4.20 (*a*) If $E_c - E_F = 0.28$ eV in gallium arsenide at $T = 375$ K, calculate the values of n_0 and p_0. (*b*) Assuming the value of n_0 in part (*a*) remains constant, determine $E_c - E_F$ and p_0 at $T = 300$ K.

- Assume E_g is temperature independent.

a) From Table B.4, we get $N_c = 4.7 \times 10^{17}$ #/cm³, $N_v = 7.0 \times 10^{18}$ #/cm³, and $E_g = 1.42$ eV at 300K for GaAs.

Per (4.10) $N_c = 2\left(\dfrac{2\pi m_n^* k_B T}{h^2}\right)^{3/2}$, we can scale N_c to 375 K as

$$N_c = 4.7\times10^{17}\left(\frac{375}{300}\right)^{3/2} = 5.59017\times10^{17}\ \text{\#/cm}^3.$$

Per (4.11), $n_0 = N_c e^{-(E_c-E_F)/k_BT} = 5.59017\times10^{17} e^{-(0.28)/[(8.617333\times10^{-5}\ \text{eV/K})\,375\,\text{K}]}$

$\Rightarrow$ **$n_0 = 9.64696 \times 10^{13}$ #/cm³**.

Per (4.18) $N_v = 2\left(\dfrac{2\pi m_p^* k_B T}{h^2}\right)^{3/2}$, we can scale N_v to 375 K as

$$N_v = 7.0\times10^{18}\left(\frac{375}{300}\right)^{3/2} = 9.782797\times10^{18}\ \text{\#/cm}^3.$$

Per (4.19), $p_0 = N_v e^{-(E_F-E_v)/k_BT}$ where $E_F - E_v = E_g - (E_c - E_F) = 1.42 - 0.28$ eV.

$$p_0 = N_v e^{-(E_F-E_v)/k_BT} = 9.782797\times10^{18} e^{-(1.42-0.28)/[(8.617333\times10^{-5}\ \text{eV/K})\,375\,\text{K}]}$$

$\Rightarrow$ **$p_0 = 4672.367$ #/cm³**.

b) At 300 K, assuming $n_0 = 9.64696 \times 10^{13}$ #/cm³, we can solve (4.11) to get

$$E_c - E_F = -k_BT\ln\left(\frac{n_0}{N_c}\right) = k_BT\ln\left(\frac{N_c}{n_0}\right)$$

$$= (8.617333\times10^{-5}\ \text{eV/K})\,300\,\text{K}\ln\left(\frac{4.7\times10^{17}}{9.64696\times10^{13}}\right)$$

$\Rightarrow$ **$E_c - E_F = 0.2195166$ eV**.

Per (4.19), $p_0 = N_v e^{-(E_F-E_v)/k_BT}$ where $E_F - E_v = E_g - (E_c - E_F) = 1.42 - 0.2195166$ eV.

$$p_0 = N_v e^{-(E_F-E_v)/k_BT} = 7.0\times10^{18} e^{-(1.42-0.2195166)/[(8.617333\times10^{-5}\ \text{eV/K})\,300\,\text{K}]}$$

$\Rightarrow$ **$p_0 = 0.0476272$ #/cm³**.