Example of a Si p^+N junction

23/9/2014

$N_D = 10^{15}/cm^3$

$N_A = 10^{18}/cm^3$

$A = 10^{-3}\,cm^2$

Diode length of each side $= 2\times10^{-2}$ cm

$\tau_p = \tau_n = \tau_0 = 1\,\mu sec.$

n-side

$\mu_p = 480\,cm^2/V\text{-}s$

$\mu_n = 1280\,cm^2/V\text{-}s$

$D_p = 12.4\,cm^2/sec$

$D_n = 33\,cm^2/sec.$

$L_p = \sqrt{D_p \tau_p} = 3.5\times10^{-3}$ cm

p-side

$\mu_p = 110\,cm^2/V\text{-}s$

$\mu_n = 280\,cm^2/V\text{-}s$

$D_p = 2.8\,cm^2/s$

$D_n = 7.25\,cm^2/s$

$L_n = 2.7\times10^{-3}$ cm

Long-base diode

Contact potential $V_0 = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right) = 0.75\,V$

$\varepsilon_{Si} = 11.8\times 8.85\times10^{-14}$ F/cm.

$V = -4\,V$ (reverse bias)

$$W = \sqrt{\frac{2\varepsilon_{si}}{q}(V_0 - V)\left(\frac{N_A + N_D}{N_A N_D}\right)} \approx \sqrt{\frac{2\varepsilon_{si}(V_0 - V)}{q N_D}}$$

$$= 2.5 \times 10^{-4}\,\text{cm}$$

$$|I_{rev}| = I_0 + I_{gen} = qAn_i^2\left(\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A}\right) + \frac{qAWn_i}{2\tau_0}$$

$$= 1.6 \times 10^{-19} \times 10^{-3} \times 2.25 \times 10^{20}\left(\frac{12.4}{3.5 \times 10^{-3} \times 10^{15}} + \frac{7.25}{2.7 \times 10^{-3} \times 10^{18}}\right) + \frac{qAWn_i}{2\tau_0}$$

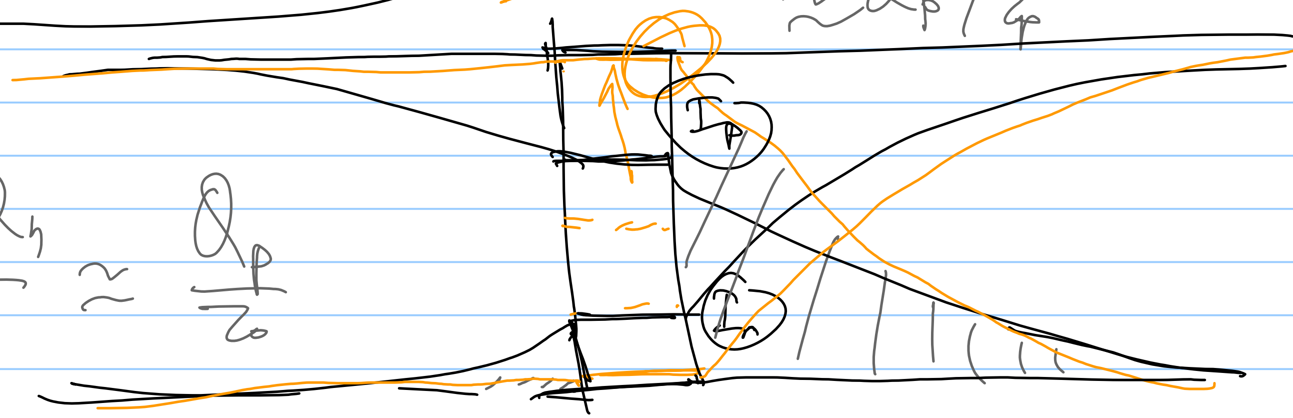
$$= 3.6 \times 10^{-14}\,(3.54 + 0.0027) + 3 \times 10^{-10}$$

$$I_{ideal} = I_p(x = x_n) + I_n(x = -x_p) \qquad I_0 = 1.27\times10^{-13}\,A$$

$$= qA\left(\frac{D_p}{L_p}\Delta p_n + \frac{D_n}{L_n}\Delta n_p\right) \qquad \approx I_{p0}$$

$$I_{ideal} = \underbrace{qA\left(\frac{D_p}{L_p}p_{n0} + \frac{D_n}{L_n}n_{p0}\right)}_{I_0}\left(e^{V/V_T} - 1\right) \qquad = \frac{Q_p}{\tau_p} + \frac{Q_n}{\tau_n} \approx Q_p/\tau_p$$

$$\frac{Q_p}{\tau_p} + \frac{Q_n}{\tau_n} = \frac{Q_p + Q_n}{\tau_0} \simeq \frac{Q_p}{\tau_0}$$



