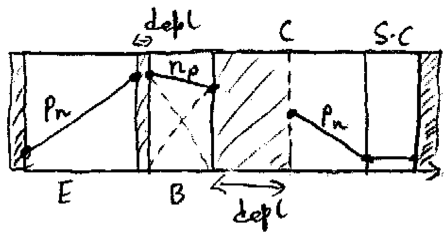
(a) Minority carrier diffusion lengths: $L_n = \sqrt{D_n \tau_n} = \sqrt{\mu_n \cdot \frac{kT}{q} \cdot \tau_n} = 44\,\mu m$ (very large!)

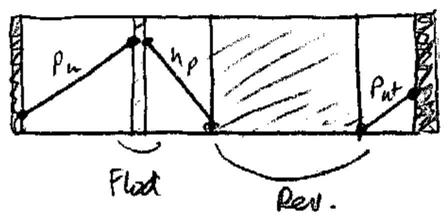
$L_p = \sqrt{D_p \tau_p} = \sqrt{\mu_p \frac{kT}{q} \tau_p} = 24\,\mu m$ (" ")

$W_E, W_B << (L_n, L_p)$ => both emitter & base are "short".

∴ both E-B & B-C fwd biased:



(b)



(c) Emitter injection efficiency: $\gamma_E = \dfrac{1}{1 + \dfrac{D_{pE}}{D_{nB}} \dfrac{W_B N_{AB}}{W_E N_{DE}} \cdot \dfrac{n_{iE}^2}{n_{iB}^2}}$ ($\frac{n_{iE}^2}{n_{iB}^2} \approx 1$)

$$= \frac{1}{1 + \frac{450}{1500} \cdot \frac{(500\,nm)(10^{17}/cm^3)}{(2000\,nm)(10^{18}/cm^3)}}$$

$$\gamma_E = \frac{1}{1 + 0.0075} = \boxed{0.9925 = \gamma_E}$$

$$\alpha_T = 1 - \frac{W_B^2}{2 D_n \tau_n} = 1 - \frac{1}{2}\left(\frac{W_B}{L_n}\right)^2 = 1 - \frac{1}{2}\left(\frac{0.5\,\mu m}{44\,\mu m}\right)^2$$

$$\boxed{\alpha_T \simeq 0.99994}$$

∴ $\alpha_F = \gamma_E \alpha_T = 0.9925$ => $\beta_F = \dfrac{\alpha_F}{1-\alpha_F} = 135.3$

=> $\boxed{\beta_F \simeq 135}$ (Not too high!)

Contd... →

(d)

$N_{AB} \gg N_{DC} \Rightarrow$

Required width is given by

$$\frac{q N_{DC} W_C^2}{2 \epsilon_s} \simeq V_{bi} = \frac{kT}{q} \ln\left(\frac{N_{DC} N_{AB}}{n_i^2}\right) \simeq 0.72 \text{ Volts.}$$

$$\therefore \quad W_C \simeq \sqrt{\frac{2 \epsilon_s}{q N_{DC}} V_{bi}} = \boxed{965.3 \text{ nm} = W_C}$$

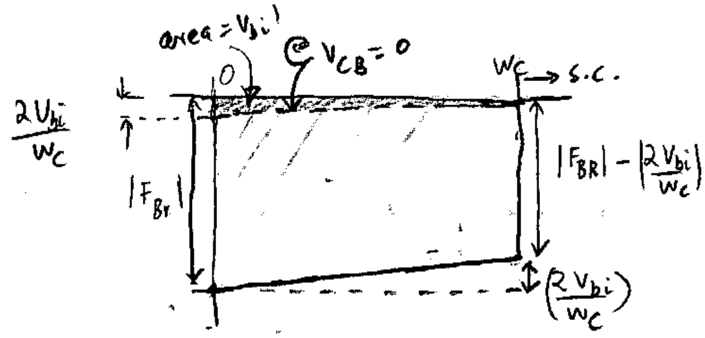
(e)

$$V_A = \frac{Q_B}{C_{jC}} \approx \frac{q N_{AB} W_B}{\epsilon / W_C} = \frac{q N_{AB} W_B W_C}{\epsilon}$$

$$\boxed{V_A \simeq 75 \text{ Volts}}$$

(f)

@ breakdown, the field in the B-C looks like -



$$V_{bi} + V_{CB} = \frac{1}{2}\left(|F_{BR}| + |F_{BR}| - \left|\frac{2V_{bi}}{W_C}\right|\right) * W_C$$

$$V_{CB} = |F_{BR}| \cdot W_C - 2V_{bi}$$

$$= \left(3 \cdot 10^5 \frac{V}{cm}\right) \cdot (965.3 * 10^{-7} cm) - 2(0.72)$$

$$\boxed{V_{CB} = 27.5 \text{ Volts}}$$

(g)

Clearly, if $W_C \uparrow$, the breakdown voltage will improve.

Price paid: (a) Severe Kirk effect $\Rightarrow \beta_F \downarrow$ @ high currents.

(b) Collector transit time $\tau_c = \frac{W_C}{2 v_{sat}} \uparrow$, Slower device ($f_T \downarrow$)