12.4 An npn silicon bipolar transistor has the following base parameters: $D_n = 22$ cm^2/s, $x_B = 0.80$ μm, and $n_{B0} = 2 \times 10^4$ cm^{-3}. (*a*) The collector current is to be $|i_C| = 2$ mA when biased at $v_{BE} = 0.60$ V. What is the required cross-sectional area A_{BE}? (*b*) Using the results of part (*a*), what is the value of v_{BE} such that $|i_C| = 5$ mA?

a) Per (12.37), $J_{nc} = \frac{e D_B n_{B0}}{L_B}\left\{\frac{e^{V_{BE}/V_t} - 1}{\sinh(x_B/L_B)} + \frac{1}{\tanh(x_B/L_B)}\right\}$

@ 300K, $V_t = 0.025852$ V. $\Rightarrow e^{V_{BE}/V_t} >> 1$

Assuming $x_B << L_B$, $\sinh(x_B/L_B) \simeq \frac{x_B}{L_B}$

and $\tanh(x_B/L_B) \simeq x_B/L_B$.

Therefore, $J_{nc} \simeq \frac{e D_B n_{B0}}{x_B} e^{V_{BE}/V_t}$

and $I_c = J_{nc} A_{BE} \simeq \frac{e D_B n_{B0}}{x_B} e^{V_{BE}/V_t} A_{BE}$

$$0.002 = \frac{1.6021766634\times10^{-19}(22)10^{-4}(2\times10^{10})}{0.8\times10^{-6}} e^{0.6/0.025852} A_{BE}$$

$$\hookrightarrow \underline{A_{BE} = 1.8897\times10^{-8}\ m^2 = 1.8897\times10^{-4}\ cm^2}$$

b) $0.005 = 1.665228\times10^{-13} e^{V_{BE}/0.025852}$

$$\hookrightarrow V_{BE} = 0.025852 \ln\left(\frac{0.005}{1.665228\times10^{-13}}\right)$$

$$\underline{V_{BE} = 0.6237\ V}$$