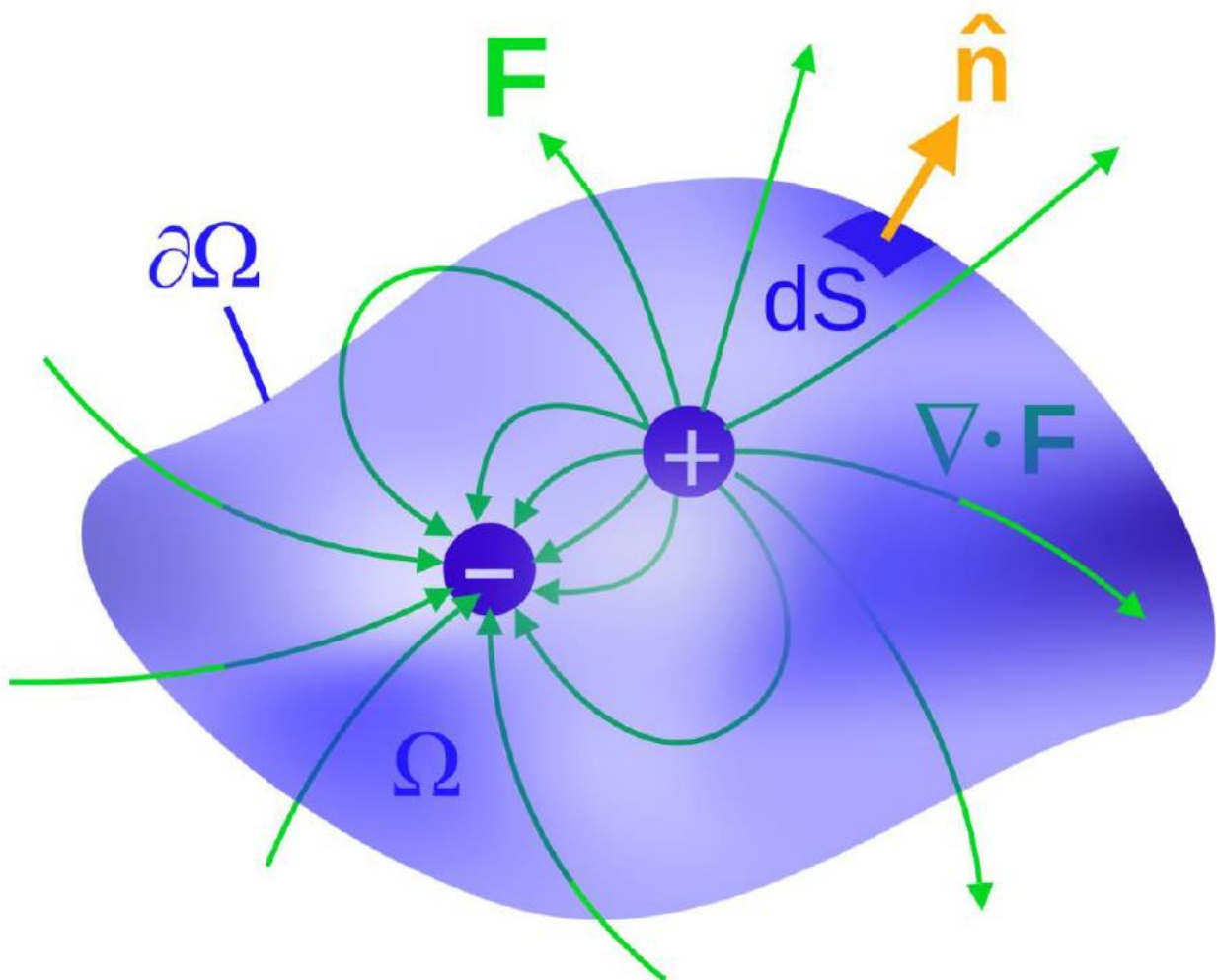# Lab 2: Numerical Solution of Magnetostatic Problems

Carleton University, Department of Electronics

ELEC 3105 Laboratory Exercise 2

Updated ANSYS Lab

Lab 2: Numerical Solution of Magnetostatic Problems

ELEC 3105

Updated ANSYS Lab

1. Before You Start

- You will need to obtain an account on the VLSI network if you do not already have one from another course
- Please refer to Lab 0: Orientation to ANSYS for remote login procedure
- You can work alone or with a partner
- You can discuss the lab with peers but the lab reports are to contain only individual work
- Show units in all calculations, all graphs require a legend.
- Plots can be made in Maxwell and added into reports as screenshots

