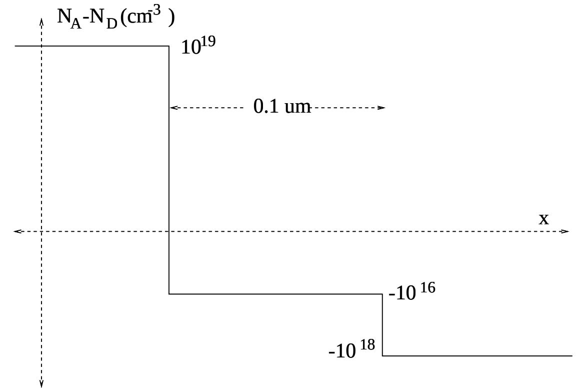
Homework #4 - EE 482

due 11/6/02

1. (a) Find and sketch the built-in field and potential for a silicon *pin* junction with the doping profile shown to the right. Indicate the length of each depletion region. (The symbol *i* represents a lightly doped or intrinsic region. In this case the central region is lightly *n*-doped, also called a *pνn* diode.)



   (b) Compare the maximum field in the *pin* diode to that in a *pn* junction without the lightly doped *n* region, but with the same dopant concentrations in the other regions. Why are they different?

   (c) Discuss how the depletion capacitance for the *pin* structure varies with voltage, comparing it as in part (b) to the normal *pn* junction with the same doping (but no lightly-doped *n*-region). Sketch C versus applied bias, using a single set of axes for both plots.

2. In a p-n junction, the doping density as a function on depth (x) in the neighborhood of the junction is given by $N_d - N_a = A\exp(-x/L) - B$.

   (a) Sketch the charge density, electric field and potential as functions of position.

   (b) Find (do not solve) algebraic expressions which could be used to find the depletion region widths in the n- and p-type regions (x_n and x_p) as a function of A, B and L, temperature, and fundamental constants (q, K, ϵ_0, etc.).

   (c) How does the capacitance vary with applied voltage for large reverse bias ($|V| \gg \phi_i$)?

3. Calculate the breakdown voltage at 300K of an abrupt silicon diode whose parameters are:

$$N_d = 10^{19}\text{cm}^{-3} \qquad W_n = 200\mu\text{m}$$
$$N_a = 10^{16}\text{cm}^{-3} \qquad W_p = 0.5\mu\text{m}$$

   (a) Consider all three possible breakdown mechanisms. Use breakdown fields from plot in notes (pg. 13).

   (b) Repeat if the acceptor doping is 10^{18}cm^{-3}.

4. In an abrupt **silicon** p-n junction at 300K, $N_a = 10^{19}\text{cm}^{-3}$, $N_d = 10^{17}\text{cm}^{-3}$, $\tau_n = \tau_p = 0.5\mu\text{s}$, $W_p = 0.1\mu\text{m}$ and $W_n = 500\mu\text{m}$. If the p-region is biased at +0.6V relative to the n-region, sketch the current densities as functions of position and calculate (neglecting recombination in the depletion regions):

   (a) The hole current density in the n-region at the edge of the depletion region.

   (b) The hole current density in the p-region at the edge of the depletion region.

   (c) The electron current density at the contact to the p-region.

   (d) The electron current density at the contact to the n-region.

5. For the same diode and biasing as in previous problem (ignore recombination in the depletion region):

   (a) Calculate the excess hole and electron concentrations in the quasi-neutral (undepleted) n and p-regions as functions of position.

   (b) Calculate the minority currents in the quasi-neutral regions as functions of position.

   (c) Calculate the drift and diffusion components of the majority currents.

   (d) Use the results from (c) to calculate the electric field as a function of position within the quasi-neutral regions.

   (e) Is the Diffusion Approximation valid or not?

   (f) Use the results from (d) to calculate the charge density as a function of position. Is the Quasi-Neutrality Assumption justified?