Lab 2: Numerical Solution of Magnetostatic Problems

ELEC 3105 A – A5

Name: Youssef Ibrahim

1.0 INTRODUCTION

The purpose of this lab is to use finite-element program Maxwell to analyze two basic magnetic structures: A Magnetic Dipole, and A Solenoid.

2.0 PROBLEM 1: A MAGNETIC DIPOLE

2.1 Sketch the shape of the magnetic field lines

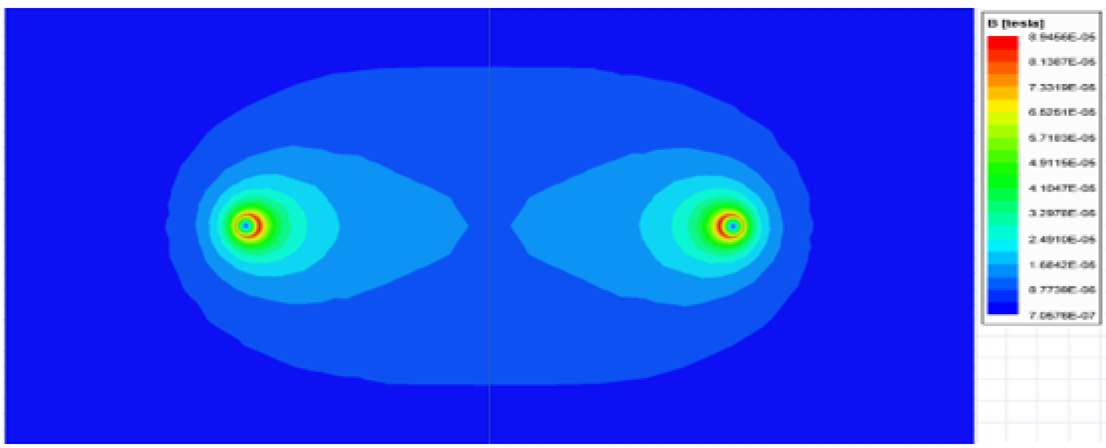

Figure 2.1: Magnetic Field Lines of the Magnetic Dipole in Problem 1

2.2 Plot the magnitude of B along the z-axis at r = x = 0

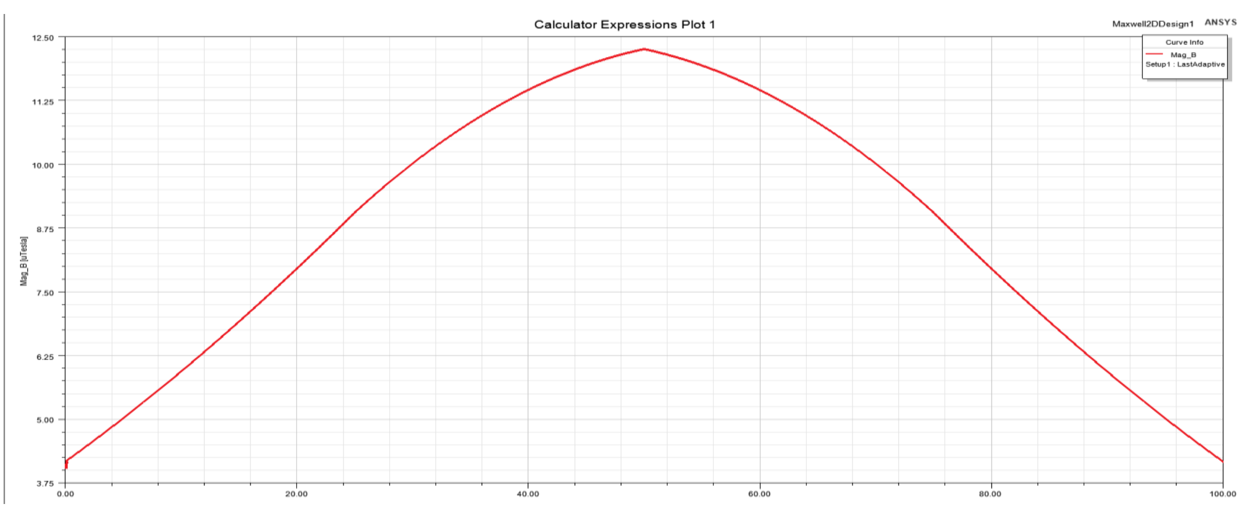

Figure 2.2: Magnitude of B of the Magnetic Dipole in Problem 1 along the z-axis at r = x = 0

