EECE 480 FINAL 2008

1(b) – A V_T of around 0.25V is needed to maintain an acceptable I_{OFF}/I_{ON} ratio for digital logic.

2 – In CMOS65, $V_T < V_{TO}$ because of short-channel effects, so V_{TO} must be made > 0.25V.

5 (a) L, t_{ox} ↓ to increase I_{ON}, & L to reduce size
x_j ↓ to reduce SCE
N_A ↑ counter the effect of C_{ox} on V_{TO} – i.e. keep it $\simeq$ 0.25V.

(c)

$$V_{TO} = V_{fb} + 2\phi_B + \gamma\sqrt{2\phi_B}$$

$$V_{fb} = \Phi_G - \Phi_S$$

1

$$2\phi_B = 2V_{th} \ln \frac{N_A}{n_i} = 2V_{th} \ln 10^8 = 0.954\text{ V}$$

$$\gamma = \frac{1}{C_{ox}}\sqrt{2q\varepsilon_s N_A} = \frac{8\times10^{-7}}{\underbrace{16\times8.85\times10^{-14}}_{\cancel{1.77\times10^{-6}\,F/cm^2}}}\sqrt{2\times1.6\times10^{-19}\times11.9\times8.85\times10^{-14}\times10^{18}}$$

1

$$= 0.328\,V^{1/2}$$

$$\gamma\sqrt{2\phi_B} = 0.320\text{ V}$$

$$\therefore V_{fb} = 0.45 - 0.954 - 0.320 = -0.824\text{ V} = \Phi_G - \Phi_S$$

1

$$\therefore \Phi_G = -0.824 + 5.144 = \underline{\underline{4.32\text{ eV}}}$$

2

$$\Phi_S = \chi + (E_C - E_F) \qquad E_C - E_F = kT \ln \frac{N_C N_A}{n_i^2} = 1.044\text{ eV}$$

$$\Phi_S = 4.1 + 1.044 = 5.144\text{ eV}$$

2 a) $n(y) = n_i e^{\frac{E_{FB} - E_{Fi}(y)}{kT}}$ is correct

$n(B) = n_i e^{\frac{E_{FB} - E_{Fi}(B)}{kT}} = n_i^2 / N_A$

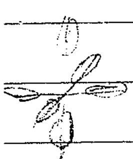
$q\phi_B = E_{Fi}(B) - E_{FB}$

$\therefore n(y) = n_i \exp \frac{1}{kT} \left[E_{FB} - E_{Fi}(B) + E_{Fi}(B) - E_{Fi}(y) \right]$

4 $= n_i \exp \frac{1}{kT} \left[-q\phi_B + q\psi \right]$

b) $\frac{1}{m_{e\,con}^*} = \frac{1}{6} \left[\frac{2}{m_l^*} + \frac{4}{m_t^*} \right]$ unstrained based on equal prob. of occupancy of each valley.

On straining



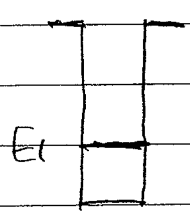
$$\frac{1}{m_{e\,con}^*} = \left[\frac{0.1}{m_l^*} + \underset{\Delta_4}{\frac{0.1}{m_t^*}} + \underset{\Delta_2}{\frac{0.8}{m_t^*}} \right]$$

$\rightarrow m_e^*$ (unstrained) $= 0.26$

m_e^* strained $= 0.206$

4 $\mu \propto 1/m$ $\therefore$ % change $= \dfrac{\frac{1}{0.206} - \frac{1}{0.26}}{1/0.26} \rightarrow$ 26%

c)



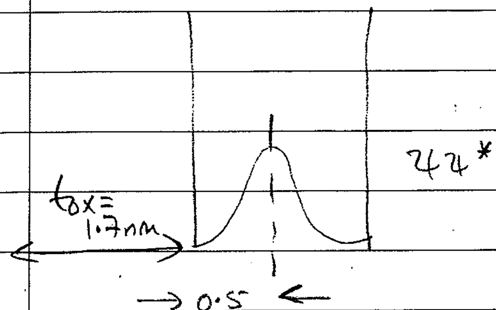
$$E_1 = \frac{\hbar^2 \pi^2}{2m^* a^2}$$