2. Objectives

In this lab you will use the finite-element program Maxwell to analyze two basic magnetic structures: **1. a magnetic dipole** and **2. a solenoid.**

The lab will run **on the VLSI server Eli (access instructions in Lab 0)**. The software package we will use is **ANSYS Electronics Desktop - Maxwell 2D/3D Solver** from **Ansys Corporation**. This software will enable you to visualize the electric fields and the voltage equipotential in cross sections of structures consisting of conductors and insulators.

3. Running ANSYS Maxwell 2D

Note: It is always a good idea to regularly save your projects to prevent losing progress. If the instructions below are not clear for you, research what you are trying to accomplish on the internet to try and find a solution. Please read this section before performing the steps.

1. Start the **ANSYS Electronics Desktop** program and select **Project**, then **Insert Maxwell 2D Design**.
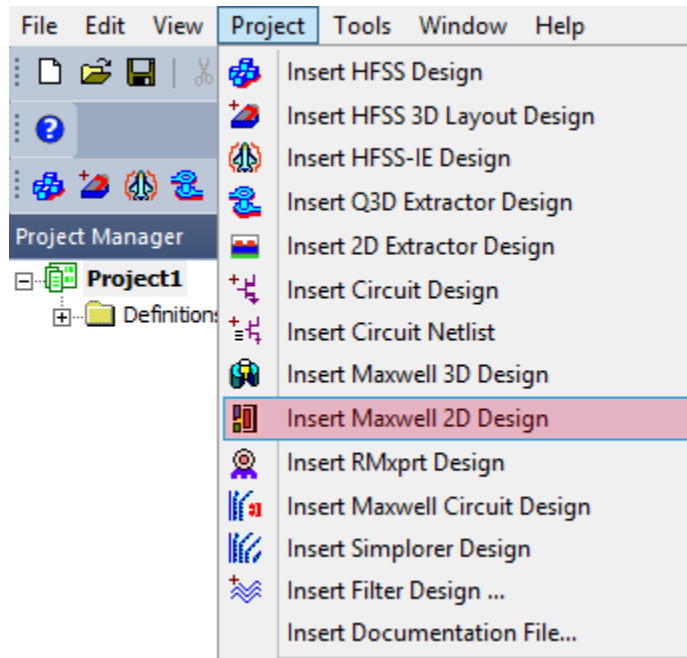

Now, select the **Maxwell 2D** menu option and click on **Solution type**.
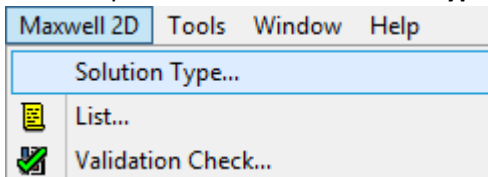

In the window that opens, **select the required solution type**, for **lab #1 it is Electrostatic**, for **lab #2 it is Magnetostatic**. For lab #2, set the set the geometry mode to **Cylindrical about Z**. **Click OK** once you select the correct option for you.

2. In order to plot 2D results, draw a line after the project is analyzed. (If there is a popup **click yes**). You can then plot values along the distance of this line by right clicking on **Results** from within the **Project Manager pane** and choose **Create Fields Report** then select **Rectangular plot**.