2.3 Plot the magnitude of B as a function of radius r at z = a

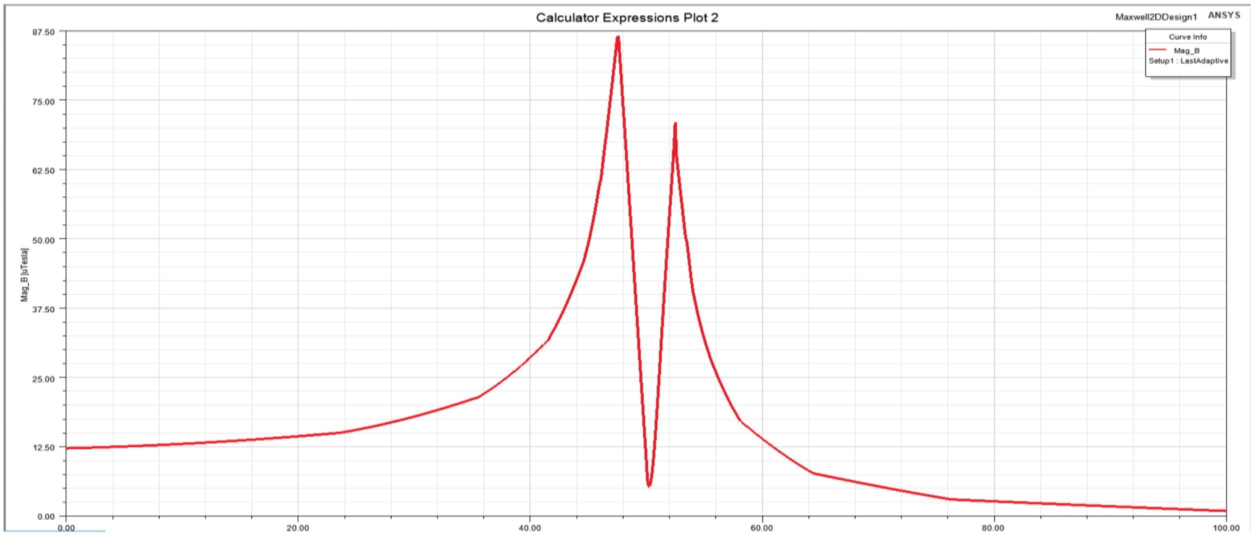

Figure 2.3: Magnitude of B of the Magnetic Dipole in Problem 1 as a function of radius r at z = a

2.4 Compare your results with those for the ideal magnetic dipole. What is the strength of the magnetic dipole?

The maximum magnitude of B along the z-axis at r = x = 0 is 1.225 x 10^{-5} Tesla. The maximum magnitude of B as a function of radius r at z = a is 8.75 x 10^{-5} Tesla.

The maximum magnitude of B as a function of radius r at z = a is greater than the maximum magnitude of B along the z-axis at r = x = 0 because when r = x = 0 the z-axis is further from the circle and when the distance increases, the magnetic field strength decreases. The peak magnitude of B along the z-axis at r = x = 0 is at z = a, as it is the nearest point to the circle on z-axis.

