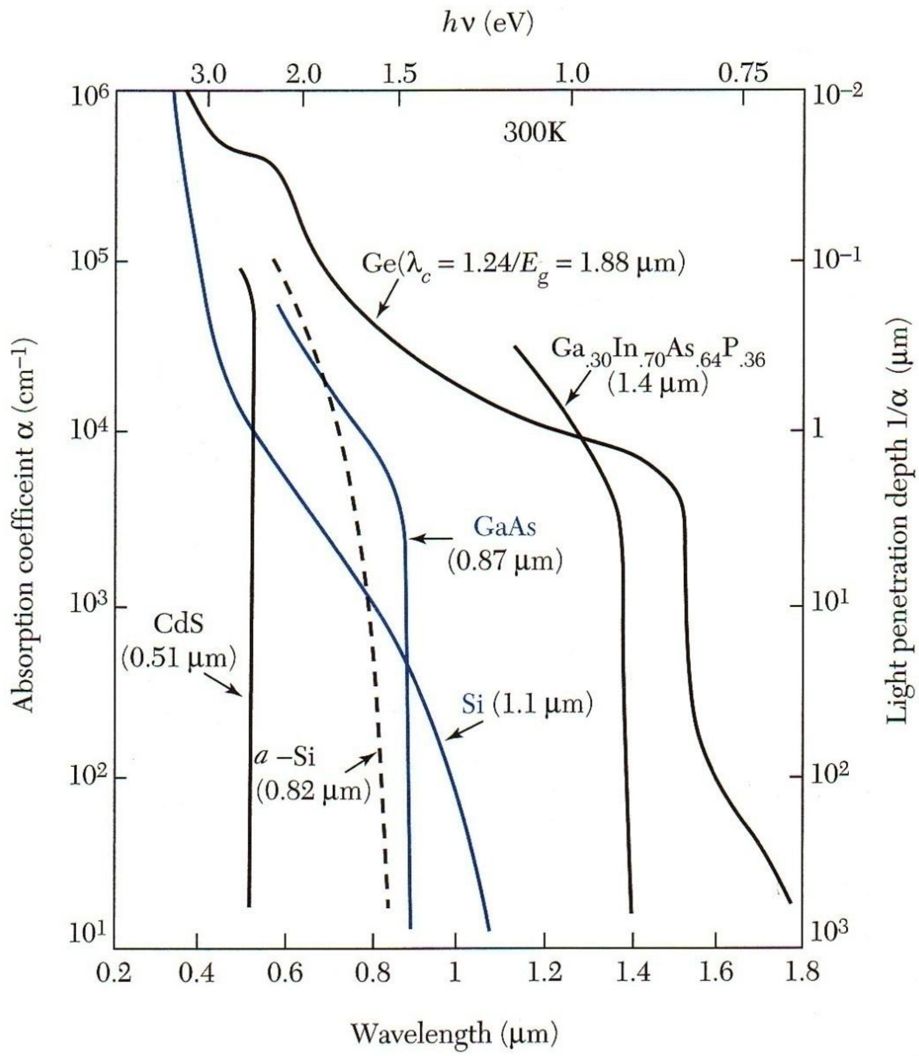
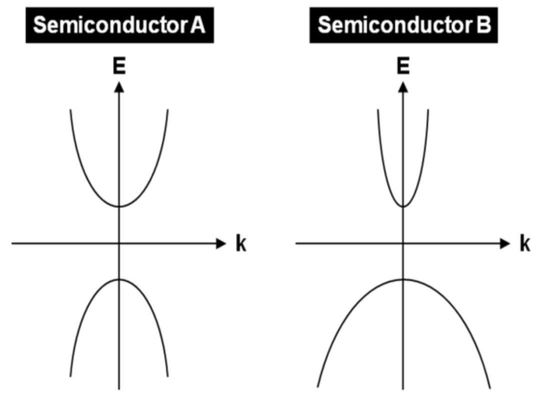
HW #2
Due September 20 (Thursday) in class

1. Calculate the absorption coefficient of GaAs at 300 K as a function of the photon energy, from 1 to 2 eV, using material parameters listed in Appendix K of Chuang's textbook (pp. 708-711). For the hole effective mass, use that of the heavy hole. Assume effective mass approximation (parabolic E-k relation). Superimpose your plot on the data shown below, and observe how well they match. (Digitize the absorption curve below so you can include them in your plotting program).



2. Consider two semiconductors with the following energy band diagrams: Both semiconductors have the same bandgap energy (1 eV) and the same optical matrix elements.
   a. Which semiconductor has larger absorption coefficient for a photon energy of 1.1 eV? What is the ratio of their absorption coefficients?
   b. Which semiconductor has wider separation of quasi-Fermi levels when the electron and hole concentrations are both $N = P = 5\times10^{18}\,\text{cm}^{-3}$?



$m_e^* = m_h^* = 0.2m_0$ $\qquad$ $m_e^* = 0.1m_0$, $m_h^* = 0.4m_0$

3. Refer to the diagram below. Under biased condition, both conduction and valence bands are populated. The electron distribution in conduction band is described by Fermi-Dirac distribution, $f_C(E_2)$, with quasi-Fermi energy F_C. The electron distribution in valence band is described by Fermi-Dirac distribution, $f_V(E_1)$, with quasi-Fermi energy F_V. Here, E_1 and E_2 are related by an optical transition (i.e., they have the same k).
    a. Use the energy reference below (i.e, $E_V = 0$ and $E_C = E_g$, the bandgap energy), find E_1 and E_2 as functions of the photon energy, $\hbar\omega$.
    b. Derive $f_C(E_2(\hbar\omega))$ as a function of $\hbar\omega$.
    c. Derive $f_V(E_1(\hbar\omega))$ as a function of $\hbar\omega$.
    d. Assuming $E_g = 1$ eV, $F_C - F_V = 1.2$ eV, $m_e^* = 0.1m_0$, $m_h^* = 0.4m_0$. Calculate and plot the emission probability $f_e(\hbar\omega) = f_C(E_2(\hbar\omega)) \cdot 1 - f_V(E_1(\hbar\omega))$ for photon energies from 0.8 to 1.5 eV. Plot for two temperatures: T = 0 and T = 300 K.
    e. Repeat part d) for the Fermi inversion factor: $f_g(\hbar\omega) = f_C(E_2(\hbar\omega)) - f_V(E_1(\hbar\omega))$