ECE 340 Homework IX Spring 2003
Due: Monday, March 17, 2003

1. When a prolonged diffusion or a high-energy implantation is conducted to form a p/n junction. The doping profile near the junction is usually graded, and the step-junction approach is no longer suitable to find the relationship between the width of the depletion region and the contact potential. However, the underlying principle used to establish equations 5-13 to 5-23 remains intact, and they can still be used to determine similar equations for the graded junction. Assume that the doping profile varies as N_a-N_d=Gx where G is $10^{20}/cm^4$ in a linear junction.

   (a) Find and plot the electric field, $\mathcal{E}(x)$, for $-\infty < x < +\infty$.
   (b) Determine the relationship between the width of the depletion region and contact potential for the junction at equilibrium.

2. An abrupt Si p-n junction has the following properties at 300 K:

p-side	n-side	A = $10^{-4}cm^2$
$N_a = 2x10^{17}/cm^3$	$N_d = 1x10^{16}/cm^3$	
$\tau_n = 0.1\ \mu s$	$\tau_p = 10\ \mu s$	
$\mu_p = 180\ cm^2/V\text{-}s$	$\mu_n = 1080\ cm^2/V\text{-}s$	
$\mu_n = 600\ cm^2/V\text{-}s$	$\mu_p = 400\ cm^2/V\text{-}s$	

   (a) Determine the contact potential V_o of the junction, and the depletion widths at equilibrium, under a forward bias of $V_o/2$ and under a reverse bias of $4V_o$.
   (b) Draw the band diagrams qualitatively at equilibrium and under forward and reverse bias showing the varying depletion widths, Fermi level and the quasi-Fermi levels.
   (c) Calculate the reverse saturation current due to holes, due to electrons and the total reverse saturation current.
   (d) Calculate the total injected minority carrier current for $V = V_o/3$ and $V_o/2$.
   (e) Poor heat dissipation often leads to a rise of the device temperature. Assuming μ's and τ's do not change with temperature, repeat part (c) for a temperature of T = 350 K at which the intrinsic carrier concentration $n_i = 4x10^{11}/cm^3$.

3. Assume that an abrupt Si p-n junction with area 10^{-4} cm^2 has $N_a = 5x10^{16}/cm^3$ on the p-side and $N_d = 2 x 10^{17}/cm^3$on the n side. The diode has a forward bias 0.5 volts.

   (a) Using mobility values from Fig. 3-23 (or better yet from the information sheet used for HR Exam) and assuming that $\tau_n = \tau_p = 1\ \mu s$, plot I_p and I_n versus distance on a diagram such as Fig. 5-17, including both sides of the junction. Neglect recombination within the space charge region, W.
   (b) Plot $\delta n(x_p)$ and $\delta p(x_n)$.
   (c) Determine the separation of quasi-Fermi levels at the position 5 μm into the quasi-neutral region in both sides of the junction.