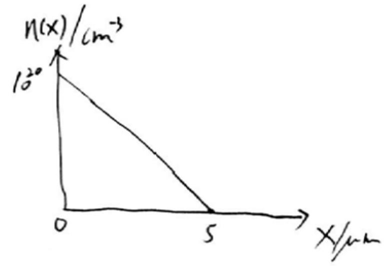
1. ECE 132 HW3 Solutions



The overall current density for electrons is $J_n = q\mu_n nE + qD_n \frac{dn(x)}{dx}$

And in this case since the Electrical Field is negligible, we have E=0, which means we only have a diffusion current, and no drift current.

Therefore, $J_n = qD_n \frac{dn(x)}{dx}$

Using the Einstein Relationship $D_n = \mu_n \frac{kT}{q}$,

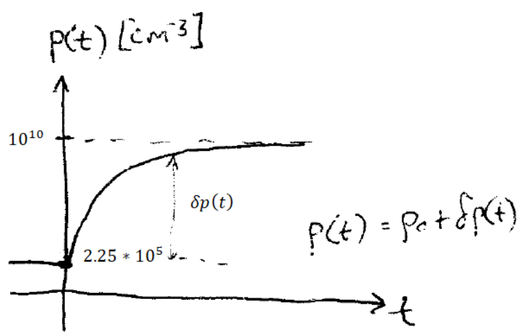
D_n =(500$\frac{cm^2}{V*s}$)(0.0259V) = 13 $\frac{cm^2}{s}$ assuming room temperature

Looking at the graph, we can see that $\frac{dn(x)}{dx}$ = $-2 * 10^{19} cm^{-3} \mu m^{-1}$

Hence $J_n = 1.6 * 10^{-19} C * 13 \frac{cm^2}{s} * -2 * 10^{19} cm^{-3} \mu m^{-1}$

$= -4.16 * 10^5 \frac{A}{cm^2}$

2. (a) $P_{fin} = (10^{16} cm^{-3} s^{-1})(10^{-6} s)$ = $10^{10} cm^{-3}$



$$p_o = \frac{{n_i}^2}{N_d} = \frac{(1.5 * 10^{10})^2}{10^{15}} = 2.25 * 10^5 cm^{-3}$$

$t \geq 0$: $\frac{dp(t)}{dt} = G_{tot} - R_{tot}$,

$\frac{dp(t)}{dt} = \frac{d[\delta p(t)]}{dt}$,

$G_{total} = g_{ther} + g_{op} = \propto_r n_o p_o + g_{op}$

$R_{total} = \propto_r [n_o + \delta n(t)][p_o + \delta p(t)]$

$n_o + \delta n(t) \approx n_o$ since $n_o \gg \delta n(t)$ in n-type material at all times t

$\frac{d[\delta p(t)]}{dt} = \propto_r n_o p_o + g_{op} - \propto_r n_o p_o - \propto_r n_o \delta p(t)$

$\frac{d[\delta p(t)]}{dt} = g_{op} - \frac{\delta p(t)}{\tau_p}$

$\tau_p \frac{d[\delta p(t)]}{\delta p(t) - g_{op}\tau_p} = -dt$

$\tau_p * ln[\delta p(t) - g_{op}\tau_p] = -t + c_1$

$\delta p(t) - g_{op}\tau_p = c_2 e^{-t/\tau_p}$ B.C.: $\delta p(0) = 0 \rightarrow c_2 = -g_{op}\tau_p$

$\delta p(t) = g_{op}\tau_p[1 - e^{-t/\tau_p}]$

(b) $\delta p = 0.1 * g_{op}\tau_p$ when $1 - e^{-t/\tau_p} = 0.1 \rightarrow t = \tau_p \ln\left[\frac{10}{9}\right]$

$= 1.05 * 10^{-7} s$

(c) $\delta p = 0.9 * g_{op}\tau_p$ when $1 - e^{-t/\tau_p} = 0.9 \rightarrow t = \tau_p \ln[10]$

$= 2.3 * 10^{-6} s$

3. From equations (4-36) and figure 4.17 in Streetman's book,

$$J_n = q\frac{D_n}{L_n} * \delta n = -q\frac{D_n}{L_n} * \Delta n e^{-x/L_n}$$

$$D_n = \mu_n \frac{kT}{q} = 2000\frac{cm^2}{V*s} * 0.0259 * \frac{500}{300} = 86.7\frac{cm^2}{s}$$

