PH-1020
Problem Set - 5
Department of Physics, IIT Madras
Magnetic Fields in Matter
March-June 2023 Semester

Notation:

- Notation throughout follows that of Griffiths, Electrodynamics.
- Bold face characters, such as $\boldsymbol{v}$, represent three-vectors.

---

1. Show that the force on an infinitesimal current loop with dipole moment $\mathbf{m}$, in the presence of a magnetic field $\mathbf{B}$ is

$$\boldsymbol{F} = \nabla\left(\boldsymbol{m}.\boldsymbol{B}\right).$$

2. The magnetization of a long cylinder is found to be proportional to square of the distance measured from the axis and is directed along the azimuthal direction. Calculate the magnetic field inside and outside the cylinder.

3. A very long cylinder of radius R carries a magnetization $\boldsymbol{M} = ks\hat{\boldsymbol{z}}$. Here, k is a constant and s is the distance from the axis which lies along $\hat{\boldsymbol{z}}$. Find the magnetic field inside and outside the cylinder by (a) employing Ampere's law and (b) calculating the bound currents.

4. A large piece of material have"frozen-in" magnetization $\boldsymbol{M}$. The field measured inside the material is $\boldsymbol{B_0}$. Now a cavity is hollowed out of the material. Calculate the fields $\boldsymbol{B}$ and $\boldsymbol{H}$ at the centre of the cavity, if it is

   (a) a small spherical cavity,

   (b) a long needle-shaped cavity running parallel to $\boldsymbol{M}$,

   (c) a thin wafer-shaped cavity perpendicular to $\boldsymbol{M}$.

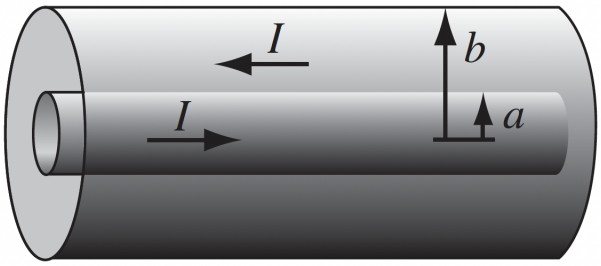

Figure 1:

5. A coaxial cable consists of two very long cylindrical tubes, separated by linear insulating material of magnetic susceptibility χ_m. A current I flows down the inner conductor and returns along the outer one; in each case, the current distributes itself uniformly over the surface (see Figure 1). Find the magnetic field in the region between the tubes. As a check, calculate the magnetization and the bound currents, and confirm that (together, of course, with the free currents) they generate the correct field.