3.0 PROBLEM 2A: SOLENOID WITH AIR CORE

3.1 Sketch the shape of magnetic field lines in your lab book

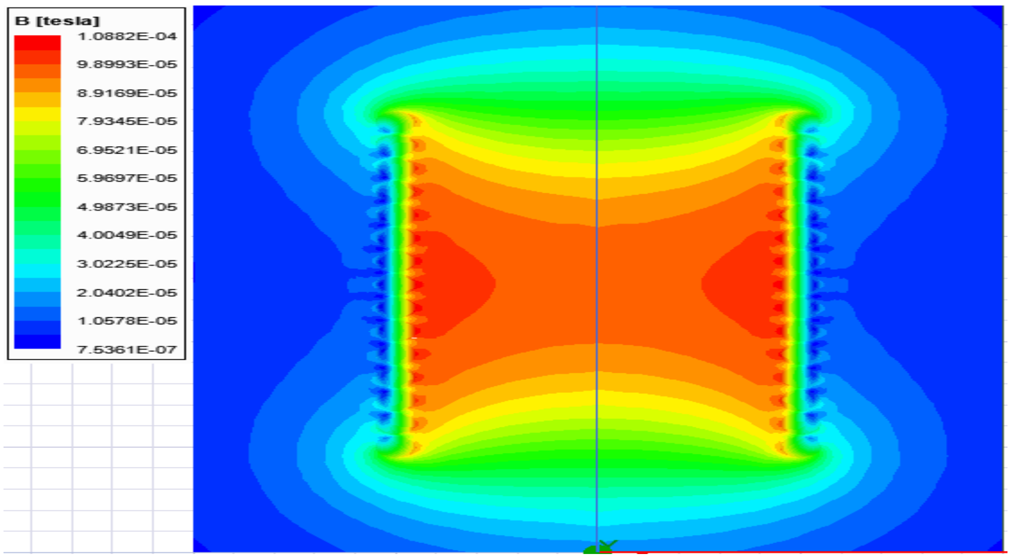

Figure 3.1: Magnetic Field Lines of the Solenoid with Air Core in Problem 2A

3.2 Plot the magnitude of B along the z-axis using the steps described in section 3.10

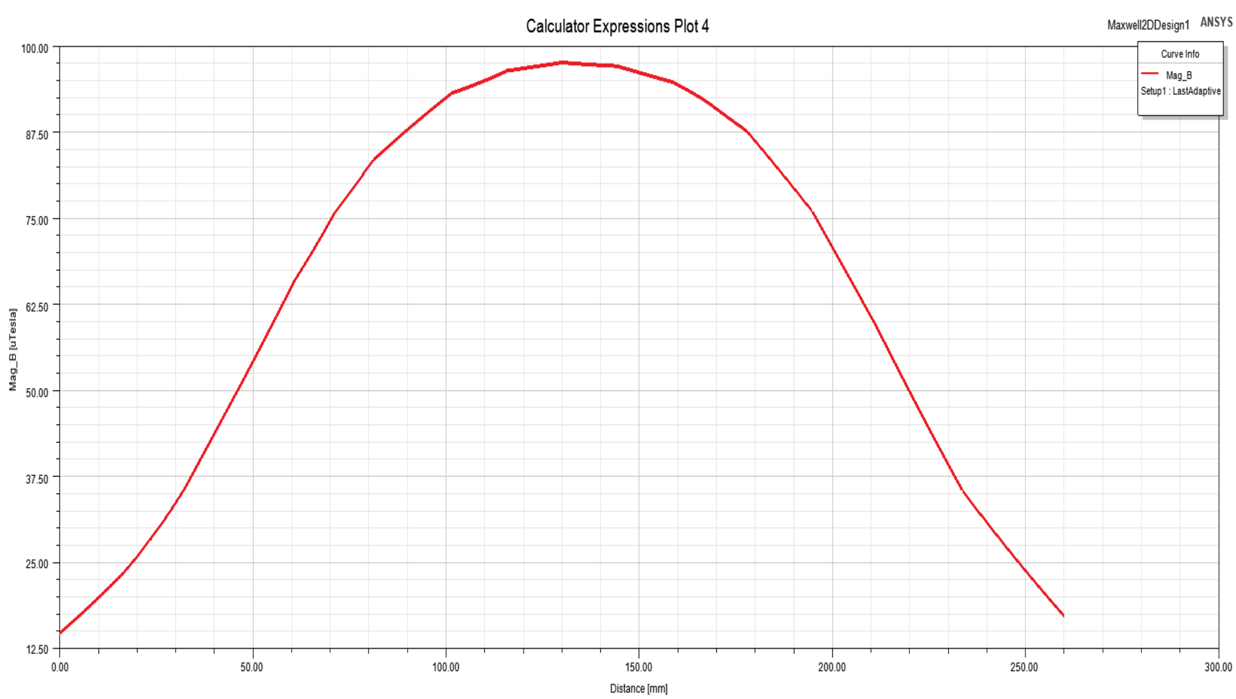

Figure 3.2: Magnitude B of the Solenoid with Air Core in Problem 2A along z-axis

3.3 Plot the magnitude of B as a function of radius at z = 12.7cm using the steps described in section 3.10

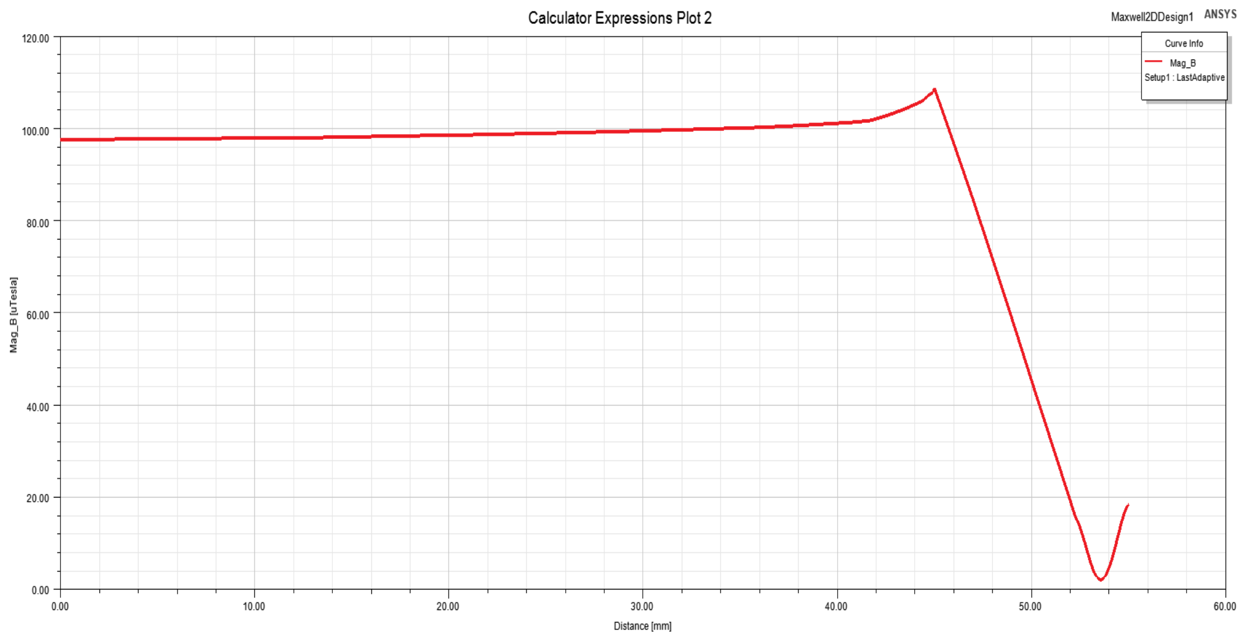

Figure 3.3: Magnitude B of the Solenoid with Air Core in Problem 2A as a function of radius at z = 12.7cm

