Assignment 6.1

Q1: (a) $N_c = 2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2} = 2\left[\frac{2\pi(0.56\times 9.1\times10^{-31})(1.38\times10^{-23})400}{(6.626\times10^{-34})^2}\right]^{3/2}$

$= 1.62\times10^{25}\,m^{-3}$

$N_V = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} = 2\left[\frac{2\pi(0.4\times 9.1\times10^{-31})(1.38\times10^{-23})400}{(6.626\times10^{-34})^2}\right]^{3/2}$

$= 9.75\times10^{24}\,m^{-3}$

$n_i = (N_c N_V)^{1/2}\exp\left(-\frac{E_g}{2kT}\right) = \left[(1.62\times10^{25})(9.75\times10^{24})\right]^{1/2} \cdot \exp\left(-\frac{0.66\times1.6\times10^{-19}}{2(1.38\times10^{-23})400}\right)$

$= 8.81\times10^{20}\,m^{-3} = \underline{8.81\times10^{14}\,cm^{-3}}$

(b) $n_i = (N_c N_V)^{1/2}\exp\left(-\frac{E_g}{2kT}\right) = \left[(1.04\times10^{19})(6.0\times10^{18})\right]^{1/2} \cdot \exp\left(-\frac{0.66\times1.6\times10^{-19}}{2(1.38\times10^{-23})300}\right)$

$= 2.28\times10^{19}\,m^{-3} = \underline{2.28\times10^{13}\,cm^{-3}}$

(c) $\rho = \frac{1}{\sigma} = \frac{1}{e n_i(\mu_h+\mu_e)} = \frac{1}{(1.6\times10^{-19})(2.28\times10^{13})(3900+1900)}$

$= \underline{46.85\ \Omega cm}$

Q2: $E_{Fi} = E_V + \frac{1}{2}E_g - \frac{3}{4}kT\ln\left(\frac{m_e^*}{m_h^*}\right)$

$= E_V + \frac{1}{2}E_g - \frac{3}{4}(8.62\times10^{-5}\,eVK^{-1})(300K)\left(\ln\left(\frac{0.067m_e}{0.5m_e}\right)\right)$

$= E_V + \frac{1}{2}E_g + \underline{0.039\,eV}$ (∴ assumption of E_{Fi} at middle of E_g is valid!)

Q3: $\sigma = e n \mu_e + e p \mu_h$

$\cong e N_d \mu_e$

$= (1.6\times10^{-19}\,c)(10^{15}cm^{-3})(1350\,cm^2V^{-1}s^{-1})$

$= 0.216\,\Omega^{-1}cm^{-1}$

$\rho = \frac{1}{\sigma} = \underline{4.63\,\Omega cm}$

Q4: $\sigma = \frac{1}{\rho} = 1\,\Omega^{-1}cm^{-1}$

(a) For p-type Si: $\sigma = en\mu_e + ep\mu_h = eN_a\mu_h$

$$N_a = \frac{\sigma}{e\mu_h} = \frac{1}{1.6\times10^{-19}\times450} = 1.39\times10^{16}\ cm^{-3}$$

(b) $$E_{Fp} - E_{Fi} = -kT\left(\ln\left(\frac{N_a}{n_i}\right)\right) = -(8.62\times10^{-5}\ eV\,K^{-1})(300K) \cdot \ln\left[\frac{1.39\times10^{16}\ cm^{-3}}{10^{10}\ cm^{-3}}\right] = -0.37\ eV$$

Q5: