Home Work Set # 11, Physics 217, Due: December 12, 2001

Problem 1

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 bound currents and confirm that (together of course with the free currents) they generate the correct field.

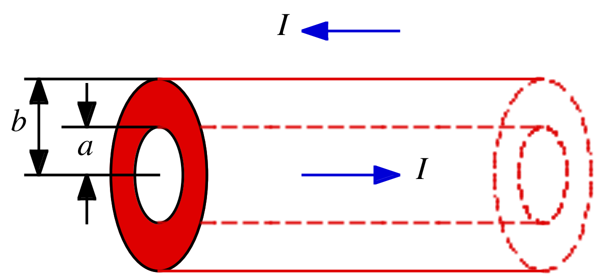

Figure 1. Problem 1.

Problem 2

a) A current I flows down a straight wire of radius R. If the wire is made of linear material (copper or aluminum) with susceptibility χ_m, and the current is distributed uniformly, what is the magnetic field a distance r from the center?

b) Find all the bound currents.

c) What is the net bound current flowing down the wire?

Problem 3

Notice the following parallel:

$$\overline{\nabla} \bullet \overline{D} = 0 \qquad \overline{\nabla} \times \overline{E} = 0 \qquad \varepsilon_0 \overline{E} = \overline{D} - \overline{P} \qquad \text{(no free charge)}$$

$$\overline{\nabla} \bullet \overline{B} = 0 \qquad \overline{\nabla} \times \overline{H} = 0 \qquad \mu_0 \overline{H} = \overline{B} - \mu_0 \overline{M} \qquad \text{(no free current)}$$

Thus, the transcription $\overline{D} \to \overline{B}$, $\overline{E} \to \overline{H}$, $\overline{P} \to \mu_0 \overline{M}$, and $\varepsilon_0 \to \mu_0$ turns an electrostatic problem into an analogous magnetostatic one. Use this observation, together with your knowledge of the electrostatic results, to calculate

a) The magnetic field inside a uniformly magnetized sphere.

b) The magnetic field inside a sphere of linear magnetic material in an otherwise uniform magnetic field.

c) The average magnetic field over a sphere, due to steady currents within the sphere.

Problem 4

A familiar toy consists of donut-shaped permanent magnets (magnetization parallel to the axis), which slide frictionless on a vertical rod (see Figure 2). Treat the magnets as dipoles, with mass M and dipole moment $\overline{m}$.

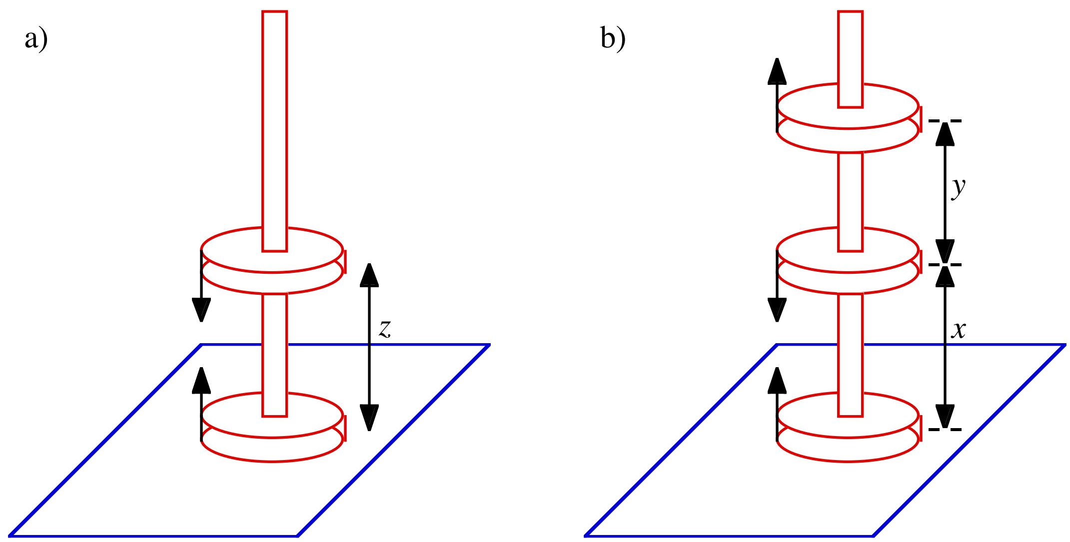

Figure 2. Problem 4.

a) If you put two back-to-back magnets on the rod, the upper one will "float" - the magnetic force upward balancing the gravitational force downward. At what height z does it float?

b) If you now add a third magnet (parallel to the bottom one), what is the ratio of the two heights? (Determine the actual number, to three significant digits).

Problem 5

At the interface between one linear magnetic material and another magnetic material the magnetic field lines bend (see Figure 3). Show that $\tan\theta_1 / \tan\theta_2 = \mu_1 / \mu_2$, assuming there is no free current at the boundary.

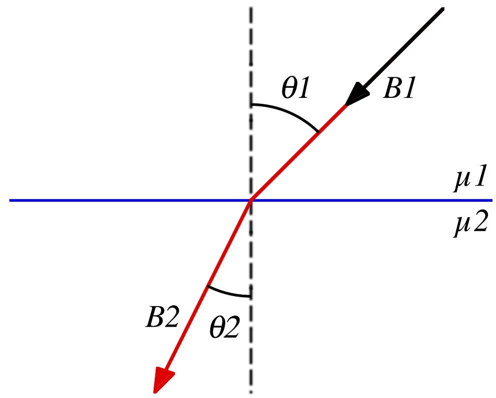

Figure 3. Problem 5.