ECE113A Fall 2003 **first Midterm Exam** Name:_____

10-20-2003 ID no.:_____

Sec.A: Peter Burke 10:00 to 10:50 am

PROBLEM ONE: (60 points)

For Si at 300 K, with $N_D=10^{16}\,cm^{-3}$, $N_A<<N_D$:

A) (20 points)
Find the equilibrium electron concentration (n) in units of cm^{-3}.

Since $N_D >> n_i$,

$$n \approx N_D = 10^{16}\,cm^{-3}$$

B) (20 points)
Find the equilibrium hole concentration (p) in units of cm^{-3}.

$$p = \frac{n_i^2}{n} = \frac{[10^{10}\,cm^{-3}]^2}{10^{16}\,cm^{-3}} = 10^4\,cm^{-3}$$

PROBLEM ONE: (*continued*)

C) (20 points)
Find $E_C - E_F$ in units of eV. Use whatever method you want.

Solution1: From class notes,

$$E_c - E_F = KT \ln\left[\frac{n}{N_C}\right]$$

$$= -0.0259\,eV \ln\left[\frac{10^{16}\,cm^{-3}}{N_C}\right]$$

From book page 51,

$$N_c = 2.51 \times 10^{19}\,cm^{-3}\left[\frac{m_n^*}{m_0^*}\right]^{3/2}$$

From book page 34, $\frac{m_n^*}{m_0^*} = 1.18$

$$\Rightarrow N_c = 2.51 \times 10^{19}\,cm^{-3} \times [1.18]^{3/2}$$
$$= 3.217 \times 10^{19}\,cm^{-3}$$

$$\Rightarrow E_c - E_F = -0.0259\,eV \times \ln\left[\frac{10^{16}\,cm^{-3}}{3.217 \times 10^{19}\,cm^{-3}}\right]$$
$$= -0.0259\,eV \times (-8.076)$$

$$\Rightarrow \boxed{E_c - E_F = 0.209\,eV}$$

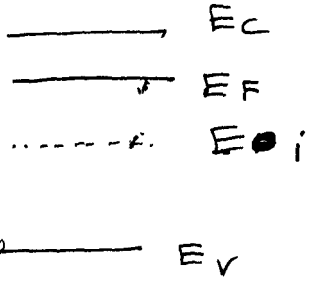
Solution 2:

Book eqn. 2.37

$$E_F - E_i = KT \ln\left[\frac{n}{n_i}\right]$$

$$= 0.0259\text{eV} \ln\left[\frac{10^{16}\text{cm}^{-3}}{10^{10}\text{cm}^{-3}}\right]$$

$$= 0.3578\text{eV}$$



$$E_C - E_F = (E_C - E_i) - (E_F - E_i)$$

$$E_C - E_i \approx \frac{E_G}{2} = 1.12\text{eV}/2 = 0.56\text{eV}$$

$$\Rightarrow E_C - E_F = 0.56\text{eV} - 0.358\text{eV} = 0.202\text{eV}$$

$$\Rightarrow \boxed{E_C - E_F = 0.202\text{eV}}$$

Note that $E_C - E_i = \frac{E_G}{2} - \frac{3}{4}KT \ln\left[\frac{m_p^*}{m_n^*}\right]$

$$= \frac{E_G}{2} + 0.007\text{eV}$$

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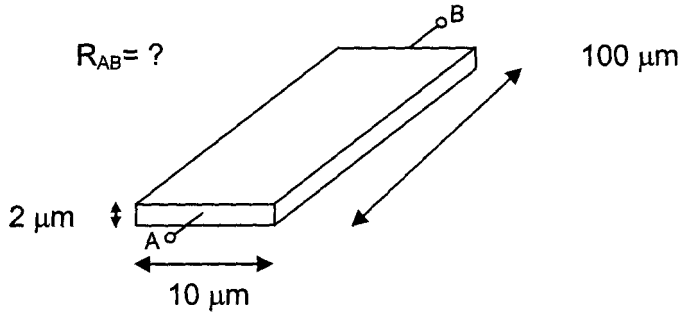
PROBLEM TWO: (40 points)



For the silicon sample at T= 300 K shown above, given $N_D=10^{16}$ cm^{-3}, $N_A<<N_D$,

A) (20 points)
Find the resistivity ρ of the Si to within 30% in units of Ω-cm.
(You may use figure 3.8 from the text.)

0.5 Ω-cm

B) (20 points)
Calculate the resistance R_{AB} in units of Ω, for the geometry shown above.

$$R_{AB} = \frac{L}{A}\rho$$

$$= \frac{100 \times 10^{-6}\ m}{2\times10^{-6}\ m \cdot 10\times10^{-6}\ m} \cdot 0.5\ \Omega\text{-cm}$$

$$= \frac{100}{10\times2\times10^{-6}\ m} \cdot 0.5\ \Omega - (1\times10^{-2}\ m)$$

$$= \frac{100}{2\times10^{-6}\times10} 0.5\times10^{-2}\ \Omega = 10^{-1}10^{2}\,10^{-2}\,10^{6}\,\tfrac{1}{2}\tfrac{1}{2}\,\Omega$$

$$= \tfrac{1}{4}\,10^{5}\,\Omega$$

$$= 0.25\times10^{5}\,\Omega = 25.0\ k\Omega$$