EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 6 (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, $E_g = 1.424$ eV, and minority excess carrier lifetime of 25 μs at **300 K**. This sample is doped only with donors to a concentration of 2.2×10^{17} #/cm^3. Determine the thermal equilibrium electron and hole concentrations (#/cm^3). Will the minority excess carriers be electron or holes? Then, find the ambipolar mobility (cm^2/V·s) and diffusion (cm^2/s) coefficients under low-level injection conditions.

Since $N_d >> n_i$ $\Rightarrow$ **$n_0 \cong N_d = 2.2 \times 10^{17}$ #/cm^3.**

(4.43) $n_i^2 = n_0 p_0 \Rightarrow p_0 = n_i^2 / n_0 = (1.79\times10^6)^2/2.2\times10^{17} \Rightarrow$ **$p_0 = 1.4564 \times 10^{-5}$ #/cm^3**.

'doped only with donors' implies an n-type semiconductor (electrons in majority)
$\Rightarrow$ **holes** will be minority excess carriers

(6.47) & (6.48) give the ambipolar diffusion $D' = D_p$ and mobility $\mu' = -\mu_p$ coefficients for an n-type semiconductor w/ low-level injection.

Using Figure 5.3 (bottom graph for GaAs), draw a vertical line up from $N_i = N_d = 2.2 \times 10^{17}$ #/cm^3 and read hole mobility to be $\mu_p = 200$ cm^2/V·s

$\Rightarrow$ **$\mu' = -200$ cm^2/V·s**.

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

$$D_p = \frac{k_B T}{e}\mu_p = \frac{1.380649\times10^{-23}(300)}{1.602176634\times10^{-19}}200 \quad \Rightarrow \quad D_p = D' = 5.1704 \text{ cm}^2/\text{s}.$$

minority excess carriers: electrons or **holes** (circle correct)

$n_0 =$ **2.2×10^{17} #/cm^3** $p_0 =$ **1.4564×10^{-5} #/cm^3**

ambipolar mobility = **$\mu' = -200$ cm^2/V·s** ambipolar diff. coeff. = **$D' = 5.1704$ cm^2/s**