3.4 Perform a surface plot of Mag_B and the B vector

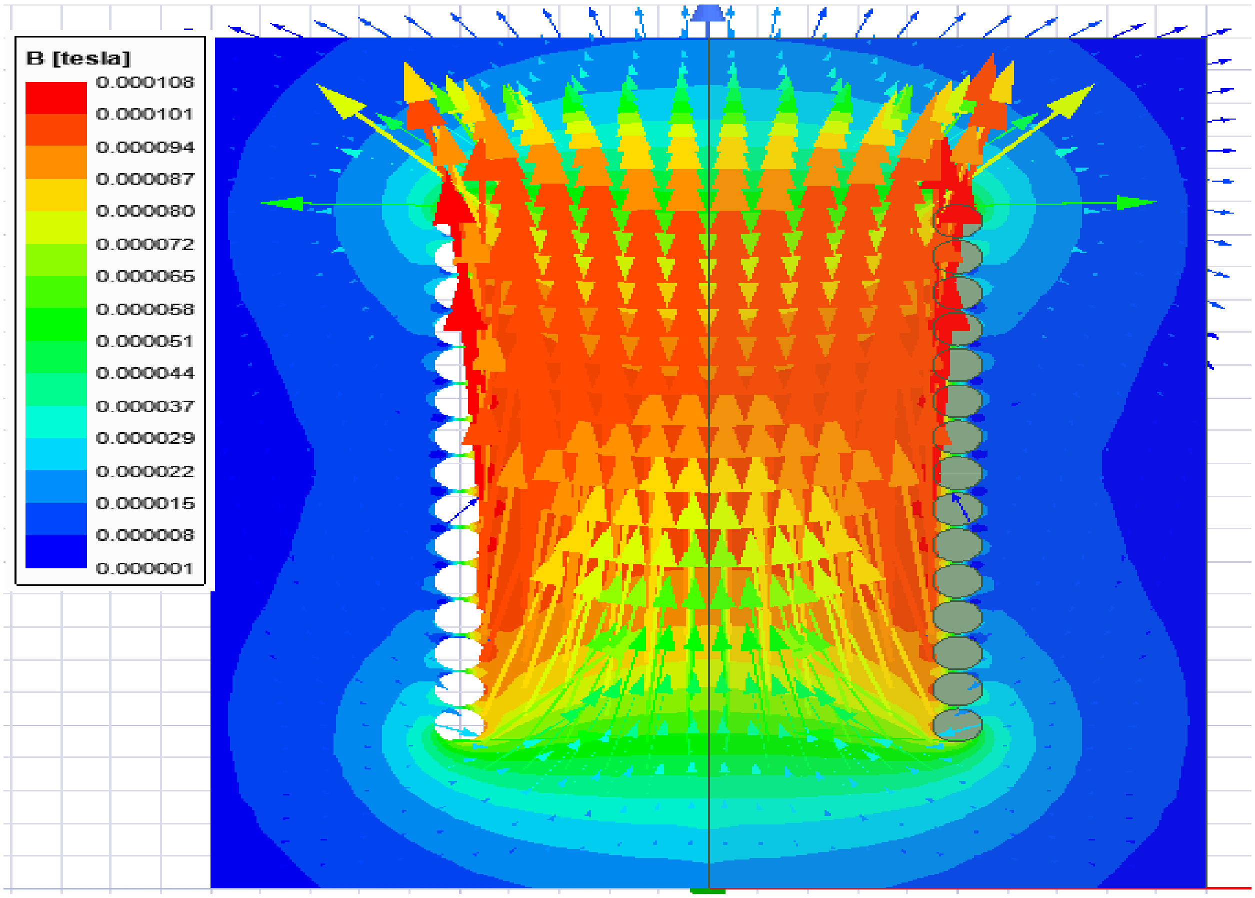

Figure 3.4: Surface plot of Mag_B and the B vector of the Solenoid with Air Core in Problem 2A

3.5 Compare your results at the center of the solenoid and at the ends of the solenoid with those for the ideal solenoid having, an air core

$B_{center} = 9.4 \times 10^{-5}$ Tesla; $B_{end} = 5.1 \times 10^{-5}$ Tesla

The magnetic field at the end of the ideal solenoid having an air core is lower than that in the center because there is nothing at the end of the solenoid, hence going upwards will reduce the magnetic field strength.

4.0 PROBLEM 2B: SOLENOID WITH MAGNETIC CORE

4.1 Sketch the shape of the magnetic field lines. What changes do you observe in the magnetic field lines when you use a magnetic core instead of an air core?

