LAB 4: MAGNETIC FIELD

Texas A&M University
College Station, TX 77843, US.

Abstract: *"This lab report primarily covers the foundation of magnetic fields produced by magnets and its interaction with different metals. The components of a magnetic field from the magnet can be measured in three dimensions utilizing a hall effect probe. These dimensions are the X, Y, and Z planes that are used to determine its orientation. When placed next to the magnet, the student can utilize the same probe to measure the metals and its effect on the magnetic field."*
Keywords: *Poles, Magnetic Field, Metal, Magnetism*

1. Introduction

The purpose of the magnetic field lab is to understand the functions of a hall effect probe in order to analyze the magnetic field of a magnet along with determining the effect different metals have on the magnetic field. The hall effect probe will give the students data, which shows the dimensions of the field X, Y, and Z planes. analyzing the field vectors, shown in the skin of the magnetic field, can help determine the position of the magnetic poles. Knowing the orientation of the different metals, help in placing them next to the magnet to be scanned. Visualizing the data from the hall effect probe helps determine the effect of metals on the magnetic field. this is because the magnetic material influences the magnetic field while the non-magnetic material does not.

2. Experimental Procedure

A magnet, a hall effect sensor (attached to CNC), an aluminum bar, and a steel bar are the materials required to perform this experiment. In order to be able to reference the orientation of the magnets in the scans, they have been labeled. For every magnet, each end is labeled "top" and " bottom" and the sides are labeled " side A" and " side B". For any position the CNC brings, the hall effect sensor measures the magnetic field in X, Y, and Z directions.

In order to collect data, edit the script script 'run_magnet_scan.py' under *examples/scanning/* to fit the parameters of the lab. The parameters that need to be updated are 'FILE_NAME', which could be named anything the user wishes, 'PLOT_2D', which should be set to true. setting it to true means that the program produces a quiver plot of the magnetic field. 'X_CENTER' and 'Y_CENTER', are the other two parameters to be updated and should be set to the distance in millimeters from the home position of the CNC to the midpoint of the table, in this case, that's '390' and '480' respectively. Lastly, 'STEP_SIZE' should be set to '17', 'X_STEPS' and 'Y_STEPS' should be set to '12', and 'Z_STEPS' should be set to only '1'.

The magnet must be scanned in four different orientations in order to determine the north and south poles. In order to run the script for the first scan, the magnet is placed alone with the "side A" faced up and "top" at the top. A .csv file is then created which contains the X, Y, and Z components of the magnetic field for every scanning point and there is a vector plot to visualize this data. This is done repeated multiple times where the magnet is placed on different sides including 'Side A' facing the right, 'Side A' facing down, and 'Side A' facing the left. By convention, the magnetic fields flow from south to north, so the vector plot helps determine the poles based on how the field vectors are aligned in at least one of the orientations.

The second set of data collected is performed to represent how the magnetic field interacts with different materials. Prior to performing any scans, the magnet is slightly offset to the left of center and the position is marked on the table with the marker so there is consistency between the trials. The orientation must stay consistent as well where "Side A" is on the left and "Top" at the top. The aluminum bar is then placed with the ends against the middle of "side B" of the magnet. In 'run_magnetic_scan.py', some parameters must be edited such as, 'FILE_NAME', chosen by the user, 'STEP_SIZE', set to '14' and 'Y_STEPS', set to '18'. This produces a similar output to the first scan, with a .csv and plots.

This scan is then repeated for other configurations using a steel bar and also no bars. There are six output files and an additional three images where pictures of the real set up has magnetic field vectors superimposed on them.