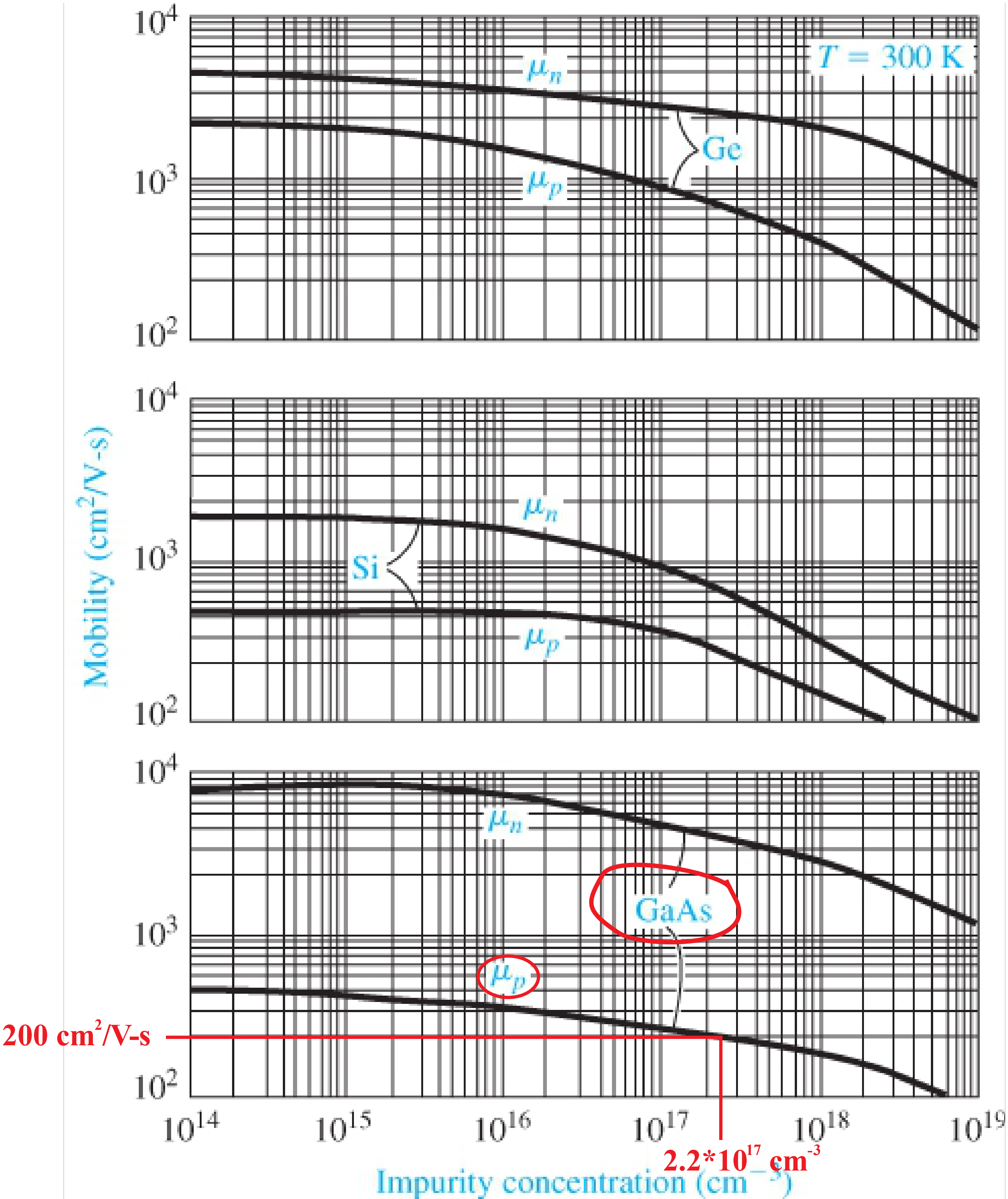

Figure 5.3 | Electron and hole mobilities versus impurity concentrations for germanium, silicon, and gallium arsenide at T = 300 K. *(From Sze [14].)*

EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 6 (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 germanium (Ge) has an intrinsic carrier concentration of 2.45×10^{13} #/cm^3, $E_g = 0.667$ eV, and minority excess carrier lifetime of 0.25 μs at **300 K**. This sample is doped only with donors to a concentration of 4.1×10^{17} #/cm^3. Determine the thermal equilibrium electron and hole concentrations (#/cm^3). Will the minority excess carriers be electron or holes? Then, find the ambipolar mobility (cm^2/V·s) and diffusion (cm^2/s) coefficients under low-level injection conditions.

Since $N_d >> n_i \quad \Rightarrow$ $\mathbf{n_0 \cong N_d = 4.1 \times 10^{17}}$ **#/cm^3.**

(4.43) $n_i^2 = n_0 p_0 \Rightarrow p_0 = n_i^2 / n_0 = (2.45\times10^{13})^2/4.1\times10^{17} \Rightarrow$ $\mathbf{p_0 = 1.464 \times 10^9}$ **#/cm^3**.

'doped only with donors' implies an n-type semiconductor (electrons in majority)

$\Rightarrow$ **holes** will be minority excess carriers

(6.47) & (6.48) give the ambipolar diffusion $D' = D_p$ and mobility $\mu' = -\mu_p$ coefficients for an **n-type** semiconductor w/ low-level injection.

Using Figure 5.3 (top graph for germanium), draw a vertical line up from $N_i = N_d = 4.1 \times 10^{17}$ #/cm^3 and read hole mobility to be $\mu_p = 500$ cm^2/V·s

$\Rightarrow$ $\mathbf{\mu' = -500}$ **cm^2/V·s**.

