HW #3
Due October 16 (Tuesday) in class

1. Consider an infrared intersubband photodetector made of p-doped GaAs quantum wells. The hole effective mass is $m_h^* = 0.5m_0$, and the refractive index is 3.5.
   a. Find the width of the quantum well so the absorption peak is at 10 μm wavelength.
   b. Assume a lorentzian lineshape with an intraband scattering time of 0.1 ps, find the peak absorption coefficient for a doping concentration of 10^{18} cm^{-3}.
   c. What is the full-width-at-half-maximum width of the absorption spectrum?
   d. Plot the absorption spectra. Please use your favorite numeric program to calculate and plot the spectrum (no hand sketch). Be quantitative in both axes.
   e. What is the optimum doping concentration to achieve maximum absorption coefficient?
2. Consider an optical transition from E_a to E_b in a 10-nm wide GaAs single quantum well. Here, E_a and E_b are related by an optical transition (i.e., they have the same k). Use the following effective masses: $m_e^* = 0.067m_0$ and $m_h^* = 0.5m_0$. The bandgap energy of GaAs is 1.42 eV. Use infinite potential well for the calculation. Use the valence band edge as the reference for all energies (i.e., E_V = 0 eV).
   a. Find E_a and E_b as functions of the photon energy, $\hbar\omega$.
   b. Derive the Fermi-Dirac distribution for electrons in the first conduction subband with a quasi-Fermi level of F_C, $f_C(E_b(\hbar\omega))$, as a function of $\hbar\omega$.
   c. Similarly, derive the Fermi-Dirac distribution for electrons in the first valance subband with a quasi-Fermi level of F_V, $f_V(E_a(\hbar\omega))$, as a function of $\hbar\omega$.
   d. Calculate and plot optical gain spectra for the GaAs quantum well for photon energy from 1.4 eV to 2 eV at T = 300 K. Plot the spectra for two quasi Fermi level separations: ΔF = 1.5 and 1.8 eV. (Again, use your numeric program for calculation and plotting)
   e. Calculate and plot the spontaneous emission spectra for the GaAs quantum well for photon energy from 1.4 eV to 2 eV at T = 300 K. Plot the spectra for two quasi Fermi level separations: ΔF = 1.5 and 1.8 eV. (Again, use your numeric program for calculation and plotting)