NAME ______________________ UCID ______________

1. Answer all 8 questions. Maximum mark is 48.
2. Answer questions 1-4 on the question paper itself.
3. Show your work as much as possible, within time and space constraints.

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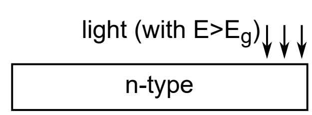
1. *(4 marks)* A semiconductor is doped with $20n_i$ acceptors at $x = 0$ and with $40n_i$ acceptors at $x = L$. Carriers will diffuse and eventually the process will stop. At that point, which of the following is true and why (no credit without explanation)? p is the hole concentration, not a probability.

(a) p(x=0)=p(x=L) (b) p(x=0)>p(x=L) (c) p(x=0)<p(x=L) (d) could be any of (a), (b) or (c)

2. *(4 marks)* When connected to the same resistive load and the same input sine wave, a half wave rectifier built with silicon diodes (cut-in voltage of 0.7 V) had the same peak to peak ripple as a full wave rectifier built with germanium diodes (cut-in voltage of 0.3 V). Find the peak-to-peak voltage of the input sine wave.

3. *(4 marks)* An n-type semiconductor is exposed to light near the right end as shown. Answer the following at a location left of the lighted part. **Note:** I'm looking for the direction of the current flow, not the direction of the carrier movement.



	Does not exist	Flows in $+x$	Flows in $-x$
(a) Electron drift current	○	○	○
(b) Electron diffusion current	○	○	○
(c) Hole drift current	○	○	○
(d) Hole diffusion current	○	○	○

4. *(4 marks)* Recall that semiconductor mobility depends on the temperature (even though this dependence is often ignored). You have two semiconductors A which is intrinsic and B which is heavily doped. Both the samples are heated.

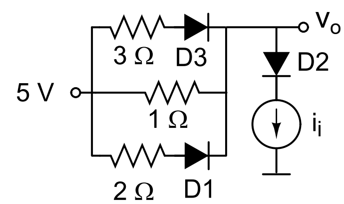
	Increases	Decreases	Stays the same	Can't say for sure
(a) Mean free time in A	○	○	○	○
(b) The resistance of A	○	○	○	○
(c) Mean free time in B	○	○	○	○
(d) The resistance of B	○	○	○	○

5. *(8 marks)* A semiconductor wire of length L has a linearly increasing acceptor doping concentration from $x = 0$ to $x = L$. At the center of the wire, there were N_{A0} dopants/cm^3 and the hole diffusion current there was found to be J_0. Find an expression for the electric field at $x = L/3$ and indicate its direction. Assume symbols for any material constants you need.

6. *(8 marks)* A 1×1×1 cm^3 cube of intrinsic germanium needs to be donor doped to create a 4 Ω resistor.
(a) What doping concentration is required?
(b) Unfortunately, the company you bought the germanium cube from shipped you germanium with the Fermi level 248.7 meV above the valence band instead of the intrinsic sample you wanted. If you still dope it as in (a) what resistor will you get?

7. *(8 marks)* On heating a sample of intrinsic semiconductor X, quasi-Fermi levels with an energy difference of $10kT$ from each other were created. If the intrinsic carrier concentration of X is $10^{12}/\text{cm}^3$ (assume independent of temperature) and the heating caused a steady state generation rate of $10^{18}/\text{cm}^3$s, find
(a) The steady state electron concentration
(b) The excess hole concentration at steady state
(c) The carrier lifetime of X

8. *(8 marks)* In the circuit to the right, D1 is an ideal silicon diode with a cut-in voltage of 0.7 V, D2 is an ideal gallium arsenide diode with a cut-in voltgee of 0.5 V and D3 is an ideal germanium diodes with a cut-in voltages of 0.3 V. Find v_o as a function of i_i for $i_i \geq 0$.



$$
\begin{aligned}
n &= \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2} \\
&= N_D - N_A \text{ if } N_D - N_A > 10n_i \\
p &= \frac{N_A - N_D}{2} + \sqrt{\left(\frac{N_A - N_D}{2}\right)^2 + n_i^2} \\
&= N_A - N_D \text{ if } N_A - N_D > 10n_i \\
n &= N_C e^{-(E_C - E_F)/kT} \\
p &= N_V e^{-(E_F - E_V)/kT} \\
np &= n_i^2 \text{ at equilibrium} \\
n &= n_0 + n' \; ; \; E_F \longrightarrow E_{Fn} \\
p &= p_0 + p' \; ; \; E_F \longrightarrow E_{Fp} \\
dn'/dt &= dp'/dt = n'/\tau = p'/\tau = \text{gen. rate} = \text{recomb. rate} \\
f(E) &= \frac{1}{1 + e^{(E - E_F)/kT}} \\
|\mu| &= q\frac{\tau_m}{m_{eff}} \\
J_{\text{drift}} &= q(n\mu_n + p\mu_p)E \\
J_{\text{diffusion}} &= qD_n\frac{dn}{dx} - qD_p\frac{dp}{dx} \\
D &= (kT/q)\mu \\
V_{\text{rip,pp}} &= I_{\text{out,max}}/\left(f_{\text{out}}C\right)
\end{aligned}
$$

Universal

$$
\begin{aligned}
k &= 1.38 \times 10^{-23} \text{ J/K} \\
q &= 1.60 \times 10^{-19} \text{ C} \\
kT &= 26 \text{ meV at 300K} \\
kT/q &= 26 \text{ mV at 300K}
\end{aligned}
$$

Silicon@300K

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

Germanium@300K

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