ECE 113A
Professor Burke Section B
Homework #4 Solutions and Grading Criteria

1) For Si at 300K, with no light, and under steady state conditions, with $N_A = 10^{17}$ cm^{-3}, and zero electric field:
   a) Find $\Delta n_p(x)$ from 0 to infinity if $\Delta n_p(0) = 10^{14}$ cm^{-3}; $\Delta n_p(\infty) = 0$. (Use $\tau = 1\mu s$.) **(10 pts total)**

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

   2 pts $L_N = \sqrt{D_N\tau_n} = \sqrt{(kt/q)}\, \mu_n \tau_n = [(.0259V)(801cm^2/V\text{-}s)(1\mu s)]^{1/2} = 45.5\ \mu m$

   2 pts $\Delta n_p(x) = A\, e^{-(x/LN)} + B\, e^{(x/LN)}$

   2 pts $\begin{cases} \Delta n_p(0) = A + B = 10^{14}\ cm^{-3} \\ \Delta n_p(\infty) = B\, e^{(\infty)} = 0 \Rightarrow B = 0 \\ A = 10^{14}\ cm^{-3} \end{cases}$

   2 pts $\Delta n_p(x) = 10^{14}\, e^{-(x/45.5\mu m)}\ cm^{-3}$

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

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

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

   Either answer 4 pts $\begin{cases} = 10^{14}\, e^{-(x/45.5\mu m)}\ cm^{-3} + 10^3\ cm^{-3} \\ \cong 10^{14}\, e^{-(x/45.5\mu m)}\ cm^{-3} \end{cases}$

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

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

   5 pts $= 10^{17}\ cm^{-3}$

2) For Si at 300K, with no light, and under steady state conditions, with $N_D = 10^{17}$ cm^{-3}, and zero electric field:
   a) Find $\Delta p_n(x)$ from x=0 to x=1μm if $\Delta p_n(0) = 10^{11}$ cm^{-3}; $\Delta p_n(x=1\mu m) = 10^8$ cm^{-3}. Use $\tau = 1\mu s$. **(10 pts total)**

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

   2 pts $L_P = \sqrt{D_P\tau_p} = \sqrt{(kt/q)}\, \mu_p \tau_p = [(.0259V)(331\ cm^2/V\text{-}s)(1\mu s)]^{1/2} = 29.3\ \mu m$

   2 pts $\Delta p_n(x) = A\, e^{-(x/LP)} + B\, e^{(x/LP)}$

   2 pts $\begin{cases} \Delta p_n(0) = A + B = 10^{11}\ cm^{-3} \\ \Delta p_n(1\mu m) = A\, e^{-(1/29.3)} + B\, e^{(1/29.3)} = 10^8\ cm^{-3} \\ A = 1.51x10^{12}\ cm^{-3}\ \&\ B = -1.41x10^{12}\ cm^{-3} \end{cases}$

   2 pts $\Delta p_n(x) = [1.51x10^{12}\, e^{-(x/29.3\mu m)} - 1.41x10^{12}\, e^{(x/29.3\mu m)}]cm^{-3}$

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

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

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

   Either answer 4 pts $\begin{cases} = [1.51x10^{12}\, e^{-(x/29.3\mu m)} - 1.41x10^{12}\, e^{(x/29.3\mu m)}]cm^{-3} + 10^3\ cm^{-3} \\ \cong [1.51x10^{12}\, e^{-(x/29.3\mu m)} - 1.41x10^{12}\, e^{(x/29.3\mu m)}]cm^{-3} \end{cases}$

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

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

   5 pts $= 10^{17}\ cm^{-3}$

3) For a Si p-n diode at 300K, with no applied voltage, with $N_A = 10^{14}$ cm^{-3}, and $N_D = 10^{19}$ 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 $= (.0259V)ln[(10^{14})(10^{19})/(10^{10})^2]$

   3 pts $= 0.775V$

   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 $= [(2)(11.8)(8.85x10^{-14}F/cm)(10^{19}cm^{-3})(.775V)/(1.6x10^{-19})(10^{14}cm^{-3})(10^{14}cm^{-3}+10^{19}cm^{-3})]^{1/2}$

   3 pts $= 3.181\ \mu m$

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

   4 pts $x_n = N_A x_p/N_D$

   3 pts $= (10^{14})(3.181\ \mu m)/10^{19}$

   3 pts $= 3.181x10^{-5}\ \mu m$

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

   5 pts $W = 3.181\ \mu m + 3.181x10^{-5}\ \mu m$

   5 pts $= 3.181\ \mu m$