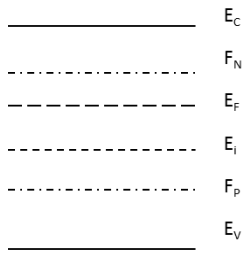
ECE 3030 Spring 2025 HOMEWORK ASSIGNMENT NO. 4
Due: Friday, February 19th, 11:59 pm upload to Carmen 3030 SpeedGrader

1. (10 pts) (a) Under equilibrium conditions and T> 0 K, what is the probability of an electron state being occupied if it is located at the Fermi level? (b) If E_F is positioned at E_V, calculate the probability of finding electrons in states at $E_V - k_BT$. What is the probability of finding holes at this energy?
2. (15 pts) Construct a semi-logarithmic plot such as Streetman Fig. 4.7 for Si doped with 1×10^{16} donors/cm^3 and having 5×10^{15} EHP/cm^3 created uniformly at t = 0. Assume that $\tau_n = \tau_p = 7$ μs. Calculate the slope of p(t).
3. (15 pts) Consider a semiconductor in which $n_0 = 10^{15}$ cm^{-3} and $n_i = 10^{11}$ cm^{-3}. Assume that the excess-carrier lifetime is 10^{-6} sec. Determine the electron - hole recombination rate if the excess-hole concentration is $\delta p = 5 \times 10^{13}$ cm^{-3}. (Hint: The majority carrier concentration is ~ unchanged here.)
4. (15 pts) A semiconductor device requires n-type material. It is to be operated at 500 K. Would Si doped with 10^{15} cm^{-3} of arsenic be useful in this application? Could GaAs with this doping be used? How about Ge with this doping?
5. (15 pts) A semiconductor in thermal equilibrium has a hole concentration of $p_0 = 10^{16}$ cm^{-3} and an intrinsic concentration of $n_i = 10^{10}$ cm^{-3}. The minority carrier lifetime is 2×10^{-7} sec. (a) Determine the thermal-equilibrium recombination rate of electrons. (b) Determine the change in the recombination rate of electrons if an excess electron concentration of $\delta n = 10^{14}$ cm^{-3} exists.
6. (15 pts) A Si sample with 10^{15} cm^{-3} donors is uniformly optically excited at room temperature such that 10^{19} cm^{-3} electron-hole pairs are generated per second. (a) Find the separation of the quasi-Fermi levels upon shining the light. Electron and hole lifetimes are both 10 μs. (b) Draw a band diagram such as at right, showing the positions of F_n and F_p relative to E_i and E_F.



7. (15 pts) Find $F_n - F_p$ in problem 6 for T = 500 K. Is it larger or smaller than at room temperature? Why? (Assume the same δn and δp. Ignore any change in band gap.)

8. BONUS (10 pts): ((a) A Ge sample is doped with 10^{16} As (arsenic) atoms / cm^3. What is the electron concentration n_0 at 300K?
(b) A Si sample is doped with 10^{15} As atoms/cm^3. Using the requirements of space charge neutrality, calculate the electron concentration n_0 at 500 K.