MN-1

August 2012 QE

1. (25 points) Discuss, conceptually, how energy bands arise in a crystalline material, such as a semiconductor. Key points that must be addressed are:
    a. Periodic potentials
    b. The Bloch Theorem
    c. Band gap
    d. Holes
    e. Effective masses of holes and electrons

2. (25 points) Sketch the equilibrium energy band diagram (show E_C, E_V, E_F, and E_i) of a 1D semiconductor device that has the following properties:
    a. A 1 micron thick (x = 0 to 1 micron) degenerately doped p-type semiconductor with a 2.0 eV band gap.
    b. A 5 micron thick (x = 1 to 6 microns) lightly doped n-type semiconductor with a 1.0 eV band gap.
    c. Assume that there is no valence band offset.
    d. Assume that there a very large <u>positive</u> sheet charge at x = 6 microns.

3. (25 points) For a uniform nondegenerate semiconductor with band gap E_G, effective densities-of-state N_C & N_V, and doped with both N_A acceptors and N_D donors (assume full ionization of the dopants) – derive an expression for the equilibrium hole concentration, p, at temperature T in terms of only E_G, N_C, N_V, N_A, N_D, T, and k (Boltzmann's constant). Of course, you may also include dimensionless numbers (i.e. 2, *e*, π, etc.) as necessary.

4. (25 points) The Auger recombination rate can be written as $R=\left(C_p p+C_n n\right)\left(pn-n_i^2\right)$. For <u>high injection</u> conditions, derive an expression for $qV=F_n-F_p$, the difference between the electron and hole quasi-Fermi energies, at temperature T in terms of only R, C_p, C_n, p, n, n_i, T, and k (Boltzmann's constant). Of course, you may also include dimensionless numbers (i.e. 2, *e*, π, etc.) as necessary. Assume Boltzmann statistics.

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