NNSE 508 EM

Home assignment # 4 **Due: March 03, 2014**

1. A region between the capacitor plates is filled by amorphous selenium with a dielectric constant of 6.0 and a concentration of 3.67×10^{28} atoms/m^3.
(a) Estimate the polarizability of a selenium atom.
(b) Estimate the local field at a selenium atom if the charge on the plates produces a field (without selenium between plates) of 1500 V/m.
(c) Estimate the dipole moment of a Se atom in the field of part b.
(d) What would the dielectric constant be if the local field were the same as the macroscopic field.?

2. Equation describing energy levels in an infinitely deep potential well may be applied to a quantum well formed in a layer of one semiconductor material bound by the layers of a different semiconductor (heterostructure quantum well). What should be the thickness of the semiconductor layer to ensure that the difference between the ground (i.e. the lowest) energy level and the first excited level is equal to the thermal energy ($k_B T$) at room temperature (T = 300 K)? Assume $m_n = 0.1\, m_e$.
Note: this thickness may be considered as a criterion for visibility of quantum effects in semiconductors.

3. Consider a one-dimensional chain consisting of 3 identical potential wells (atoms) with non-degenerate levels and corresponding wave functions $\phi(x)$. Inter-atomic distance is a. Using periodic boundary conditions find Bloch functions of this "crystal" and allowed pseudo-wavevectors within first Brillouin zone .

4. A hypothetical isotropic energy band can be fitted approximately to the expression

$$E(k) = E_0\left[1 - \exp\left(-2a^2k^2\right)\right],$$

where a is the lattice constant of a cubic crystal. Calculate:
a) The effective mass at the Γ-point.
b) The value of k for maximum electron velocity.
c) The effective mass at the edge of the Brillouin zone.

5. . Using tight-binding model calculate dispersion E(k) in the first Brillouin zone along one of the major symmetrical axes <100> and effective mass (in the units of free electron mass, m_0) in the Γ-point along the same direction for an s-band in a BCC structure. Consider overlap integrals γ = 1 eV.
[bonus 20 points if solved] Calculate dispersion E(k) and effective masses along <110> and <111> axes. Is effective mass isotropic or anisotropic?