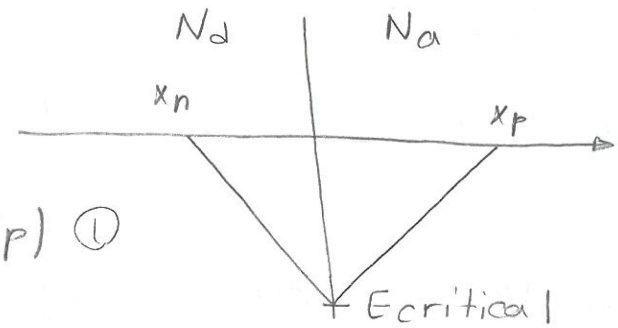
Home Work #6

1 a) $N_d = 10^{19}\ cm^{-3}$ $W_n = 200\mu m$

$N_a = 10^{17} cm^{-3}$ $W_p = 0.2\mu m$

I Zener → does not occur because both doping concentrations should be at least $10^{18} cm^{-3}$

II Avalanche → from Fig. 3.12 (P. 13) we know that $\mathcal{E}_{cr} = 6\times10^5 Vcm^{-1}$



We know that →

$\varphi_i - V_A = \frac{1}{2} E_{critical} (x_n + x_p)$ ①

$x_n = -\dfrac{\mathcal{E}_{critical} \times K\epsilon_0}{q N_d} = -3.88\times10^{-7} cm$

$x_p = \dfrac{\mathcal{E}_{critical} \times K\epsilon_0}{q N_a} = 3.88\times10^{-5} cm$

② $\varphi_i = \frac{KT}{q}\ln\left(\frac{N_d N_a}{n_i^2}\right) = 0.943V$

①,② ⟹ $\varphi_i - V_A = \frac{1}{2}\times 6\times10^5 V cm^{-1} \times 3.88\times10^{-5} cm = 11.64 V$

$\Rightarrow V_A = -10.69 V$

III Punch-through

This happens when $x_p = W_p = 0.2\mu m = 2\times10^{-5} cm$

$$xp = \left(\frac{2K\epsilon_0}{q} (\varphi_i - Va) \frac{Nd}{Na(Nd+Na)} \right)^{\frac{1}{2}}$$

$\Longrightarrow \varphi_i - Va = 3.09 \Longrightarrow Va = -\underline{2.15V} \Longrightarrow$

Punch-through happens

I) 1b) Zener breakdown $\longrightarrow$ For $Na = 10^{18}$ $E_{critical} = 10^6 \vec{Vcm}$

II) Avalanche $\longrightarrow$

$$x_n = \frac{E_{critial} \times K\epsilon_0}{q N_d} = 6.47nm \qquad xp = \frac{E_{critical} \times K\epsilon_0}{q Na} = 64.7nm$$

$\varphi_i - V_A = \frac{1}{2} E_{critical} (X_n + X_p) \doteq 3.56V \Longrightarrow \underline{\underline{V_A = -2.58V}}$ 1

Both Can Occur

III) Punch-through $\longrightarrow$ This happens when $xp = Wp = 0.2\mu m$

$\Longrightarrow \varphi_i - V_A = 33.99 \Longrightarrow \underline{\underline{V_A = -33.02V}}$ 2

1, 2 $\longrightarrow$ Both Zener and avalanche occur.

1) c) $N_d = N_a = 10^{19} \Longrightarrow E_{critical} = 3\times10^{6}\ V\,cm^{-1}$

Punch-through $\longrightarrow$

$$x_p = W_p = 2\times10^{-5}\ cm = \left(\frac{2K\epsilon_0}{q}(\varphi_i - V_A)\frac{10^{19}}{10^{19}\times2\times10^{19}}\right)^{\frac{1}{2}}$$

$$\varphi_i = \frac{KT}{q}\ln\left(\frac{(10^{19})^2}{10^{20}}\right) = 1.06\,V$$

$$\Longrightarrow V_A = -617.03\ V$$

Zener $\longrightarrow$ $E_{critical} = 3\times10^{6}\ V\,cm^{-1}$

$$X_n = X_p = \frac{\mathcal{E}_{critical}\times K\epsilon_0}{q N_a} = \frac{3\times10^{6}\times11.7\times8.85\times10^{-14}}{1.6\times10^{-19}\times10^{19}}\ cm$$

$$= 1.94\times10^{-6}\ cm$$

$$\varphi_i - V_A = \frac{1}{2}E_{critical}(X_n + X_p) = 5.82 \Longrightarrow V_A = -4.76\ V$$