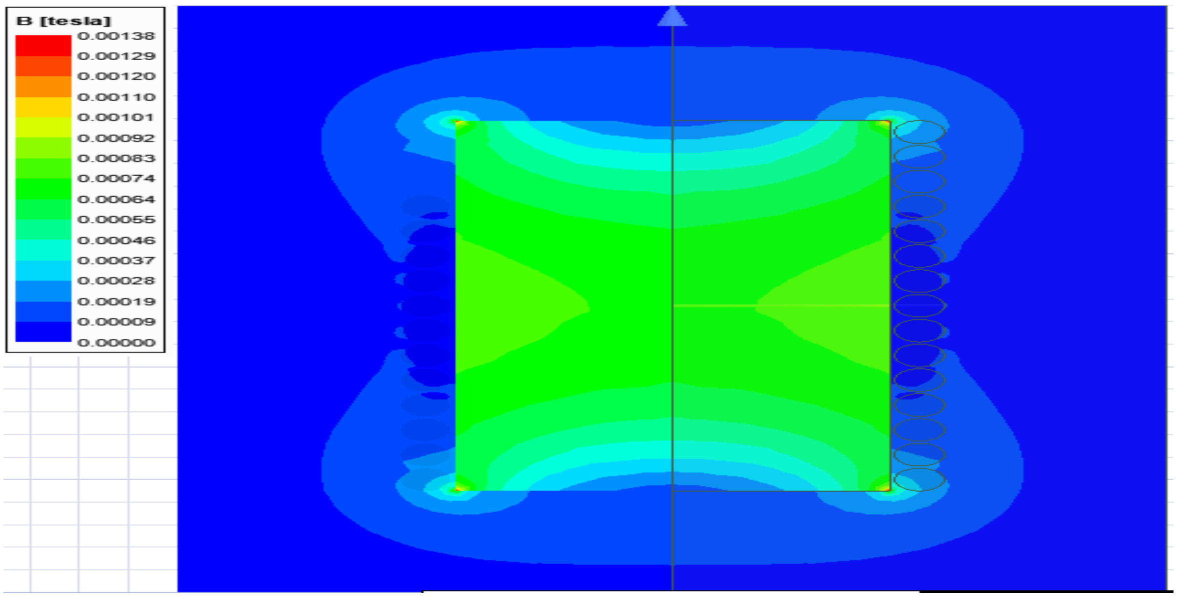

Figure 4.1: Magnetic Field Lines of the Solenoid with Magnetic Core in Problem 2B

The changes I observe in the magnetic field lines when a magnetic core is used instead of air core, is that using a magnetic core causes the magnetic field to be uniform through the solenoid.

4.2 Plot the magnitude of B along the z-axis using the steps described in section 3.10

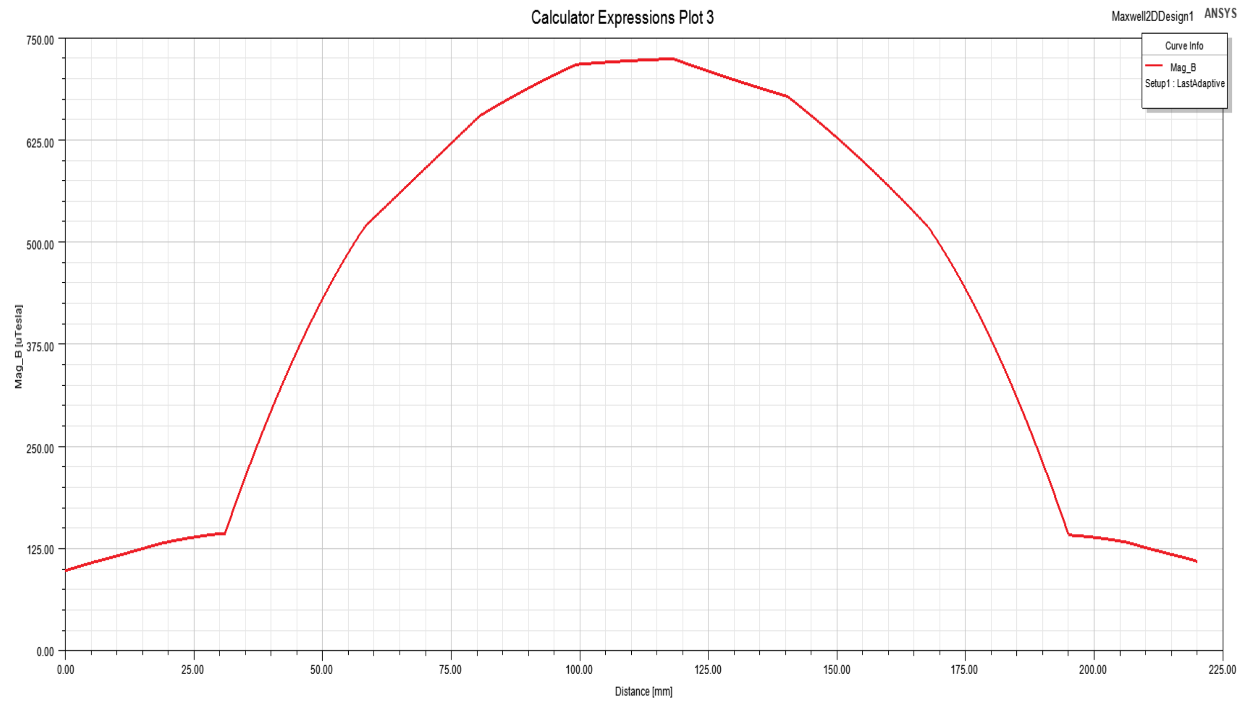

Figure 4.2: Magnitude B of the Solenoid with Magnetic Core in Problem 2B along z-axis