Take $m^* = 1\,m_0$

2c) continued.

$$a = \sqrt{\frac{(6.63\times10^{-34})^2 \pi^2}{4\pi^2 \quad 2\times1\times9.11\times10^{-31}\times0.377\times1.6\times10^{-19}}}$$

$$= \underline{1\ nm}$$



$\varepsilon_r = 3.9$	$\varepsilon_r = 11.9$
$t = 1.7nm$	$t = 0.5nm$

$$C_{ox} = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1} = \left(\frac{1.7\times10^{-9}}{3.9\,\varepsilon_0} + \frac{0.5\times10^{-9}}{11.9\,\varepsilon_0}\right)^{-1} = \varepsilon_0\times10^{9}\left(\frac{1.7}{3.9} + \frac{0.5}{11.9}\right)^{-1}$$

$$= \varepsilon_0\times10^{9}\times2.09 = \underline{\underline{1.85\times10^{-2}}}\ F/m^2$$

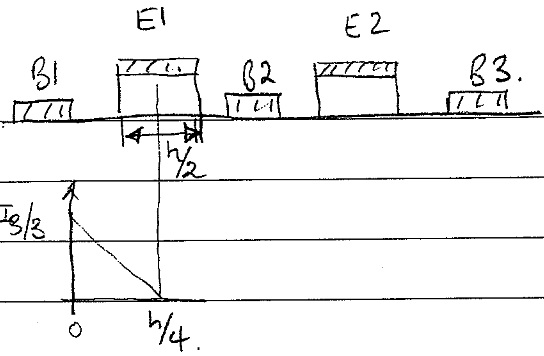
Without taking QM effects into account,

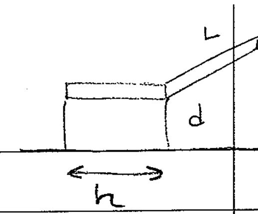
$$C_{ox} = \frac{\varepsilon_0\,3.9}{1.7\times10^{-9}} = 2.03\times10^{-2}\ F/m^2$$

4

$$\therefore \%\ \text{change} = \frac{1.85-2.03}{2.03}\times100 = \underline{-8.8\%}$$

3 a)





Originally $P_B^0 = \frac{1}{3} I_B^2 \rho \frac{h}{A}$ $\qquad N_{(\omega)} = 3 \times \frac{1}{3} \left(\frac{I_B}{3}\right)^2 \rho \frac{h}{4A}$

$$= 3 \times \frac{1}{3} \frac{I_B^2}{9} \rho \frac{h}{A} \cdot \frac{1}{4}$$

5 $$= P_B^0 \frac{1}{12}$$

b) $g_m = \frac{\partial I_c}{\partial V_{BE}} = \frac{I_c}{V_{th}} = \frac{6.5 \times 10^4 \times (.1) \times (.1)}{0.0259} = \underline{\underline{251}}\ S$

4 $g_\pi = \frac{\partial I_B}{\partial V_{BE}} \approx \frac{I_{B,rec}}{V_{th}} = \frac{0.32 \times 10^{-2}}{0.0259} = \underline{\underline{0.124}}\ S$

