EE/CE 3310.001
First Examination
Spring 2018

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Show all your work on this test paper.
For all problems use $k_BT = 0.026$ eV.
Also note that $1\ \mu m = 10^{-4}$ cm and $1\ nm = 10^{-7}$ cm.

1. Which of these chemical formulas represent semiconductor materials? (Circle correct answers)

10/10 Ge AlSb InS ZnSe CdP InAs GeAs

2. Is each of the following dopant atoms a donor (D) or an acceptor (A) in the stated semiconductor?

donor P in Si

acceptor B in Si

10/10 donor As in Ge

donor S in GaAs

donor Si in GaAs on a Ga site

3. Answer the questions below with the correct algebraic sign (+ or −).

For an electron quasi-particle in the conduction band of a semiconductor:

_−_ a) What is the sign of the electric charge?

_+_ b) What is the sign of the quasi-particle mass?

For a hole quasi-particle in the valence band of a semiconductor:

_+_ c) What is the sign of the electric charge?

_+_ d) What is the sign of the quasi-particle mass?

For an electron state near the top of the valence band of a semiconductor:

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_−_ e) What is the sign of the effective mass?

4. In a P-type semiconductor which band edge will the Fermi level be closer to? (circle answer)

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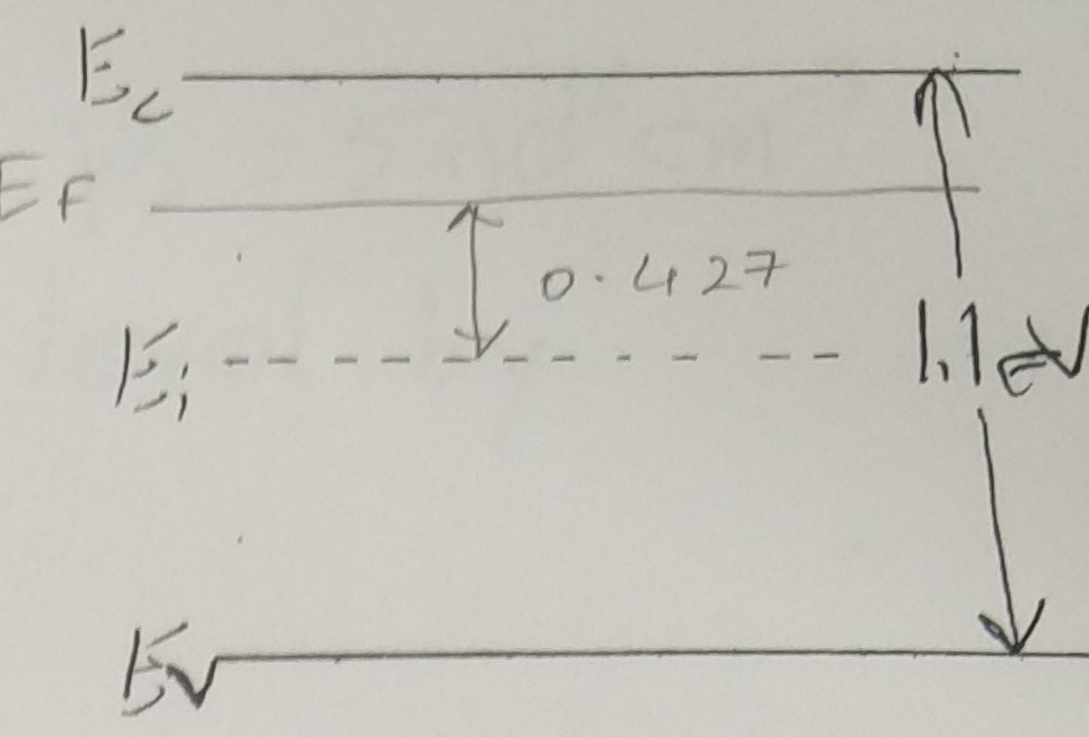
Conduction Band   Valence Band

5. A sample of Si has a Fermi level at
$E_F - E_i = 0.427\,eV$
Sketch the approximate location of the Fermi level on the band diagram and calculate the equilibrium densities n_0 and p_0.



$$n_0 = n_i e^{(E_F - E_i)/KT} = 1.5 \times 10^{10} \times e^{0.427/0.026}$$

$$n_0 = 2.03 \times 10^{17}$$

$$p_0 = \frac{n_i^2}{n_0} = \frac{(1.5 \times 10^{10})^2}{2.03 \times 10^{17}} = 1.11 \times 10^{3}$$

$n_0 = \underline{2.03 \times 10^{17}}\ cm^{-3}$

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$p_0 = \underline{1.11 \times 10^{3}}\ cm^{-3}$

6. A sample of Si is doped so that $p_0 = 5\times10^{16}\,cm^{-3}$. Find the location of the Fermi level by evaluating $E_i - E_F$

$KT \ln\left(\frac{p_0}{n_i}\right) = E_i - E_F$

$0.026 \ln\left(\frac{5\times10^{16}}{1.5\times10^{10}}\right) = 0.391$

$E_i - E_F =$ 0.391 ✓ eV

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7. An N-type semiconductor is illuminated so that a density of excess holes $\delta p = 1\times10^{15}\,cm^{-3}$ is created. If the minority-hole lifetime in this material is $\tau_p = 1.0\,\mu s$, what is the rate of electron-hole pair generation in steady state (R−G = 0)?

$\delta n = \delta p = g_{op} \times \tau$

$\therefore \frac{1\times10^{+15}}{1\times10^{-6}} = 1\times10^{-9}$

$\frac{10^{-15}}{10^{-6}} = 10^{-9}$

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$G =$ $1\times\cancel{10}^{-9}$ $cm^{-3}s^{-1}$