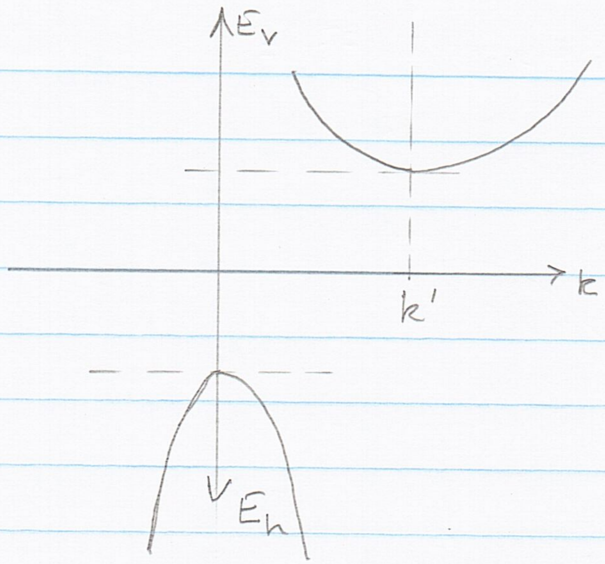
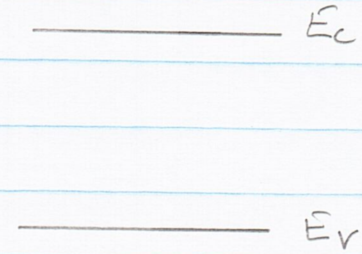
EECE 480 MID-TERM 2011

1\. a)



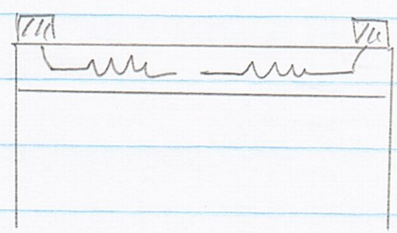
3

Band structure



Band diagram

b) The issue is lateral resistance



$\therefore$ Need high σ

$\sigma = q n \mu_e$ or $q p \mu_h$

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$\mu \propto 1/m_e^*$

$m_e^* \propto \left[\frac{d^2E}{dk^2}\right]^{-1}$ For electrons $\left[\frac{d^2E}{dk^2}\right]^{-1} = \frac{1}{\alpha}$

For holes $[\quad] = \frac{1}{3\alpha}$

$\therefore \mu_h > \mu_e$

$\therefore$ Choose p^+ emitter

2 c) $J_{ph} \propto D$ & $L = \sqrt{D\tau}$ Both $D (\propto \mu)$ & τ decrease with doping because of scattering (μ) & recombination via defects (τ)

2 (a) p-side $(E_F - E_V)_p < (E_C - E_F)_n$

(b) $qV_a = E_{Fn}(0) - E_{Fp}(L) = 0 - 0.75\,eV \therefore |V_a| = \underline{0.75\,V}$

$qV_J \; 0.312 - 0.145 = 0.167\,eV$

$V_{bi} \pm V_a = V_J \quad \therefore \quad V_{bi} = 0.167 + 0.75 = \underline{0.917\,V}$

(c) $(E_F - E_V)_p = -750 + 813 = 63\,meV$

$$p = N_V \exp \frac{E_V - E_F}{k_B T} = 1.142 \times 10^{19}\, e^{-63/25.9}$$

$$= \underline{1.003 \times 10^{18}\ cm^{-3}} \approx N_A$$

(d) At $x = x_{dp}$, $n = n_{op} \exp\left(\frac{-|V_a|}{V_{th}}\right)$

$$n_{op} = \frac{n_i^2}{p_{op}} \qquad n_i^2 = N_C N_V \exp -E_g/k_B T$$

$$E_g = 312 - (-813) = 1.125\,eV$$

$$\therefore n_i = \left[2.744 \times 10^{19} \times 1.142 \times 10^{19} \exp - \frac{1.125}{0.0259}\right]^{1/2} = 6.54 \times 10^{9}\ cm^{-3}$$

$$\therefore n_{op} = \frac{(6.54 \times 10^9)^2}{1.003 \times 10^{18}} = 42.7\ cm^{-3}$$

$$n = 42.7\, e^{\frac{0.75}{0.0259}} = \underline{\underline{1.6 \times 10^{14}\ cm^{-3}}}$$

3 (a) From Master Set: $J_e = q D_e \frac{dn}{dx}$

steady-state $0 = \frac{1}{q}\frac{dJ_e}{dx} - \frac{n - n_{op}}{\tau_e}$

$\rightarrow \quad 0 = \frac{d^2 n}{dx^2} - \frac{n - n_{op}}{\tau_e}$

General sol^n:

$$n - n_{op} = A e^{x/L_e} + B e^{-x/L_e}$$

BC:s @ $x = \infty$ $n = n_{op}$ $\therefore$ $A = 0$

@ $x = 0$ $n = n_{op} e^{-V_a/V_{th}}$ $\therefore$ $B = n_{op}\left(e^{-V_a/V_{th}} - 1\right)$

$$\therefore \; \underline{n(x) - n_{op} = n_{op}\left(e^{-V_a/V_{th}} - 1\right) e^{-x/L_e}}$$

(b) $n = N_c \exp \frac{E_{Fn} - E_c}{k_B T} \rightarrow E_{Fn} - E_c = k_B T \ln \frac{n}{N_c}$

