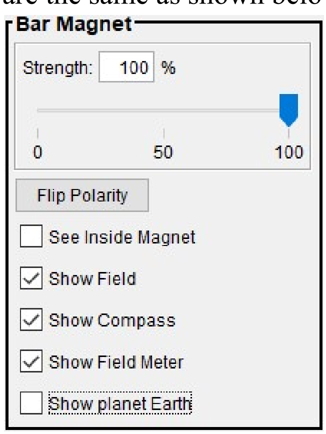
where the distances r_N and r_S are measured from the respective north and south poles on the bar magnet. The total magnetic field measured at a point in space from a dipole bar magnet follows as

$$\vec{B} \approx \vec{B}_N + \vec{B}_S$$

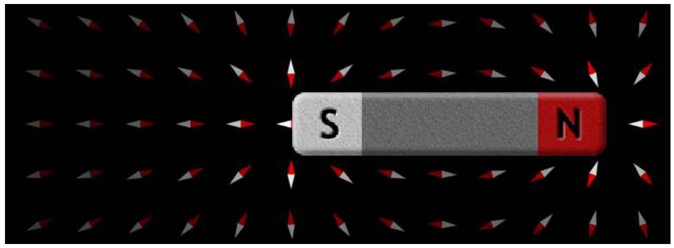
where the vector $\vec{B}_N$ points away from the north pole and the vector $\vec{B}_S$ points toward the south pole.

Laboratory assignment

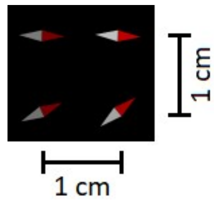
1. Run the "Magnet and compass" PhET simulation.
2. Adjust the settings so that they are the same as shown below.



3. Move the bar magnet so that it is near the right of the screen. Align the left edge of the bar magnet with the center of a small compass icon as shown below.



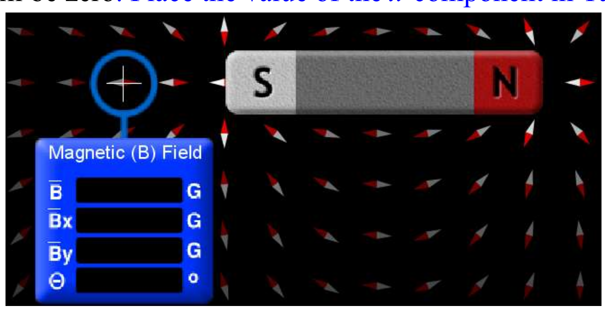
4. The compass icons are laid out in a square grid pattern. The distance between adjacent compass icons is 1 cm.



5. Estimate the length of the bar magnet to the nearest centimeter.

$L =$__________________.

6. Use the "Field Meter" to measure the magnetic field one centimeter to the left of the magnet's south pole as shown below. If measured horizontally away from the center of the bar magnet, then the y-component will be zero. Place the value of the x-component in Table I.



7. Continue to measure outwards to the left of the bar magnet in steps of centimeters. Fill in the rest of the x-component values for the B-field in Table I.

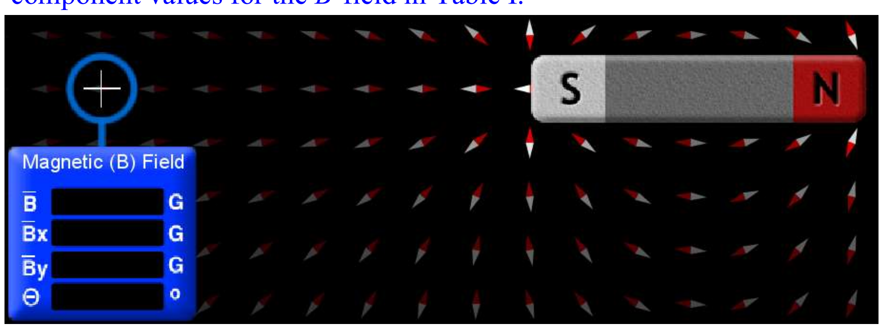
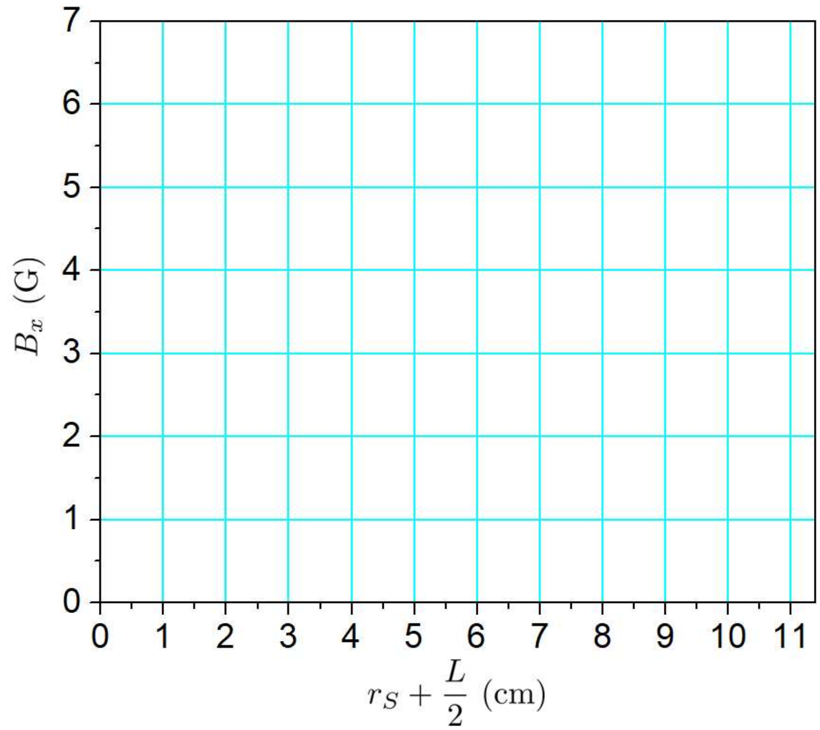


