Carleton University Physics Department

PHYS 3308 – Electromagnetism (Fall 2014)

Homework assignment #9

Handed out Thurs Nov 20; due Thurs Nov 27, 2014, at the start of class. H. Logan

Problems are worth 5 points each unless noted otherwise.

1. Derive the force on an infinitesimal magnetic dipole in a non-uniform external magnetic field as follows. Assume the dipole is an infinitesimal square current loop, with sides of length ϵ, and put one corner at the origin (see Griffiths Figure 6.8 on page 270). Calculate the force on each of the four sides using the Lorentz force law. Then expand $\vec{B}$ in a Taylor series: for example, on the right-hand side of the square,

$$\vec{B} = \vec{B}(0, \epsilon, z) \simeq \vec{B}(0, 0, z) + \epsilon \left. \frac{\partial \vec{B}}{\partial y} \right|_{(0,0,z)} . \tag{1}$$

   Finally, write the force in the form $\vec{F} = \vec{\nabla}(\vec{m} \cdot \vec{B})$ by using the definition of the gradient.

2. A very long solid rod of radius R oriented along the z axis is given a magnetization $\vec{M} = ks^2\hat{\phi}$, where k is a constant.

   (a) Find the bound currents (both surface and volume). You can ignore the ends of the rod.

   (b) Find the magnetic field everywhere.

3. What magnetic field do you need to levitate a frog? Explain any assumptions you make. *(Hint: a frog is mostly water. See page 285.)*

4. A circular loop of wire with radius R is mounted on a shaft (across its diameter) and rotated at angular frequency ω. A uniform magnetic field $\vec{B}$ points perpendicular to the shaft. Find $\mathcal{E}(t)$ for this alternating current generator. *(Note: define your coordinate system and explicitly specify the phase of $\mathcal{E}(t)$ in terms of your definition for the zero of time.)*

5. A square loop is cut out of a thick sheet of copper. It is then placed so that the top portion is in a uniform magnetic field $\vec{B}$, and allowed to fall under gravity (see Griffiths Figure 7.20 on page 312; in the figure the shading indicates the field region and $\vec{B}$ points into the page).

   (a) If the magnetic field is 1 T, find the terminal velocity of the loop (in m/s).

   (b) Find the velocity of the loop as a function of time. How long does it take (in seconds) to reach 90% of terminal velocity?

   (c) What would happen if you cut a tiny slit in the ring, breaking the circuit?

   (Note: in all cases get the explicit formulas before you plug in numbers. The dimensions of the loop should cancel out.) (Hint: see page 297.)