EECS 170A, Fall 2015, MIDTERM EXAM

NAME ID#

For all questions please use following: $kT = 0.026 eV$ at 300K, $n_{i,Si} = 10^{10} cm^{-3}$ at 300K, $E_{g\text{-}Si} = 1.12$ eV,
$m_n^* / m_0 = 1.08$, $m_p^* / m_0 = 0.56$ in Si $h = 6.626 \times 10^{-34}$ J-s, $k = 1.38 \times 10^{-23}$ J/K, $m_0 = 9.11 \times 10^{-31}$ kg

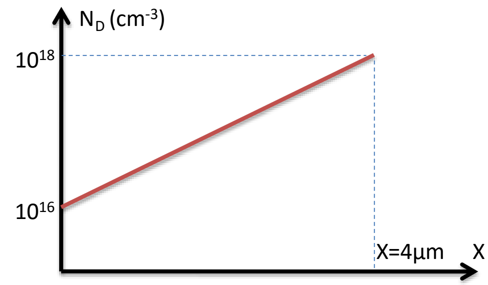
$\varepsilon_0 = 8.85 \times 10^{-14} F/cm$, $K_S = 11.7$ for silicon

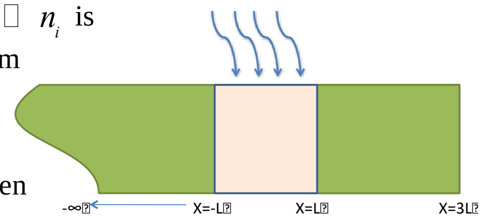
1. A sample germanium has acceptor concentration of $4 \times 10^{16} cm^{-3}$ and donor concentration of $10^{17} cm^{-3}$. Find the room temperature concentrations of electrons and holes before. Plot band diagram indicating the location of Fermi energy. Is this an n-type or a p-type semiconductor? If you wish to make a compensated semiconductor how much more and what type of dopants you need to add? Can you formulate how to find density of carriers due to the thermal generation process?

$$Ge: m_n^* = 0.55 m_0, \quad m_p^* = 0.36 m_0, \ m_0 = 9.11 \times 10^{-31} kg, \ E_g = 0.66 eV$$

2. Doping profile of a 4μm long silicon is illustrated in the figure.

a. Calculate the position of Fermi energy with respect to conduction band and plot the band diagram
b. Calculate the electric field along the sample
c. Find the force on electrons in the sample. Which directions electrons and holes are drifted





3. A non degenerate N type silicon with electron density of $n \gg n_i$ is illuminated at the middle (at $-L \leq x \leq L$) to generate uniform excess hole density of Δp_0 (cm^{-3}) between $-L \leq x \leq L$ at steady state. Assume that the recombination lifetime of holes in the semiconductor is τ_p and $\Delta p_0 \ll n$. The diffusion time between L and 3L is much shorter than τ_p, hence there is *negligible recombination* occurs between L and 3L. Also, the semiconductor surface at $x = 3L$ is grounded to have $\Delta p(3L) = 0$. Calculate the excess hole distribution along the silicon? Find the **ratio of diffusion current** generated by excess holes at $x = 2L$ *and* $x = -2L$? Assume electrons have mobility of μ_p and diffusion coefficient of D_p, and there is no electric field applied to the device. Derive your results with clear indication of your assumptions.

4. Consider a uniformly doped pn junction diode with concentrations $N_A=2x10^{17}cm^{-3}$, $N_D=10^{16}cm^{-3}$. For T=300K, calculate:

a) The built in potential,
b) Width of the depletion layer,
c) Distribution of the potential and electric field in the depletion (space charge) region
d) Maximum electric field in the depletion layer.