4.19 The electron concentration in silicon at $T = 300$ K is $n_0 = 2 \times 10^5$ cm^{-3}. (*a*) Determine the position of the Fermi level with respect to the valence band energy level. (*b*) Determine p_0. (*c*) Is this n- or p-type material?

➢ First, find N_c and N_v.

Per Table B.4, $N_c = 2.8 \times 10^{19}$ #/cm^3 $\quad m_n^* = 1.08 m_0$

$E_g = 1.12$ eV $\quad N_v = 1.04 \times 10^{19}$ #/cm^3 $\quad m_p^* = 0.56 m_0$

Per (4.10), $N_c = 2\left[\dfrac{2\pi m_n^* k_B T}{h^2}\right]^{3/2}$

$= 2\left[\dfrac{2\pi\, 1.08(9.1093837\times10^{-31})\, 1.380649\times10^{-23}\, 300}{(6.62607\times10^{-34})^2}\right]^{3/2}$

$N_c = 2.8165 \times 10^{25}$ #/m^3 $= 2.8165 \times 10^{19}$ #/cm^3

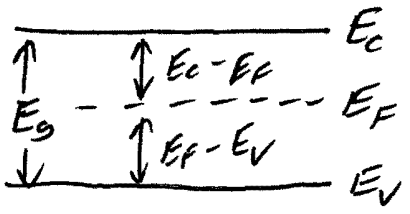
Per (4.18), $N_v = 2\left[\dfrac{2\pi m_p^* k_B T}{h^2}\right]^{3/2} = N_c\left(\dfrac{0.56}{1.08}\right)^{3/2}$

$N_v = 1.0516 \times 10^{25}$ #/m^3 $= 1.0516 \times 10^{19}$ #/cm^3

a) Per (4.11), $n_0 = N_c e^{-(E_c - E_F)/k_B T}$

↳ $E_c - E_F = k_B T \ln\left(\dfrac{N_c}{n_0}\right) = 8.617333\times10^{-5}(300)\ln\left(\dfrac{2.8165\times10^{25}}{2\times10^{11}}\right)$

$= 0.84222$ eV



$E_F - E_v = E_g - (E_c - E_F)$

$= 1.12 - 0.84222$

$E_F - E_v = 0.27778$ eV

b) Per (4.19), $p_0 = N_v e^{-(E_F - E_v)/k_B T}$

$p_0 = 1.0516 \times 10^{25}\, e^{-0.27778/(8.617333\times10^{-5}\cdot 300)}$

$p_0 = 2.2665 \times 10^{20}$ #/m^3 $= 2.2665 \times 10^{14}$ #/cm^3

c) Since $p_0 > n_0 \Rightarrow$ p-type material