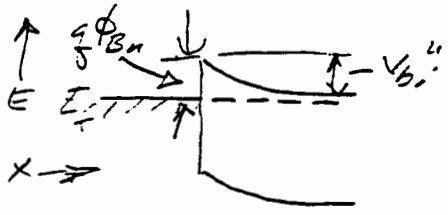
ECE 352 Homework Solution #8

Chapter 6 Solutions

Devices for Integrated Circuits
Silicon and III-V Compound Semiconductors

6.1(a)



(b) $E_c - E_f = -kT\ln(4\times10^{16}/2.34\times10^{18})$

$E_c - E_f = +0.171\ eV$

$q\phi_{Si} = q\chi_{Si} + (E_c - E_f)$

$= 4.05 + 0.171 = 4.221$

$V_{bi} = 4.75 - 4.221 = 0.529\ V$

$x_d = \sqrt{\dfrac{2\times11.7\times8.85\times10^{-14}\times0.529}{1.6\times10^{-19}\times4\times10^{16}}}$

$\boxed{x_d = 1.30\times10^{-5}\ cm}$

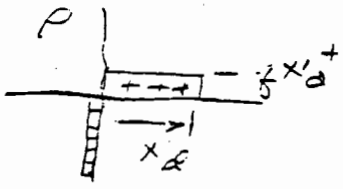
(c) $q\phi_{Bn} = q\phi_{Bn} - q\chi_{Si}$

$= 4.25 - 4.05$

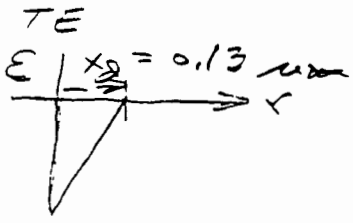
$q\phi_{Bn} = \underline{0.200\ eV}$

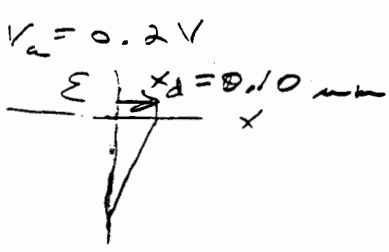
(d) $x_d = \sqrt{\dfrac{2\times11.7\times8.85\times10^{-14}(0.529-0.2)}{1.6\times10^{-19}\times4\times10^{16}}}$

$\boxed{x_d = 1.03\times10^{-5}\ cm}$

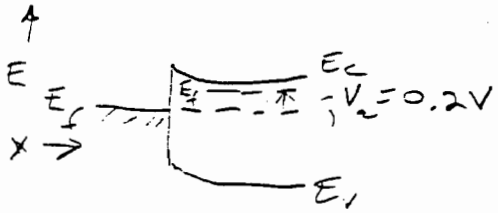


(e)

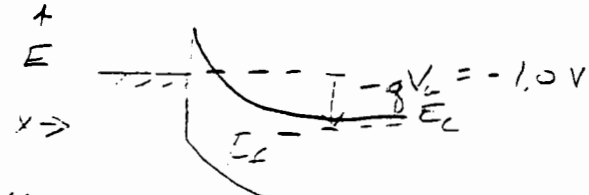




(f)



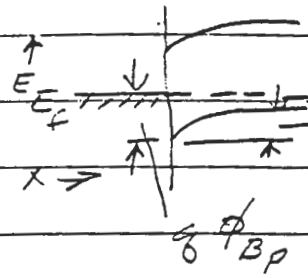
(g)



(h) $C = \varepsilon_{Si}xA/x_d = 11.7\times8.85\times10^{-14}\times5\times10^{-4}/1.30\times10^{-5}$

$C = 4.0\times10^{-11}\ F = \underline{40\ pF}$ at $V_a = 0$

6.2(a)



(b) $E_f - E_v = -kT \ln(6\times10^{15}/3.08\times10^{18})$

$E_f - E_v = 0.222$ eV

$q\Phi_{Si} = q\chi_{Si} + E_g - (E_c - E_v)$

$q\Phi_{Si} = 4.05 + 1.125 - 0.222$

$q\Phi_{Si} = 4.953$

$V_{bi} = 4.75 - 4.953 = -0.203$ V

$x_d = \sqrt{\dfrac{2\times11.7\times8.85\times10^{-14}\times0.203}{1.6\times10^{-19}\times6\times10^{15}}}$

$x_d = 0.209\times10^{-4}$ cm

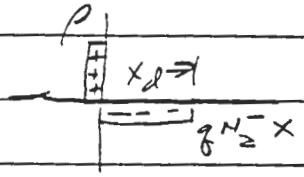
(c) $q\phi_{Bp} = q\chi + E_g - q\Phi_{Au}$

$q\phi_{Bp} = 4.05 + 1.125 - 4.75$

$q\phi_{Bp} = 0.425$ eV

(d) $x_d = \sqrt{\dfrac{2\times11.7\times8.85\times10^{-14}(0.203-0.1)}{1.6\times10^{-19}\times6\times10^{15}}}$