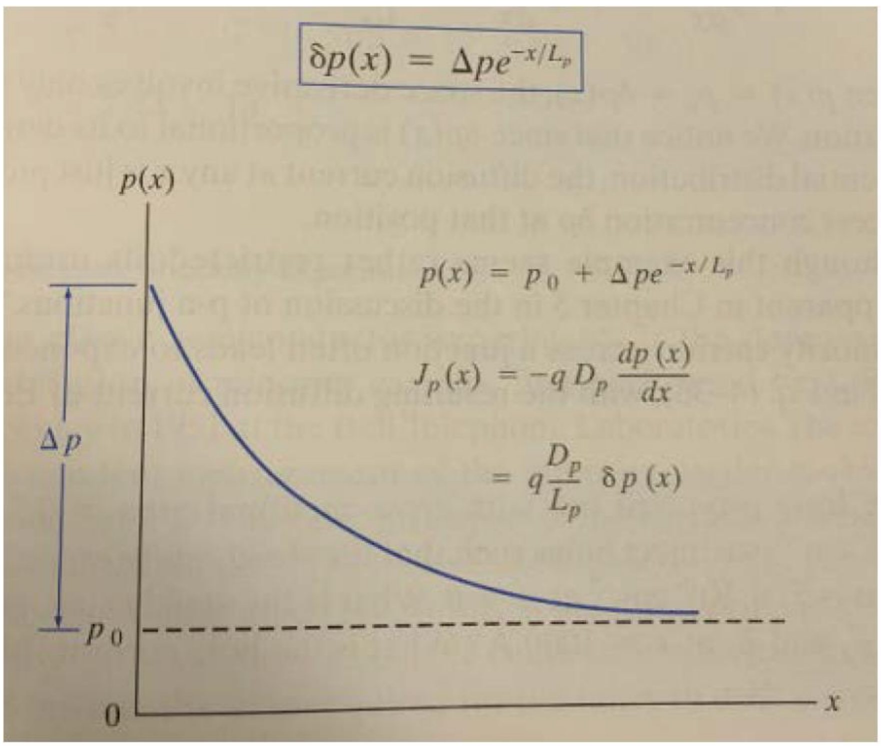
$$L_n = \sqrt{D_n * \tau_n} = \sqrt{86.7\frac{cm^2}{s} * 200ns} = 41.64\mu m$$

$$\Delta n = \delta n(0) = G_{on}\tau_n = 10^{20}cm^{-3}s^{-1} * 200ns = 2 * 10^{13}cm^{-3}$$

Therefore: $J_n(x) = -q\frac{D_n}{L_n} * \Delta n e^{-x/L_n}$, and at $x = 20\mu m$

$$= -(1.6 * 10^{-19}C) * \frac{86.7\frac{cm^2}{s}}{41.64\mu m} * 2 * 10^{13}cm^{-3} * e^{-20\mu m/41.64\mu m}$$

$$= -41.3\frac{mA}{cm^2}$$



4. (a) For Si at room temperature:

$E_g = 1.1eV,\ N_c = 2.8 * 10^{19} cm^{-3}, N_v = 1.8 * 10^{19} cm^{-3}$

For the p-side. $N_A = 10^{16} cm^{-3}$

$$P_p = N_v e^{-\frac{(E_f - E_v)}{kT}} \rightarrow (E_f - E_v) = kTln\frac{N_v}{N_A}$$

$$E_f - E_v = 0.0259eV * \ln\left[\frac{1.8 * 10^{19} cm^{-3}}{10^{16} cm^{-3}}\right] = 0.194eV$$

For the n-side, $N_D = 10^{16} cm^{-3}$

$$n_n = N_c e^{-\frac{(E_c - E_v)}{kT}} \rightarrow (E_c - E_f) = kTln\frac{N_c}{N_D}$$

$$E_c - E_f = 0.0259eV * \ln\left[\frac{2.8 * 10^{19} cm^{-3}}{10^{16} cm^{-3}}\right] = 0.206eV$$

(b) The Built in Voltage (V_{bi}) and band diagram