# EE566 Solid State Devices

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**Assignment 4**
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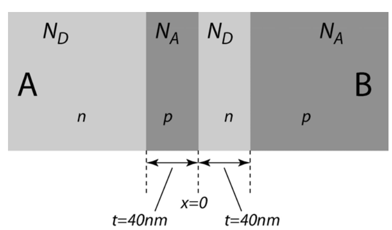
**Reading**: Chapter 2 from Shur

*p-n junction currents: The long, the short, and the funny*

**Problem 1**: *The Funny Junction*
Consider the silicon p-n junction shown below with a rather messed-up junction region.

a) Sketch the charge, electric field and band diagram for this device at zero applied bias. What is the built-in voltage between the quasi-neutral regions in A and B? Use $n_i$=6.68x$10^9/cm^3$, and $N_D$=$N_A$=$10^{17}/cm^3$. Assume regions A and B to be very long.
b) Find a *general algebraic relation* between the depletion widths $W$ in regions A and B in terms of the thickness $t$ and the built-in voltage $V_{bi}$. Do NOT neglect Gummel correction. Assume $N_D$=$N_A$=$N_o$ for simplicity. Then, calculate W for $t$=40$nm$, $N_o$ =$10^{17}/cm^3$.
c) At what bias voltage will the electric field at x=0 fall to zero? Find algebraically first, then calculate the numerical value. Is it forward-bias or reverse-bias?
d) At this bias, sketch the band diagram, showing the quasi-Fermi levels.
e) Find the total current density (in $A/cm^2$) flowing through our funny junction at this bias. Use $\tau_n$= $\tau_p$=10$\mu s$.




**Problem 2:** *Long and Short p-n junction currents*
We will henceforth call the heavily doped side of an asymmetrical p-n junction as the *EMITTER*, and the lightly doped side the *BASE*, to prepare for the jargon used in bipolar transistors. Consider an ideal $n^+$-$p$ junction made of silicon ($N_D$=$10^{17}/cm^3$, $N_A$=$10^{15}/cm^3$) at 300K. Assume that the minority carrier lifetime of electrons in the p-side and holes in the n-side is $\tau_n$=$\tau_p$=0.1$\mu s$. Look up data sheets for anything else you might need.

a) Calculate the saturation current density $J_0$ for the diode (current density is $J$= $J_0$[exp($V/V_{th}$)-1]).
b) *Sketch* the minority and majority carrier profiles outside the depletion region at zero bias, and at a forward bias of $V$=0.5Volt. Label length scales (diffusion lengths, etc).
c) Calculate and *sketch* the electron and hole current components (both diffusion and recombination) outside the depletion region as a function of distance at this forward bias. Which carriers (minority or majority) dominate the current flow on each side of the junction?
d) Redo parts a) to c) for a *short-base* diode, with the *total* base width (thickness of the p-side) $W_B$=2$\mu m$. Verify that $W_B$<<$L_n$, where $L_n$ is the minority carrier diffusion length in the base. Make reasonable approximations (linearize slow exponentials, etc) to simplify the problem.
e) Finally, what we were waiting for – when is the current larger – for long base or short base? Can you explain intuitively why this must be so?