Problem 1 (25 points)

Consider a homogeneous p-type Si semiconductor ($N_A = 1x10^{17}\ cm^{-3}$) in thermal equilibrium at t < 1μs. An external source is turned on at t = 1μs for a period of 0.1μs and produces excess carriers uniformly at the rate of $g = 10^{21}\ cm^{-3}\ s^{-1}$.

Assume:

$$D_n = 20\frac{cm^2}{s}, D_p = 10\frac{cm^2}{s}, \tau_n = 10^{-6}\,s, \tau_p = 10^{-7}\,s$$

a) (5 points) Determine the expression of $\delta n_p(t)$ for $0 \le t \le 1.0\mu s$

b) (5 points) Determine the expression of $\delta n_p(t)$ for $1.0 \le t \le 1.1\mu s$

c) (10 points) Determine the expression of $\delta n_p(t)$ for $1.1\mu s \le t \le \infty$

d) (5 points) Plot $\delta n_p(t)$ for $t = 0$ to $t = \infty$

Problem 2 (25 points)

Consider a silicon pn junction with the following parameters at T = 300K:

$$N_A = 5\times10^{15} cm^{-3}, \tau_p = 10^{-7} s, \tau_n = 10^{-6} s, \frac{kT}{e} = 0.026V$$

$$\mu_p = 400\ cm^2/V.s, \mu_n = 1000 cm^2/V.s, n_i = 1.5\times10^{10} cm^{-3}$$

a) (10 points) Determine N_D such that the ratio of the electron current to total current in the depletion region is 0.75

b) (10 points) The total current when V_a = 0.6 is 0.1mA, determine the cross-sectional area

c) (5 points) Sketch the energy-band diagram across the pn junction corresponding to part (b).

Problem 3 (25 points)

Consider a Si pn junction with $N_A = 1x10^{17}$ cm^{-3} and $N_D = 1x10^{15}$ cm^{-3}.

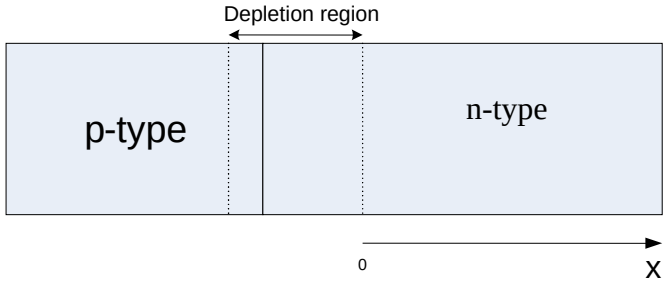
The critical electric field is $3x10^5$ V/cm and $\varepsilon_s = 11.7x8.85x10^{-14}$ F/cm.

a) (5 points) Is this a symmetrical or one-sided pn junction?
b) (10 points) Determine the breakdown voltage. Plot the electric field along the pn junction at this voltage.
c) (5 points) The measured capacitance at the breakdown voltage is 1pF. Determine the cross-sectional area.

Problem 4 (25 points)

Consider a silicon pn junction at T = 300 K, $N_A = 5x10^{16}\,cm^{-3}$, $N_D = 1x10^{16}\,cm^{-3}$. The minority carrier lifetimes are $\tau_n = 0.01\ \mu s$ and $\tau_p = 0.01\ \mu s$. The junction is forward biased with $V_A = 0.6V$. The minority carrier diffusion coefficients are $D_n = 25\ cm^2/s$, $D_p = 10\ cm^2/s$.

$$n_i = 1.5\times10^{10} cm^{-3},\ \frac{kT}{e} = 0.026V$$



a) (5 points) Calculate the excess hole concentration as a function of x in the n side (see the figure above).
b) (10 points) Calculate the hole diffusion current density at $x = 2L_p$
c) (10 points) Calculate the electron current at $x = 2L_p$