EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 5 (Spring 2025)

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.

A sample of gallium arsenide (GaAs) has an intrinsic carrier concentration of 1.79×10^6 #/cm^3 and a band gap of 1.424 eV at **300 K**. It is doped only with acceptors at a concentration of 1.8×10^{16} #/cm^3. Determine the majority carrier type, i.e., electrons or holes, and concentration (#/cm^3). Then, find the majority carrier mobility (cm^2/V·s) and diffusion coefficient (cm^2/s) as well as the conductivity (S/m) of the doped GaAs.

'doped only with acceptors' & $N_a >> n_i$ $\Rightarrow$ **holes** & $\boldsymbol{p \cong N_a = 1.8 \times 10^{16}}$ **#/cm^3.**

Using Figure 5.3 (bottom graph for GaAs), draw vertical line up from $N_i = N_a = 1.8 \times 10^{16}$ #/cm^3 and read hole mobility to be $\Rightarrow$ $\boldsymbol{\mu_p = 300}$ **cm^2/V·s = 0.03 m^2/V·s.**

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

$$D_p = \frac{k_B T}{e}\mu_p = \frac{1.380649 \times 10^{-23}\,(300)}{1.602176634 \times 10^{-19}}\,300 \quad \Rightarrow \quad \boldsymbol{D_p = 7.7556}\ \textbf{cm}^2\textbf{/s.}$$

Use (5.23), $\sigma = e(\mu_n n + \mu_p p) \approx e\mu_p p$ to get the conductivity (used all MKS units)-

$$\sigma \approx 1.602176634 \times 10^{-19}\ \text{C}\,(0.03\ \text{m}^2/\text{V}\bullet\text{s})\,1.8 \times 10^{22}\ \#/\text{m}^3 \quad \Rightarrow \quad \boldsymbol{\sigma = 86.5175}\ \textbf{S/m.}$$

electrons or **holes** ? (circle correct) majority carrier conc. = $\boldsymbol{p \cong N_a = 1.8 \times 10^{16}}$ **#/cm^3**

mobility = $\boldsymbol{\mu_p = 300}$ **cm^2/V·s** diff. coeff. = $\boldsymbol{D_p = 7.756}$ **cm^2/s** conductivity = $\boldsymbol{\sigma = 86.52}$ **S/m**