$\Longrightarrow$ Zener Occurs (Avalanche Can not occur because the dopings are both greater than $10^{18}\ cm^{-3}$ so ionized impurity scattering becomes dominant which makes carriers unable to gain as much energy before being scattered)

2a) $N_d >> N_a$, $N_a = 5\times10^{16}\,cm^{-3}$ $\tau_n = \tau_p = 1\mu s$ $T = 300k$

One-Sided junction $\Longrightarrow$ diode current is mainly electrons injected into the p-Side.

$$J = 50\,A\,cm^{-2} \cong \underbrace{J_{np}}_{\bar{e}\ \text{current},\ \text{p-side}} = \frac{Q_n}{\tau_n} \Longrightarrow Q_n = (50\,A\,cm^{-2})(10^{-6}s)$$

$$= \underline{\underline{5\times10^{-5}\,\frac{C}{cm^2}}}$$

2b) $Q_d = \sqrt{2K\epsilon_0 q N_a(\varphi_i - V_a)}$ $\longrightarrow$ need both of φ_i and V_a

For V_a, we can find it with the current density:

$$J_{np} = q\frac{n_i^2}{N_a}\left(\frac{D_n}{L_n}\right)\exp\left(\frac{qV_a}{KT}\right) \Longrightarrow$$

$$V_a = \frac{KT}{q}\ln\left(\frac{J_{np} N_a L_n}{n_i^2 q D_n}\right)$$

@ $N_a = 5\times10^{16}\,cm^{-3} \Longrightarrow \mu_n = 975\,cm^2V^{-1}s^{-1}$

$D_n = \frac{KT}{q}\mu_n = 24.96\,cm^2s^{-1} \Longrightarrow L_n = \sqrt{D_n\tau_n} \cong 5\times10^{-3}\,cm$

$$\Longrightarrow V_a = 0.0256\ln\left(\frac{50\,Acm^{-2}\times5\times10^{16}\,cm^{-3}\times5\times10^{-3}\,cm}{10^{20}\,cm^{-6}\times1.6\times10^{-19}\,C\times24.96\,cm^2s^{-1}}\right)$$

$= 0.795\,v$ / and $\varphi_i = \frac{KT}{q}\ln\left(\frac{N_d N_a}{n_i^2}\right)$ $\longrightarrow$

Need N_d! Since $N_d >> N_a$ assume that $E_F = E_C$ and full ionization $\Rightarrow$ $n = N_d = N_C \exp\left(\frac{0}{KT}\right) = N_C = 2.8 \times 10^{19} cm^{-3}$

$$\Rightarrow \varphi_i = 0.0256 \ln\left(\frac{5\times10^{16} \times 2.8\times10^{19}}{10^{20}}\right) v = 0.952 v$$

$$\Rightarrow Q_d = [2(11.7)(8.85\times10^{-14} Fcm)(1.6\times10^{-19} C)(5\times10^{16} cm^{-3})(0.952-0.795)v]$$

$$= \underline{5.1 \times 10^{-8} \; C cm^{-2}}$$

Charge Stored @equilibrium ($V_a = 0$) $\Rightarrow$

$$\underline{\underline{Q_d = 1.26\times10^{-7} \; C cm^{-2}}}$$

2c) There are two parts to the switching. We have to address the change in the depletion charge and the stored charge in the nuetral region.

as Vdiode rises, first only the depletion charge is changing significanty.

$$\Delta Q_d = Q_d@0 - Q_d@50A = 7.5\times10^{-8} \; C cm^{-2}$$

$$t_1 = \frac{\Delta Q_d}{50 Acm^{-2}} = \frac{7.5\times10^{-8}}{50} S = \underline{\underline{1.5 \; ns}}$$

2C) after that, Q_n and $\frac{Q_n}{\tau_n}$ (recombination) become significant.

using the continuity equation:

$$I_f = \frac{Q_n}{\tau_n} + \frac{dQ_n}{dt}$$ ← not zero, not in equilibrium.

$$Q_n = I_f \tau_n \left[1 - \exp\left(-\frac{t}{\tau_n}\right)\right] = 50 \times 10^{-6} \left[1 - \exp\left(-\frac{t}{\tau_n}\right)\right] \frac{C}{cm^2}$$

(i) Turn-on defined as Q_n reaches 63% of its final value.

$$\rightarrow \left[1 - \exp\left(-\frac{t_2}{\tau_n}\right)\right] = 63\% \Rightarrow t_2 = 1.02 \times 10^{-6} S = \underline{1.02\mu}$$

Turn on time $= t_1 + t_2 \simeq 1.02\mu s$ (Filling Q_d is really fast)

