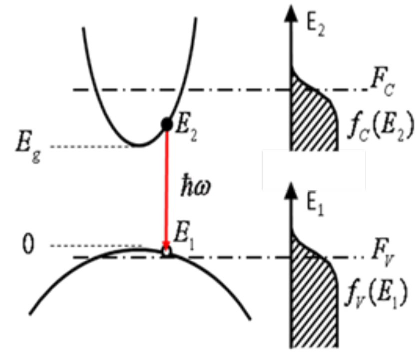
HW #1
Due 3/11/18
Electronic Submission to bCourses

1. Refer to the diagram on the right. 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). The optical matrix element is



$$\left|\hat{e}\cdot\vec{P}_{cv}\right|^2 = \frac{m_0}{6}E_p \quad \text{with } E_p = 25.7 \text{ eV}$$

and the refractive index of the semiconductor is 3.5. In calculating f_C and f_V, you can assume charge neutrality, i.e., electron concentration is equal to hole concentration, and assume the doping concentration is negligible compared with injected electrons/holes.

   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 $f_e(\hbar\omega) = f_C(E_2(\hbar\omega))\cdot\left[1 - f_V(E_1(\hbar\omega))\right]$ 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: $f_g(\hbar\omega) = f_C(E_2(\hbar\omega)) - f_V(E_1(\hbar\omega))$

   f. Plot the gain spectra for T = 0 and T = 300 K for the condition given in d).

   g. Plot the spontaneous emission spectra for T = 0 and T = 300 K for the condition given in d).