Homework Problem Set #6

(Due date: 2011/4/18)

This problem set covers materials of Lesson 7. The full score is 45 points + 20 bonus points.

1) When a metal is in contact with an *n*-type semiconductor (both extend infinitely in the *yz*-plane) at $x = 0$, free electrons of the semiconductor will diffuse into the metal and are deposited on the interface, leaving a positively charged depletion layer $\{0 < x < d\}$ with constant volume charge density ρ_v (C/m^3) and permittivity ε (Fig. 1).

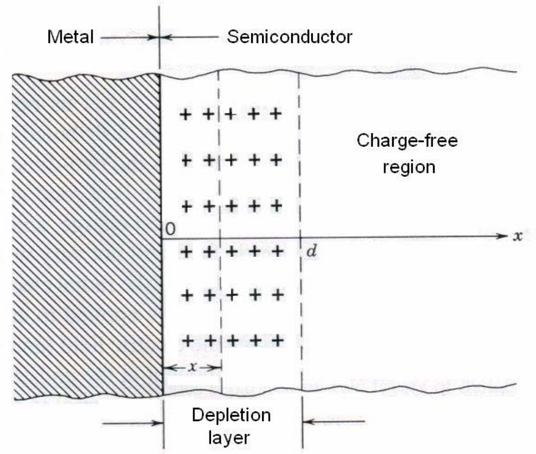

Fig. 1. Metal-semiconductor junction.

1a) (5%) What are the electric field intensities $\vec{E}$ in the regions of: (i) $x < 0$, and (ii) $x > 0$, respectively? Justify your answer.

1b) (5%) What is the electric field intensity $\vec{E}(x)$ in the depletion layer $\{0 < x < d\}$? (*Hint*: Use Gauss's law.)

2) Consider a dielectric sphere with radius R_0 and uniform polarization vector $\vec{P} = \vec{a}_z P$.

2a) (5%) Find the surface polarization charge density distribution ρ_{ps} in spherical coordinates.

2b) (10%) Find the electric field intensity $\vec{E}_0$ at the spherical center.

(*Hint*: Apply the result of Problem 1 of HW5.)

2c) (Bonus 20 points) Write a program to plot the normalized electric field intensity along the *z*-axis:

$$\left|\frac{\vec{E}(0,0,z)}{\vec{E}_0}\right|, \quad 0 \le z/R_0 \le 5.$$

3) Consider two large parallel conducting plates of area S separated by a distance d. The region between the two conducting plates is filled with two dielectric materials with $\varepsilon_1 = 2\varepsilon_0$, $d_1 = \frac{d}{2}$, $\varepsilon_2 = \varepsilon_0$, $d_2 = \frac{d}{2}$ (Fig. 2). The top and bottom plates are deposited with free charge $+Q$ and $-Q$, respectively.

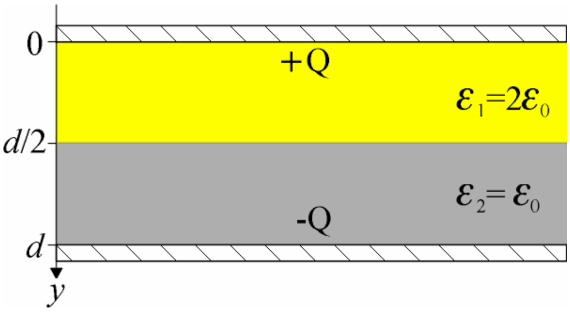

Fig. 2. Parallel-plate capacitor.

3a) (10%) What are the electric flux densities $\vec{D}_1$, $\vec{D}_2$, the electric field intensities $\vec{E}_1$, $\vec{E}_2$, and the polarization vectors $\vec{P}_1$, $\vec{P}_2$ between the two plates?

(*Hint*: Use Gauss's law.)

3b) (10%) What are the polarization surface charge densities ρ_{ps} at the three interfaces $y = 0^+$, $\frac{d}{2}$, and d^-, respectively.

(*Hint*: $\rho_{ps}\left(\frac{d}{2}\right) = \rho_{ps}\left(\frac{d^-}{2}\right) + \rho_{ps}\left(\frac{d^+}{2}\right)$)