ECE 113A
Professor Burke (15400) Section A
Homework #4 Solutions and Grading Criteria

1) For Si at 300K, with no light, and under steady state conditions, with $N_A = 10^{18}$ cm^{-3}, and zero electric field:

a) Find $\Delta n_p(x)$ from 0 to infinity if $\Delta n_p(0) = 10^{15}$ cm^{-3}; $\Delta n_p(\infty) = 0$. Use $\tau = 1\mu$s. **(10 pts total)**

2 pts $D_N\, d^2\Delta n_p(x)/dx^2 + \Delta n_p(x)/\tau_n = 0$

$L_N = (D_N\tau_n)^{1/2}$

$= [(kT/q)\,\mu_n\tau_n]^{1/2}$

$= [(.0259V)(270cm^2/V\text{-}s)(1\mu s)]^{1/2}$

2 pts $= 26.4\ \mu m$ *(credit given for 26-27 μm)*

2 pts $\Delta n_p(x) = A\exp[-x/L_N] + B\exp[x/L_N]$

2 pts
- $\Delta n_p(0) = A + B = 10^{15}\ cm^{-3}$
- $\Delta n_p(\infty) = B\exp[\infty] = 0 \Rightarrow B = 0$
- $A = 10^{15}\ cm^{-3}$

2 pts $\Delta n_p(x) = 10^{15}\exp[-x/26.4\mu m]\ cm^{-3}$

b) Find n(x) under same conditions. **(10 pts total)**

3 pts $n_o = n_i^2/p_o = 10^2\ cm^{-3}$

3 pts $n(x) = \Delta n(x) + n_o$

Either answer 4 pts
- $= 10^{15}\exp[-x/26.4\mu m]\ cm^{-3} + 10^2\ cm^{-3}$
- $\cong 10^{15}\exp[-x/26.4\mu m]\ cm^{-3}$

c) Find p(x) under same conditions. **(10 pts total)**

Because $\Delta n_p << p_o$, low level conditions prevail. Therefore, the majority carrier concentration is approximately unchanged.

5 pts $p(x) = p_o = N_A$

5 pts $= 10^{18}\ cm^{-3}$

2) For Si at 300K, with no light, and under steady state conditions, with $N_D = 10^{15}$ cm^{-3}, and zero electric field:

a) Find $\Delta p_n(x)$ from x=0 to x=1μm if $\Delta p_n(0) = 10^{10}$ cm^{-3}; $\Delta p_n(1\mu m) = 10^8$ cm^{-3}. Use $\tau = 1\mu$s. **(10 pts total)**

2 pts $D_P\, d^2\Delta p_n(x)/dx^2 + \Delta p_n(x)/\tau_p = 0$

$L_P = [D_P\tau_p]^{1/2}$

$= [(kT/q)\,\mu_p\tau_p]^{1/2}$

$= [(.0259V)(459\ cm^2/V\text{-}s)(1\mu s)]^{1/2}$

2 pts $= 34.5\ \mu m$ *(credit given for 34-35 μm)*

2 pts $\Delta p_n(x) = A\exp[-x/L_P] + B\exp[x/L_P]$

2 pts
- $\Delta p_n(0) = A + B = 10^{10}\ cm^{-3}$
- $\Delta p_n(1\mu m) = A\exp[-1/34.5] + B\exp[1/34.5] = 10^8\ cm^{-3}$
- $A = 1.76x10^{11}\ cm^{-3}\ \&\ B = -1.66x10^{11}\ cm^{-3}$

2 pts $\Delta p_n(x) = (1.76x10^{11}\exp[-x/34.5\mu m] - 1.66x10^{11}\exp[x/34.5\mu m])cm^{-3}$

b) Find p(x) under same conditions. **(10 pts total)**

3 pts $p_o = n_i^2/n_o = 10^5 cm^{-3}$

3 pts $p(x) = \Delta p(x) + p_o$

Either answer 4 pts
- $= [1.76x10^{11}\exp[-x/34.5\mu m] - 1.66x10^{11}\exp[x/34.5\mu m]]cm^{-3} + 10^5\ cm^{-3}$
- $\cong (1.76x10^{11}\exp[-x/34.5\mu m] - 1.66x10^{11}\exp[x/34.5\mu m])cm^{-3}$

c) Find n(x) under same conditions. **(10 pts total)**

Because $\Delta p_n << n_o$, low level conditions prevail. Therefore, the majority carrier concentration is approximately unchanged.

5 pts $n(x) = n_o = N_D$

5 pts $= 10^{15}\ cm^{-3}$

3) For a Si p-n diode at 300K, with no applied voltage, with $N_A = 10^{15}$ cm^{-3}, and $N_D = 10^{18}$ cm^{-3}

a) Calculate V_{bi} in units of V **(10 pts total)**

4 pts $V_{bi} = (kT/q)\ ln(N_A N_D/n_i^2)$

3 pts $=(.0259V)ln[(10^{15})(10^{18})/(10^{10})^2]$

3 pts $= 0.775V$ *(credit given for 0.7-0.8V)*

b) Calculate x_p in units of μm **(10 pts total)**

4 pts $x_p = [(2K_s\varepsilon_0/q)V_{bi}\ N_D /\ N_A(N_A + N_D)]^{1/2}$

3 pts $= [(2)(11.8)(8.85x10^{-14}F/cm)(10^{18}cm^{-3})(0.775V)/(1.6x10^{-19})(10^{15}cm^{-3})(10^{15}cm^{-3}+10^{18}cm^{-3})]^{1/2}$

3 pts $= 1.005\ \mu m$ *(credit given for 1-1.1 μm)*

c) Calculate x_n in units of μm **(10 pts total)**

4 pts $x_n = N_A x_p/N_D$

3 pts $= (10^{15})(1.005\ \mu m)/10^{18}$

3 pts $= 1.005x10^{-3}\ \mu m$ *(credit given for $1\text{-}1.1x10^{-3}$ μm)*

d) Calculate $W = x_n + x_p$ in units of μm **(10 pts total)**

5 pts $W = 1.005\ \mu m + 1.005x10^{-3}\ \mu m$

5 pts $= 1.006\ \mu m$ *(credit given for 1-1.1 μm)*