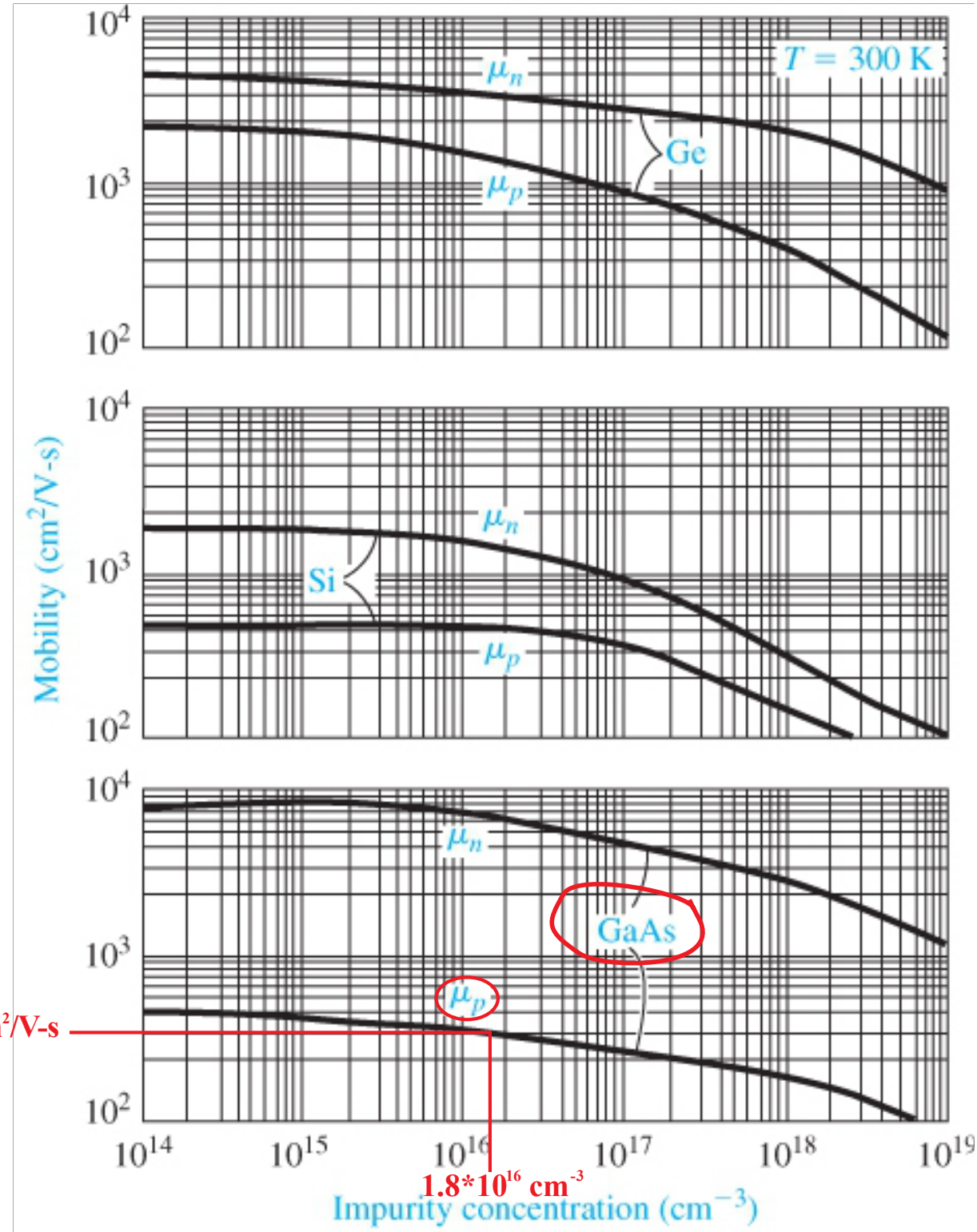

Figure 5.3 | Electron and hole mobilities versus impurity concentrations for germanium, silicon, and gallium arsenide at $T = 300$ K. *(From Sze [14].)*

EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 5 (Spring 2025)

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.

A sample of gallium arsenide (GaAs) has an intrinsic carrier concentration of 1.79×10^6 #/cm^3 and a band gap of 1.424 eV at **300 K**. It is doped only with donors at a concentration of 4.5×10^{16} #/cm^3. Determine the majority carrier type, i.e., electrons or holes, and concentration (#/cm^3). Then, find the majority carrier mobility (cm^2/V·s) and diffusion coefficient (cm^2/s) as well as the conductivity (S/m) of the doped GaAs.

'doped only with donors' & $N_d >> n_i$ $\Rightarrow$ **electrons** & $\boldsymbol{n \cong N_d = 4.5 \times 10^{16}}$ **#/cm^3.**

Using Figure 5.3 (bottom graph for GaAs), draw vertical line up from $N_i = N_d = 4.5 \times 10^{16}$ #/cm^3 and read electron mobility to be $\Rightarrow$ $\boldsymbol{\mu_n = 5000}$ **cm^2/V·s = 0.5 m^2/V·s.**

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

$$D_n = \frac{k_B T}{e}\mu_n = \frac{1.380649 \times 10^{-23}\,(300)}{1.602176634 \times 10^{-19}}\,5000 \quad \Rightarrow \quad \boldsymbol{D_n = 129.26}\ \textbf{cm}^2\textbf{/s.}$$

Use (5.23), $\sigma = e(\mu_n n + \mu_p p) \approx e\mu_n n$ to get the conductivity (used all MKS units)-

$$\sigma \approx 1.602176634 \times 10^{-19}\ \text{C}\ (0.5\ \text{m}^2/\text{V}\bullet\text{s})\ 4.5 \times 10^{22}\ \#/\text{m}^3 \quad \Rightarrow \quad \boldsymbol{\sigma = 3604.9}\ \textbf{S/m.}$$

electrons or holes ? (circle correct) majority carrier conc. = $\boldsymbol{n \cong N_d = 4.5 \times 10^{16}}$ **#/cm^3**

mobility = $\boldsymbol{\mu_n = 5000}$ **cm^2/V·s** diff. coeff. = $\boldsymbol{D_n = 129.26}$ **cm^2/s** conductivity = $\boldsymbol{\sigma = 3604.9}$ **S/m**

