1(a) What is the probability, f, to find an electron when E=EF (fermi level) according to the Fermi-Dirac equation?

Ans: f=0.5

(b) For any given semiconductor at E=EF+0.5 eV, what is the temperature required to have 1%, 5%, and 10% probability of finding an electron at that energy?

Hint: Substitute E_F+0.5 eV into E in f(E) equation1. Next for each value of f, evaluate temperature T.

Answer (i) f=0.01, T=1260K or 990C; f=0.05, Ans T=1970K or 1700C; f=0.10 Ans T=2640K or 2370C

Ridiculously high numbers for temperature, but this gives you an idea of how the fermi-dirac equation relates temperature to probability of electron occupation at a given energy level.

2. Use of fermi function to obtain the value of f(E) for E-Ef = 0.01 at 200 K.

Hint: The problem is as simple as it can get!!!!

3. Calculate the probability that an energy level (a) kT (b) 3 kT (c) 10 kT above the fermi-level is occupied by an electron?

Answer:

Probability that an energy level E is occupied is given by f(E) = $\dfrac{1}{e^{\frac{E-E_F}{kT}}+1}$

For $(E-E_F)$ = kT , f(E) = $\dfrac{1}{e^{\frac{kT}{kT}}+1} = \dfrac{1}{e+1} = 0.268$

For $(E-E_F)$ = 3kT, f(E) = $\dfrac{1}{(e^3+1)} = 0.047$

For $(E-E_F)$ = 10kT, f(E) = $\dfrac{1}{(e^{10}+1)} = 4.5\times10^{-5}$

4. The fermi-level in a semiconductor is 0.35 eV above the valence band. What is the probability of non-occupation of an energy state *at the top* of the valence band, at (i) 300 K (ii) 400 K ?

The probability that an energy state in the valence band is not occupied is

(i) T=300K

1-f(E) = $1-\dfrac{1}{(e^{\frac{E_V-E_F}{kT}}+1)}$ = $1-\dfrac{1}{(e^{-\frac{0.35}{0.0259}}+1)}$

$$=1.353\times10^{-6}$$

(ii) T=400K 1-f(E) $\cong$ $e^{\frac{E_V-E_F}{kT}} = 3.9\times10^{-5}$

5. The fermi-level in a semiconductor is 0.35 eV above the valence band. What is the probability of non-occupation of an energy state at a level kT *below* the top of the valence band, at (i) 300 K (ii) 400 K?

The probability that an energy state in the valence band is not occupied is

(i) T=300K 1 - f(E) = $1-\frac{1}{(e^{\frac{E-E_F}{kT}}+1)} \cong e^{\frac{E-E_F}{kT}}$ for E_F- E > kT

$$e^{\frac{E-E_F}{kT}} = e^{\frac{-(0.35+0.0259)}{0.0259}} = 4.97\times10^{-7}$$

(ii) T=400K

1- f(E) $\cong$ $e^{\frac{E-E_F}{kT}} = e^{\frac{-(0.35+0.0345)}{0.0345}} = 1.448\times10^{-5}$ Note (E -E_F) is -ve

6. For copper at 1000K find the energy at which the probability P(E) that a conduction electron state will be occupied is 90%. The Fermi energy is 7.06eV.

The fermi factor f(E) = $\frac{1}{(e^{\frac{E-E_F}{kT}}+1)}$ = 0.90

The fermi factor f(E) = $\frac{1}{(e^{\frac{E-E_F}{kT}}+1)}$

$$e^{\frac{E-E_F}{kT}} = \left[\frac{1}{0.90}-1\right] = 0.11$$

$$E = E_F + k\,T\,(\ln 0.11)$$

$$= 7.06 - 0.19 = 6.87\,eV$$

7. The Fermi energy for potassium is 2.1 eV. Calculate the velocity of the electrons at the Fermi level.

$E_F=\frac{1}{2}mv^2$ = 0.74 x 10^{12} m^2s^{-2}

8. At what temperature we can expect a 10% probability that electrons in silver have an energy which is 1% above the Fermi energy? The Fermi energy of silver is 5.5 eV.

The fermi factor f(E) = $\frac{1}{(e^{\frac{E-E_F}{kT}}+1)}$ = 290 K