$\therefore \; E_c - E_{Fn} = k_B T \ln\left(\frac{N_c}{n}\right)$

$$E_c - E_{Fn} = k_B T\left[\ln N_c - \ln n\right]$$

$$\doteq k_B T\left[\ln N_c - \left\{\ln\left(n_{op} e^{-V_a/V_{th}} - 1\right) - x/L_e\right\}\right] \quad \text{for } n > n_0$$

$$= \underline{\underline{k_B T \frac{x}{L_e} + k_B T \ln\left\{\frac{N_c}{n_{op} e^{-V_a/V_{th}} - 1}\right\}}}$$

$$\therefore \frac{d(E_c - E_{Fn})}{dx} = \frac{k_B T}{L_e} = \frac{25.9\,\text{meV}}{0.1\,\mu m} = 259\ \text{meV}/\mu m$$

$$E_{Fn}(x_{dp}) - E_{Fp}(\cancel{x} \text{ in } p\text{-QNR}) = 750\ \text{meV}$$

$$\therefore \quad E_{Fn} \rightarrow E_{Fn} \text{ after about } \frac{750}{259} \simeq 3\,\mu m$$

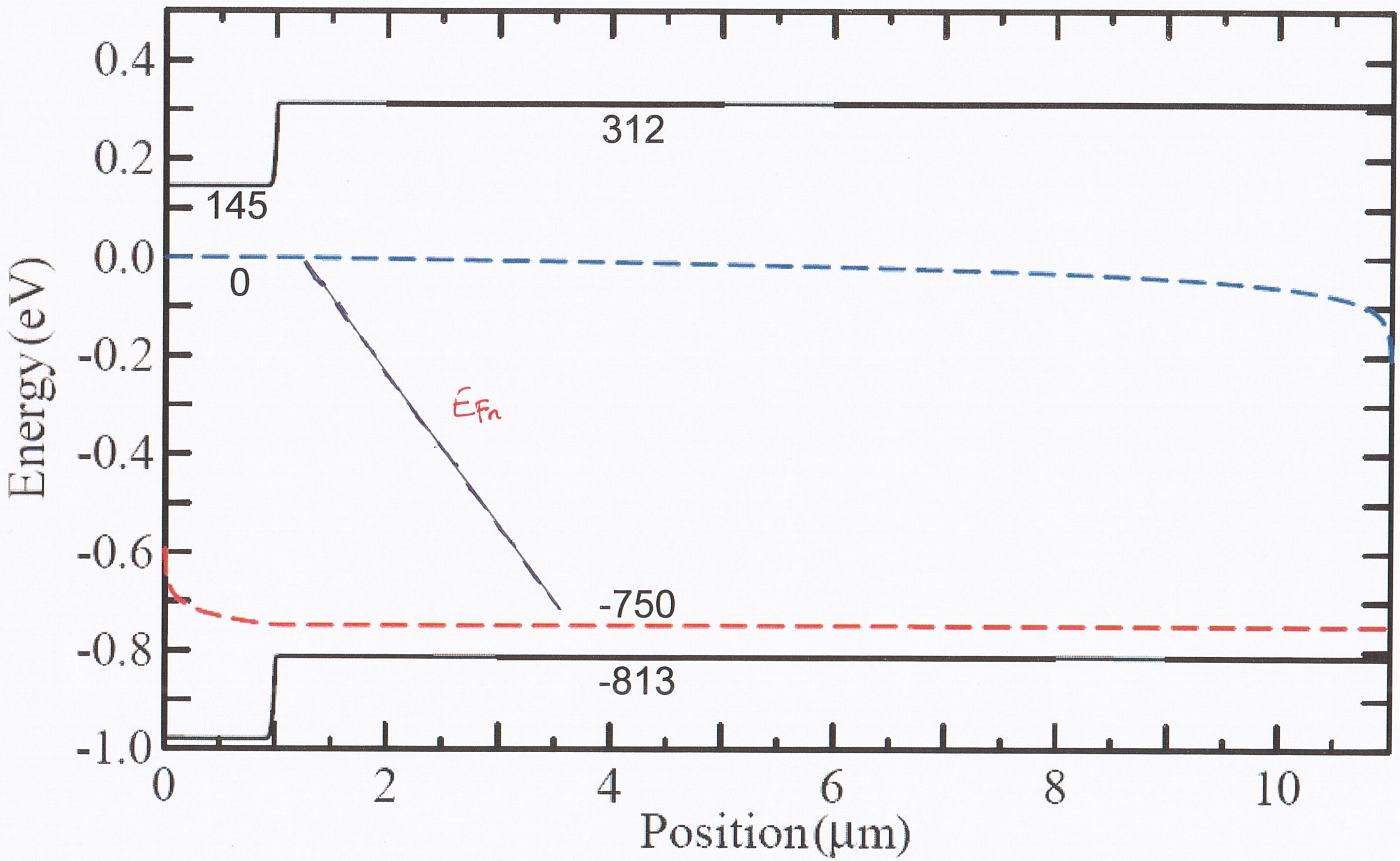

Figure 1: Energy band diagram (E_C, E_V, E_{Fn}, E_{Fp}) for a forward-biassed diode with no recombination. $N_C = 2.744 \times 10^{19}\ \mathrm{cm}^{-3}$, $N_V = 1.142 \times 10^{19}\ \mathrm{cm}^{-3}$, $k_B T = 25.9\ \mathrm{meV}$ at $T = 300\ \mathrm{K}$.

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