Lab Four Report:

ENGR217-203

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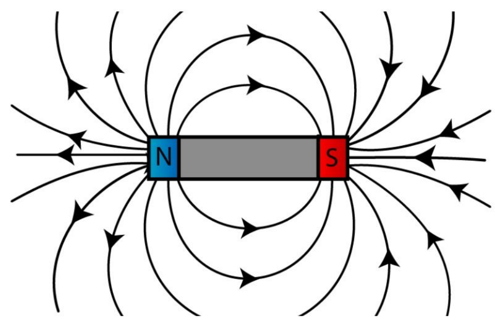
Abstract:

Magnetic field lines were discovered to travel from the north end of magnets towards the south. Different materials were observed in magnetic fields and it was discovered that aluminum does not interact with the field. Steel did however because it is ferromagnetic. Plots were generated for varying arrangements of magnets and materials to bring about these results. Earth magnetic field was also estimated, but the results did not turn out as expected. It was concluded that the CNC table had a magnetic field of its own interfering with the measurements taken.

Introduction:

This report exploring magnetic fields consists of several sections. First, the *Theory* section discusses Earth's magnetic field and how magnetic fields work. Next the equations used in this laboratory are lined out in the *Equations* section. The *Experimental Procedures* section lays out how the experiment was conducted. Finally, the *Results* and *Conclusion* sections discuss the data and summarize the lab.

Theory:



Magnetism is a force caused by moving charged particles and is closely associated with the electric field. While the force of magnetism deals with moving objects, some materials have properties that make them permanently magnetic, these materials are known as magnets.

Magnets create a magnetic field similar to an electric field, however, magnets are bipolar meaning the fields always diverge from a common point and converge back to a single point. Magnets must have a north and south pole, as shown in *equation 1* below. If the field always diverges to zero by Gauss's Law, then a mono pole can never exist The magnetic field's lines of force exit the magnet's north pole and enter through its south pole (*above).* At any point, the magnetic field lines exit perpendicular to the magnet. Some materials, like iron, are classified as ferromagnetic, which means that they are influenced by the magnetic field from a magnet and can be magnetised themselves. Other materials, like aluminium, are not ferromagnetic, and thus do not interact with magnetic fields.

The Earth produces a magnetic field. This is due to the iron in the Earth's metallic core. The strength of the force produced by the magnetic field is dependent upon location on Earth. Namely, the force is stronger at the poles and weaker at the equator, and ranges between 25 and 65 microteslas. The Earth's magnetic field interferes with all other generated magnetic fields, thus allowing for the estimation of Earth's magnetic field at a specific location. Equation 2 can be used to calculate the magnitude of a measured magnetic field if the indicuvadul x, y, and z components are known.

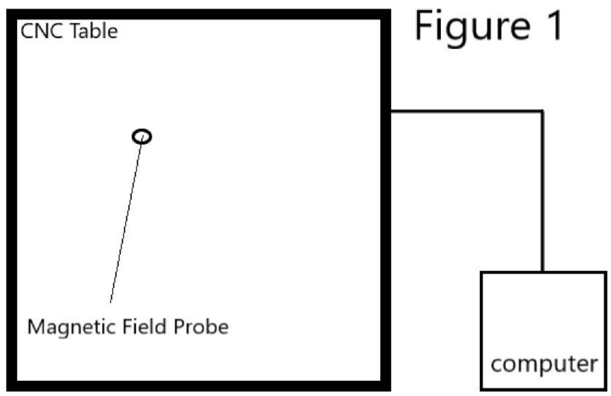
Equations:

1. $\nabla \cdot \mathbf{B} = 0$

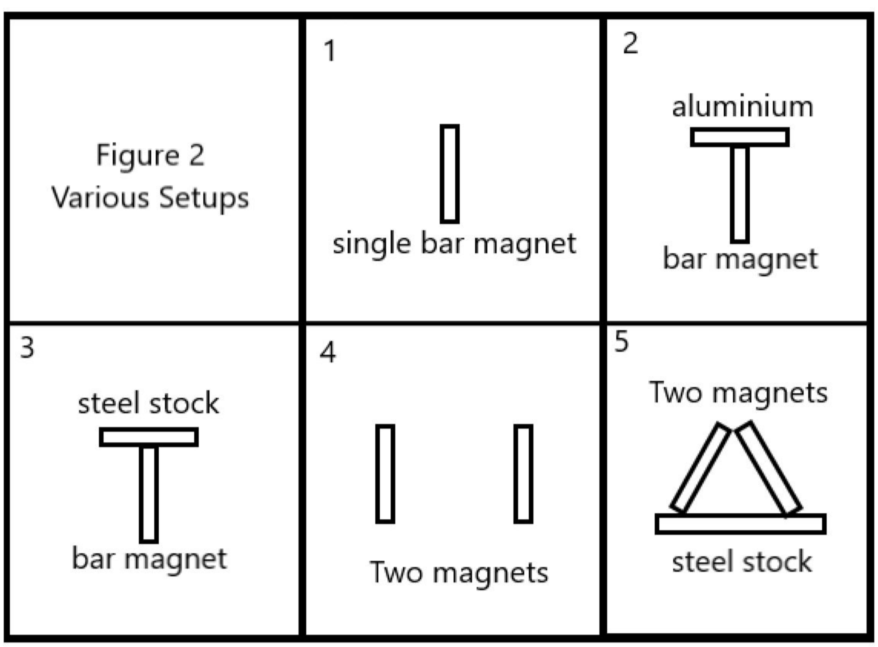
2. $\sqrt{x^2 + y^2 + z^2}$

Experimental Procedure:

