Example- Let's examine a pn junction in germanium at 300 K where $N_a = 6*10^{15}$ cm^{-3} (p-region) and $N_d = 3*10^{15}$ cm^{-3} (n-region) with $V_a = 0.07$ V. Assume the carrier lifetimes are $\tau_{p0} = 2*10^{-8}$ s and $\tau_{n0} = 8*10^{-8}$ s.

$kB\_eV := 8.617333 \cdot 10^{-5}$ eV/K

$\varepsilon 0 := 8.8541878 \cdot 10^{-12}$ F/m

$kB := 1.380649 \cdot 10^{-23}$ J/K

$qe := 1.602176634 \cdot 10^{-19}$ C

Given

$T := 300$ K

$Na := 6 \cdot 10^{21}$ m^{-3}

$Nd := 3 \cdot 10^{21}$ m^{-3}

$Va := 0.07$ V

$\tau p0 := 2 \cdot 10^{-8}$ s

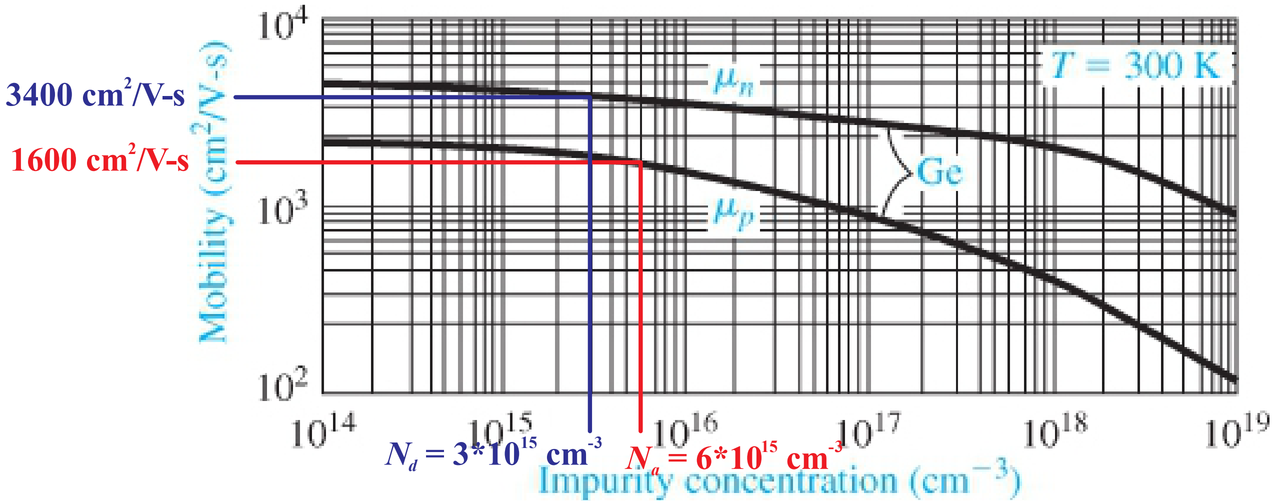
$\tau n0 := 8 \cdot 10^{-8}$ s

Table B.4

$\varepsilon r\_Ge := 16$

$ni\_Ge := 2.4 \cdot 10^{19}$ m^{-3}

Figure 5.3



$\mu p := 1600$ cm^2/V-s

$\mu n := 3400$ cm^2/V-s

(5.47) Einstein relation

$$Dp := \mu p \cdot \frac{kB \cdot T}{qe}$$

$Dp = 41.363$ cm^2/s

$$Dn := \mu n \cdot \frac{kB \cdot T}{qe}$$

$Dn = 87.897$ cm^2/s

(7.10) $Vt := \frac{kB \cdot T}{qe}$ $\boxed{Vt = 0.025852}$ V

$Vbi := Vt \cdot \ln\left(\frac{Na \cdot Nd}{ni\_Ge^2}\right)$ $\boxed{Vbi = 0.267562}$ V

Use V_{bi} - V_a in (7.28), (7.29), & (7.31)

(7.28) $xn := \sqrt{\frac{2 \cdot \varepsilon r\_Ge \cdot \varepsilon 0 \cdot (Vbi - Va)}{qe} \cdot \left(\frac{Na}{Nd}\right) \cdot \frac{1}{Na + Nd}}$ $\boxed{xn = 2.78638 \times 10^{-7}}$ m

(7.29) $xp := \sqrt{\frac{2 \cdot \varepsilon r\_Ge \cdot \varepsilon 0 \cdot (Vbi - Va)}{qe} \cdot \left(\frac{Nd}{Na}\right) \cdot \frac{1}{Na + Nd}}$ $\boxed{xp = 1.39319 \times 10^{-7}}$ m

(7.31) $W := \sqrt{\frac{2 \cdot \varepsilon r\_Ge \cdot \varepsilon 0 \cdot (Vbi - Va)}{qe} \cdot \left(\frac{Na + Nd}{Na \cdot Nd}\right)}$ $\boxed{W = 4.17957 \times 10^{-7}}$ m

Calculate diffusion lengths in meters

$Ln := \frac{\sqrt{Dn \cdot \tau n0}}{100}$ $\boxed{Ln = 2.651744 \times 10^{-5}}$ m

$Lp := \frac{\sqrt{Dp \cdot \tau p0}}{100}$ $\boxed{Lp = 9.095405 \times 10^{-6}}$ m

p region $pp0 := Na$ $pp0 = 6 \times 10^{21}$ m^{-3} **majority**

$np0 := \frac{ni\_Ge^2}{pp0}$ $\boxed{np0 = 9.6 \times 10^{16}}$ m^{-3} **minority**

(8.6) $np\_xp := np0 \cdot e^{\frac{Va}{Vt}}$ $\boxed{np\_xp = 1.44 \times 10^{18}}$ m^{-3} **minority**

n region $nn0 := Nd$ $nn0 = 3 \times 10^{21}$ m^{-3} **majority**

$pn0 := \frac{ni\_Ge^2}{nn0}$ $\boxed{pn0 = 1.92 \times 10^{17}}$ m^{-3} **minority**

(8.7) $pn\_xn := pn0 \cdot e^{\frac{Va}{Vt}}$ $\boxed{pn\_xn = 2.879 \times 10^{18}}$ m^{-3} **minority**

Now, plot charge carrier concentrations

$n := 0..99 \qquad x\_nreg_n := xn + Ln \cdot \frac{n}{100} \qquad x\_preg_n := -xp - Ln \cdot \frac{n}{100}$

$$\delta pn_n := pn0 \cdot \left(e^{\frac{Va}{Vt}} - 1 \right) \cdot e^{\frac{(xn - x\_nreg_n)}{Lp}} \qquad pn_n := \delta pn_n + pn0$$

$$\delta np_n := np0 \cdot \left(e^{\frac{Va}{Vt}} - 1 \right) \cdot e^{\frac{(xp + x\_preg_n)}{Lp}} \qquad np_n := \delta np_n + np0$$