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EE214000 Nonlinear Optics, Fall 2012

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EE214000 Electromagnetics, Fall
Quiz #6, Open books, notes (21 points)

1. (3 points) What is the energy density stored in a thin parallel-plate capacitor with an electrode separation of *d* and a voltage of *V* across the two capacitor electrodes? Assume the permittivity of the dielectric between the electrodes is ε.

Ans: The electric field across a thin parallel-plate capacitor is E = V/d. The energy density is $\frac{\varepsilon}{2}E^2$.

2. (3 points) In "1", the surface area of the electrode plate is S. Calculate the capacitance of the parallel-plate capacitor from the stored energy.

Ans: the total stored energy is $\frac{\varepsilon}{2}E^2 Sd = \frac{1}{2}CV^2$

$\Rightarrow \quad C = \frac{\varepsilon S}{d}$

3. (5 points) In "1", the top electrode is biased at V and the bottom electrode is grounded. What is the surface polarization charge density right below the top electrode?

Ans: $\vec{P} = \vec{D} - \varepsilon_o \vec{E} = (\varepsilon - \varepsilon_o)\vec{E} = (\varepsilon - \varepsilon_o)\frac{V}{d}(-\hat{a}_y)$

The surface polarization charge density is $\hat{a}_n \cdot \vec{P} = \hat{a}_y \cdot \vec{P} = -(\varepsilon - \varepsilon_o)\frac{V}{d}$

4. (5 points) Calculate the capacitance per unit length of a coaxial transmission line with an inner conductor radius of R_i and outer conductor radius of R_o. Assume the permittivity of the dielectric between the two conductors is ε.

Ans: Assume a line charge density ρ_l on the inner conductor. The electric field at *r* is $\vec{E} = \frac{\rho_l}{2\pi r \varepsilon_0}\hat{a}_r$. The voltage across the two conductors is therefore

$V = -\int_{R_0}^{R_i}(\vec{E} = \frac{\rho_l}{2\pi r \varepsilon_0}\hat{a}_r)\cdot \hat{a}_r dr = \frac{\rho_l}{2\pi\varepsilon_0}\ln(R_o/R_i)$. The capacitance per unit length is

$$C_l = \frac{\rho_l}{V} = \frac{2\pi\varepsilon_0}{\ln(R_o / R_i)}$$