This is a closed book exam. You may use a calculator and the formula sheet at the end of this exam.

There are four equally weighted questions. To receive full credit, you must show your work (scratch paper is attached).

The exam is designed to be taken in 60 minutes, but you may use the full, 75 minute class period.

Be sure to fill in your name and Purdue student ID at the top of the page.

DO NOT open the exam until told to do so, and stop working immediately when time is called.

40 points possible, 10 per question

1a) 2 points
1b) 3 points
1c) 3 points
1d) 2 points

2a) 2 points
2b) 3 points
2c) 2 points
2d) 3 points

3a) 2 points
3b) 4 points
3c) 4 points

4a) 3 points
4b) 3 points
4c) 2 points
4d) 2 points
1) Consider P-type GaAs with the following parameters:

\[ N_A = 10^{20} \text{ cm}^{-3} \quad \tau_n = \tau_p = 0.2 \times 10^{-9} \text{ sec} \text{ (SRH parameters)} \]

\[ B = 2 \times 10^{-10} \text{ cm}^3/\text{sec} \quad C_p = 7 \times 10^{-30} \text{ cm}^6/\text{sec} \]

1a) Defects that are responsible for SRH recombination are typically near the middle of the bandgap. Which type of defect would lower the SRH lifetime the most - donor-like or acceptor like? Be sure to explain your answer.

1b) Compute the low-injection, minority electron lifetime due to band-to-band (radiative) recombination. **Hint:** begin with the general expression and simplify for low-injection.

1c) Compute the low-injection, minority electron lifetime due to Auger recombination. **Hint:** begin with the general expression and simplify for low-injection.

1d) Compute the low-injection, minority electron lifetime with SRH, radiative, and Auger recombination are **all present** at the same time.
2) Consider a P-type GaAs in equilibrium with non-uniform doping density resulting in the hole concentration sketched below.

Answer the following questions.

2a) What is the numerical value of the equilibrium hole current density at $x = 0$?

2b) What is the numerical value of the equilibrium hole diffusion current density at $x = 0$?

2c) What is the numerical value of the equilibrium hole drift current density at $x = 0$?

2d) What is the numerical value of the equilibrium electric field at $x = 0$?
3) For this problem, consider a P-type GaAs sample, moderately doped at $N_A = 10^{17}$ cm$^{-3}$.
The semiconductor is at room temperature, in low-level injection and is 1 micrometer long.
At $x = 0$, $\Delta n(0) = 10^{14}$ cm$^{-3}$
At $x = L = 1$ micrometer, the surface recombination velocity is $S_B = 10^5$ cm/sec
$\mu_n = 5500$ cm$^2$/V-sec and $\tau_n = 10$ nanoseconds.

3a) Assume low-level injection, no generation, and steady-state conditions, write down the Minority Carrier Diffusion Equation (MDE) and the boundary conditions for this problem. Make reasonable assumptions.

3b) Sketch the expected steady-state solution to the MDE for three cases: I) $S_B = 0$ cm/sec, II) $S_B \rightarrow \infty$ cm/sec, and III) $S_B = 10^5$ cm/sec (a moderate value).

3c) Solve the MDE for this problem.
4) This problem concerns a junction with a heavily doped N-type region, a thin intrinsic layer, and a moderately doped P-type region as sketched below. Assume the depletion approximation and assume that the width of the depletion region on the P-side is greater than the thickness of the intrinsic layer.

4a) Sketch the electric field vs. position assuming the depletion approximation.

4b) Using the sketch in 4a), develop an expression for the depletion layer width in the p-region, \( W \). Your answer should be in terms of \( V_{bi} \) and \( N_A \).
4) continued

4c) Compared to the same structure without the intrinsic layer, explain what effect the intrinsic layer will have on the built-in potential, $V_{bi}$.

4d) Compared to the same structure without the intrinsic layer, explain what effect the intrinsic layer will have on the maximum electric field in the junction.
SCRATCH PAPER