4.3 Plot the magnitude of B as a function of radius r at z = 12.7cm using the steps described in section 3.10

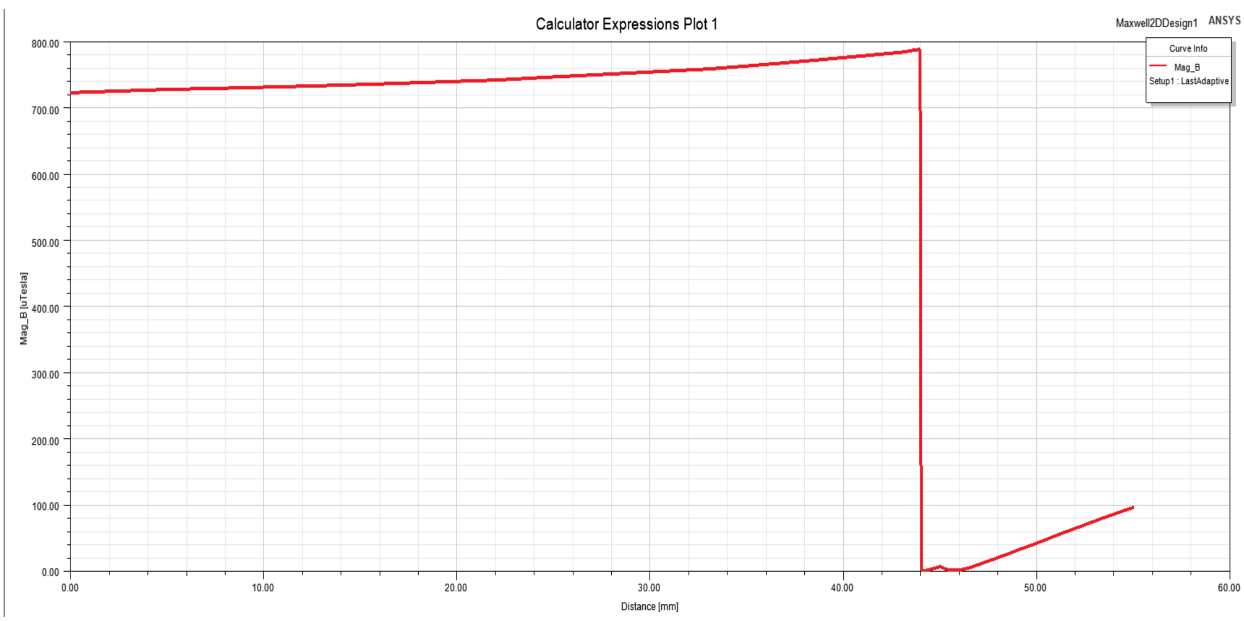

Figure 4.3: Magnitude B of Solenoid with Magnetic Core in Problem 2B as a function of radius r at z=12.7cm

4.4 Perform a surface plot of Mag_B and the B vector

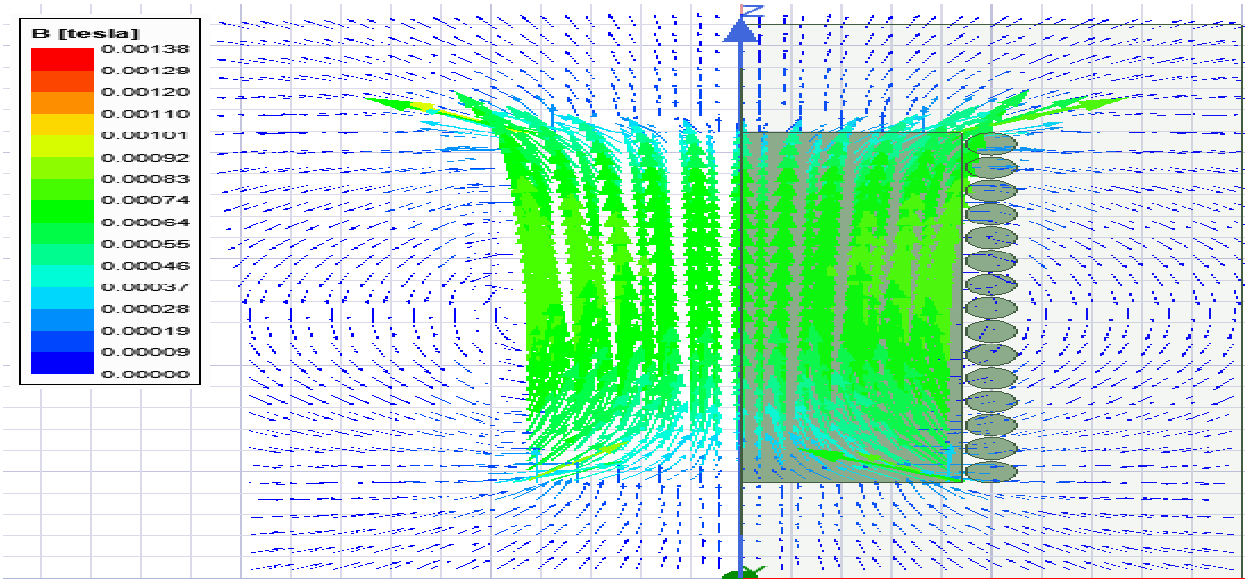

Figure 4.4: Surface plot of Mag_B and the B vector of the Solenoid with Magnetic Core in Problem 2B

4.5 Compare your results at the center of the solenoid and at the ends of the solenoid with those for the ideal solenoid having an iron core

The magnetic field of solenoid with air core is less than the magnetic field of solenoid with iron core. The ideal solenoid having an iron core magnetic field at center is same as that found in the end of solenoid because the magnetic field is uniform throughout the solenoid's iron core, hence the position would not alter the magnetic field.