c) From (11.11) $\left|i_c\right|^2_{\omega \to 0} = g_m^2 v_{b'e}^2$

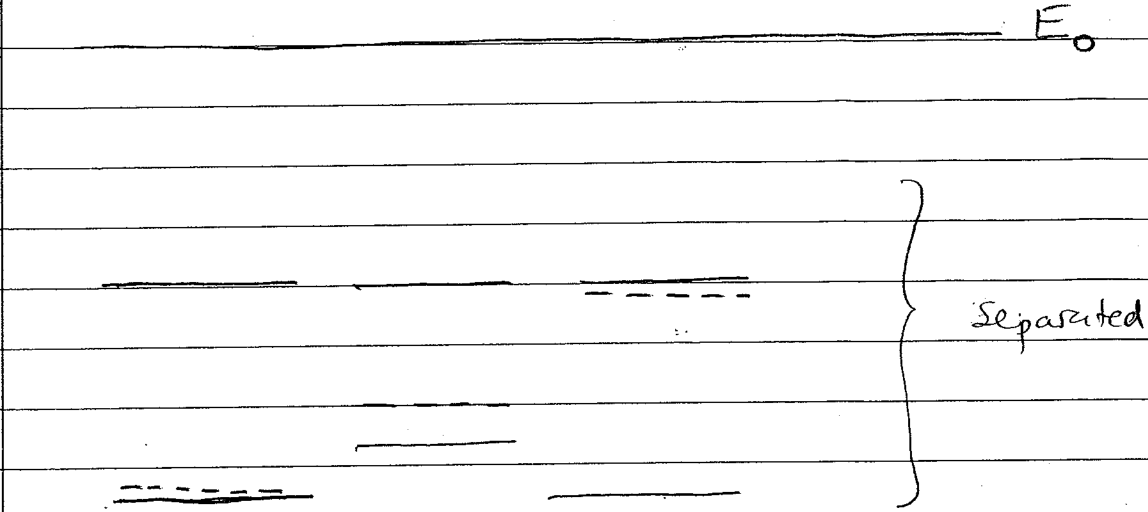
From (11.13) $\left|i_b\right|^2_{\omega \to 0} = g_\pi^2 v_{b'e}^2$

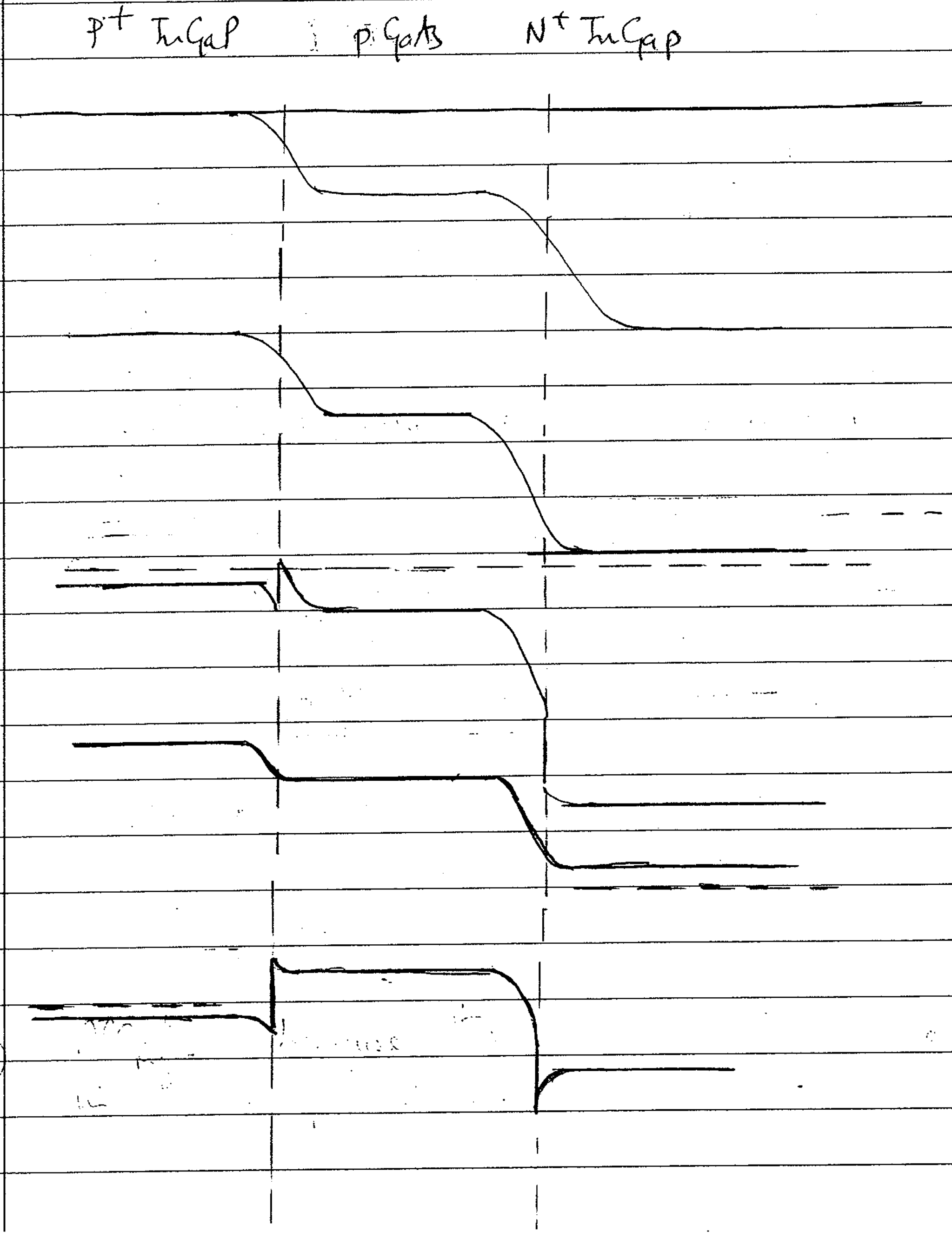
3 $\therefore \left|\frac{i_c}{i_b}\right|^2_{\omega \to 0} = \left(\frac{g_m}{g_\pi}\right)^2$

