EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
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Assignment 4
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Reading: Chapters 4 & 5 of the Textbook (MS).

Problem 1* **(Practice problem for p-n junctions)**
Consider a p-n junction made of GaAs at T=300K. (Doping densities: $N_A=10^{17}/cm^3$ and $N_D=10^{16}/cm^3$).
a) *Sketch* the charge-field-band diagrams under the depletion approximation. Label it with the *calculated* values of all important quantities such as x_n, x_p, W, F_{max}, V_{bi}, etc. Use natural units like *nm* for lengths, *V/cm* for fields, and *Volts* for potential. Your sketch should be roughly *to scale*. Which side is the depletion region large? Remember this property of the ratio of depletion region thickness in p-n junctions. How does the maximum electric field in the depletion region compare with the breakdown voltage of GaAs? What is the capacitance of the depletion region?
b) Use 1-D Poisson to simulate the junction, and *plot* the charge-field-band diagram *neatly*. Compare the values you calculated from part a) and explain the critical differences invoking the Gummel correction.

Problem 2 (The Planar-Doped Barrier)
Solve Problem 4.28 from the Textbook (MS).

Problem 3 (A strange p-n Junction)
Solve Problem 4.29 from the Textbook (MS).

Problem 4 (*Exact* solution for a homojunction)
Consider a n^- - n^+ homojunction made of GaAs. Let the doping densities on the two sides of the junction be $N_{D1}=10^{15}/cm^3$ and $N_{D2}=10^{17}/cm^3$, and the two sides to be long (>2000nm). Note that this is NOT a p-n junction, and you are asked here to solve the problem *exactly*, without the depletion approximation.
a) Find the potential barrier to electron flow across the junction. Is the junction ohmic or rectifying?
b) Sketch (qualitatively) the charge-field-band diagram for the junction. Denote the variation of the bands across the junction (parabolic, exponential, flat), and relate them to the Debye lengths on the two sides.
c) Calculate the maximum electric field at the junction *exactly*. (Do not neglect Gummel corrections!).
d) Simulate this band diagram using 1D Poisson. Compare the simulated maximum electric field with your calculated *exact* value in part c), and the smearing length of the free charge densities on the two sides with your calculation of Debye lengths in part b). Are they consistent?

Problem 5 (A nanoscale p-n Junction)
In class, we discussed planar (2D) p-n junctions. Imagine that you have a long semiconductor nanowire (intrinsic carrier conc n_i) – with a very small diameter (say 50 nm or so). Assume that along the nanowire you have a p-n junction, with the p- and n-sides doped degenerately ($N_D \sim N_C$, $N_A \sim N_V$). This nanowire p-n junction has air surrounding it. Answer the following –

a) If instead of a nanowire, you had a similarly doped 2D p-n junction, what would be the built-in voltage and the depletion region width? Draw a charge/field/band diagram.
b) Now considering the fact that there is air around the nanowire, and the electric field lines escape into the air in the depletion region, will the depletion region thickness in the wire be larger or smaller than the 2D case? Answer qualitatively first, and try to make it as quantitative as possible.

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* Remember to use proper units and label every figure/plot. Turn in your answers worked out neatly.
Please attach this question sheet to your solution when you turn it in.