PHYS580 Lab 8, Oct 10, 2019

Assignment:

1. The two starter codes provided (*loop.m* and *loop_calculate_field.m*) use the simple rectangular panel method of integration to compute the magnetic field $\boldsymbol{B}$ of a current loop. The loop is in the *x*-*y* plane and is centered at the origin, just like in the setup discussed in class. (By the way, for this problem, the rectangular panel method is actually the same as the trapezoidal rule. Why?) Extend the programs (or create your own equivalent ones) to calculate the $\boldsymbol{B}$ field of <u>two</u> identically shaped parallel loops that share a common axis (the *z*-axis) and are situated symmetrically about the origin with their respective planes a distance *d* apart. First, calculate the field when the loops carry equal currents in the same direction, which is the Helmholtz coil configuration that is known to produce a nearly uniform magnetic field at the center. Then, investigate what happens if equal currents are carried in the opposite directions.

2. Extend your programs further to implement the same calculation for a helical coil of multiple loops (i.e., a current-carrying wire wrapped around a cylinder). The coil is centered at the origin, its axis coincides with the *z* axis, and it has a given *pitch* *P* (i.e., the location of the wire advances by distance *P* in the axial direction as the angle of winding along the wire goes through 2π). Using your program, calculate the magnetic field both inside and outside the coil for various lengths and numbers of winding, with the current set such that $\frac{\mu_0 I}{4\pi} = 1$. Show results for at least one case with loose winding, illustrating how $\boldsymbol{B}$ leaks through the coil, and a case with tight winding, showing how $\boldsymbol{B}$ approaches the field of an ideal solenoid.

   Note: the analytic result for $\boldsymbol{B}$ <u>on the axis</u> of an *ideal* (i.e., tightly wound) solenoid of radius *R* extending along the *z* axis from $z = -L/2$ to $L/2$ is:

   $$\boldsymbol{B} = \hat{\boldsymbol{e}}_z \frac{1}{2}\mu_0 n I \left(\frac{L/2 + z}{\sqrt{(L/2+z)^2 + R^2}} + \frac{L/2 - z}{\sqrt{(L/2-z)^2 + R^2}} \right),$$

   where *n* is the winding number per unit length and the current *I* is counter-clockwise when viewed from above the *x*-*y* plane. However, away from the axis, for example, at point on the *x* axis, $\boldsymbol{B}$ is much harder to calculate or approximate analytically (especially when *x* is of the same order as *R*).