ECE 3030: Physical Foundations of Computer Engineering
Fall 2021
Homework 3—Total points 100
Due on Thursday 9/23/2020 at 11.59 am.

Q1 Have you downloaded the textbook: Modern Semiconductor Devices for Integrated Circuits by Chenming Calvin Hu? Write down the web address of the textbook where one can freely download it from. [20 pts]

Solution to Q1: Yes, I have downloaded the text book from this address:
`https://people.eecs.berkeley.edu/~hu/Book-Chapters-and-Lecture-Slides-download.html`

Q2 Draw the band diagram (the relative positions of conduction band edge E_C, valence band edge E_v, Fermi level E_F) for the four following cases. Clearly note $E_C - E_F$, $E_F - E_V$, $E_i - E_F$, $E_G = E_C - E_V$. E_i is the intrinsic Fermi level. Take N_C=N_V=10^{25} m^{-3}, E_G=1.1 eV, n_i=1.5×10^{16} m^{-3}, kT=0.026 eV. [60 pts]

(Q1.1) p-type, N_A=5×10^{23} m^{-3}.

(Q1.2) p-type, N_A=5×10^{21} m^{-3}.

(Q1.3) n-type, N_D=5×10^{23} m^{-3}.

(Q1.4) n-type, N_D=5×10^{21} m^{-3}.

Solution to Q2: Solution in the next two pages.

5.

$E_G = 1.1\,eV, \; N_C = N_V = 10^{25}\,m^{-3}$

$n_i = 1.5 \times 10^{16}\,m^{-3}, \; kT = 0.026\,eV$

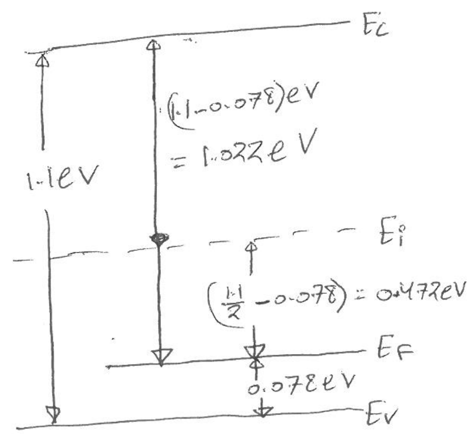
(5.1) p type, $N_A = \cancel{10}\; 5 \times 10^{23}\,m^{-3}$

$$P = N_A = N_V\, e^{\frac{E_V - E_F}{K_B T}}$$

$$\Rightarrow E_V - E_F = K_B T \ln \frac{N_A}{N_V}$$

$$= 0.026 \ln \frac{5 \times 10^{23}}{10^{25}}$$

$$= -0.078\,eV$$



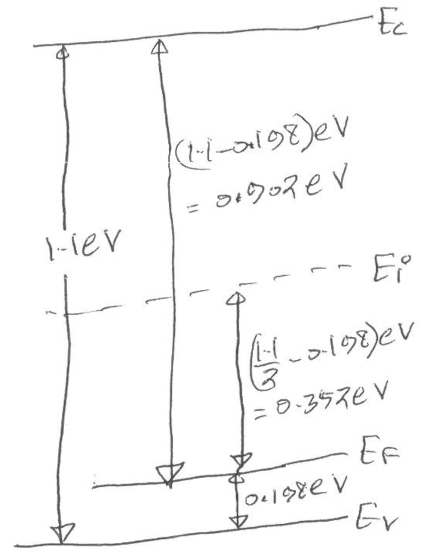
(5.2) p type, $N_A = 5 \times 10^{21}\,m^{-3}$

$$P = N_A = N_V\, e^{\frac{E_V - E_F}{K_B T}}$$

$$\Rightarrow E_V - E_F = K_B T \ln \frac{N_A}{N_V}$$

$$= 0.026 \ln \frac{5 \times 10^{21}}{10^{25}}$$

$$= -0.198\,eV$$



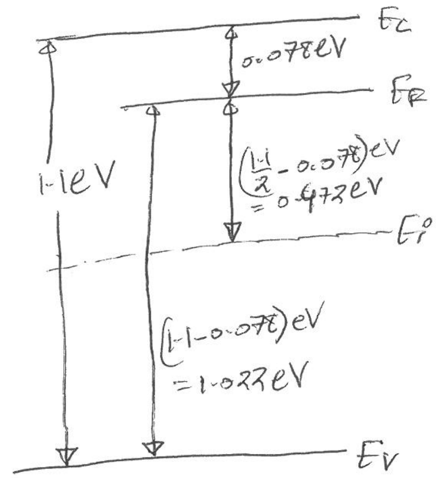
(5.3) n type, $N_D = 5\times10^{23}\,m^{-3}$

$$n = N_D = N_c\, e^{\frac{E_F - E_C}{K_B T}}$$

$$\Rightarrow E_F - E_C = K_B T \ln\left(\frac{N_D}{N_C}\right)$$

$$= 0.026 \ln\left(\frac{5\times10^{23}}{10^{25}}\right)$$

$$= -0.078\,eV$$



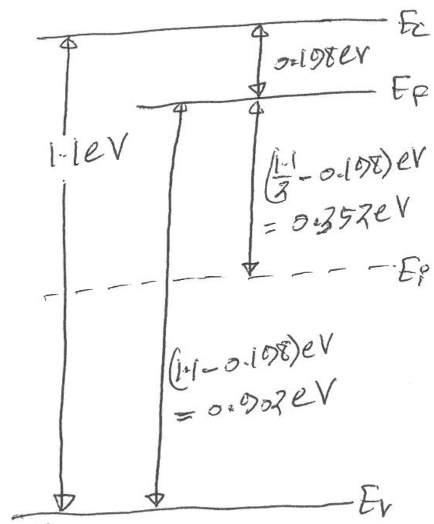
(5.4) n type, $N_D = 5\times10^{21}\,m^{-3}$

$$n = N_D = N_C\, e^{\frac{E_F - E_C}{K_B T}}$$

$$\Rightarrow E_F - E_C = K_B T \ln\left(\frac{N_D}{N_C}\right)$$

$$= 0.026 \ln\left(\frac{5\times10^{21}}{10^{25}}\right)$$

$$= -0.198\,eV$$



Q3 Explain in short why at absolute zero temperature silicon will not conduct any electric current. [20 pts]

Solution to Q3: Absolute temperature (0K) means there is no thermal energy. At this temperature, the valence electrons of Si are bound to its nucleus. Hence, when we apply a voltage across Si, there is no free electron, which means there is no current flowing through Si.