In the window that opens, select the line you want to plot data along in the **Geometry** option. Set the category as **Calculator Expressions**, and choose the quantity you want to plot. Leave Function set to **<none>**. Click on **New Report** to plot. You may change these settings and click **Add trace** to plot another value on the same plot.
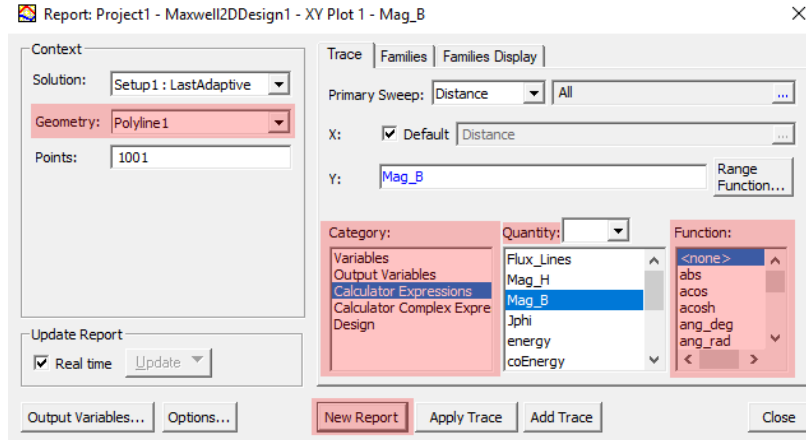
Below is an example plot for values **Mag_B** and **Mag_H** along a line.
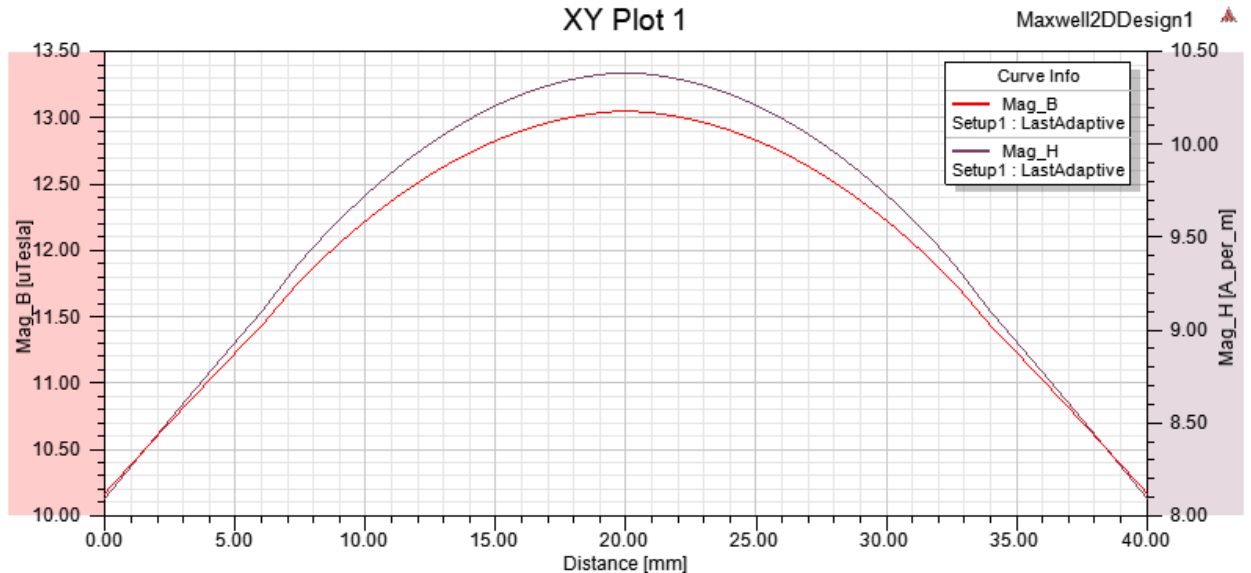
3. Explore the **Project Manager** pane as it contains lots of useful information. You can modify field overlays by **right clicking on Field Overlays** and clicking on **Modify Plot Attributes**. This is useful for changing the resolution, color, and scale of the legend. You may also see your excitations and boundaries along with other parameters. If you right click on one of your plot reports within the **Results** tree, you may edit your 2D plots by clicking **Modify Report**. Explore the **Properties** pane for useful settings too. You can rename shapes that you have created to custom names for easier identification if needed.

    This brief tutorial on using the ANSYS Maxwell Solver should be enough to get you started, there is plenty of documentation available on the internet as well as built into the program itself.

4   Problem 1: A Magnetic Dipole

A wire of cross-sectional diameter "**d**" and radius "**a**" is located in the XY-plane (i.e. it rotates around the z-axis). The wire carries current I. The structure is shown in Figure 1. As d becomes infinitesimally small, this structure becomes a structure known as the "magnetic dipole".

Use diameter d = 5 mm, and radius a = 50 mm away from the z-axis (or V). The material of the loop is copper and everything around it is air or vacuum. To draw the model, use the Circle. The current supplied to the loop is 1 Amp. (So, one circle with 1 A away from the z axis by 50 mm and the program will rotate it to model the loop.) The center of the circle should be at Z = 50mm.

