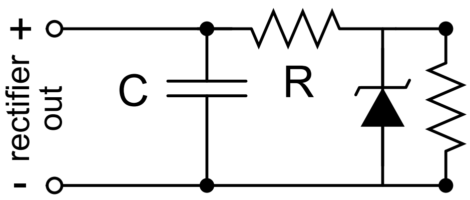
NAME UCID

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

1. *(2 marks)* Consider the statement below. Is anything wrong with the statement? If so, what is wrong?

An n type semiconductor has a bandgap of 0.7 eV. The Fermi level is located 0.4 eV below the conduction band.

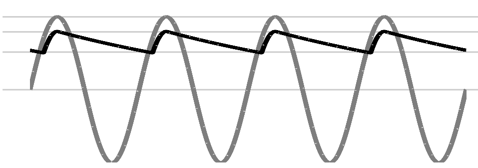
2. *(2 marks)* Consider the regulator shown below. Using $100\ \Omega < R < 200\ \Omega$ and $C > 300\ \mu F$ satisfies all the constraints. Initially you choose $R = 150\ \Omega$ and some appropriate capacitance. If you now replace the 150 Ω resistor by 180 Ω, what happens to the power dissipated by the Zener diode.



(a) Increases (b) Stays the same

(c) Decreases (d) Depends on C

3. *(2 marks)* The figure below shows the input and output of a rectifier with a smoothing capacitor C. The maximum load current is I_L and frequency is f leading to an approximate ripple of I_L/fC. Answer the two questions next to the figure.



(i) Mark the peak-to-peak ripple on the figure.

(ii) How does the actual ripple relate to I_L/fC *(hint: no math needed)*

(a) Actual ripple is larger (b) Actual ripple is smaller

4. *(12 marks)* (a) In updoped silicon, what is the probability of finding a hole at an energy $20kT$ below the conduction band?
(b) How should you dope (acceptor/donor and concentration) silicon to get the Fermi level 0.8 eV below the conduction band?
(c) What is the minority carrier and its concentration in the silicon after doping as in (b)?
(d) To the doped silicon from (b), $10^{14}/\text{cm}^3$ donors are added. What are the final majority and minority carrier concentrations?

$$
\begin{aligned}
n &= \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2} \\
&= N_D - N_A \text{ if } N_D - N_A > 10 n_i \\
p &= \frac{N_A - N_D}{2} + \sqrt{\left(\frac{N_A - N_D}{2}\right)^2 + n_i^2} \\
&= N_A - N_D \text{ if } N_A - N_D > 10 n_i \\
np &= n_i^2 \\
n &= N_C e^{-(E_C - E_F)/kT} \\
p &= N_V e^{-(E_F - E_V)/kT} \\
N_C &= 2\left(\frac{2\pi m_n kT}{h^2}\right)^{3/2} \\
N_V &= 2\left(\frac{2\pi m_p kT}{h^2}\right)^{3/2}
\end{aligned}
$$

Silicon@300K

$$
\begin{aligned}
N_C &= 2.8 \times 10^{19}/cm^3 \\
N_V &= 1.0 \times 10^{19}/cm^3 \\
n_i &= 1.0 \times 10^{10}/cm^3 \\
E_g &= 1.1\, eV
\end{aligned}
$$

$$
\begin{aligned}
D_C(E) &= \frac{8\pi m_n \sqrt{2m_n(E - E_C)}}{h^3} \\
D_V(E) &= \frac{8\pi m_p \sqrt{2m_p(E_V - E)}}{h^3} \\
f(E) &= \frac{1}{1 + e^{(E - E_F)/kT}}
\end{aligned}
$$

Constants

$$
\begin{aligned}
k &= 1.38 \times 10^{-23}\, J/K \\
h &= 6.63 \times 10^{-34}\, Js \\
q &= 1.60 \times 10^{-19}\, C
\end{aligned}
$$

@300K

$$
\begin{aligned}
kT &= 26\, meV \\
\frac{kT}{q} &= 26\, mV
\end{aligned}
$$

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
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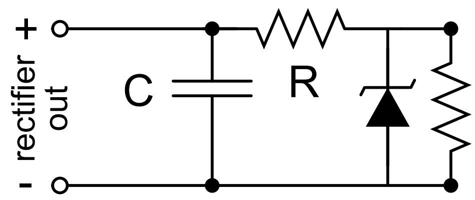
2. *(2 marks)* Consider the regulator shown below. Using $100\ \Omega < R < 200\ \Omega$ and $C > 300\ \mu F$ satisfies all the constraints. Initially you choose $R = 150\ \Omega$ and some appropriate capacitance. If you now replace the $150\ \Omega$ resistor by $120\ \Omega$, what happens to the power dissipated by the Zener diode.



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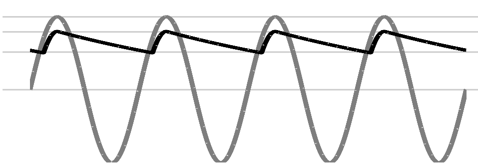

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Silicon@300K

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Constants

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@300K

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Germanium@300K

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