VE320 Intro to Semiconductor Devices
Summer 2024 — Problem Set 4
Due: 11:59pm 30th June

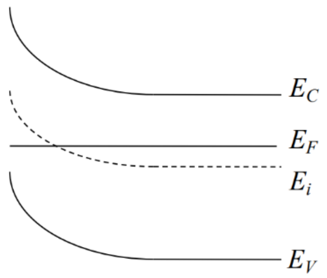
Since we notice that there are several midterm exams next week, the due date is set on next Sunday evening. But the next homework will still be posted on next Friday and due in one week.

1) What are the two main mechanisms of scattering discussed in the lecture? State their effects on the electron's mobility.

2) Consider a homogeneous gallium arsenide semiconductor at 300 K with $10^{16}cm^{-3}$ donors and $0cm^{-3}$ acceptors. μ_p=$310cm^2$/V-s, μ_n=$7500cm^2$/V-s.

a) Calculate the thermal-equilibrium values of electron and hole concentrations.
b) For an applied E-field of 10 V/cm, calculate the drift current density.

3) Answer the following questions based on the band diagram below:



a) Is it in equilibrium?
b) Is this sample n-type or p-type or both?
c) Is there an electric field?
d) Is there a concentration gradient?
e) Is there a drift current?
f) Is there a diffusion current?
g) Is there a net current?

4) What's the difference of direct(radiative) recombination and indirect(SRH) recombination discussed in the lecture? Do they both contribute to the excess carrier lifetime?

5) A Si bar is uniformly doped with $10^{17}cm^{-3}$ donors. Suppose complete ionization. A light is casted to the left end (x = 0) of the bar, and excess carriers are only generated there. The lifetime of excess minority carrier is 1μs. D_n=$25cm^2/s$, D_p=$10cm^2/s$, δn(0) = δp(0) = $10^{15}cm^{-3}$. Neglect the induced electric field.

a) Calculate the concentration of steady-state excess holes as a function of x.
b) Calculate the steady-state hole diffusion current density at x=10μm.

6) We inject electrons instantly into a uniformly doped p-type 5μm long Si sample at 300K such that the extra electron concentration varies linearly from $10^{20}cm^{-3}$ to 0 from left to right at that moment. The mobility of electrons is $500cm^2$/V-s in this doping condition.

a) What is the current density at that moment if the induced electric field is negligible? (Refer to the lecture slide chapter 5 if the induced electric field need to be considered)

b) Qualitatively draw the energy band diagram of the semiconductor along its length at that moment, carefully labelling E_c, E_v, Ef_i and the quasi-Fermi energies Ef_n, Ef_p.

7) A Si sample is uniformly doped with $10^{16}cm^{-3}$ donors and is uniformly optically excited such that $10^{19}cm^{-3}s^{-1}$electron-hole pairs are generated. Optical excitation causes the sample to heat to 450K. Suppose the donors are completely ionized and the Si sample is in steady state. Excess electron and hole lifetimes are both 10μs. At 450K, D_p=$12cm^2/s$, D_n=$36cm^2/s$ for Si in this doping condition.

a) Find the quasi-Fermi levels Ef_n, Ef_p with respect to the intrinsic Fermi level Ef_i at 450K
b) Find the change in conductivity of the sample upon shining the light at 450K. Neglect the high electric field case.