5.0 PROBLEM 3: HELMHOLTZ COIL

5.1 Draw and plot the magnetic field along the four dotted lines shown in the figure. The top and bottom of the lines should line up with the outer edges of the circle cross-sections. Plot these on the same 2D plot

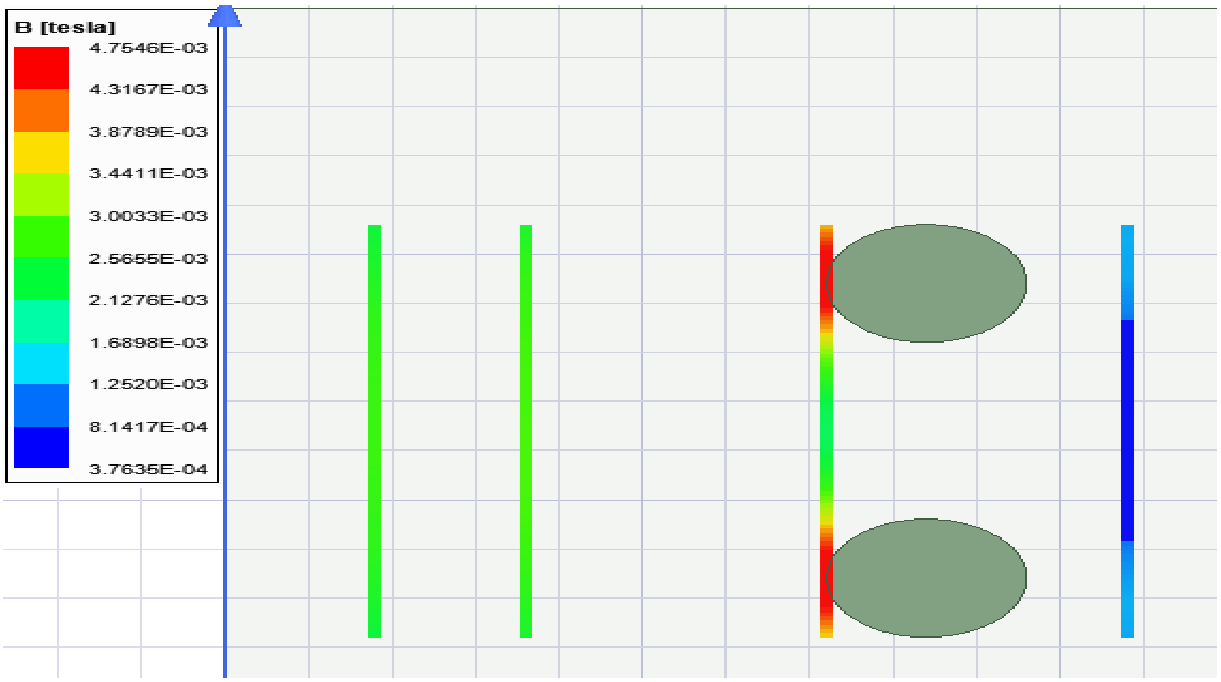

Figure 5.1: Magnetic Field Lines Along Four Dotted Lines

5.2 Perform a surface plot of Mag_B and the B vector

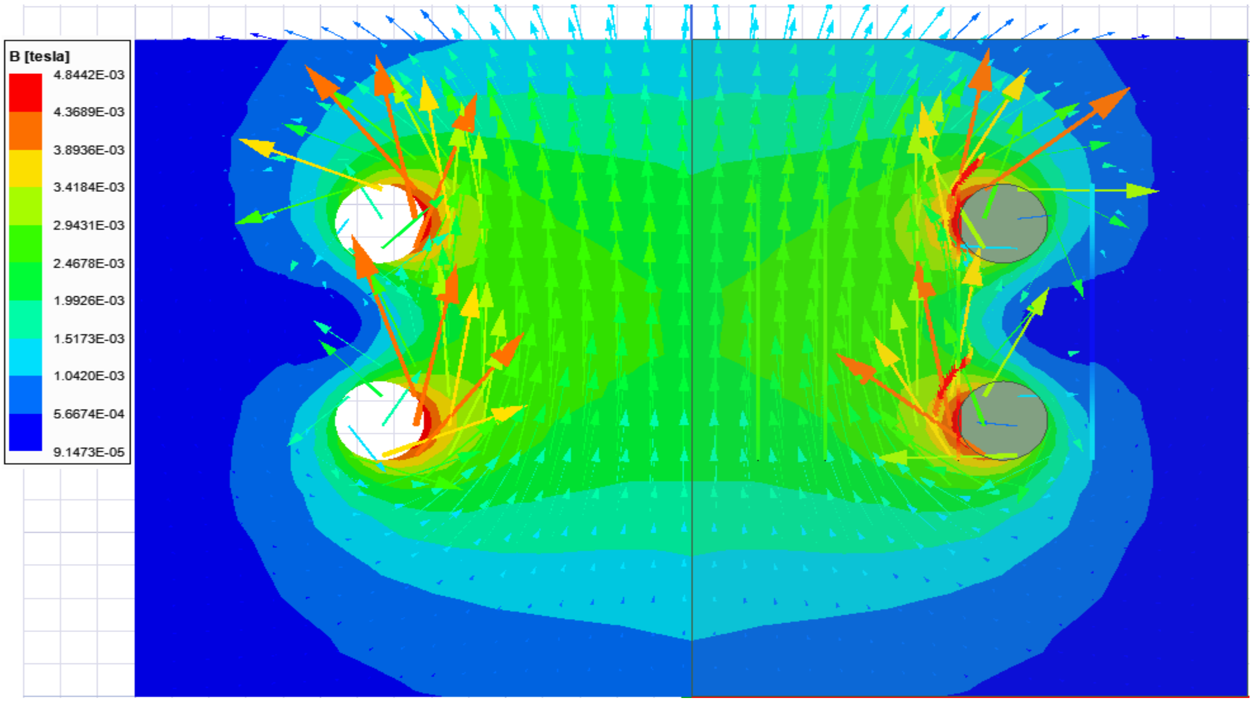

Figure 5.2: Surface Plot of Mag_B and the B vector of the Helmholtz Coil in Problem 3

5.3 Seen in the following graph is how the relationship between the separation and the magnetic field should look for any given position. Note that your results may look different but the general shape should be similar. Plots from 1) and 2) should correspond to the red and blue lines in the graph below. Additionally, the plots 3) and 4) would look similar to the green line in the graph below. They may not exactly match but the shapes should be similar. Explain why the relative magnitudes of the lines in your graph differ from those in the one below?

