PHY1510H

Classical Electromagnetism

Fall 2010

Problem Set 1

27 September 2010

HANDED OUT: Monday, 27 September 2010

DUE: 1:10 PM, Monday, 4 October, 2010
Hand in to Winnie Kam, MP 804

REMINDER: NO LECTURE THE WEEKS OF 4-15 OCTOBER 2010.

QUESTIONS:

1. Suppose that the electric force acting on charge q_1 due to charge q_2 separated by a distance $\vec{r} \equiv \vec{x_1} - \vec{x_2}$ is given by the relationship

$$\vec{E} = \frac{kq_1q_2}{r^{2+\delta}}\,\hat{r}, \tag{1}$$

where k is a constant and $\hat{r}$ is the unit vector in the direction of $\vec{r}$. The constant $\delta \ll 1$.

   (a) Calculate $\vec{\nabla} \cdot \vec{E}$ and $\vec{\nabla} \times \vec{E}$ for this electric field.

   (b) One has two concentric conducting spherical surfaces, connected by a thin conducting wire, with the inner and outer surfaces having radii b and a, respectively. Calculate the charge on the inner shell, q_b, if we place a charge q_a on the other shell. You only need to do this to lowest order in δ.

   (c) Does this suggest a way of placing limits on δ? What measurement could one make?

2. In a nuclear reactor, a nucleus of ^{235}U releases 200 MeV of energy when it decays into two nuclei. Assume that the primary fission reaction is

$$^{235}U \rightarrow ^{92}K + ^{142}Ba, \tag{2}$$

with the daughter particles being accelerated after fission due to their electrostatic repulsion. On average, about 85% of the total energy of fission is released in the form of kinetic energy of the daughter particles.

   (a) Calculate the mean separation r_{sep} of the daughter particles immediately after the fission process takes place. You can assume that the nuclei accelerate to a distance $\gg r_{sep}$ before they thermalize and transfer their kinetic energy in the form of heat.

   (b) The fission can create several different pairs of daughter nuclei. If the f is the ratio of one daughter nuclei's atomic number to the parent nucleus's atomic number (92 in this case), how does the energy released change with f? Is there a value of f that would give a maximum energy release? Assume that the fission always produces daughter nuclei the same distance apart immediately after the decay.

3. An infinite thin sheet of conducting material has a circular hole of radius a cut into it. A thin, flat conducting disk with a slightly smaller radius lies in the plane within the hole, but separated from the sheet with a thin insulating ring. The disk is held at potential V while the infinite sheet is kept at zero potential. Let the sheet lie on the plane $z = 0$ and consider the region $z \geq 0$.

   (a) Employing the image charge method, determine the appropriate Green function for these boundary conditions. Use cylindrical coordinates ρ, z and ϕ.

   (b) Using this Green function, find an integral expression for the potential at any point.

   (c) What is the potential above any point above the center of the disk (i.e., along the z axis).