SSP Exercise 6

1. Calculate the probability of the occupancy of the lowest energy state in the conduction band if the Fermi level is 3 kT below the conduction band edge.

[5 marks]

Answer:
We have E_C-E_f=3*kT

$f(\varepsilon) = \frac{1}{1+e^{\frac{\varepsilon_C-\varepsilon_F}{kT}}} = \frac{1}{1+e^3} \approx 0.047$ which is close to 5%.

2. Find the built-in potential for a p-n Si junction at room temperature if the bulk resistivity of Si is 1 Ω cm. Electron mobility in Si at RT is 1400 $cm^2V^{-1}s^{-1}$; $\mu_n/\mu_p = 3.1$; $n_i = 1.05 \times 10^{10}$ cm^{-3} (where μ_n and μ_p are majority carrier mobilities on *n* and *p* side, and n_i is intrinsic carrier concentration). **Hint** - please use the following relationships: $\sigma = en\mu_e$ on *n*-side and $\sigma = ep\mu_p$ on *p*-side since conductivity is dominated by the majority of carriers on each side.

[15 marks]

Answer:
In thermal equilibrium with $V_{ext} = 0$ the elctron density on the n side must be equal to the electron density on p side:

$$\frac{n_i^2}{N_A} = N_D e^{-eV_B/kT}$$

and finally

$$V_B = \frac{kT}{e} \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

from

$\sigma = 1/\rho$ and $\sigma_e = N_A e\mu_n$ and $\mu_n/\mu_p = 3.1$ we get:
$N_A = \frac{1}{e\mu_n\rho}$ and $N_D = \frac{3.1}{e\mu_n\rho}$ and hence
$N_A N_D = \frac{3.1}{e^2\mu_n^2\rho^2}$ and

$$V_B = \frac{kT}{e} \ln\left(\frac{3.1}{e^2\mu_n^2\rho^2 n_i^2}\right)$$

For room T = 300 K and (all in SI units, so need to convert cm to m where appropriate):
$e^2\mu_n^2\rho^2 n_i^2 \approx (1.6)^2 10^{-38} * (1400)^2 * 10^{-8} 10^{-4} * 10^{32} \approx$
$\approx 5 * 10^6 * 10^{32} * 10^{-50} = 5 * 10^{-12}$, and $ln(6.2 * 10^{11}) \approx 27.2$

$$V_B \approx \frac{1.4 * 10^{-23} * 300 * 27.2}{1.6 * 10^{-19}} \approx 0.71\text{V}$$