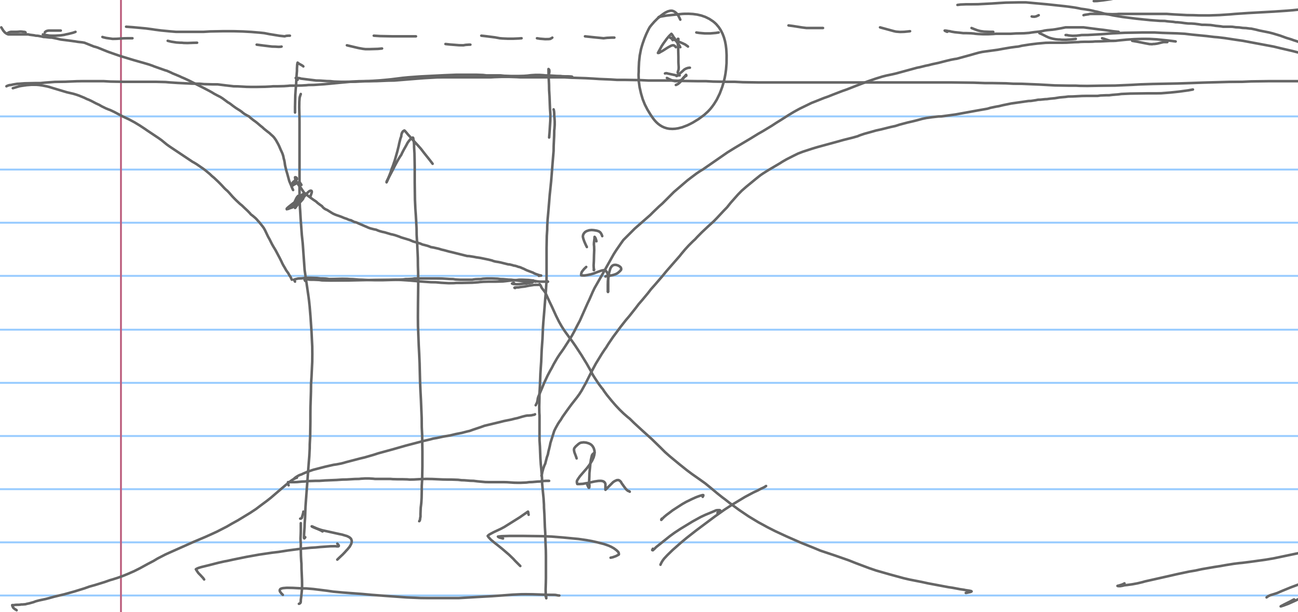
$$I_{gen} >> I_0$$

$$(n_i) \qquad (n_i^2)$$

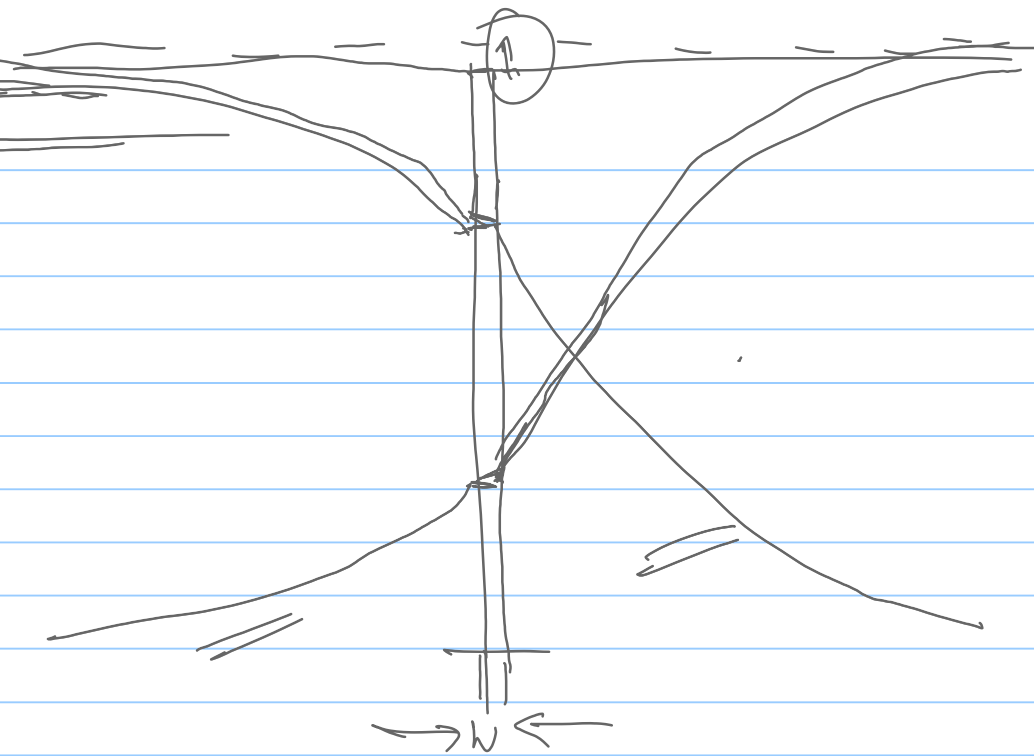
$$I_0 = I_{gen} \Rightarrow n_i = ?$$

$$\cancel{qA}\, n_i^2 \left(\frac{D_p}{L_p N_D}\right) = \frac{\cancel{qA}\, W n_i}{2\tau_0}$$

