3.40 The Fermi energy level for a particular material at $T = 300$ K is 5.50 eV. The electrons in this material follow the Fermi–Dirac distribution function. (*a*) Find the probability of an electron occupying an energy at 5.80 eV. (*b*) Repeat part (*a*) if the temperature is increased to $T = 700$ K. (Assume that E_F is a constant.) (*c*) Determine the temperature at which there is a 2 percent probability that a state 0.25 eV below the Fermi level will be empty of an electron.

a) Per (3.79), $f_F(E) = \dfrac{1}{1 + e^{E-E_F/k_BT}}$

@ 300K, $k_BT = (8.617333 \times 10^{-5}\ \text{eV/K})(300\text{K}) = 0.025852\ \text{eV}$

$$f_F(5.80\text{eV}) = \frac{1}{1 + e^{(5.8-5.5)/0.025852}}$$

$$\underline{\underline{f_F(5.80\text{eV}) = 9.12468 \times 10^{-6} \text{ or } 9.12468 \times 10^{-4}\ \%}}$$

b) @ 700K, $k_BT = (8.617333 \times 10^{-5})700 = 0.060321\ \text{eV}$

$$f_F(5.80\text{eV}) = \frac{1}{1 + e^{(5.8-5.5)/0.060321}}$$

$$\underline{\underline{f_F(5.80\text{eV}) = 6.87227 \times 10^{-3} \text{ or } 0.68723\ \%}}$$

c) Per Example 3.7, the probability of empty state is $1 - f_f(E)$.

$$0.02 = 1 - \frac{1}{1 + e^{-0.25/k_BT}}$$

↳ $k_BT = 0.06423729\ \text{eV}$

$$T = \frac{0.06423729}{8.617333 \times 10^{-5}} \Rightarrow \underline{\underline{T = 745.4429\ \text{K}}}$$