How to plot the graph along lines:

(a) magnetic dipole.   (b) magnetic dipole 2D model
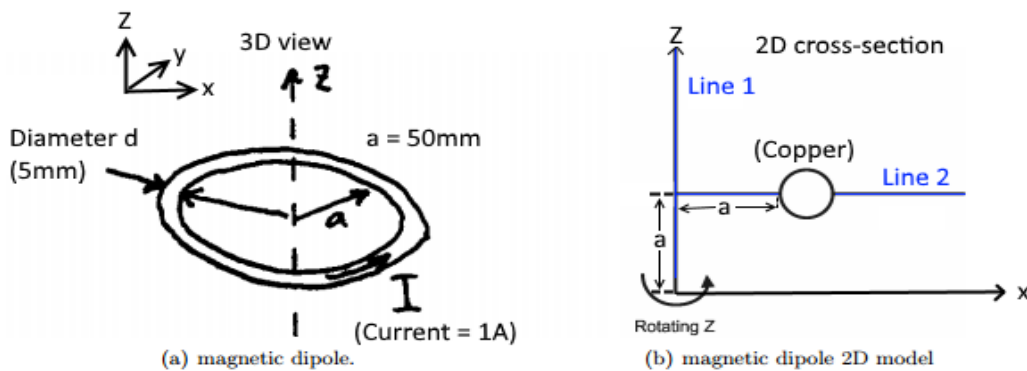
1) Add **line 1** and **line 2** as shown in the figure. You will make 2D line plots for values of the magnetic field at each point along these lines.

2) Plot the value **Mag_B** over each of these lines. Follow the instructions located earlier in this document in order to do this.

3) Perform a surface plot of Mag_B and the B vector.

Answer the following questions in your lab report:

1) Sketch the shape of the magnetic field lines. **1 mark**

2) Plot the magnitude of B along the z-axis at r = x = 0 **1 mark**

3) Plot the magnitude of B as a function of radius r at z = a. **1 mark**

4) Compare your results with those for the ideal magnetic dipole. What is the strength of the magnetic dipole?
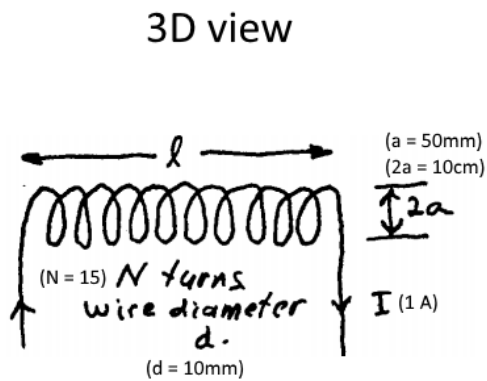   You should compare magnitude and direction of B field in your simulation with the theoretical equation, and explain **2 marks**

$$B_{fafield} = \frac{\mu_o Ia^2 \left(2\cos(\theta)\hat{r} + \sin(\theta)\hat{\theta}\right)}{4r^3} \tag{1}$$
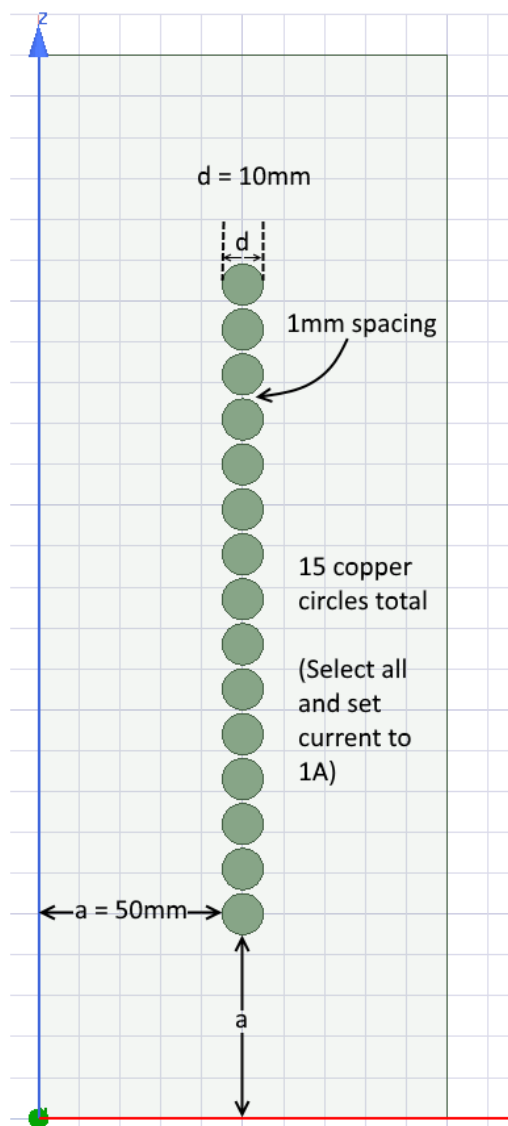
For further details related to this problem see your textbook.