$\chi_{InGaP} = \chi_{GaAs} = 4.07eV$

E_g " $= 1.82eV$, $E_{g\,GaAs} = 1.42eV$

4a)





b)

4 b) Good "well" for holes, but not for electrons.

3 ∴ AlGaAs LED will give higher η_c.

4c) (i) $WPE = \frac{S_{out}}{P_{in}} = \frac{1 \times 10^{-3}}{1 \times 10^{-3} \times 2} \times 100 = 50\%$

For both LEDs

(ii) Luminous efficacy $= \frac{\Phi}{S'_{out}} = \frac{683\, \gamma\, S'_{out}}{S'_{out}}$ for monochromatic

4

$= 683 \times 10^{-1} = \underline{68.3 \text{ lm/W}}$ for B

$= \underline{0}$ for A

(iii) Luminous efficiency $= \frac{\Phi}{P_{in}} = \frac{68.3 \times 1 \times 10^{-3}}{1 \times 10^{-3} \times 2}$

$= \underline{34.15 \text{ lm/W}}$ for B

$= \underline{0}$ for A

5(a) We need $V_T = 1.5V$

$\therefore \Delta V_T = +0.5V$

$$\Delta V_T = -\Delta Q_F \frac{t_{ox}}{\varepsilon_{ox}} = qN \frac{t_{ox}}{\varepsilon_{ox}}.$$

$$\therefore N = \frac{\Delta V_T}{q} \frac{\varepsilon_0}{t_{ox}} = \frac{0.5}{1.6\times10^{-19}} \times \frac{3.9\times 8.85\times10^{-12}}{20\times10^{-9}} /m^2$$

$$= 5.39\times10^{15} /m^2$$

4/3 $= 5.39\times10^{15}\times10^{-14} = \underline{\underline{53.9 \text{ electrons}}}$