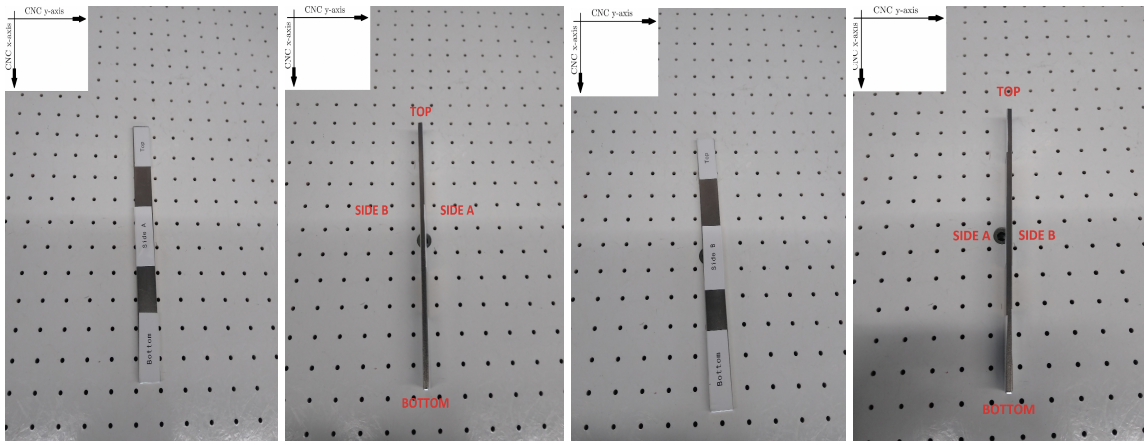


Figure 1: Setup of all orientations

3. Results and Analysis

For Magnetic fields

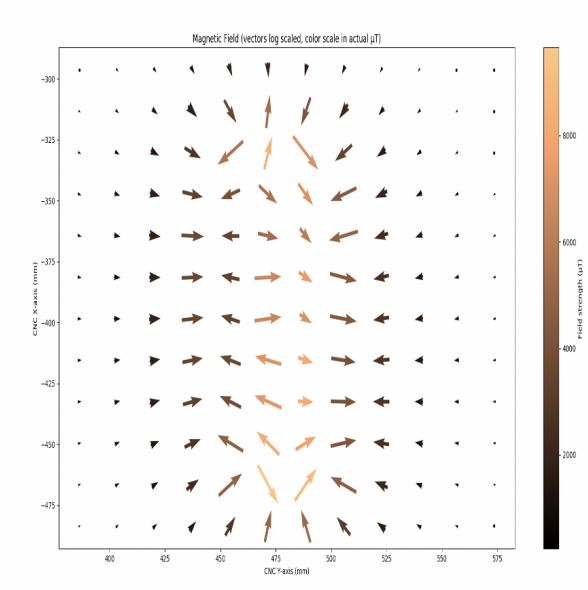


Figure 2: Plot for Orientation 1

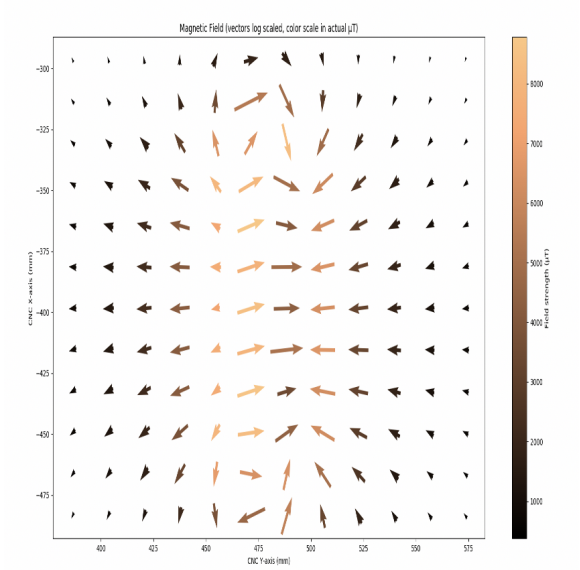


Figure 3: Plot for Orientation 2

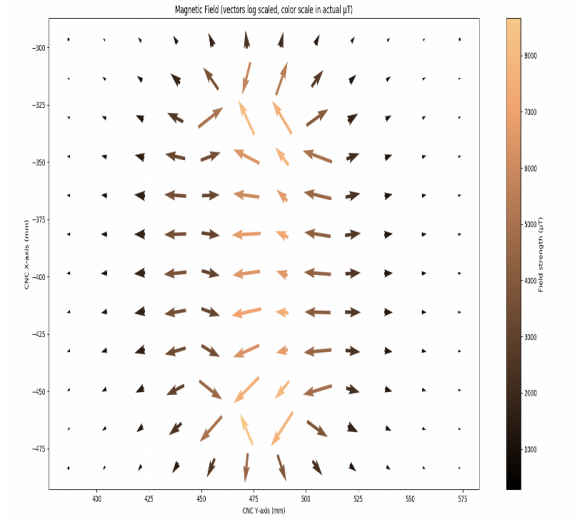


Figure 4: Plot for Orientation 3

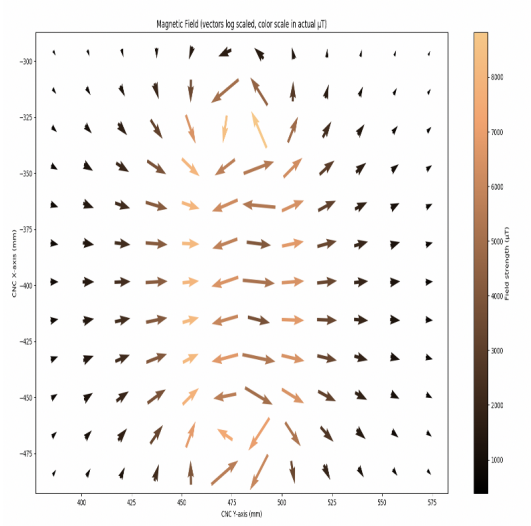


Figure 5: Plot for Orientation 4

The first four figures (2-5) are 2-dimensional magnetic field lines represented for each side of the magnet. Based on these plots, 'Side A' is the South pole because the magnetic field lines are going inwards, and 'Side B is the North pole because the magnetic field lines are going outwards. In orientation 2 represents the lines looping from 'Side A' to 'Side B', while orientation 3 represents a similar behavior but in the opposite direction.

