DEPARTMENT OF PHYSICS
INDIAN INSTITUTE OF TECHNOLOGY, MADRAS

PH1020 Physics II **Problem Set 7** **March 2019**

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1. An infinitely long cylinder of radius a has its axis along the z-axis. Its magnetization is given in cylindrical polar coordinates by $\mathbf{M} = M_0\,(\rho/a)^2\,\hat{e}_\phi$, where M_0 is a constant. Find $\mathbf{J}_b$ and $\mathbf{K}_b$ as well as $\mathbf{B}$ and $\mathbf{H}$ both inside and outside the cylinder.

2. Consider a toroid in which a wedge-shaped region of small angle ψ is absent, as shown in the figure. A steady current I flows in it. The inner radius of the toroid is R, and the total number of turns in it is N. Assume that the magnetic field $\mathbf{B}$ in the air gap is still along $\hat{e}_\phi$. Find $\mathbf{H}$ in the toroid given that the core of the toroid is a LIH magnetic material with magnetic susceptibility χ_m.

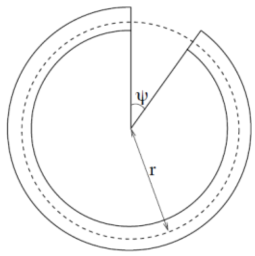

Figure 1: Top view of the toroid

3. An infinite planar magnetic sheet of thickness d having a nonuniform permeability given by $\mu(z) = \mu_0\,[1 + (z/d)]^2$ occupies the region $0 \leq z \leq d$. There is vacuum on either side of the sheet. A magnetic field $\mathbf{B} = B_0\,\hat{e}_y$ (where B_0 is a constant) is applied in the entire space. The sheet has no free current on it. Find the magnetization surface current densities at $z = 0$ and $z = d$, and also the magnetization volume current density as a function of z.

4. Suppose the field inside a large piece of magnetic material is $\mathbf{B_0}$ so that $\mathbf{H_0} = (1/\mu_0)\,\mathbf{B_0} - \mathbf{M}$. Where **M** is 'frozen-in'magnetization. Find the field,

   (a) at the centre of a small spherical cavity hollowed out of the material, in terms of $\mathbf{B_0}$ and **M**. Also find **H** at the centre of the cavity, in terms $\mathbf{H_0}$ and **M**.

   (b) a long needle shaped cavity running parallel to **M**

   (c) a thin wafer shaped cavity perpendicular to **M**

5. A coaxial cable consists of two very long thin cylindrical tubes of radius a and b ($a < b$) separated by linear insulating materials of magnetic susceptibility χ_m. A current I, uniformly distributed over the cylinder, flows down the inner cylinder and returns along the outer one. Find the magnetic field in the region between the tubes. As a check, calculate magnetization and bound current, and confirm that together with free currents they generate the correct field.