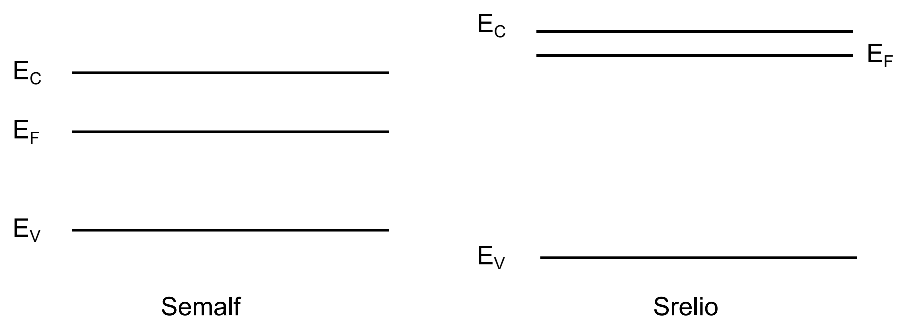
ENEL361 QUIZ 2 50 MINUTES Feb 26 2019

NAME | UCID

1. Answer all four questions. Maximum mark is 18.
2. For multiple-choice questions, indicate the correct answer. There may be more than one correct answer, in which case indicate all correct answers.
3. Show your work as much as possible, within time and space constraints.
4. Only this one sheet of paper will be collected and graded

1. Two semiconductors have energy bands as below. Mark the appropriate boxes below *(3 marks)*



	Larger for Semalf	Larger for Srelio	Can't say
Probability of finding an electron at E_C	○	○	○
Intrinsic carrier concentration	○	○	○
Hole concentration in the valence band	○	○	○

2. Strike out the incorect options in the statements below. *(2 marks)*

(a) Donor doping increases / decreases / does not change the hole concentration.

(b) Acceptor doping increases / decreases / does not change the intrinsic carrier concentration.

3. The Boltzmann approximations state p(electron) $= f(E) \sim e^{-\frac{E-E_F}{kT}}$ and p(hole) $= 1 - f(E) \sim e^{\frac{E-E_F}{kT}}$. Why is p(electron)+p(hole) not equal to 1? *(1 mark)*

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

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

Constants

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

@300K

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

Silicon@300K

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

Germanium@300K

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

4. A singly doped semiconductor is doped with acceptors or donors, not both. Consider singly doped Ge and Si. The electron concentration was the same at $10^{13}/\text{cm}^3$. Answer the questions below. *(12 marks)*
(a) Identify both semiconductors as n or p type with one-line justifications.
(b) Find the dopant type and concentration for Si
(c) Find the dopant type and concentration for Ge
(d) What are **two** ways (be specific: which sample will you dope, with what and at what concentration) to make hole concentrations equal in the two samples?

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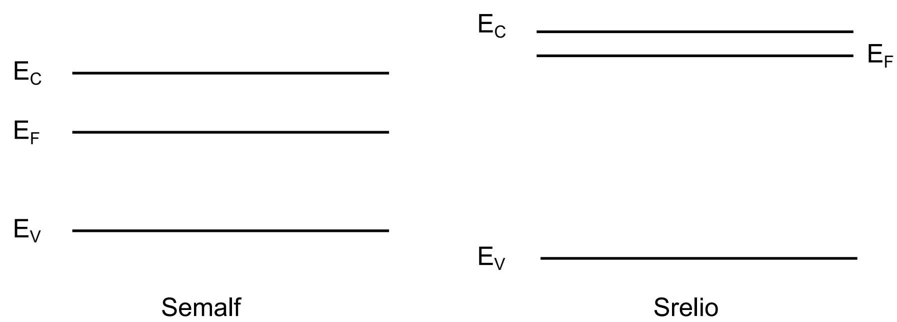

	Larger for Semalf	Larger for Srelio	Can't say
Probability of finding an electron at E_V	○	○	○
Intrinsic carrier concentration	○	○	○
Electron concentration in the conduction band	○	○	○

2. Strike out the incorect options in the statements below. *(2 marks)*

(a) Acceptor doping decreases / increases / does not change the hole concentration.

(b) Donor doping decreases / increases / does not change the intrinsic carrier concentration.

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