To complete this lab, 6 total magnetic field plots had to be obtained. To do this, a magnetic field probe attached to the CNC arm was used. The arm was moved back and forth with software over various configurations of magnetic and nonmagnetic objects. To run this software the users computer had to be connected to the CNC table. First, Earth's magnetic field had to be measured. To do so, background subtraction had to be disabled in the python script. After this was disabled, the script was run with nothing on the table. The setup is shown below in Figure 1.



For the next 5 magnetic field plots, various configurations were used of magnets and different objects were used. These configurations are seen below. Within Figure 2.1 shows the single magnet configuration. Figure 2.2 shows the magnet with aluminum stock. Figure 2.3 shows the magnet with steel stock. Figure 2.4 shows two magnets separated by a distance. Figure 2.5 shows a configuration of our own choosing. Again, the script was run for each of these tables, outputting the magnetic field plots.



Results and Discussion:

Our first step was to run the magnetic sensor over the empty table to measure the magnitude of the Earth's magnetic field, for this trial, background subtraction was turned off to accurately measure the earth's field.. Figure 1 shows the vector field of the measured results. Contrary to the expected result, our field points towards the south which is the opposite direction of the magnetic north pole. Multiple trials produced the same results, so it was determined that there might be some configuration issue with the probe or a background source of magnetic field was present in our experiment.

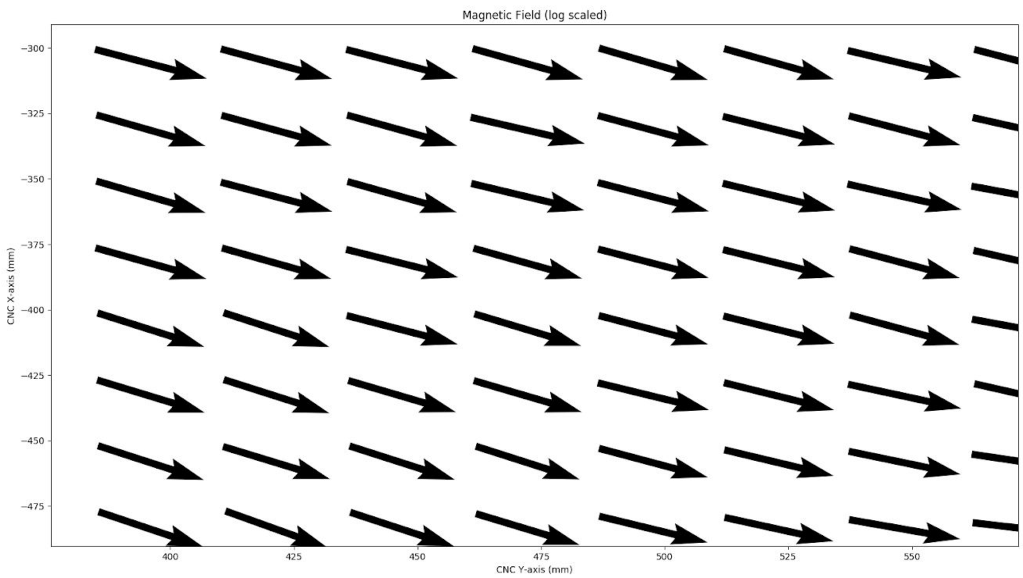


Fig. 1 Vector Field of Earth's Magnetic Field

To approximate the average magnetic field of the earth, the magnitude of each measurement was taken and all measurements were averaged together to get an approximate value using a python script. This value was calculated to be 486 microteslas, which is an order of magnitude larger than the surface level value of the Earth's field, which is measured to be between 25-65 microteslas. This could support the theory that some larger magnetic field was causing interference in our measurements, since both the direction and magnitude of our result produced unexpected results.

The next part of the lab included measuring the magnetic field around 5 different configurations of magnets and objects. For these trials, background subtraction was turned on to reduce interference from any outside sources.

