EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 5 (Spring 2026)

Name __KEY A__

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 **3-4** significant figures.

At 300 K, a sample of Germanium has been doped only with donors at a concentration of 4×10^{17} #/cm^3. Determine the minority and majority carrier types, i.e., electrons or holes, as well as equilibrium carrier concentrations (#/cm^3). Then, find the majority carrier mobility (cm^2/V·s) and diffusion coefficient (cm^2/s) of the doped Germanium.

Per Table B.4, Germanium at 300 K has $n_i = 2.4 \times 10^{13}$ #/cm^3.

Given 'doped only with donors' and that $N_d >> n_i$, we can say that the majority charge carriers are **electrons** with a concentration of **$n \cong N_d = 4 \times 10^{17}$ #/cm^3.**

If the majority charge carriers are electrons, then the minority charge carriers are **holes**. The hole concentration can be found using (4.43) $n_0 p_0 = n_i^2$

$$p = n_i^2 / n = (2.4 \times 10^{13})^2 / 4 \times 10^{17} \quad \Rightarrow \quad \mathbf{p = 1.44 \times 10^9 \text{ \#/cm}^3}.$$

Using Figure 5.3 (top graph for Ge), draw vertical line up from $N_i \approx N_d = 4 \times 10^{17}$ #/cm^3 and read **electron** mobility to be $\Rightarrow$ **$\mu_n = 2000$ cm^2/V·s**.

Use Einstein Relation (5.47), $\dfrac{D_n}{\mu_n} = \dfrac{k_B T}{e}$ to get electron diffusion coefficient-

$$D_n = \frac{k_B T}{e}\mu_n = \frac{1.380649 \times 10^{-23}(300)}{1.602176634 \times 10^{-19}} 2000 \quad \Rightarrow \quad \mathbf{D_n = 51.704 \text{ cm}^2/\text{s}}.$$

majority **[electrons]** or holes ? (circle correct) majority carrier conc. = **4×10^{17} #/cm^3**

minority electrons or **[holes]** ? (circle correct) minority carrier conc. = **1.44×10^9 #/cm^3**

majority mobility = **$\mu_n = 2000$ cm^2/V·s** majority diffusion coefficient = **$D_n = 51.704$ cm^2/s**