Table I: Magnetic field outside of a bar magnet.

r_S (cm)	2	3	4	5	6	7	8
B_x (G)							

8. The distance from the center of the bar magnet to the point at which the field was measured at the edge of the south pole is given by $|\vec{r}| = \left|\vec{r}_S + \frac{\vec{L}}{2}\right| = r_S + \frac{L}{2}$.

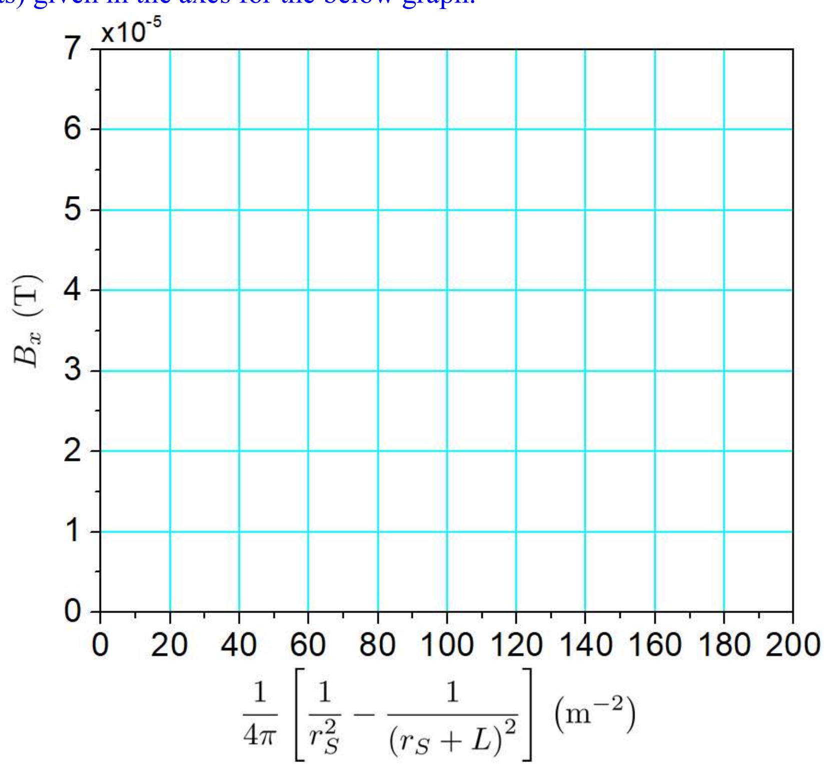
9. Plot the data from Table I in the below graph.



10. What type of curve is the above graph (linear, quadratic, exponential, inverse squared, etc.)?

    Type of curve: _________________________.

11. Knowing that 10^5 G = 1 T, convert the x-component of the magnetic field from Gauss to Tesla.
12. We also from our measurement and magnet geometry that $|\vec{r}_N| = |\vec{r}_S + \vec{L}| = r_S + L$. Plot the data (in SI units) given in the axes for the below graph.



13. Determine the magnetic flux and the uncertainty (use SI units) out of a single magnetic pole using the slope of the above graph in SI units.

Φ_{pole} =____________±_____________.

14. Write a conclusion to this laboratory assignment [the conclusion should also discuss the analogous relationship between electric dipoles and bar magnets as well as 2) the geometric relationship of fields known as Gauss's laws which is well-understood for gravitation, electricity, and magnetism].

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