5   Problem 2: The Solenoid

This problem models a solenoid consisting of a helix of radius a and length *l* tightly wound with N turns of insulated wire carrying current I, as a stack of N loops similar to the loop used in Problem 1. Each loop has a cross-sectional diameter d =10 mm and radius a = 50 mm. Use N = 15 loops so that *l* ≈ 15d = 150 mm. Use a current 1 Amp for each loop. The set of loops are to be centered along z axis, that is a distance a = 50 mm away. When drawing use a 1mm spacing between each circle. The end result should look as shown below.

2D view (approximation)

3D view

(a = 50mm)
(2a = 10cm)

2a

(N = 15) N turns
wire diameter
d.
(d = 10mm)

I (1 A)

d = 10mm

d

1mm spacing

15 copper
circles total

(Select all
and set
current to
1A)

a = 50mm

a

5.A   Solenoid with air core

First draw the bottom circle then select it and open the right click menu: edit, duplicate, along line in order to make 15 cross-sections total. Afterwards select them all and set the current excitation to 1A, and the material to copper. The boundary rectangle should be set to air.

Answer the following questions in your lab report:

1) Sketch   the   shape   of   the   magnetic   field   lines   in   your   lab   book.   **1   mark**
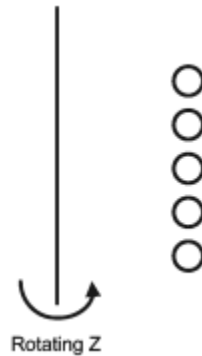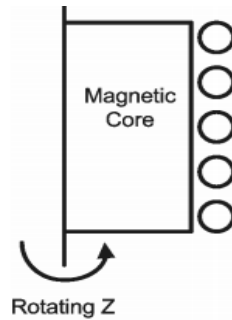

Rotating Z

2) Plot the magnitude of B along the z-axis using the steps described in section 3.10. **1 mark**

3) Plot the magnitude of B as a function of radius r at z = 12.7cm using the steps described in section 3.10. **1 mark**

4) Perform a surface plot of Mag_B and the B vector. **1 mark**

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. Calculate the theoretical B magnitudes at the center and ends, and compare with respective simulated values from the plots. Explain any discrepancies **2 marks**

$$B_{z_1 center} = \frac{\mu_o NI}{\sqrt{4a^2 + l^2}} \tag{2}$$

$$B_{z_1 end} = \frac{\mu_o NI}{2\sqrt{a^2 + l^2}} \tag{3}$$

5.B   Solenoid with magnetic core

Add a magnetic core rectangle made of **iron.** Leave a 1mm gap between the iron core and copper cross-sections. Make sure the top and bottom edges of the core are aligned with the top and bottom edges of the top most and bottom most circles, as shown in the figure below.

Answer the following questions in your lab report:

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? **1 mark**

2) Plot the magnitude of B along the z-axis using the steps described in section 3.10. **1 mark**

3) Plot the magnitude of B as a function of radius r at z = 12.7cm using the steps described in section 3.10. **1 mark**

4) Perform a surface plot of Mag_B and the B vector. **1 mark**

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.

