EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 4 (Spring 2026)

Name <u>KEY A</u>

Instructions: Open book & notes. Place answers in indicated spaces. Show all work. Use **5-6** significant figures.

At 300 K, a semiconductor has a bandgap of 0.5 eV, an effective density of states in the conduction band $N_c = 8 \times 10^{18}$ #/cm^3, an effective density of states in the valence band $N_v = 1.2 \times 10^{19}$ #/cm^3, and an intrinsic carrier concentration $n_i = 3 \times 10^{13}$ #/cm^3 . At 360 K, find $N_{c,360}$, $N_{v,360}$, and $n_{i,360}$ (assume effective masses and bandgap are temperature-independent). If the semiconductor is doped such that the Fermi energy is 0.09 eV **below** the intrinsic Fermi energy, determine $n_{0,360}$ and $p_{0,360}$. Express all concentrations in #/cm^3.

Per (4.10) $N_c = 2\left(\frac{2\pi m_n^* k_B T}{h^2}\right)^{3/2}$, we can scale N_c to 360 K as

$$N_{c,360} = N_{c,300}\left(\frac{360}{300}\right)^{3/2} = 8\times10^{18}\left(\frac{360}{300}\right)^{3/2} \Rightarrow \mathbf{N_{c,360} = 1.0516273 \times 10^{19}\ \#/cm^3}.$$

Per (4.18) $N_v = 2\left(\frac{2\pi m_p^* k_B T}{h^2}\right)^{3/2}$, we can scale N_v to 360 K as

$$N_{v,360} = N_{v,300}\left(\frac{360}{300}\right)^{3/2} = 1.2\times10^{19}\left(\frac{360}{300}\right)^{3/2} \Rightarrow \mathbf{N_{v,360} = 1.577441 \times 10^{19}\ \#/cm^3}.$$

Per (4.23), $n_{i,360}^2 = N_{c,360} N_{v,360}\, e^{-E_g/k_BT} \Rightarrow n_{i,360} = \sqrt{N_{c,360} N_{v,360}\, e^{-E_g/k_BT}}$.

$$n_{i,360} = \sqrt{1.0516273\times10^{19}(1.577441\times10^{19})\,e^{-0.5/[8.617333\times10^{-5}(360)]}} = \sqrt{1.65888\times10^{38}\, e^{-0.5/0.0310224}}$$

$$\Rightarrow \mathbf{n_{i,360} = 4.0743789 \times 10^{15}\ \#/cm^3}.$$

Per (4.39),

$$n_0 = n_i\, e^{(E_F - E_{F,i})/k_BT} \Rightarrow n_{0,360} = 4.0743789\times10^{15}\, e^{-0.09/0.0310224} \Rightarrow \mathbf{n_{0,360} = 2.23932 \times 10^{14}\ \#/cm^3}.$$

Per (4.40),

$$p_0 = n_i\, e^{-(E_F - E_{F,i})/k_BT} \Rightarrow p_{0,360} = 4.0743789\times10^{15}\, e^{0.09/0.0310224} \Rightarrow \mathbf{p_{0,360} = 7.41320 \times 10^{16}\ \#/cm^3}.$$

$N_{c,360}$ = **<u>1.05163 × 10^{19} #/cm^3</u>** $N_{v,360}$ = **<u>1.57744 × 10^{19} #/cm^3</u>** $n_{i,360}$ = **<u>4.07438 × 10^{15} #/cm^3</u>**

$n_{0,360}$ = **<u>2.23932 × 10^{14} #/cm^3</u>** $p_{0,360}$ = **<u>7.41320 × 10^{16} #/cm^3</u>**

EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 3 (Spring 2026)

Name KEY B

Instructions: Open book & notes. Place answers in indicated spaces. Show all work. Use **5-6** significant figures.

At 300 K, a semiconductor has a bandgap of 0.7 eV, an effective density of states in the conduction band $N_c = 7\times10^{18}$ #/cm^3, an effective density of states in the valence band $N_v = 1.0\times10^{19}$ #/cm^3, and an intrinsic carrier concentration $n_i = 8\times10^{12}$ #/cm^3 . At 380 K, find $N_{c,380}$, $N_{v,380}$, and $n_{i,380}$ (assume effective masses and bandgap are temperature-independent). If the semiconductor is doped such that the Fermi energy is 0.08 eV **below** the intrinsic Fermi energy, determine $n_{0,380}$ and $p_{0,380}$. Express all concentrations in #/cm^3.

Per (4.10) $N_c = 2\left(\frac{2\pi m_n^* k_B T}{h^2}\right)^{3/2}$, we can scale N_c to 380 K as

$$N_{c,380} = N_{c,300}\left(\frac{380}{300}\right)^{3/2} = 7\times10^{18}\left(\frac{380}{300}\right)^{3/2} \qquad \Rightarrow \underline{\mathbf{N_{c,380} = 9.97791041\times10^{18}\ \#/cm^3}}.$$

Per (4.18) $N_v = 2\left(\frac{2\pi m_p^* k_B T}{h^2}\right)^{3/2}$, we can scale N_v to 380 K as

$$N_{v,380} = N_{v,300}\left(\frac{380}{300}\right)^{3/2} = 1.0\times10^{19}\left(\frac{380}{300}\right)^{3/2} \qquad \Rightarrow \underline{\mathbf{N_{v,380} = 1.4255863\times10^{19}\ \#/cm^3}}.$$

Per (4.23), $n_{i,380}^2 = N_{c,380}N_{v,380}\,e^{-E_g/k_BT} \Rightarrow n_{i,380} = \sqrt{N_{c,380}N_{v,380}\,e^{-E_g/k_BT}}$.

$$n_{i,380} = \sqrt{9.97791\times10^{18}(1.425586\times10^{19})\,e^{-0.7/[8.617333\times10^{-5}(380)]}} = \sqrt{1.422607\times10^{38}\,e^{-0.7/0.032745865}}$$

$$\Rightarrow \underline{\mathbf{n_{i,380} = 2.7204543\times10^{14}\ \#/cm^3}}.$$

Per (4.39),

$$n_0 = n_i\,e^{(E_F-E_{F,i})/k_BT} \Rightarrow n_{0,380} = 2.720454\times10^{14}\,e^{-0.08/0.032745865} \Rightarrow \underline{\mathbf{n_{0,380} = 2.36393\times10^{13}\ \#/cm^3}}.$$

Per (4.40),

$$p_0 = n_i\,e^{-(E_F-E_{F,i})/k_BT} \Rightarrow p_{0,380} = 2.720454\times10^{14}\,e^{0.08/0.032745865} \Rightarrow \underline{\mathbf{p_{0,380} = 3.13074\times10^{15}\ \#/cm^3}}.$$

$N_{c,380}$ = **9.97791×10^{18} #/cm^3** $N_{v,380}$ = **1.42559×10^{19} #/cm^3** $n_{i,380}$ = **2.72045×10^{14} #/cm^3**

$n_{0,380}$ = **2.36393×10^{13} #/cm^3** $p_{0,380}$ = **3.13074×10^{15} #/cm^3**