EE 207 [Spring 24-25] ***HW-5***

1. Consider a p-n junction with comparable n and p doping.

(a) Draw the band diagram schematically when the junction is in reverse bias. Show the quasi-fermi levels clearly. Draw the profiles of the electric field and potential in comparison with their equilibrium profiles (i.e. on the same figure).

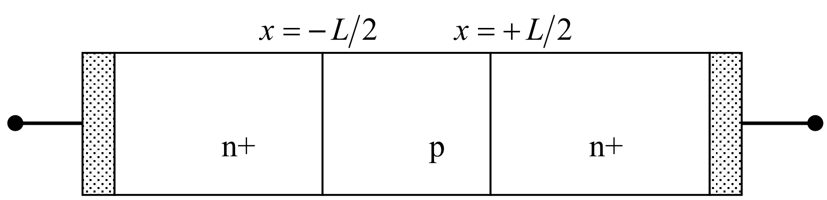
(b) Assuming this to be silicon, with uniform n and p side doping of 10^{15} and 5×10^{15} cm^{-3} respectively, calculate the depletion widths and potential drops on either side of the junction in equilibrium, and, for a reverse bias of 1V.

2. Consider an n+/p/n+ structure shown below. It is made of a semiconductor material with relative permittivity κ_s and bandgap E_g. The thickness of the p-region is L. Assume that the doping in the n+ region (N_d) is non-degenerate but much larger than the doping in the p-region (N_a), both being uniform. All questions pertain to the equilibrium situation.

(a) For warm-up, show that for a single long n+/p junction, the potential drop is almost wholly in the p region. Thus, we assume that the depletion width W is in the p region.

(b) Now, draw the electric field profiles and comparative band-diagrams for the n+/p/n+ structure when (i) $L > 2W$ and (ii) $L < 2W$.

(c) As you can tell, electrons see a potential barrier between the n+ regions – plot the barrier height schematically as a function of L covering both regimes (i) and (ii).



3. Consider a long semiconductor homo-junction that is n^{++} on one side and p^{++} on the other, with fully-ionized doping concentration N_d and N_a respectively. The doping on both sides is high enough that the Fermi-level is inside the corresponding band. The intrinsic carrier concentration is $n_i = \sqrt{N_C N_V}\exp\left(-E_g/2k_B T\right)$, where the symbols have their usual meaning. Please feel free to make *reasonable* approximations.

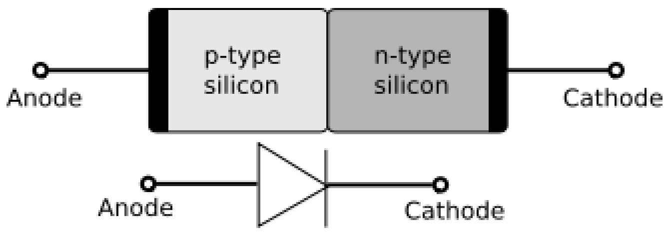
(a) First, some background. Show that the equilibrium electron concentration in a bulk homogeneous n^{++} semiconductor may be written as $n_0 \simeq \alpha_n (E_F - E_C)^{\frac{3}{2}}$ where α_n is a material parameter. [The hole concentration in a bulk homogeneous p^{++} semiconductor may, similarly, be expressed as $p_0 \simeq \alpha_p (E_V - E_F)^{\frac{3}{2}}$.]

(b) Draw, schematically, the equilibrium band-diagram for this device.

(c) Derive an expression for the equilibrium built-in potential.

(d) Write down an expression for the forward-bias current in this device, along with the justification thereof.

4. Let us try to derive the p-n diode I-V relation using a different method. Consider the electron current density from left to right $J_{n,L\rightarrow R}(V)$ and that from right to left $J_{n,R\rightarrow L}(V)$ in the diode illustrated below (drawing a band-diagram might help).



(a) Taking the difference between them, I get: $J_n(V) = J_{n0}\left[e^{qV/k_BT} - 1\right]$. How? Explain with detailed reasoning. Why is it that drift/diffusion considerations seem to have no role now?

(a) Derive J_{n0} in terms of device parameters (doping, lifetime, mobility etc.) with reasoning.