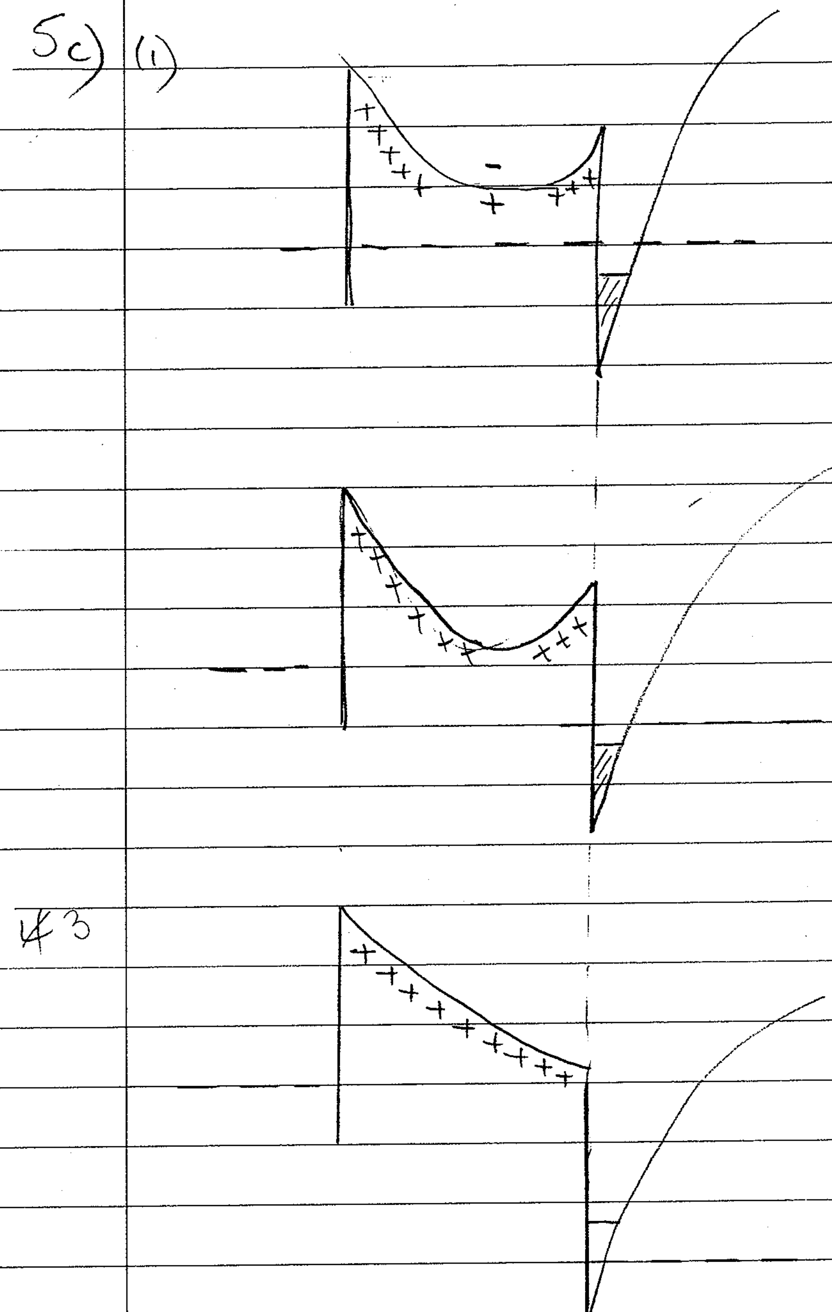
5 b) From Assignment 5 I_{off} (CMOS65) $= 9\times10^{-12}$ A/µm

$\therefore I_{off} = 9\times10^{-12}\times 0.1 = \underline{9\times10^{-13} \text{ A}}$

$C = \frac{Q}{V}$ $Q = 1\times10^{-12}\times1 = 10^{-12}$ C

3 $\therefore t_{50\%} = \frac{0.5\times10^{-12}}{9\times10^{-13}} = \underline{\underline{\frac{5}{9} \text{ sec}}}$

5c) (1)



2 d) A more −ve V_{GS} is required to reach threshold in this case.

∴ HJFET A has the more +ve threshold voltage.