PHYSICS 7b MIDTERM 2

Prof. C. F. McKee Nov 2, 2009

Partial credit will be given, so show your reasoning carefully. The number of points for each problem is listed at the left. You are permitted one 3x5 card of notes, written on both sides. Relevant constants are given at the end.

1. [10] A D battery that costs $1.70 delivers 25 mA at 1.5 V for 820 hr. What is the ratio of the cost of this power to that from the 120 V power we get from the wall socket, at $0.10 per kwh?

2. [15] (Giancoli 23-15.) Consider two conducting spheres, of radius r_1 and r_2. The spheres are separated by a distance much greater than the size of either one. Initially, the first sphere has a charge Q and the second one is uncharged. The two are then connected by a conducting wire. What is the charge on the second sphere once a steady state is reached?

3. [15] An electron is fired through a tiny hole into a capacitor at a velocity of 10^7 m s^{-1}. The capacitor is charged so that the field inside is $E = 2.6 \times 10^4$ V m^{-1}, pointing in the direction of the electron velocity. The capacitor plates are separated by a distance d such that the electron comes to rest just as it reaches the second plate. Find d.

4. [15] Two infinite insulating slabs of thickness d are placed one on top of the other. The top slab has a uniform volume charge density ρ and the bottom one has a uniform volume charge density $-\rho$. There are no other charges. Find $\boldsymbol{E}(z)$ for all z, where $\hat{\boldsymbol{z}}$ is normal to the surfaces of the slabs and $z = 0$ on the plane between the slabs.

5. [20] Two capacitors, C_1 and C_2, with $C_2 > C_1$ are connected in series with a battery of potential V_0, and the energy in the capacitors is measured to be U. If instead, the capacitors are connected in parallel to the same battery, the total energy is found to be $5U$.

   a) [10] For the case of the capacitors in series, show that the sum of the energies in the two capacitors is the same as the energy of the equivalent single capacitor. (The same is true for the parallel capacitors, but you need not show that.)

   b) [10] What is the ratio C_2/C_1?

6. [25] A long, straight wire of radius r_1 is at the center of a hollow conducting pipe of inner radius r_2 and outer radius r_3. The wire has a charge per unit length λ_1 and the pipe has a charge per unit length $\lambda_p = \lambda_2 + \lambda_3$, where λ_2 and λ_3 are the values of the charge per unit length on the inner and outer radius of the pipe.

a) [5] Using Gauss's law, find the electric field inside the pipe, for $r_1 < r < r_2$.

b) [5] Choose a reference point and evaluate the potential for $r_1 < r < r_2$.

c) [5] Evaluate E outside the pipe, for $r > r_3$.

d) [5] Evaluate the potential for $r > r_3$. You must use the same reference point as in part (b).

e) [5] Find the charge/length on the outer surface of the pipe, λ_3, in terms of the total charge/length on the pipe, λ_p and the charge/length on the wire, λ_1.

Constants

$$\begin{aligned}
\text{Electron mass } m_e &= 9.11 \times 10^{-31} \text{ kg} \\
\text{Electron charge } e &= 1.60 \times 10^{-19} \text{ C}
\end{aligned}$$