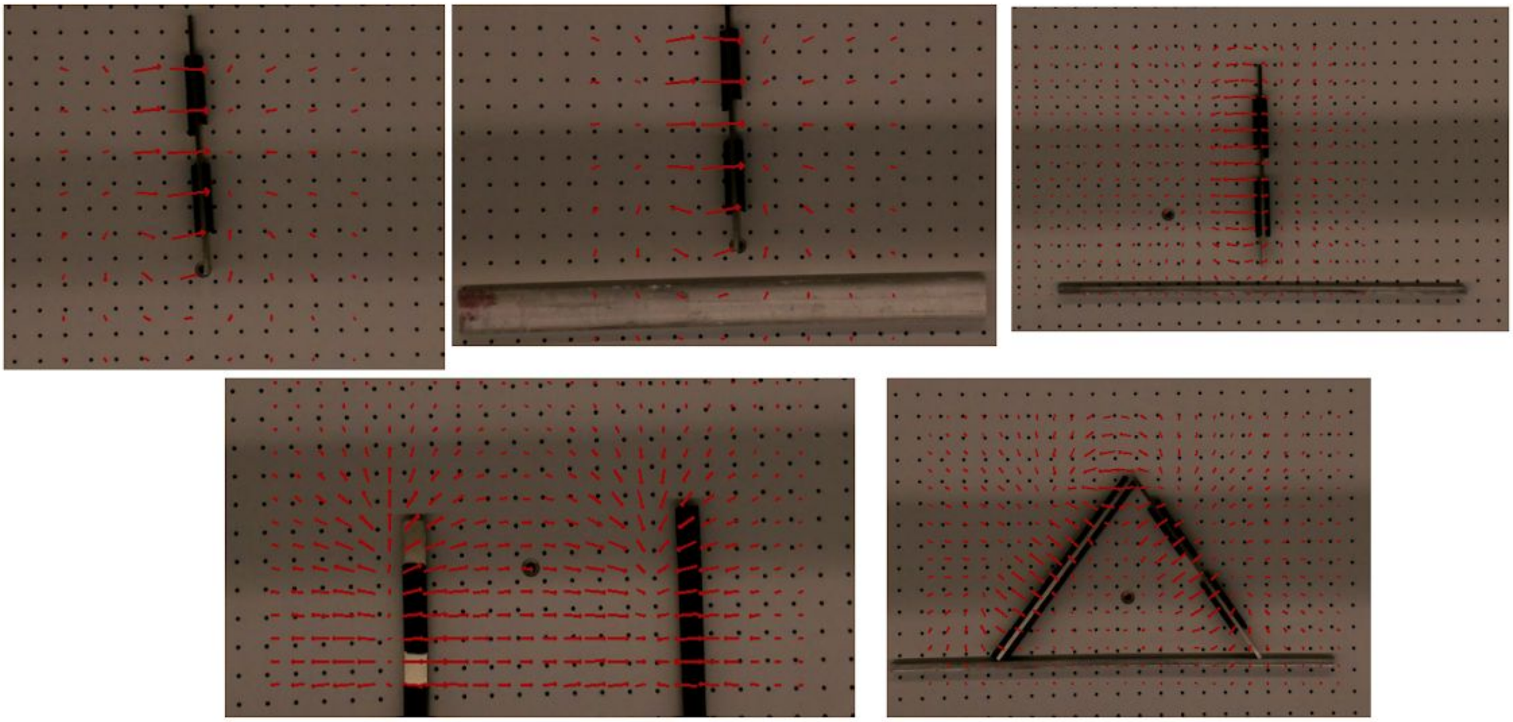


Fig. 2 Measured configurations of a bar magnet. Top Left: Single Magnet, Top Middle: Single magnet with aluminum stock, Top Right: Single magnet with steel stock, Bottom Left: Two magnets, Bottom Right: Arbitrary configuration with two magnets touching next to steel stock.

The single magnet correctly illustrates the behavior of a magnetic field. Field lines diverge from the magnet's north and converge towards the south. Since there are two magnets on this bar, each magnet has its own north and south pole, thus, two curls can be seen in the field. The configuration for the aluminium and steel stock trials have the same set up, but similar results. In the aluminum trial, the field lines simply pass through the stock and are not affected by the stock. In the steel trial, the steel seems to produce its own magnetic field, much smaller in magnitude than the magnet. Field lines appear to radiate from the two ends of the steel stock and merge into the lines from the bar magnet. These results are consistent with the theoretical prediction, since aluminium is not ferromagnetic and does not interact with a magnetic field, however, steel is magnetic, thus becomes magnetized whenever under the influence of a strong magnet. This is confirmed by our experimental results,

The last two trials show interactions with two magnets. Trial 4 is just the interaction of two magnets together, and shows the fields of the magnets converging together, from north of one magnet, to the south of the other. In trial 5, the magnets were angled to emphasize the converging of the magnetic field, shown by the curl of the field at the junction. A steel stock was also added in to show that the steel becomes magnetized within the field as well.

Conclusion:

The magnet field measurements all looked as expected, except for that of Earth. Field lines traveled from the north to south ends of magnets. Steel became polarized when subjected to a field because it is composed of iron. Aluminium did not because it is not ferromagnetic. Ferromagnetism is an inherent property of a material and likely deals with the crystalline structure of materials and how much freedom electrons have to align themselves with an external magnetic field. Earth's magnetic field did not look as expected, and it is hypothesised that there was a field interfering with it put off from the CNC machine. Whenever two or more magnetic sources were measured, their field lines converged to the larger field.