NAME _____ UCID _____

$$
\begin{aligned}
n &= \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2} \\
&= N_D - N_A \text{ if } N_D - N_A > 10n_i \\
p &= \frac{N_A - N_D}{2} + \sqrt{\left(\frac{N_A - N_D}{2}\right)^2 + n_i^2} \\
&= N_A - N_D \text{ if } N_A - N_D > 10n_i \\
np &= n_i^2 \text{ at equilrium} \\
n &= N_C e^{-(E_C - E_F)/kT} \\
p &= N_V e^{-(E_F - E_V)/kT} \\
D &= (kT/q)\mu \\
R &= \rho l/A \\
E &= \frac{1}{q}\frac{dE_C}{dx} = \frac{1}{q}\frac{dE_V}{dx} \\
dE/dx &= \rho/\epsilon \\
dV/dx &= -E \\
V_{bi} &= (kT/q)\ln(N_A N_D/n_i^2) \\
W_{dep} &= \sqrt{\frac{2\epsilon(V_{bi} - v)}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)} \\
x_N N_D &= x_P N_A \\
C &= \epsilon A/d \\
E_p &= hc/\lambda
\end{aligned}
$$

$$
\begin{aligned}
k &= 1.38 \times 10^{-23}\ J/K \\
h &= 6.63 \times 10^{-34}\ Js \\
q &= 1.60 \times 10^{-19}\ C \\
\epsilon_o &= 8.85 \times 10^{-12}\ F/m \\
v_T = kT/q &= 26\ mV \text{ @300K} \\
&\text{Silicon@300K} \\
N_C &= 2.8 \times 10^{19}/cm^3 \\
N_V &= 1.0 \times 10^{19}/cm^3 \\
n_i &= 1.0 \times 10^{10}/cm^3 \\
E_g &= 1.1\ eV \\
\epsilon_r &= 12 \\
\mu_n &= 1400\ cm^2/Vs \\
\mu_p &= 470\ cm^2/Vs \\
&\text{Germanium@300K} \\
N_C &= 1.0 \times 10^{19}/cm^3 \\
N_V &= 6.0 \times 10^{18}/cm^3 \\
n_i &= 2.0 \times 10^{13}/cm^3 \\
E_g &= 0.67\ eV \\
\epsilon_r &= 16 \\
\mu_n &= 3900\ cm^2/Vs \\
\mu_p &= 1900\ cm^2/Vs
\end{aligned}
$$

1. Consider real LEDs A(@λ_1) and B(@λ_2) with $\lambda_1 > \lambda_2$. Both are equally efficient: for every 100 electrons that flow through, 50 photons are produced. The diodes are connected in parallel to each other and to a current source such that current goes from the common anode to the common cathode. Answer with explanation.

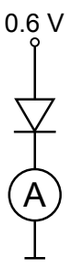
a. *(2 marks)* The value of the current source is gradually increased from 0.

(i) A emits light first (ii) B emits light first (iii) Both emit light together (iv) Insufficient information

b. *(2 marks)* At any given current in the circuit above, which LED generates more photons?

(i) A (ii) B (iii) Same (iv) Insufficient information

2. *(2 marks)* A photodiode is hooked up as shown below. If light (with energy $> E_g$) is made incident on the diode, will the ammmeter reading (magnitude) increase or decrease? Why? Recall an ammeter acts like a short circuit.



3. *(12 marks)* A silicon junction has two sides A and B. When B is grounded and 4 V applied to A, the peak electric field in the junction increases by a factor of 3, compared to when both A and B sides were grounded. Under the 4 V bias, $2/3$ of the depletion region was in side B.

(a) Identify the anode (p side) of the junction along with a justification.

(b) Find the built-in potential.

(c) Find the minority carrier concentration on sides A and B.

(d) Calculate the depletion capacitance per unit area at zero bias.

(e) At equilibrium, what fraction of the depletion region is in side A?

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(d) Calculate the depletion capacitance per unit area at zero bias.

(e) At equilibrium, what fraction of the depletion region is in side B?