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

$$D_p = \frac{k_B T}{e}\mu_p = \frac{1.380649\times10^{-23}(300)}{1.602176634\times10^{-19}}500 \quad \Rightarrow \quad D_p = D' = 12.926 \text{ cm}^2/\text{s}.$$

minority excess carriers: electrons or **holes** (circle correct)

$n_0 =$ **4.1×10^{17} #/cm^3** $\qquad p_0 =$ **1.464×10^9 #/cm^3**

ambipolar mobility = **$\mu' = -500$ cm^2/V·s** $\qquad$ ambipolar diff. coeff. = **$D' = 12.926$ cm^2/s**

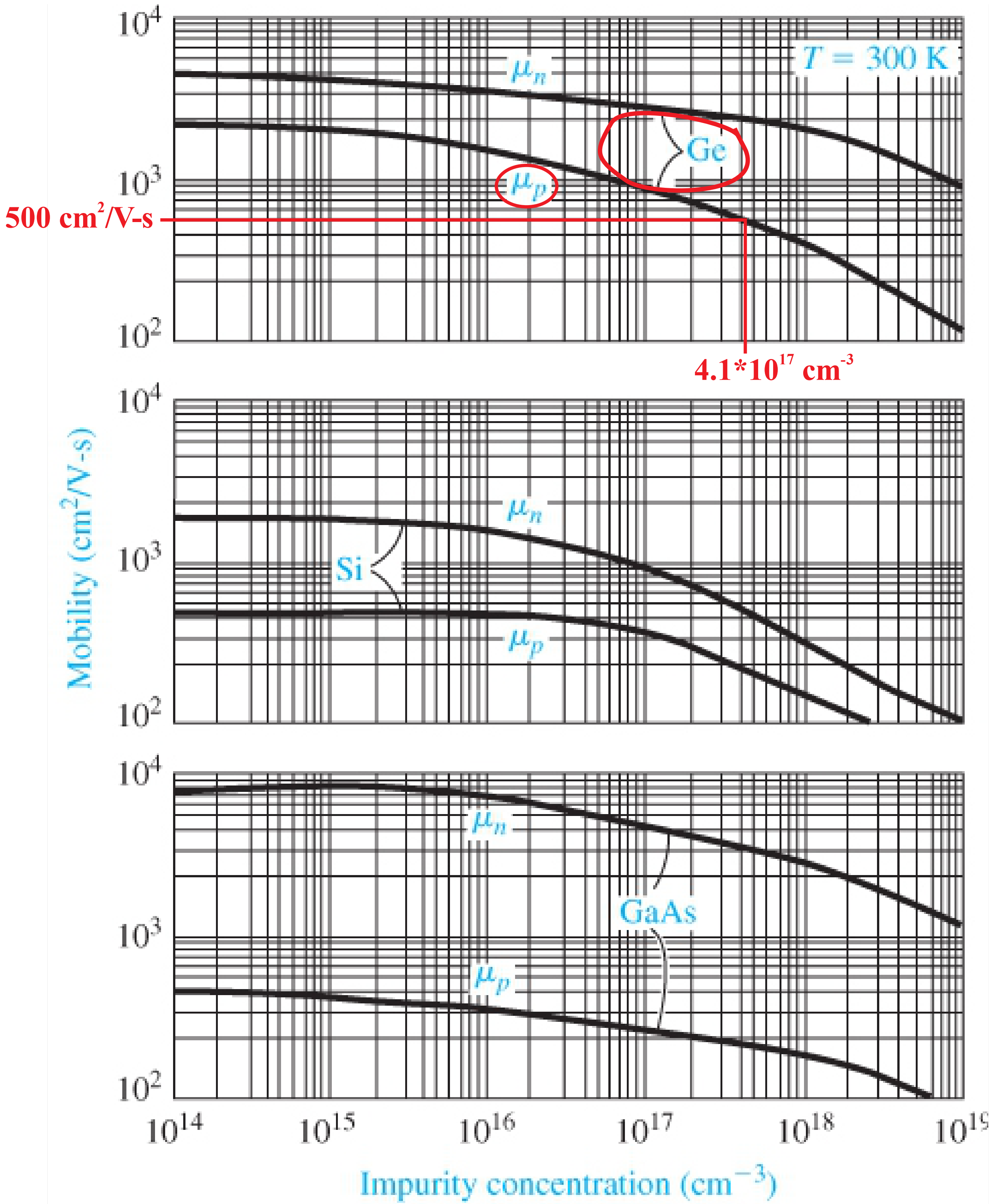

Figure 5.3 | Electron and hole mobilities versus impurity concentrations for germanium, silicon, and gallium arsenide at $T = 300$ K. *(From Sze [14].)*