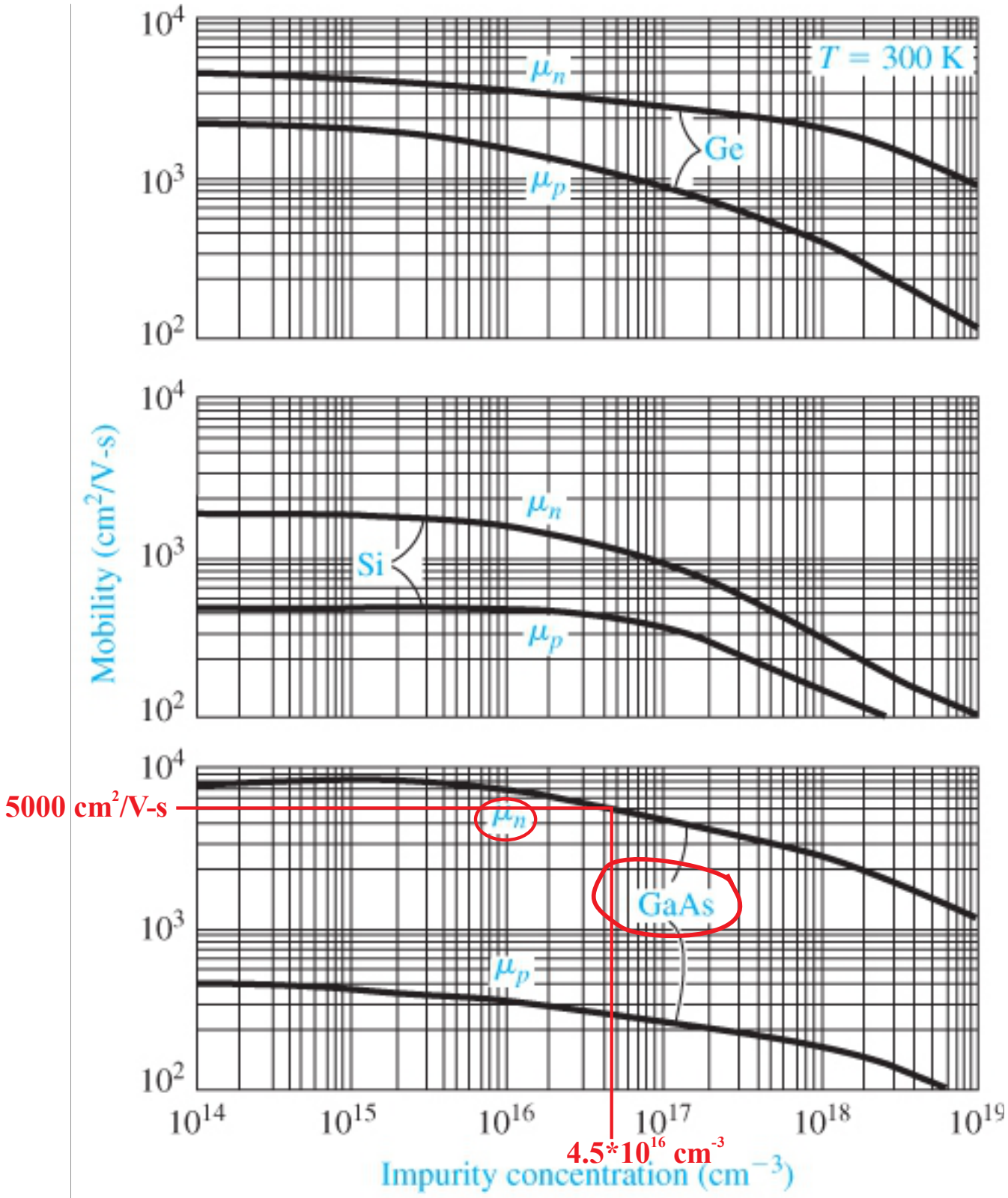

Figure 5.3 | Electron and hole mobilities versus impurity concentrations for germanium, silicon, and gallium arsenide at $T = 300$ K. *(From Sze [14].)*