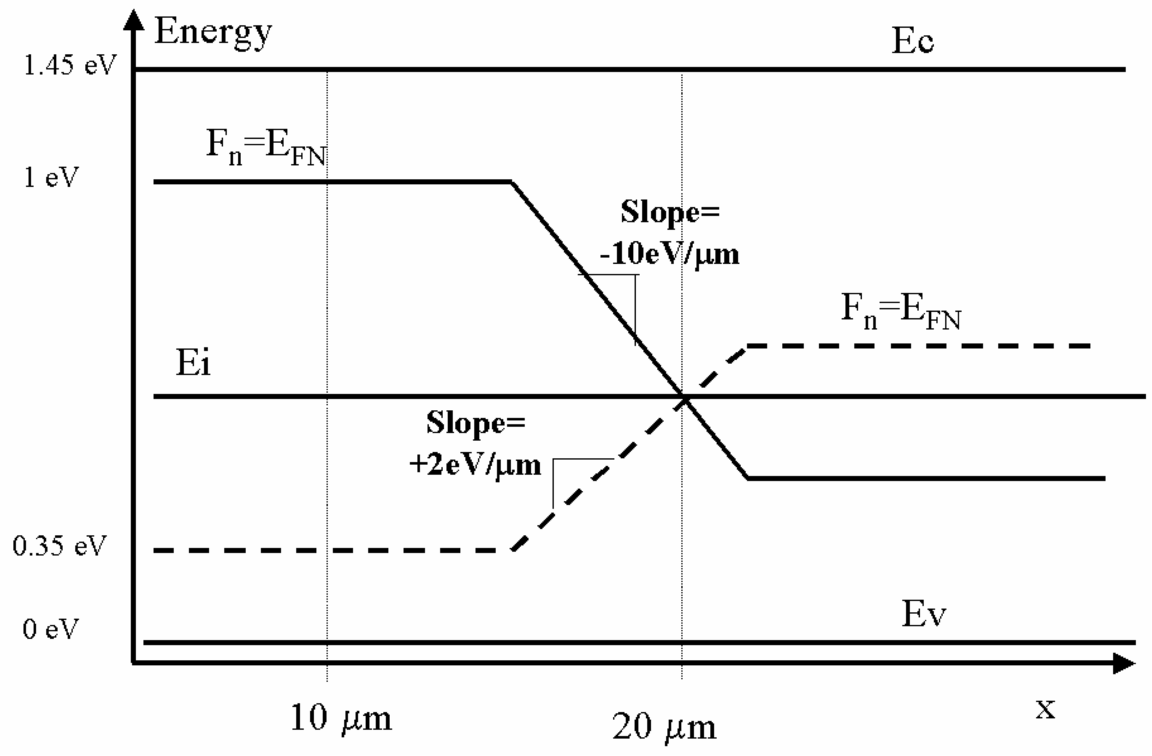
Homework 4

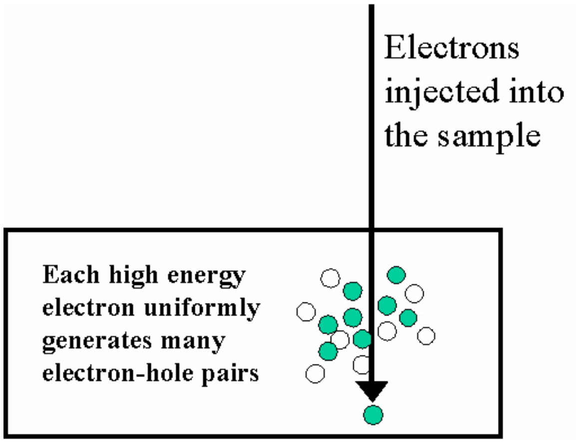
1) A semiconductor at room temperature (27 degrees C) has the following parameters:
Hole Diffusion coefficient, D_p=11.86 cm^2/Sec
Electron Diffusion coefficient, D_n=33.625 cm^2/Sec
Substrate intrinsic concentration, n_i=1e10 cm^{-3}
Also, these conversion factors may help: Amp=Coulomb/Sec, and Coulomb=Joule/Volt

The sample is in non-equilibrium with the following energy band relationships



a.) What are the electron and hole current densities, J_n and J_p at position x=10 µm? Make sure you support your answer with equations or a discussion.

b.) What are the electron and hole current densities, J_n and J_p at position x=20 µm? Make sure you support your answer with equations or a discussion.