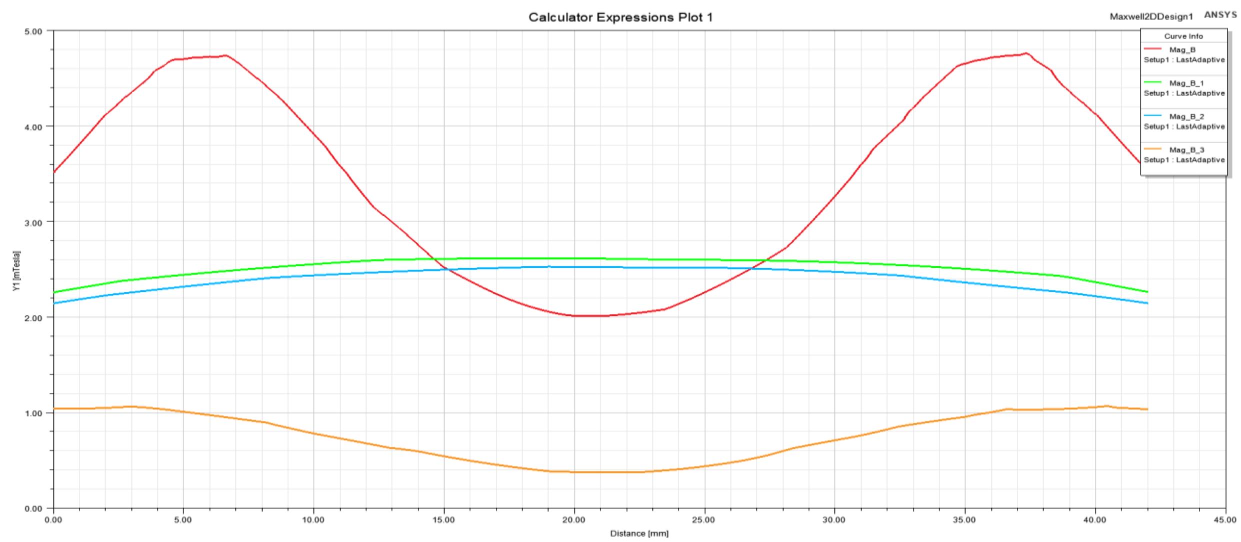

Figure 5.3: Magnitude of the Magnetic Field of the Four Dotted Lines

Line 9 and line 18 which are represented by blue and green dotted lines are in the region inside the coil hence they should have a relatively similar magnitude, but line 18 will have a slightly greater magnitude since it is nearer to the circles.

Line 54 (Orange) is outside of the region of the coil wrapped around, which causes very little magnetic field to be reached to it, having its two highest points of magnetic field at the points that is closest to the circles.

Line 36 (Red) magnetic field peaked at two points where the line was touching the circles.

The reason why the magnitudes of the lines found in my plot differ from the graph given can be anticipated to the distance between the lines and the two circles.

6.0 CONCLUSION

In conclusion, ANSYS software is a great way to analyze magnetic structures to provide a better visualization and understanding of concepts.