

Physics Cup 2018 - Problem 3. March 18, 2018

Find the inductance of a circular loop of wire around an infinite ferromagnetic cylinder of radius r . The cylinder is made from a ferromagnetic material of relative permeability $\mu \gg 1$ (if needed, you can also assume that $\ln \mu \gg 1$); the radius of the loop is slightly larger than r so that it sits tightly around the cylinder.

The hints of 4th and 11th March.

Keep in mind fact IX-30 from <https://www.ioc.ee/~kalda/iphof/formulas.pdf>. Also, it might be somewhat useful to read the solutions of <http://www.ipho2012.ee/physicscup/problem-no-2/>, see <http://www.ipho2012.ee/physicscup/problem-no-2/solution/>.

It appears to be convenient to write down differential equations for two unknown functions: (a) axial magnetic field inside the cylinder (the component parallel to the axis of the cylinder), and (b) radial magnetic field outside of the cylinder, near the surface of the cylinder. Although differential equations are involved, the mathematics is actually simple.

Third hint, March 18, 2018. One of the two equations relating axial magnetic field inside the cylinder and radial magnetic field outside of the cylinder to each other can be obtained by writing down Ampere's circulation theorem for the loop shown in the figure. You still need to find a way for resolving the problem of diverging integrals along the radial infinite legs of this loop (you'll obtain a natural logarithm of something).

