Chapter 3 Homework

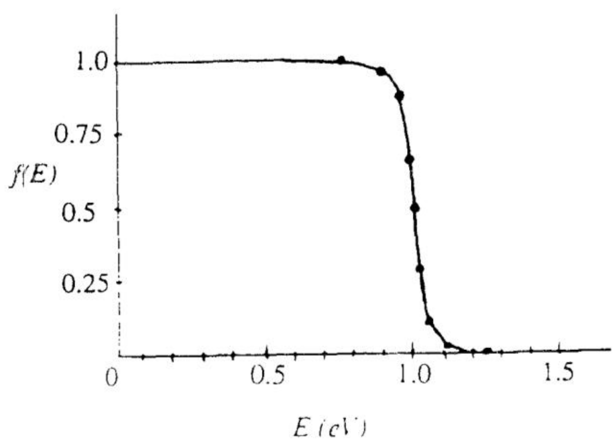
Prob. 3.2

Plot Fermi function for $E_F = 1$ eV.

$$f(E) = [1 + e^{(E-E_F)/kT}]^{-1}$$

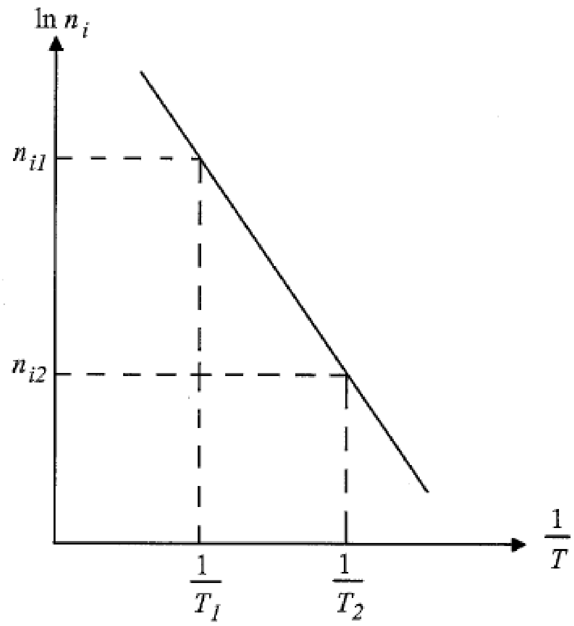
We will choose E in eV and therefore use $kT = 0.0259$

E(eV)	$(E-E_F)/kT$	$f(E)$
0.75	-9.6525	**0.99994**
0.90	-3.8610	**0.97939**
0.95	-1.9305	**0.87330**
0.98	-0.7722	**0.68399**
1.02	+0.7722	**0.31600**
1.05	+1.9305	**0.12669**
1.10	+3.8610	**0.02061**
1.25	+9.6525	**0.00006**



Prob. 3.6

Find Eg for Si from Figure 3-17.



for n_{i1} and n_{i2} on graph

$$n_{i1} = 3\cdot 10^{14} \quad \frac{1}{T_1} = 2\cdot 10^{-3}\,\tfrac{1}{K}$$

$$n_{i2} = 10^{8} \quad \frac{1}{T_2} = 4\cdot 10^{-3}\,\tfrac{1}{K}$$

This result is approximate because the temperature dependences of N_C, N_V, and E_g are neglected.

$$n_i = \sqrt{N_C N_V}\cdot e^{-\frac{E_g}{2kT}} \rightarrow E_g = -2kT\cdot \ln\frac{n_i}{\sqrt{N_C N_V}} \rightarrow \ln n_i = -\frac{E_g}{2kT} + \ln\sqrt{N_C N_V}$$

$$\ln\frac{n_{i1}}{n_{i2}} = \ln n_{i1} - \ln n_{i2} = \left(-\frac{E_g}{2kT_1} + \ln\sqrt{N_C N_V}\right) - \left(-\frac{E_g}{2kT_2} + \ln\sqrt{N_C N_V}\right) = \frac{E_g}{2k}\cdot\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

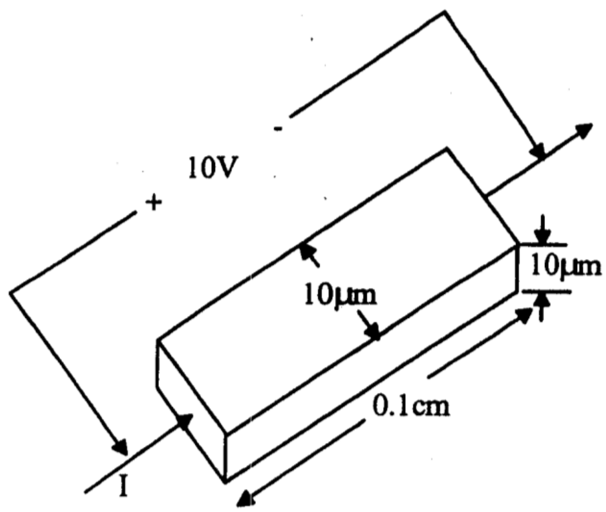
for Si (see above) $\rightarrow$ $$E_g = 2k\cdot\left(\frac{\ln\frac{n_{i1}}{n_{i2}}}{\frac{1}{T_2} - \frac{1}{T_1}}\right) = 2\cdot 8.62\cdot 10^{14}\cdot\left(\frac{\ln\frac{3\cdot 10^{14}}{10^{8}}}{4\cdot 10^{-3}\,\frac{1}{K} - 2\cdot 10^{-3}\,\frac{1}{K}}\right) = 1.3\text{eV}$$

Prob. 3.10

At t = 400K, Figure 3-17 indicates that n>>n_i for Si doped with Nd= 10^{15} cm^{-3}; so, the Si would be n-type. At T = 400K, Figure 3-17 indicates that n ~ n_i ~ $10^{15}cm^{-3}$ for Ge doped with N_d = 10^{15} cm^{-3}; so, the Ge would require more donors for useful n-type doping.

Prob. 3.13 (FROM 5th EDITION, see 6th edition answers following)

(a) A Si bar 0.1 cm long and 100 μm² in cross sectional area is doped with 10^{17} cm^{-3} antimony. Find the current at 300K with 10V applied.



From Fig.3-23, μ_n = 700 cm²/V-s

$$\sigma = q\mu_n n_0 = 1.6\times10^{-19}\times700\times10^{17} = 11.2\,(\Omega\cdot\text{cm})^{-1} = \rho^{-1}$$
$$\rho = 0.0893\,\Omega\cdot\text{cm}$$
$$R = \rho L/A = 0.0893\times0.1/10^{-6} = 8.93\times10^{3}\,\Omega$$
$$I = V/R = 10/(8.93\times10^{3}) = \mathbf{1.12\,mA}$$

Prob. 3-13, 6th Edition Answers are:

a. 0.16 A (10V/10^{-4}cm → velocity saturation, making V_s=10^7 cm/s from Fig. 3-24., and then $I=q*A*n*V_s$)

b. low field 0.74 ns, high field 10 ps.