$$n_i = \frac{W \cdot L_p N_D}{2 D_p \tau_0} = \frac{W N_D}{2 L_p} = 3.57\times10^{13}/cc$$

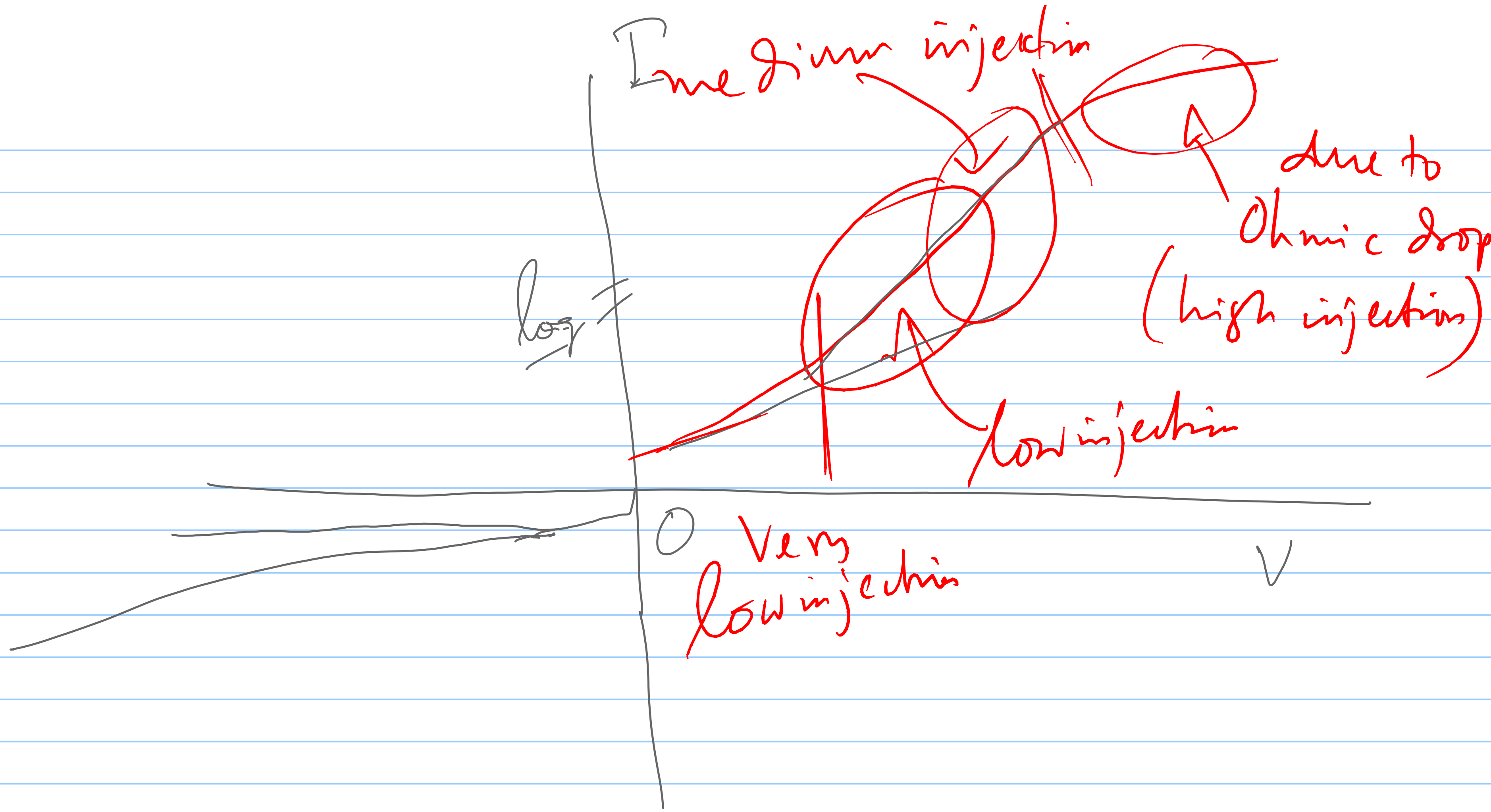


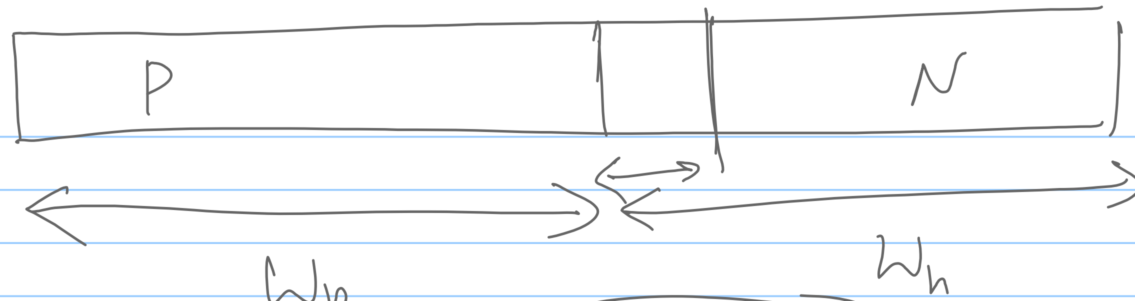
V = 0.15V



V = 0.6V

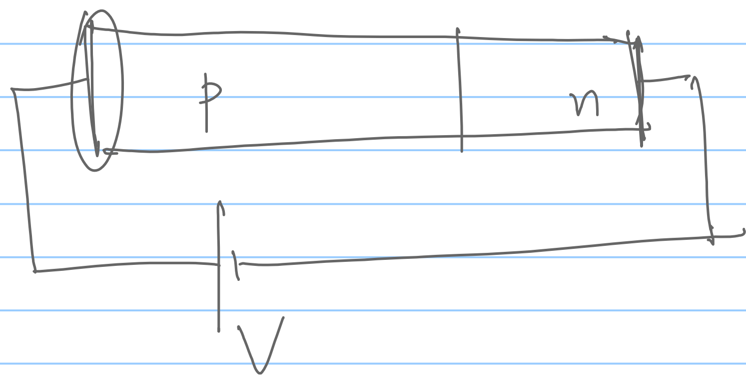
$I = I_{ideal}$ if V is <u>high</u>


I
medium injection
log I
O
Very low injection
low injection
due to Ohmic drop (high injection)
V



$W_p, W_n >> L_p, L_n$

Short base diode if $W_n << L_p$



n-side

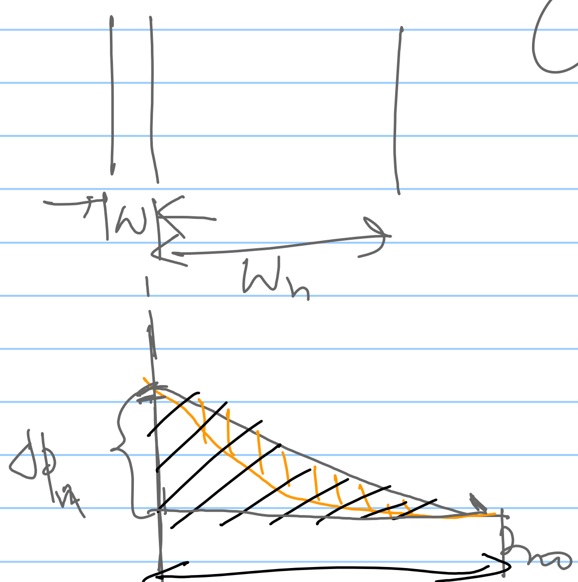
→ p will diffuse

→ p will not recombine

→ contact will eat all excess carrier

$$0 = \frac{\partial \delta p(x,t)}{\partial t} = -\frac{1}{q}\frac{\partial}{\partial x} J_p(x,t) - \frac{\delta p(x,t)}{\tau_p}$$

steady state



$$\frac{d^2 \delta p(x)}{dx^2} = \frac{\delta p(x)}{D_p \tau_p} = \frac{\delta p(x)}{L_p^2} = 0$$

$$\delta p(x) = mx + C$$

$x = x_n$

$\underline{\delta p(x_n) = \Delta p_n}$

$\underline{\delta p(x_n + W_n) = 0}$

$$I_p(x = x_n) = \frac{Q_p}{\tau_t} = \frac{qA \int_0^{W_n} \delta p(x)\, dx}{\tau_t} = \frac{qA}{2} \cdot \frac{\Delta p_n W_n}{\tau_t}$$

$$I_p(x = x_n) = -qAD_p \frac{d}{dx}\delta p(x)\Big|_{x = x_n} = qAD_p \cdot \frac{\Delta p_n}{W_n} = \frac{qA\,\Delta p_n W_n}{2\tau_t}$$

$$\boxed{\tau_t = \frac{W_n^2}{2D_p}}$$