2) Betavoltaic power sources (generating power using energetic particles from a radioactive source) pre-date photovoltaic (solar cell) power sources but have never caught on due to the limited power produced compared to the defects created due to the radiation damage. A thin SiC semiconductor material of thickness 2 um with energy bandgap 3.2 eV is placed in a vacuum chamber (or flown in space where radiation is prevalent) and is bombarded with electrons at a rate equivalent to 1 nanoampere of current per square cm (1 nA/cm^2). The extra electrons are absorbed in the material. Due to the high energy of the electrons used for this bombardment, valence electrons are "knocked" into the conduction band in a process analogous to light induced photogeneration. Each high-energy bombarding electron has 10,000 eV of energy and thus, can generate multiple electron-hole pairs before all of its energy is dissipated. On average, each high energy electron only converts 1/3 of its energy into generating electron-hole pairs – the other 2/3 being lost as heat (this condition is based on real life observations). The wafer is p-type and is uniformly doped with 10^{18} cm^{-3} acceptors. The electron beam was turned on January 1, 2008 and is completely absorbed throughout the material uniformly. At 12 noon on March 5th 2008, a Clemson engineer knocked out power and the electron beam instantly shut off. A) Determine the excess electron concentration in the SiC for all positions AFTER the beam is turned off. Assume room temperature, a minority carrier lifetime of 0.1 μS and a mobility of 30 cm^2/V-sec and effective masses of $m_n^*=0.355m_o$ and $m_p^*=0.8m_o$. B) If the extra minority carriers are collected at the edge of a depletion region (before the beam is shut off), and assuming low level injection applies (so $p \sim p_0$) what voltage is produced by this radiation source?

NOTE: This is a real world example of a typical betavoltaic system or conversely from a system known as an Electron Beam Induced Current (EBIC) system used to map out the minority carrier lifetime vs position.

Given: $0 = D_n \dfrac{d^2\Delta n_p}{dx^2} - \dfrac{\Delta n_p}{\tau_n}$ General Solution is: $\Delta n_p(x) = Ae^{-x/L_n} + Be^{+x/L_n}$

Given: $0 = D_n \dfrac{d^2\Delta n_p}{dx^2} - \dfrac{\Delta n_p}{\tau_n} + G_L$ General Solution is: $\Delta n_p(x) = Ae^{-x/L_n} + Be^{+x/L_n} + G_L\tau_n$

Given: $0 = D_n \dfrac{d^2\Delta n_p}{dx^2}$ General Solution is: $\Delta n_p(x) = A + Bx$

Given: $0 = D_n \dfrac{d^2\Delta n_p}{dx^2} + G_L$ General Solution is: $\Delta n_p(x) = Ax^2 + Bx + C$

Given: $0 = D_n \frac{d^2 \Delta n_p}{dx^2} + G_{LO} f(x)$ General Solution is: $\Delta n_p(x) = \left[\frac{G_{LO}}{D_N} \iint f(x)dx \right] + Bx + C$

Given: $\frac{d\Delta n_p}{dt} = -\frac{\Delta n_p}{\tau_n}$ General Solution is: $\Delta n_p(t) = \Delta n_p(t = 0) e^{-t/\tau_n}$

Given: $0 = -\frac{\Delta n_p}{\tau_n} + G_L$ General Solution is: $\Delta n_p = G_L \tau_n$