Use the same equations as in Problem 2A.5), but replace μ_0 with $k\mu_0$,where k is the relative permeability of the iron

2 marks

6   Helmholtz Coil

Follow the steps in Problem 1, while taking into account the following modifications:

Draw geometry to look like the figure below. The radius of each circle should be 6 mm. Select both circle cross-sections and **set the current to 100A**. (In 3D they are actually two loops, forming a Helmholtz Coil.)
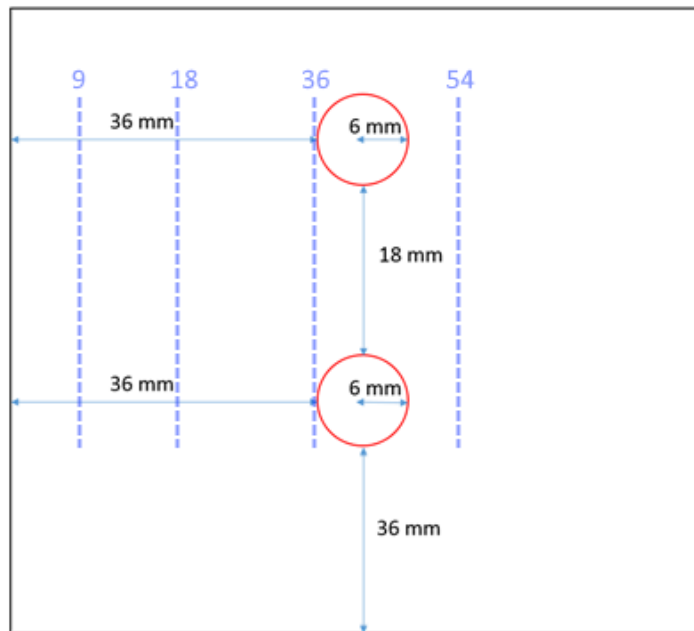
1) Draw and plot the magnetic field along the four dotted lines shown in the figure. The top and bottom of the lines should line up with the outer edges of the circle cross-sections. Plot these on the same 2D plot. **2 marks**

2) Perform a surface plot of Mag_B and the B vector. **1 mark**

3) Seen in the following graph (next page) 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 from 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? Focus on explaining the similarities between your simulated plots and the plot below. Explain what are your plots of Mag_B showing and why do they look similar to the plot below? **2 marks**
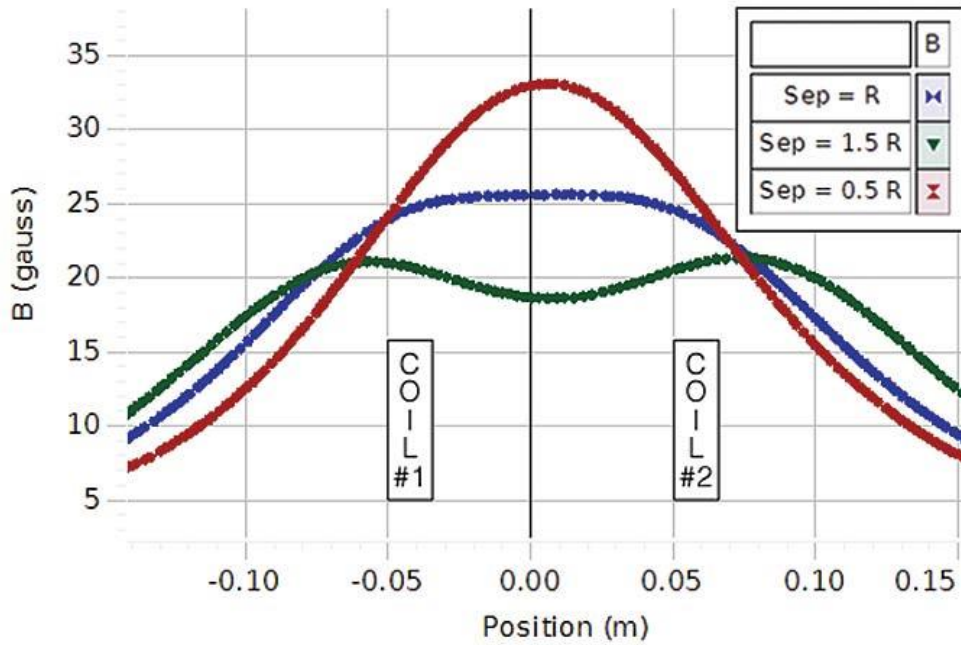
Helmholtz Coil

(http://www.pascocanada.com/images/products/ex/EX5540_screenshot_XLG_130313.jpg)