EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
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1st Mid-Term Exam
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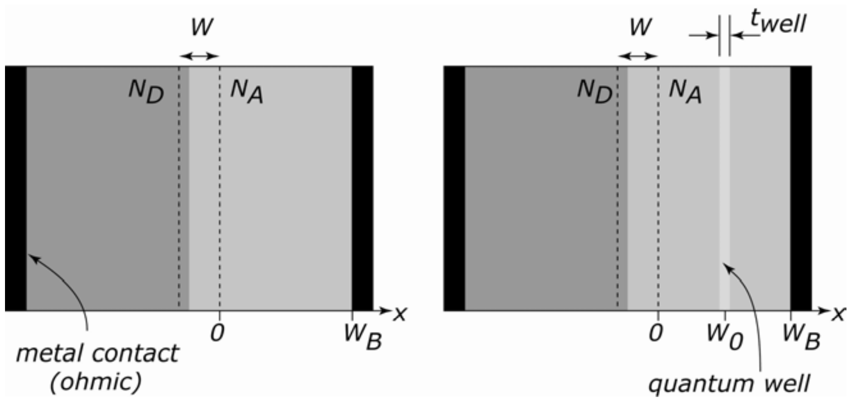
Problem (20 Points)



The above figure shows two short-base n^+-p diodes each of cross-section area A. They are identical in all aspects except for the fact that for the one on the right, the base-region has a very thin quantum well in it. $N_D >> N_A$, and the space-charge region widths for both diodes are W. Assume that there is no recombination/generation in the space charge region, and the change in the space-charge region thickness with applied bias is negligible. The quasi-neutral base thickness is W_B for both diodes. Assume the diffusion constant of electrons to be D_n, and the electron minority carrier lifetime in the base to be τ_n. For the diode on the right, the quantum well is at a distance W_0 from the edge of the space-charge region, and the thickness of the quantum well is much smaller than the base width, and all other lengths ($t_{well} << W, W_0, W_B$) in the device. Inside the quantum well, the recombination rate in $(cm^3.s)^{-1}$ is known to be R_{well}.

a) Plot the *excess* minority carrier profile $\Delta n_p(x)$ in the base of the first diode under a forward bias V. Find the total excess minority carriers stored in the base under this bias. (**2 Points**)
b) What is the current flowing in the first diode at a forward bias V? Neglect hole injection into the emitter, but explain why it is ok to do so. (**2 Points**)
c) Find the recombination current in the quantum well region of the second diode. (**2 Points**)
d) The second diode is also forward biased with the same voltage V as the first diode. Write down the current continuity equation across the well and solve it to find the *excess* minority carrier density at the location of the quantum well $\Delta n_p(W_0)$. (**5 Points**)
e) Show that as the recombination rate R_{well} increases, the excess minority carrier concentration in the well decreases. Plot the minority carrier profile $\Delta n_p(x)$ for the second diode and compare with the first. Use it to explain which diode will switch faster. (**3 Points**)
f) What is the current that flows in the second diode for the same bias? Is it larger or smaller than for the first diode? Explain why. (**4 Points**)
g) If you were required to increase the current flowing in the second diode by moving the quantum well (changing W_0), which way (left or right) would you move the well? Explain. (**2 Points**)

Use sketches with proper LABELS!! (wherever the situation demands). State your approximations clearly, and use your intuition to cut down on the math.