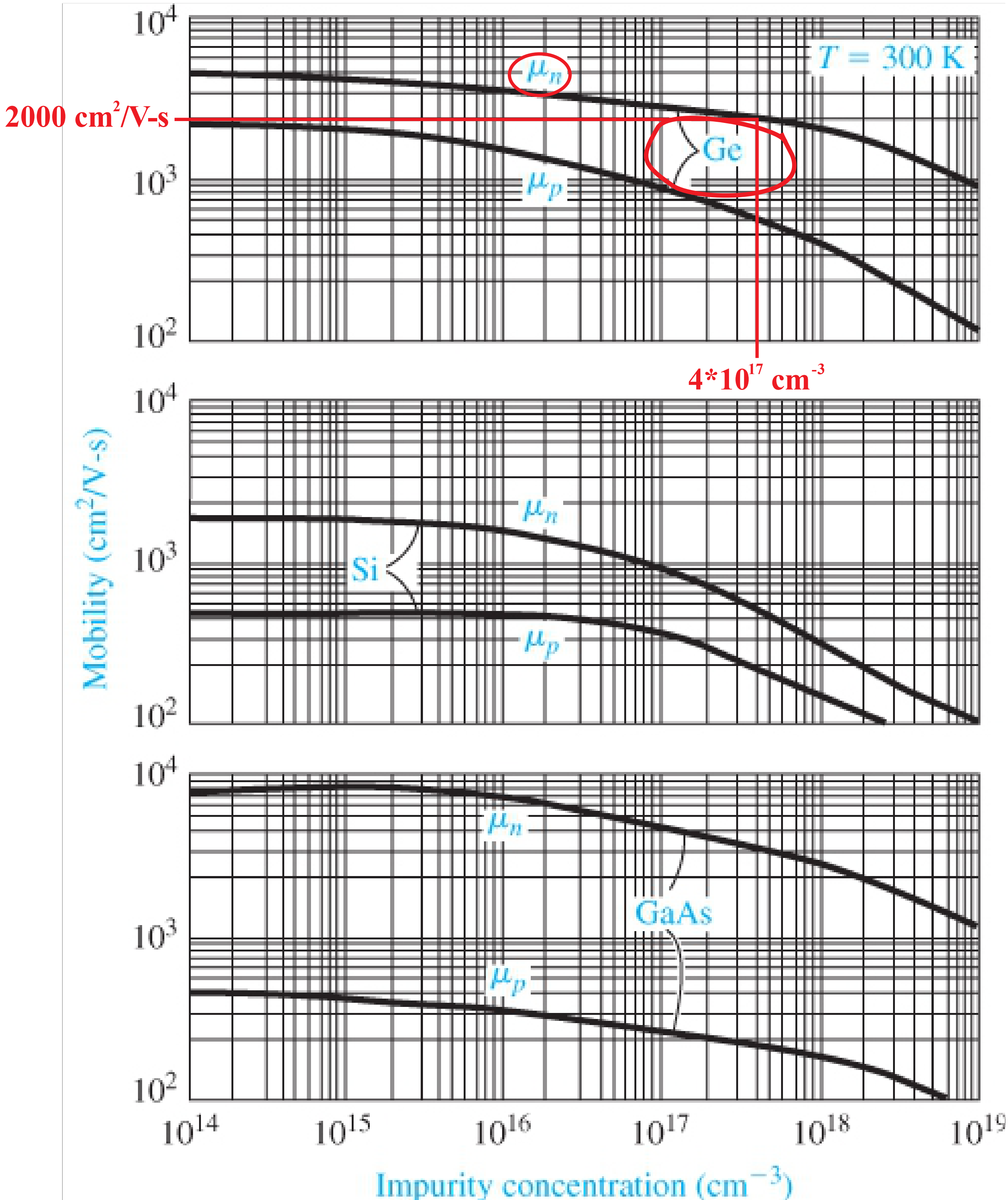

Figure 5.3 | Electron and hole mobilities versus impurity concentrations for germanium, silicon, and gallium arsenide at T = 300 K. *(From Sze [14].)*

EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 5 (Spring 2026)

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 **3-4** significant figures.

At 300 K, a sample of Germanium has been doped only with acceptors at a concentration of 7×10^{17} #/cm^3. Determine the minority and majority carrier types, i.e., electrons or holes, as well as equilibrium carrier concentrations (#/cm^3). Then, find the majority carrier mobility (cm^2/V·s) and diffusion coefficient (cm^2/s) of the doped Germanium.

Per Table B.4, Germanium at 300 K has $n_i = 2.4 \times 10^{13}$ #/cm^3.

Given 'doped only with acceptors' & that $N_a >> n_i$, we can say that the majority charge carriers are **holes** with a concentration of $\mathbf{p \cong N_a = 7 \times 10^{17}}$ **#/cm^3.**

If the majority charge carriers are holes, then the minority charge carriers are **electrons**. The electron concentration can be found using (4.43) $n_0 p_0 = n_i^2$

$$n = n_i^2 / p = (2.4 \times 10^{13})^2 / 7 \times 10^{17} \quad \Rightarrow \quad \mathbf{n = 8.22857 \times 10^8 \text{ \#/cm}^3}.$$

Using Figure 5.3 (top graph for Ge), draw vertical line up from the impurity concentration $N_i \approx N_a = 7 \times 10^{17}$ #/cm^3 & read **hole** mobility $\mathbf{\mu_p = 400}$ **cm^2/V·s**.

Use Einstein Relation (5.47), $\frac{D_p}{\mu_p} = \frac{k_B T}{e}$ to get hole diffusion coefficient-

$$D_p = \frac{k_B T}{e} \mu_p = \frac{1.380649 \times 10^{-23} (300)}{1.602176634 \times 10^{-19}} 400 \quad \Rightarrow \quad \mathbf{D_p = 10.3408 \text{ cm}^2/\text{s}}.$$

majority electrons or **[holes]** ? (circle correct) majority carrier conc. = **7×10^{17} #/cm^3**

minority **[electrons]** or holes ? (circle correct) minority carrier conc. = **8.229×10^8 #/cm^3**

majority mobility = **$\mu_p = 400$ cm^2/V·s** majority diffusion coefficient = **$D_p = 10.34$ cm^2/s**

