Electrical and Computer Engineering
ECE3712 Electromagnetic Fields and Waves

MATLAB Project on Magnetostatics

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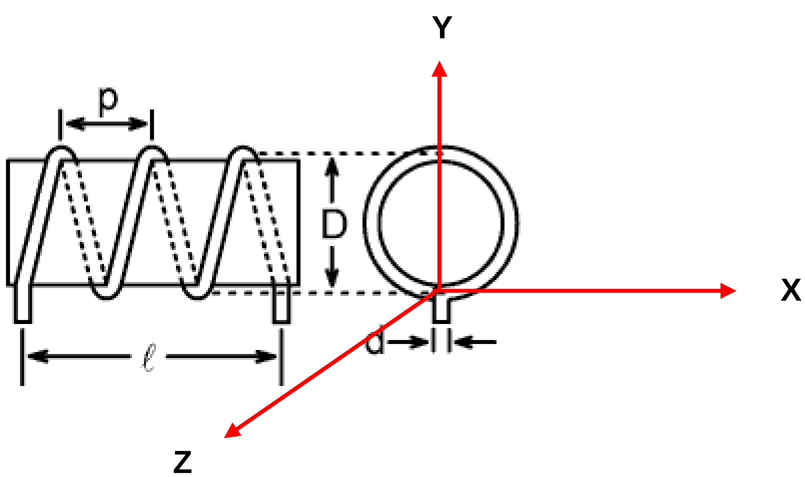
A circular cross-section solenoid is often modeled as multiple *rings of current* ignoring the pitch of the actual turns of the current carrying wire. In this Project the circular cross-section solenoid has a pitch p which is not to be ignored, a length ℓ and a diameter D, as shown inn the Figure. The wire diameter d can be considered << D and ignored. The number of turns N = ℓ / p and is a whole integer number.

The first turn of the circular cross-section solenoid begins at the origin (0, 0, 0), is wound counter-clockwise in the −z direction ending at (0, 0, $-\ell$), carries a DC current I and is in air ($\mu = \mu_o$).



Using the discrete summation solution in MATLAB of the integral form of the Biot-Savart Law with discrete DC current carrying lengths ΔL, the resulting **H** at an arbitrary point P(x,y,z) can be determined:

$$\mathbf{H} = \int \frac{I\, d\mathbf{L} \times \mathbf{a}_R}{4\pi R^2}$$

$$\mathbf{H} = \sum \frac{I\,\Delta\mathbf{L} \times \mathbf{a}_R}{4\pi R^2}$$

Task 1: This Project should use Cartesian coordinates for the general geometrical solution for $\mathbf{a}_R$ and R from the location of the discrete current IΔ**L** to the arbitrary point P(x,y,z) (see Task 2).

- The general geometrical solution must be carefully determined and discussed in the Project Report.

Task 2: The point P(x,y,z) for the determine the resulting **H** should be entered as a variable for x, y and z should range from:

$$-D/4 \leq x \leq D/4 \qquad -6\ell \leq z \leq 5\ell \qquad D/4 \leq y \leq 3D/4$$

Out of range entries should be *flagged.* For the diameter D and length ℓ use your birth date in cm and birth month in cm with the smaller (or equal) number as D and the larger (or equal) number as ℓ. For example, June 16th means D = 6 cm and ℓ = 16 cm.

The number of turns N is the last two digits of your TU ID modulo 8 + 3. For example, if the last two digits are 66 then N = 2 + 3 = 5.

Then the pitch p = ℓ / N and, for example, would be 16 cm / 5 = 3.2 cm.

The current I is the last three digits of your TU ID modulo 12 + 6 in mA. For example, if N = 666, I = 6 + 6 = 12 mA.

- Describe the parameters D, ℓ, p, N and I in the Project Report.

- Describe the entry and calculation of **H** at an in-range point P(x,y,z) in the Project Report.

You should use a value for ΔL that can approximate the integral formulation for **H** from the discrete summation. To show this, and only as an example, you can compare the ΔL = 0.1 cm solution to that obtained for ΔL = 0.01 cm and ΔL = 0.001 cm for the resultant **H** at an arbitrary point, for example, P = (0, D/2, $-\ell/2$) the center of the solenoid.

- Calculate and critically describe of the resultant **H** at an arbitrary point when ΔL is varied over at least three orders of magnitude in the Project Report.

Note that your choice of ΔL requires an integer number of steps in the discrete summation, so the length of the winding L should be calculated and discussed in the Project Report. You can also use both a coarser and finer ΔL to clearly demonstrate and discuss the *trade-offs* pf calculation time verses precision for the discrete summation solution for **H** at an arbitrary point, for example, P = (0, D/2, $-\ell/2$) the center of the solenoid.

- The length ΔL is an arc of a circle but this complication can be ignored if ΔL is small enough. Show this degree of the approximation of the arc length to the straight-line segment in the Project Report for the choices of ΔL and the solenoid parameters D, ℓ, p and N.

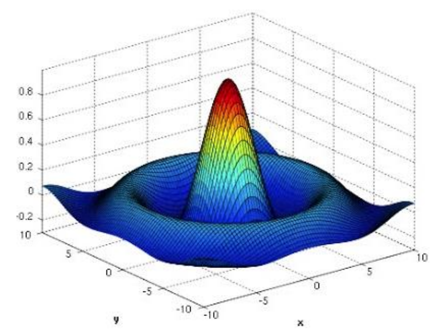
Task 3: Plot you results for the resulting **H** in Cartesian coordinates. Plot the results for **H** for:

1. x as a variable $-D/4 \leq x \leq D/4$ and fixed y = D/2 and z = $-\ell/2$

2. z as a variable $-6\ell \leq z \leq 5\ell$ and y = D/2 and x = 0

- For these data describe the uniformity (deviation from a constant) of the resultant **H** in the Project Report

- You are required to investigate and utilize methods of plotting 3D data in MATLAB for the resultant **H** in the Project Report, including surface and contour plots, as part of an engineering analysis, see:



  https://www.mathworks.com/help/matlab/examples/creating-3-d-plots.html

Queries and concerns for you project should be directed to the Instructor in a timely manner *well before* the Project deadline.

This project is to be written using the *Project Report Format* and uploaded to *Canvas* by no later than 11:59 PM Wednesday April 25, 2018. A hard copy is due no later than 3:30 PM Thursday April 26, 2018 in class (the last day of classes).

Late submission will result in a *grade reduction of one-half a letter grade per day*.

This project is an example of the advanced magnetostatic solution for **H** of a practical circular cross-section solenoid with pitch.