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Physics 441: Assignment #6 - Magnetic Fields in Matter

Due on Wednesday, June 19, 2013

June 17, 2013

Problem 6.3

Find the force of attraction between two magnetic dipoles, $\boldsymbol{m}_1$ and $\boldsymbol{m}_2$ oriented as shown in figure 6.7, a distance r apart:

1. Using equation 6.2
2. Using equation 6.3

Problem 6.6

Of the following materials which would you expect to be paramagnetic and which diamagnetic::

- aluminium
- copper
- copper chloride ($CuCl_2$)
- carbon
- lead
- nitrogen(N_2)
- salt (NaCl)
- sulfur

- water

Problem 6.12

An infinitely long cylinder, of radius R, carries a "frozen-in" magnetization, parallel to the axis,

$$\boldsymbol{M} = kx\hat{\boldsymbol{z}}$$

where k is a constant and s is the distance from the axis; there is no free current anywhere. FInd the magnetic field inside and outside the cylinder by two different methods:

- As in Section 6.2, locate all the bound currents, and calculate the field they produce
- Use Ampere's law (in the form of equation 6.20) to find $\boldsymbol{H}$, and then get $\boldsymbol{B}$ from equation 6.18 (Notice that the second method is much faster, and avoids any explicit reference to the bound currents.)

Problem 6.23

A familiar toy consists of donut-shaped permanent magnets (magnetization parallel to the axis), which slide frictionlessly on a vertical rod (Figure 6.31). Treat the magnets as dipoles, which mass m_d and dipole moment $\boldsymbol{m}$.

1. If you put two back-to-back magnets on teh rod, the upper one will :float: – the magnetic force upward balancing the gravitational force downward. At what height (z) does it float?
2. 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 3 significant digits)

Problem 6.25

Notice the following parallel:

$$\begin{cases} \nabla \cdot \boldsymbol{D} = 0, \quad \nabla \times \boldsymbol{E} = 0, \quad \epsilon_0 \boldsymbol{E} = \boldsymbol{D} - \boldsymbol{P} & \text{(no free charge)} \\ \nabla \cdot \boldsymbol{B} = 0, \quad \nabla \times \boldsymbol{H} = 0, \quad \mu_0 \boldsymbol{H} = \boldsymbol{B} - \mu_0 \boldsymbol{M} & \text{(no free charge)} \end{cases}$$

Thus, the transcription $\boldsymbol{D} \to \boldsymbol{B}, \boldsymbol{E} \to \boldsymbol{H}, \boldsymbol{P} \to \mu_0 \boldsymbol{M}, \epsilon_0 \to -\mu_0$ turn an electrostatic problem into an analogous magnetostatic one. Use this, together with your knowledge of the electro-static results to re-derive:

1. The magnetic field inside a uniformly magnetized sphere

2. The magnetic field inside a sphere of linear magnetic material in an otherwise uniform magnetic field (problem 6.18)

3. The average magnetic field over a sphere, due to steady currents within the sphere (equation 5.93)