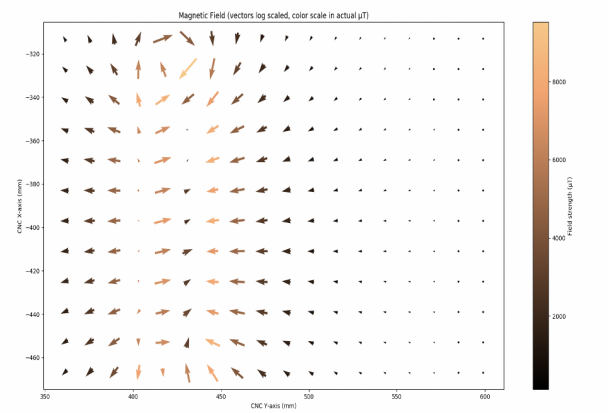


Figure 6: Magnetic Field - Aluminum Bar

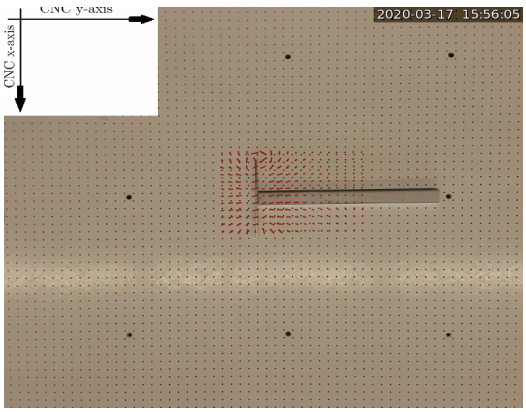


Figure 7: Aluminum Bar

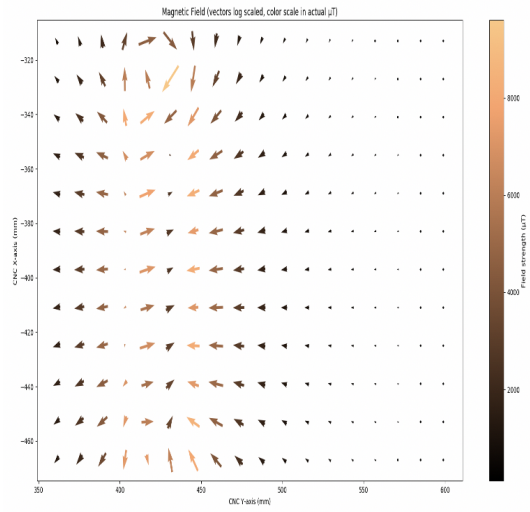


Figure 8: Magnetic Field - No Bar

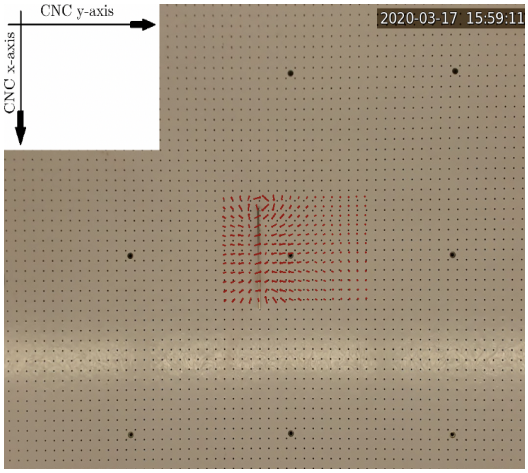


Figure 9: No Bar

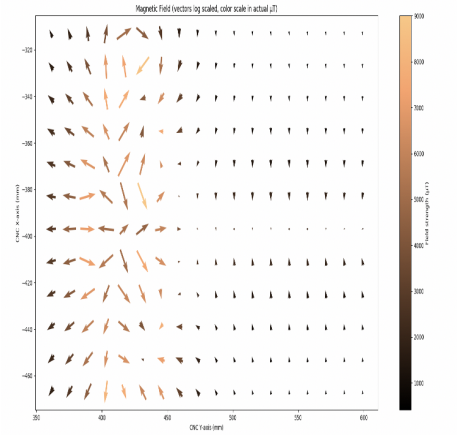


Figure 10: Magnetic Field - Steel Bar

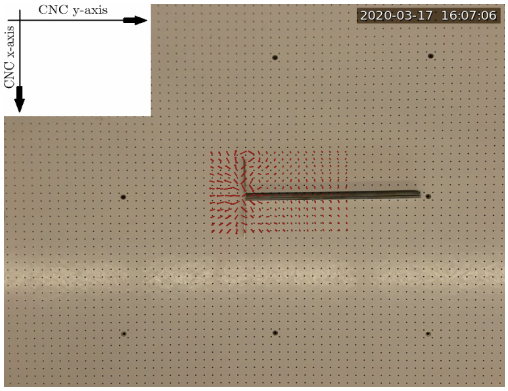


Figure 11: Steel Bar

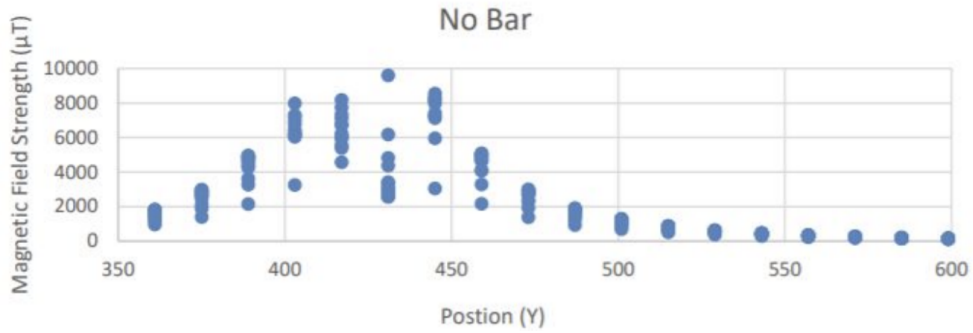
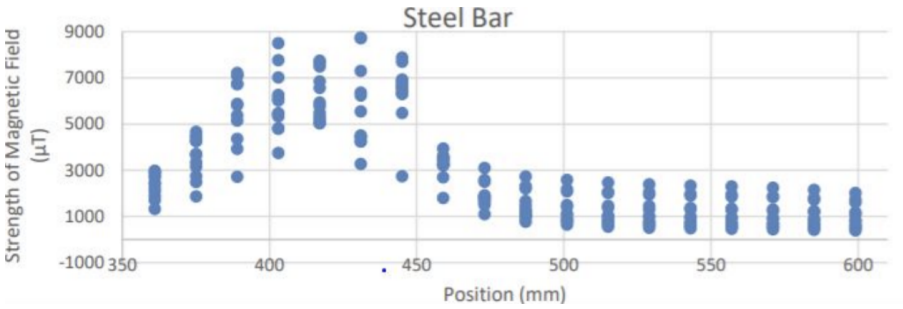
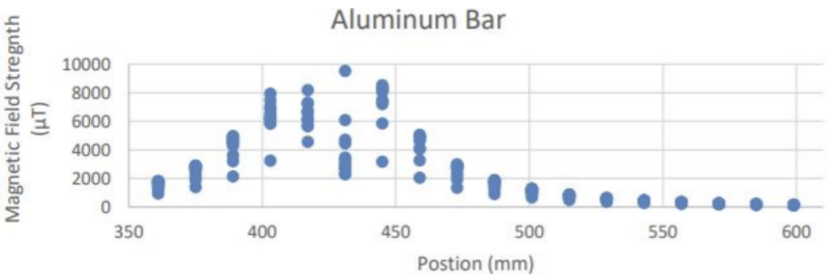


Figure 8 represents the natural behavior where the lines point from 'Side B' and wrap towards 'Side A'. Figure 9 shows the magnetic field on the physical setup to visualize the formation of field lines on the magnet.



In Figure 11, the steel bar temporarily replaced the magnet when it was in contact with the magnet. In Figure 10, 'Side B' connects with the steel bar which is indicated by the direction of the line arrows.



When an aluminum bar is perpendicular to 'Side A' the magnetic field doesn't change. Figures 7 and 8 means that aluminum is permeable to magnetic fields.

$$|B| = \sqrt{B_x^2 + B_y^2 + B_z^2}$$

Equation 1: This equation is utilized in order to calculate the magnitude of the magnetic field.

4. Conclusions

After the successful execution of the lab, the position of the magnetic poles was determined by analyzing the data, specifically looking for the components of the magnetic field. Electric field plots show that 'Side A' was the South pole and 'Side B' was the North pole. Magnetized material will impact the magnetic field whereas nonmagnetic material will not, and the aluminum and steel bar had no influence. Aluminum was nonmagnetic and permeable to magnetic fields, while steel only temporarily extends to the south pole, but isn't considered completely magnetic.