$x_d = 0.149\times10^{-4}$ cm



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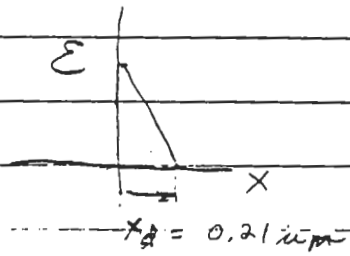

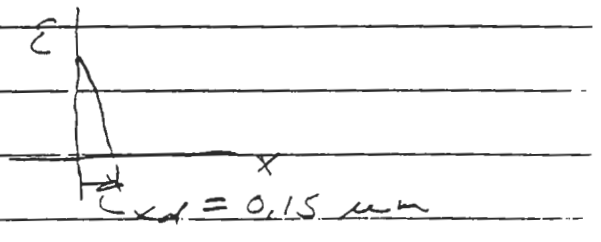

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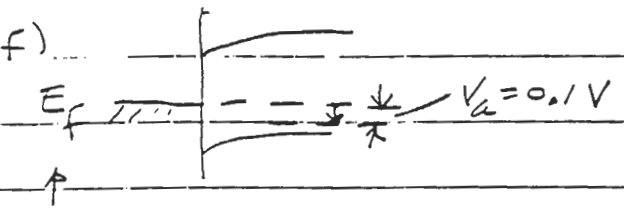
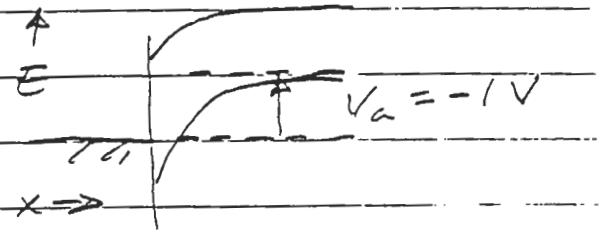


(g)



(h) $C = \dfrac{\epsilon_{Si}A}{x_d} = \dfrac{11.7\times8.85\times10^{-14}\times5\times10^{-4}}{0.209\times10^{-4}}$

$C = 2.477\times10^{-11}$ or 24.8 pF

6.4(a) $q V_{bi}'' = q(\Phi_{Acc} - \Phi_{Si})$ $\quad q\Phi_{Si} = q\chi_{Si} + (E_c - E_f)$

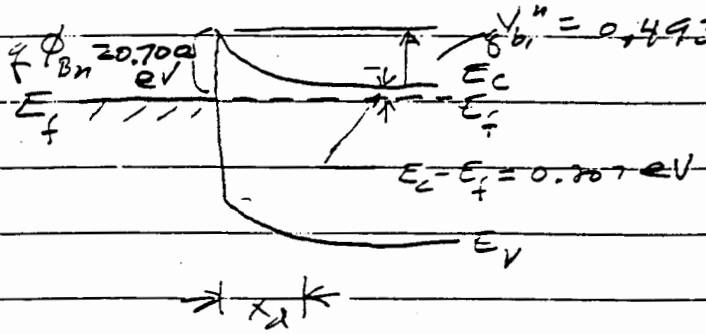
$= 4.05 - kT\ln(N_d^+/N_c)$

$q V_{bi}'' = 4.75 - 4.257$ $\quad = 4.05 - 0.026\ln(1\times10^{16}/2.84\times10^{19})$

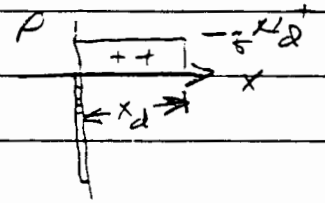
$q V_{bi}'' = 0.493\ eV$ $\quad = 4.05 + 0.207 = 4.257\ eV$

(b) $x_d = \sqrt{\dfrac{2\epsilon V_{bi}''}{q N_d^+}} = \sqrt{\dfrac{2\times11.7\times8.85\times10^{-14}\times0.493}{1.6\times10^{-19}\times1\times10^{16}}} = 0.253\ \mu m$

(c)



(d)



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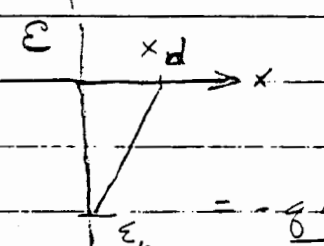
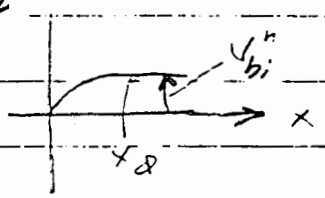


$= -\dfrac{q N_d^+}{\epsilon_{Si}} x_d = \dfrac{1.6\times10^{-19}\times1\times10^{16}\times0.253\times10^{-4}}{11.7\times8.85\times10^{-14}}$

$= 3.9\times10^4\ V/cm$

(f)