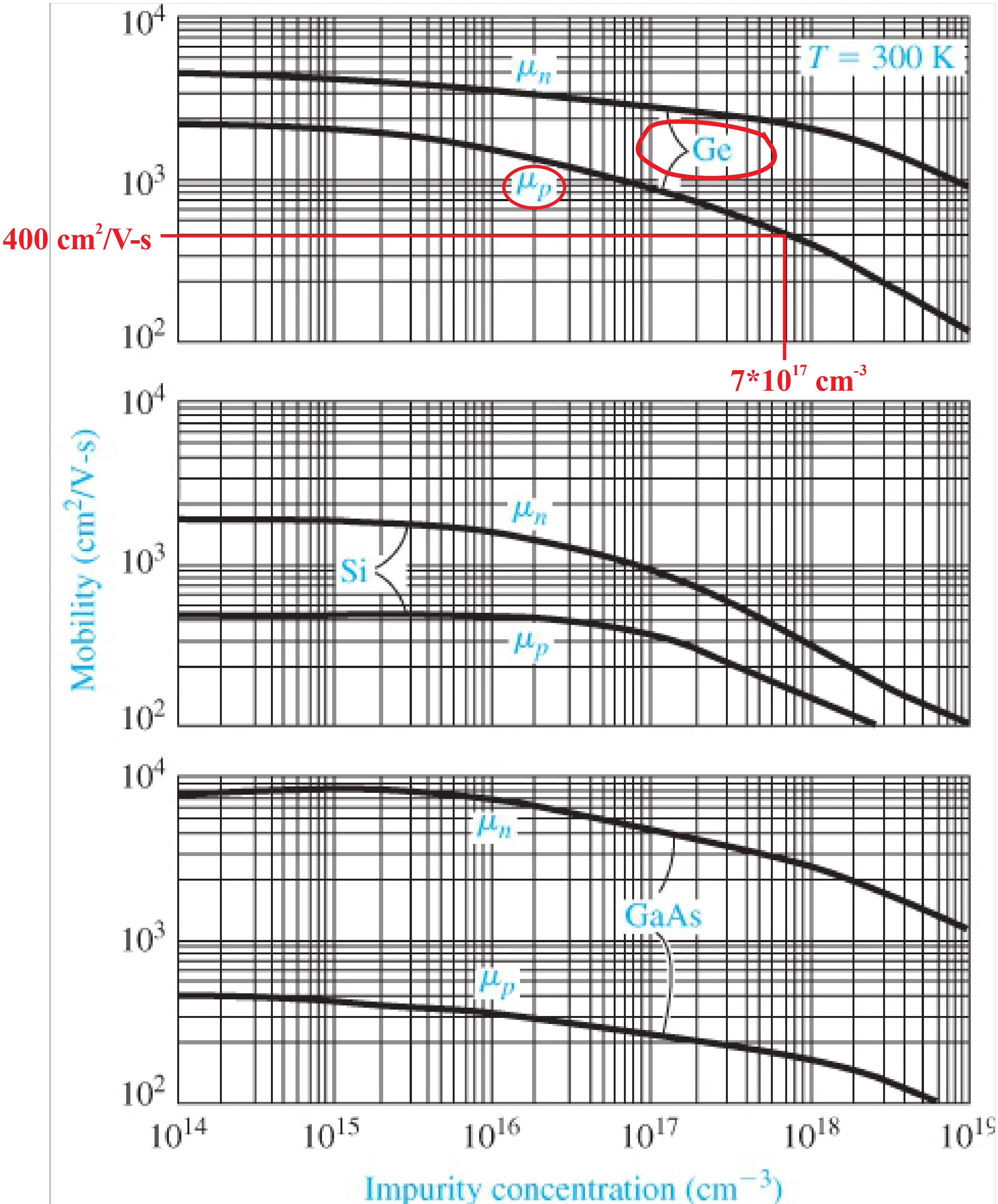

Figure 5.3 | Electron and hole mobilities versus impurity concentrations for germanium, silicon, and gallium arsenide at $T = 300$ K. *(From Sze [14].)*