EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 8 (Spring 2025)

Name <u>**KEY A**</u>

Instructions: Open book/notes. Place answers in indicated spaces and **show all** work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **4-5** significant figures.

A wafer of gallium arsenide (GaAs) has an intrinsic carrier concentration of 1.93×10^8 cm^{-3} and $E_g = 1.4$ eV at 350 K. Further, the diffusion coefficients are 220 cm^2/s (electron) and 11 cm^2/s (hole) while the minority carrier lifetimes are 48 ns (electron) and 9 ns (hole). A pn junction is created on the wafer with uniform doping concentrations of 5×10^{15} cm^{-3} acceptor atoms on p side and 8×10^{15} cm^{-3} donor atoms on n side. First, find the thermal equilibrium electron and hole concentrations (cm^{-3}) on the p-side (p_{p0} & n_{p0}) and n-side (p_{n0} & n_{n0}). Next, calculate the ideal reverse saturation current density J_s (A/m^2) for holes, electrons, and overall.

p-side

Since $N_a >> n_i$ $\Rightarrow$ $p_{p0} \cong N_a = 5 \times 10^{15}$ cm^{-3}.

Using (4.43), $n_{p0} = n_i^2 / p_{p0} = (1.93\times10^8)^2/5\times10^{15}$ $\Rightarrow$ $n_{p0} = 7.4498$ cm^{-3}.

n-side

Since $N_d >> n_i$ $\Rightarrow$ $n_{n0} \cong N_d = 8 \times 10^{15}$ cm^{-3}.

Using (4.43), $p_{n0} = n_i^2 / n_{n0} = (1.93\times10^8)^2/8\times10^{15}$ $\Rightarrow$ $p_{n0} = 4.656125$ cm^{-3}.

Per (8.26), $J_s = \dfrac{eD_p p_{n0}}{L_p} + \dfrac{eD_n n_{p0}}{L_n} = J_{s,p} + J_{s,n}$ where, in MKS units,

$$L_p = \sqrt{D_p \tau_{p0}} = \sqrt{11(1/100^2)(9\bullet10^{-9})} = 3.1464265\bullet10^{-6} \text{ m and}$$

$$L_n = \sqrt{D_n \tau_{n0}} = \sqrt{220(1/100^2)\,(48\bullet10^{-9})} = 3.2496154\bullet10^{-5} \text{ m}.$$

$$J_{s,p} = \frac{eD_p p_{n0}}{L_p} = \frac{1.60217663\bullet10^{-19}(11/100^2)\,4.656125\bullet10^6}{3.1464265\bullet10^{-6}} \Rightarrow J_{s,p} = 2.608 \times 10^{-10} \text{ A/m}^2.$$

$$J_{s,n} = \frac{eD_n n_{p0}}{L_n} = \frac{1.60217663\bullet10^{-19}(220/100^2)\,7.4498\bullet10^6}{3.2496154\bullet10^{-5}} \Rightarrow J_{s,n} = 8.0806 \times 10^{-10} \text{ A/m}^2.$$

$$J_s = J_{s,p} + J_{s,n} = 2.60802 \times 10^{-10} + 8.08064 \times 10^{-10} \Rightarrow J_s = 1.06887 \times 10^{-9} \text{ A/m}^2.$$

p_{p0} = **5×10^{15} cm^{-3}** n_{p0} = **7.4498 cm^{-3}** p_{n0} = **4.656125 cm^{-3}** n_{n0} = **8×10^{15} cm^{-3}**

$J_{s,n}$ = **8.0806×10^{-10} A/m^2** $J_{s,p}$ = **2.6080×10^{-10} A/m^2** J_s = **1.0689×10^{-9} A/m^2**

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Name **KEY B**

Instructions: Open book/notes. Place answers in indicated spaces and **show all** work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **4-5** significant figures.