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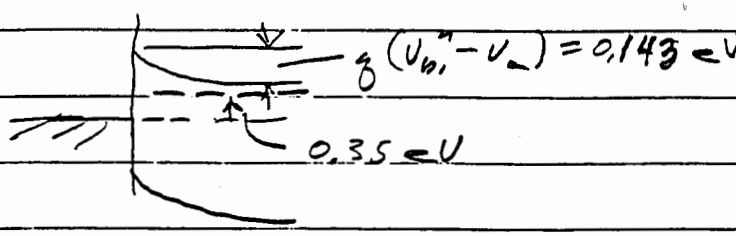
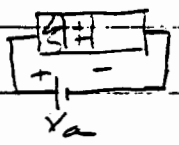
6.4(g) $C = A\left[\frac{\varepsilon_s N_d^+}{2V_{bi}^n}\right]^{1/2} = 2\times10^{-4}\left[\frac{1.6\times10^{-19}\times11.7\times8.85\times10^{-14}\times1\times10^{16}}{2\times0.493}\right]$

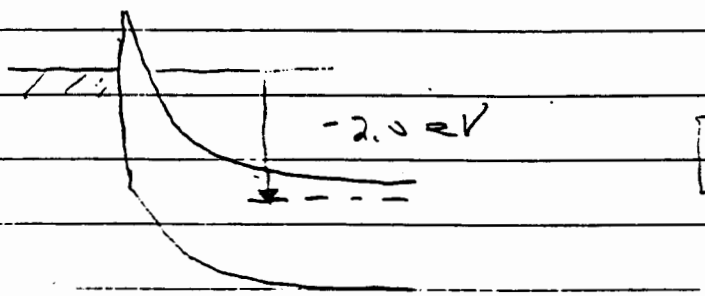
$C = 8.2\times10^{-12}\ F$

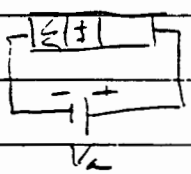
(h)



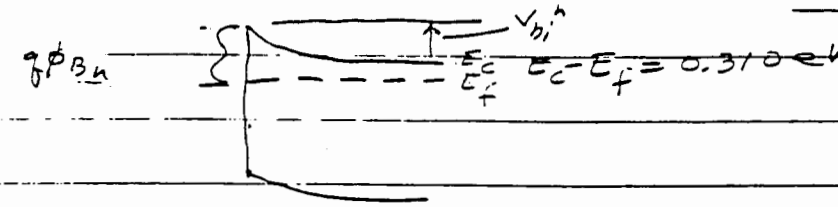


(i)





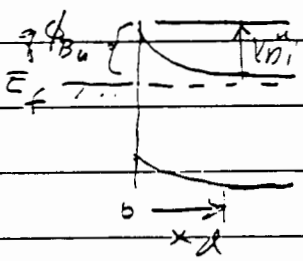
6.7.(a)



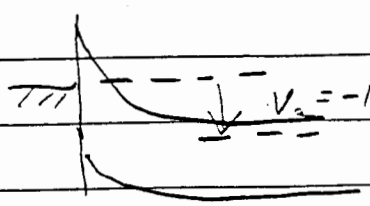
$q\phi_{B_n} = q\Phi_m - q\chi = 4.6 - 4.05 = 0.55\ eV$

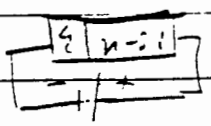
$V_{bi}^n = q\phi_{B_n} - (E_c - E_f) = 0.55 - 0.310 = 0.240\ V$

(b)

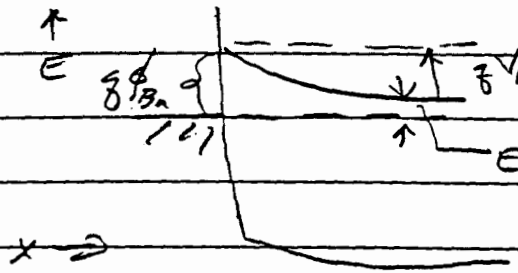


(c)





6.9(a) $E_c - E_f = -\frac{kT}{q} \ln \frac{5\times10^{16}}{2.84\times10^{19}} = 0.165 \text{ eV}$



(b) $q\phi_{B_n} = V_{bi} + (E_c - E_f) = 0.310 + 0.165 = 0.475$ eV

(c) $n = N_c \exp[-(E_c - E_f)/kT]$

$q\phi_{B_n}$

$n = 2.84\times10^{19} \exp[-0.495/(0.026)]$

$n = 3.30\times10^{11} \text{ cm}^{-3}$

6.10(a) $x_d = \sqrt{\frac{2\varepsilon V_{bi}}{q N_d^+}}$ $\quad V_{bi} = \frac{\Phi}{q_{Mn}} - [\chi_{Si} + (E_c - E_f)/q]$

$V_{bi} = 4.75 - [4.05 + 0.026 \ln \frac{2.84\times10^{19}}{5\times10^{15}}]$

$x_d = \sqrt{\frac{2\times11.7\times8.85\times10^{-14}\times0.475}{1.6\times10^{-19}\times5\times10^{15}}}$ $\quad V_{bi} = 0.475$ V

$x_d = 0.351 \ \mu\text{m}$

(b) $x_d = \sqrt{\frac{2\times11.7\times8.85\times10^{-14}(0.475+3.0)}{1.6\times10^{-19}\times5\times10^{15}}} = 0.948 \ \mu\text{m}$