NAME ____________________ UCID ____________________

1. Answer all four questions. Maximum mark is 18.
2. Show your work as much as possible, within time and space constraints.

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

$$
\begin{aligned}
k &= 1.38 \times 10^{-23}\ J/K \\
h &= 6.63 \times 10^{-34}\ Js \\
q &= 1.60 \times 10^{-19}\ C \\
\epsilon_o &= 8.85 \times 10^{-12}\ F/m \\
v_T = kT/q &= 26\ mV \text{ @300K}
\end{aligned}
$$

Silicon@300K

$$
\begin{aligned}
N_C &= 2.8 \times 10^{19}/cm^3 \\
N_V &= 1.0 \times 10^{19}/cm^3 \\
n_i &= 1.0 \times 10^{10}/cm^3 \\
E_g &= 1.1\ eV \\
\epsilon_r &= 12 \\
\mu_n &= 1400\ cm^2/Vs \\
\mu_p &= 470\ cm^2/Vs
\end{aligned}
$$

Germanium@300K

$$
\begin{aligned}
N_C &= 1.0 \times 10^{19}/cm^3 \\
N_V &= 6.0 \times 10^{18}/cm^3 \\
n_i &= 2.0 \times 10^{13}/cm^3 \\
E_g &= 0.67\ eV \\
\epsilon_r &= 16 \\
\mu_n &= 3900\ cm^2/Vs \\
\mu_p &= 1900\ cm^2/Vs
\end{aligned}
$$

1. *(2 marks)* Your ENEL361 instructor claims to have created a new photodiode which gives a responsivity of 1 A/W at 500 nm. Can you prove or disprove his claim or is additional information needed?

2. *(2 marks)* Consider a red (650 nm) and a blue (450 nm) LED. For a current of 10 mA, V_F for the red LED is 1.5 V and for the blue LED is 3.0 V. The LEDs are connected in series and an increasing voltage V is applied. Which LED will start emitting light first? Why?

3. *(2 marks)* Semiconductor rickmortium has N_C=N_V. Draw the energy band diagram of a rickmortium p$^+$n junction below showing E_F, E_C and E_V.

4. *(12 marks)* Charge densities of the left and right sides of a depletion region were 1.6 mC/cm^3 and -4.8 mC/cm^3, respectively. Unbiased depletion width on the right side was 250 nm. Depletion capacitance/area was 10.62 nF/cm^2.
(a) What is the total depletion width?
(b) Is the junction made out of silicon or germanium? How do you know?
(c) Find the hole concentrations on both the left and right sides, far from the depletion region.
(d) Find the barrier energy in eV.
(e) What bias voltage (forward/reverse and magnitude) is required to increase the depletion width to 2 μm?