A wafer of gallium arsenide (GaAs) has an intrinsic carrier concentration of 8.51×10^8 cm^{-3} and $E_g = 1.4$ eV at 370 K. Further, the diffusion coefficients are 230 cm^2/s (electron) and 12 cm^2/s (hole) while the minority carrier lifetimes are 46 ns (electron) and 8 ns (hole). A pn junction is created on the wafer with uniform doping concentrations of 9×10^{15} cm^{-3} acceptor atoms on p side and 6×10^{15} cm^{-3} donor atoms on n side. First, find the thermal equilibrium electron and hole concentrations (cm^{-3}) on the p-side (p_{p0} & n_{p0}) and n-side (p_{n0} & n_{n0}). Next, calculate the ideal reverse saturation current density J_s (A/m^2) for holes, electrons, and overall.

p-side

Since $N_a >> n_i$ $\Rightarrow$ $\underline{p_{p0} \cong N_a = 9 \times 10^{15}\ \text{cm}^{-3}}$.

Using (4.43), $n_{p0} = n_i^2 / p_{p0} = (8.51 \times 10^8)^2 / 9 \times 10^{15}$ $\Rightarrow$ $\underline{n_{p0} = 80.46678\ \text{cm}^{-3}}$.

n-side

Since $N_d >> n_i$ $\Rightarrow$ $\underline{n_{n0} \cong N_d = 6 \times 10^{15}\ \text{cm}^{-3}}$.

Using (4.43), $p_{n0} = n_i^2 / n_{n0} = (8.51 \times 10^8)^2 / 6 \times 10^{15}$ $\Rightarrow$ $\underline{p_{n0} = 120.70016\ \text{cm}^{-3}}$.

Per (8.26), $J_s = \dfrac{e D_p p_{n0}}{L_p} + \dfrac{e D_n n_{p0}}{L_n} = J_{s,p} + J_{s,n}$ where, in MKS units,

$$L_p = \sqrt{D_p \tau_{p0}} = \sqrt{12(1/100^2)(8 \cdot 10^{-9})} = 3.098387 \cdot 10^{-6} \text{ m and}$$

$$L_n = \sqrt{D_n \tau_{n0}} = \sqrt{230(1/100^2)\,(46 \cdot 10^{-9})} = 3.225269 \cdot 10^{-5} \text{ m}.$$

$$J_{s,p} = \frac{e D_p p_{n0}}{L_p} = \frac{1.60217663 \cdot 10^{-19}(12/100^2)120.7 \cdot 10^6}{3.098387 \cdot 10^{-6}} \Rightarrow \underline{J_{s,p} = 7.4897 \times 10^{-9}\ \text{A/m}^2}.$$

$$J_{s,n} = \frac{e D_n n_{p0}}{L_n} = \frac{1.60217663 \cdot 10^{-19}(230/100^2)80.467 \cdot 10^6}{3.225269 \cdot 10^{-5}} \Rightarrow \underline{J_{s,n} = 9.1162 \times 10^{-9}\ \text{A/m}^2}.$$

$$J_s = J_{s,p} + J_{s,n} = 7.48969 \times 10^{-9} + 9.11616 \times 10^{-9} \Rightarrow \underline{J_s = 1.66059 \times 10^{-8}\ \text{A/m}^2}.$$

p_{p0} = $\underline{9 \times 10^{15}\ \text{cm}^{-3}}$ n_{p0} = $\underline{80.4668\ \text{cm}^{-3}}$ p_{n0} = $\underline{120.7002\ \text{cm}^{-3}}$ n_{n0} = $\underline{6 \times 10^{15}\ \text{cm}^{-3}}$

$J_{s,n}$ = $\underline{9.1162 \times 10^{-9}\ \text{A/m}^2}$ $J_{s,p}$ = $\underline{7.4897 \times 10^{-9}\ \text{A/m}^2}$ J_s = $\underline{1.6606 \times 10^{-8}\ \text{A/m}^2}$