DEPARTMENT OF PHYSICS
INDIAN INSTITUTE OF TECHNOLOGY, MADRAS

PH1020 Physics II **Problem Set 6** **April 2024**

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1. Show that the magnetic dipole moment a particle of mass m and charge q moving with velocity $\mathbf{u}$ is given by
$$\mathbf{m} = \frac{q}{2m}\,\mathbf{L}\ ,$$
where $\mathbf{L} = \mathbf{r} \times \mathbf{p}$ is the (orbital) angular momentum of the particle. Thus a moving charge can be treated as a magnetic dipole located at the instantaneous position of the charge.

2. An infinitely long cylinder of radius a has its axis along the z-axis. Its magnetization is given in cylindrical polar coordinates by $\mathbf{M} = M_0\,(\varrho/a)^2\,\hat{e}_\varphi$, 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.

3. 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.

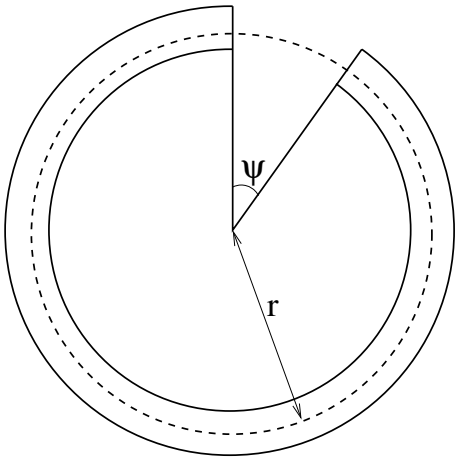

Figure 1: Top view of the toroid

4. 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 $0 \le z \le d$. 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.