6.10 Germanium at $T = 300$ K is uniformly doped with donor impurity atoms to a concentration of 4×10^{13} cm^{-3}. The excess carrier lifetime is found to be $\tau_{p0} = 2 \times 10^{-6}$ s. (*a*) Determine the ambipolar (*i*) diffusion coefficient and (*ii*) mobility. (*b*) Find the electron and hole lifetimes.

- First, find the electron and hole concentrations at thermal equilibrium.

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

$N_d = 4 \times 10^{13}$ #/cm^3 is fairly close to n_i.

Use (4.60)

$$n_0 = \frac{N_d - \cancel{N_a}^{\,0}}{2} + \sqrt{\left(\frac{N_d - \cancel{N_a}^{\,0}}{2}\right)^2 + n_i^2}$$

$$= \frac{4 \times 10^{13}}{2} + \sqrt{\left(\frac{4 \times 10^{13}}{2}\right)^2 + (2.4 \times 10^{13})^2}$$

$$\underline{\underline{n_0 = 5.1241 \times 10^{13} \ \frac{\#}{cm^3}}}$$

$$(4.43) \quad p_0 = \frac{n_i^2}{n_0} = \frac{(2.4 \times 10^{13})^2}{5.1241 \times 10^{13}}$$

$$\underline{\underline{p_0 = 1.1241 \times 10^{13} \ \#/cm^3}}$$

a) From Table 5.1, (or Fig 5.3)

$$\mu_n = 3900 \ \frac{cm^2}{V \cdot s}$$

$$\mu_p = 1900 \ \frac{cm^2}{V \cdot s}$$

$$(5.47) \quad \frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{k_B T}{e} = \frac{8.617333 \times 10^{-5} \, eV/K \, (300K)}{e} = 0.025852 \, V$$

$$D_n = 3900(0.025852) \Rightarrow D_n = 108.823 \ \frac{cm^2}{s}$$

$$D_p = 1900(0.025852) \Rightarrow D_p = 49.119 \ \frac{cm^2}{s}$$

a) cont.

(i) (6.43) $D' = \dfrac{D_n D_p (n+p)}{D_n n + D_p p}$

$$= \frac{108.823(49.119)(5.1241\times10^{13} + 1.1241\times10^{13})}{108.823(5.1241\times10^{13}) + 49.119(1.1241\times10^{13})}$$

$$\underline{\underline{D' = 54.498 \ \text{cm}^2/\text{s}}}$$

(ii) (6.41) $\mu' = \dfrac{\mu_n \mu_p (p-n)}{\mu_n n + \mu_p p}$

$$= \frac{3900(1900)(1.1241\times10^{13} - 5.1241\times10^{13})}{3900(5.1241\times10^{13}) + 1900(1.1241\times10^{13})}$$

$$\underline{\underline{\mu' = -1339.98 \ \frac{\text{cm}^2}{\text{V-s}}}}$$

b) For holes, $\underline{\underline{\tau_{pt} = \tau_{p0} = 2\times10^{-6}\ \text{s}}}$

(6.35) $\dfrac{n}{\tau_{nt}} = \dfrac{p}{\tau_{pt}}$

$$\tau_{nt} = \frac{\tau_{pt}}{p} n = \frac{2\times10^{-6}}{1.1241\times10^{13}} 5.1241\times10^{13}$$

$$\underline{\underline{\tau_{nt} = 9.1168\times10^{-6}\ \text{s}}}$$