Plasma Electrodynamics 1 May 21, 2009

Mid-Term Exam 2

(30 points)

1. Answer the following questions.
   1) Write the integral form of the fundamental postulates of electrostatics in a dielectric medium, and state their meaning in words. In this case, explain why the electric field intensity is a conservative field and how it can be obtained from a scalar potential V.
   2) What are the general boundary conditions for $\boldsymbol{E}$, $\boldsymbol{D}$ and $\boldsymbol{J}$ under steady conditions at an interface between an insulator ($\epsilon_1,\ \sigma_1 = 0$) and a lossy dielectric medium ($\epsilon_2,\ \sigma_2 = finite$)?
   3) Describe the ways in which the electric potential distribution varies with distance from a positively-charged test particle (q) in a plasma in comparison with the electric potential produced by an isolated positive point charge (q) in free space.
   4) For the method of images, draw the images of a straight line current I located at an equidistance d from two grounded perpendicular conducting half-planes?
   5) What is the relation between mobility and resistivity in a conductor? Explain how both mobility and resistivity are dependent on the collision frequency between free electron and lattice atoms in the conductor.

(15 points)

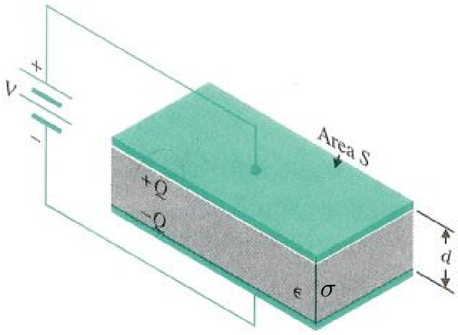
2. Solve the following problems for a parallel-plate capacitor of which the two conducting plates are 50 (mm) apart:
   1) Find the breakdown voltage if the medium between the conducting plates is air, which has a dielectric strength 3 (kV/mm).
   2) Find the breakdown voltage if the entire space between the conducting plates is filled with plexiglass, which has a dielectric constant 3 and a dielectric strength 20 (kV/mm).
   3) If a 10-(mm) thick plexiglass is inserted between the two plates, what is the maximum voltage that can be applied to the two plates without a breakdown?

(20 points)

3. Two **infinitely long** coaxial cylindrical surfaces, $r=a$ and $r=b$ $(b>a)$, carry surface charge densities ρ_{sa} and ρ_{sb} , respectively.
   1) Determine $\boldsymbol{E}(r)$ everywhere ($r<a,\ a<r<b,$ and $r>b$) <u>by applying Gauss's law</u>.
   2) Show that $\dfrac{b}{a}=-\dfrac{\rho_{sa}}{\rho_{sb}}$ in order that $\boldsymbol{E}$ vanishes for $r>b$.

(15 points)

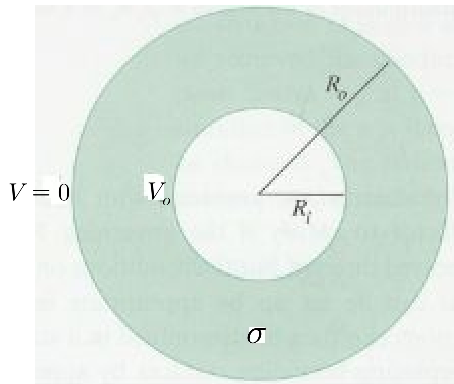
4. Consider a parallel-plate capacitor of area S and separation d charged to a voltage V as shown in the figure. The permitivity and conductivity of the lossy dielectric are ϵ and σ, respectively.



   1) Find the capacitance C by using the relation $V=-\int_0^d \boldsymbol{E}\cdot d\boldsymbol{l}$ and the boundary condition for the normal component of $\boldsymbol{D}$ at the electrode-dielectric interface.
   2) Find the electrostatic energy W_e stored in the capacitor in terms of C by deriving from the electrostatic energy density $w_e=\boldsymbol{D}\cdot\boldsymbol{E}/2=\epsilon E^2/2$.
   3) Find the resistance R between the two electrodes by using the capacitance C obtained from the above problem 1).

(20 points)

5. Consider a spherical shell between two concentric spherical surfaces of radii R_i and R_o $(R_i<R_o)$. The space between the surfaces is filled with a homogeneous and isotropic medium having a conductivity σ.



   1) Set up a boundary-value problem for V and find $V(R)$ for $R_i\le R\le R_o$.
   2) Find the electric current density $\boldsymbol{J}(R)$ for $R_i\le R\le R_o$.
   3) Find the resistance between the two spherical surfaces.