(ii) Turn-on defined as $V_d = 0.795 - 0.1 = 0.695\,V$

$$Q_n = 50 \times 10^{-6}\, C\, cm^{-2} \exp\left(-\frac{0.1V}{25mV}\right) = 916 \times 10^{-9}\, C\, cm^{-2}$$

$$\rightarrow 50 \times 10^{-6} \left[1 - \exp\left(\frac{t_2}{\tau_n}\right)\right] = 916 \times 10^{-9}\, C\, cm^{-2}$$

$$\Rightarrow t_2 = 1.85 \times 10^{-8} S = \underline{18.5 ns}$$

and since V_d has changed, Q_d has changed too

@ $0.695\,V$, $Q_d = 6.53 \times 10^{-8}\, C\, cm^{-2} \Rightarrow \Delta Q_d = 6.07 \times 10^{-8}\, C\, cm^{-2}$

$$t_1 = \frac{\Delta Q_d}{50\, A cm^{-2}} = \underline{1.21 ns} \Rightarrow t_{turn-on} = \underline{19.4 ns}$$

2d) With a $-50\ Acm^{-2}$ reverse current, we can again use the continuity equation to figure out the response.

$$I_R = \frac{Q_n}{\tau_n} + \frac{dQ_n}{dt} = -50\ Acm^{-2}$$

$$Q_n(t=0) = I_f \tau_n = 50\times10^{-6}\ A\,cm^{-2}\,s$$

$$Q_n = A + B\exp\left(\frac{-t}{\tau_n}\right)$$

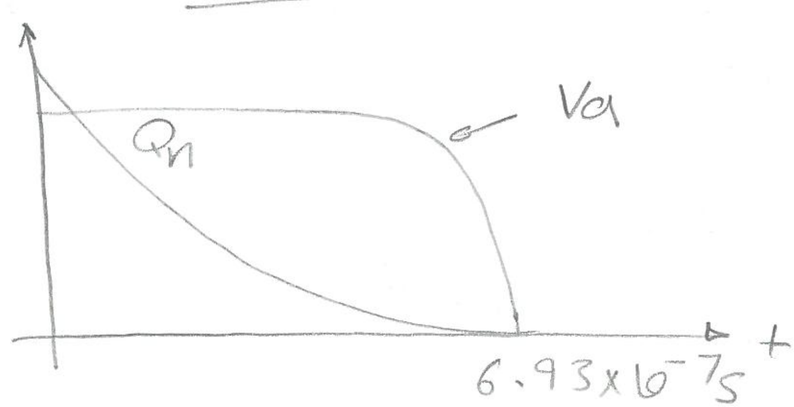
$$A + B = 50\times10^{-6}\ C\,cm^{-2}$$

$$A = I_R \tau_n = -50\times10^{-6}\ C\,cm^{-2} \Rightarrow B = 100\times10^{-6}\ C\,cm^{-2}$$

$$Q_n = 50\times10^{-6}\ C\,cm^{-2}\left(2\exp\left(\frac{-t}{\tau_n}\right) - 1\right)$$

Storage time $(t_s) \Rightarrow 2\exp\left(-\frac{t}{\tau_n}\right) - 1 = 0$

$\Rightarrow t_s = \underline{6.93\times10^{-7}\ s}$



2 e) For short-base:

$$J_{np} = q \frac{n_i^2}{N_a} \left(\frac{D_n}{W_p'} \right) \left[\exp\left(\frac{qV_a}{kT} \right) - 1 \right] \quad W_p' = |W_p - x_p|$$

$$Q_n = \frac{1}{2} W_p' q \frac{n_i^2}{N_a} \left[\exp\left(\frac{qV_a}{kT} \right) - 1 \right] = J_{np} \left(\frac{W_p'^2}{2D_n} \right)$$

$$= 50\,Acm^{-2} \left(\frac{(0.5 \times 10^{-4}\,cm)^2}{2 \times 24.96\,cm^2 s^{-1}} \right) = 2.5 \times 10^{-9}\,C\,cm^{-2}$$

$$\Rightarrow t_2 = 5.01 \times 10^{-11}\,s$$

$$V_a = \frac{kT}{q} \ln\left[\frac{2 Q_n N_a}{q n_i^2 W_p'} + 1 \right] = \underline{\underline{0.678V}}$$

$$Q_d\ @\ 0.678V = 6.74 \times 10^{-8}\,C\,cm^{-2}$$

$$\Rightarrow t_1 = \frac{6.74 \times 10^{-8}\,C\,cm^{-2}}{50\,Acm^{-2}} = 1.35\,ns$$

$\Rightarrow$ Total Switching time $\cong$ 1.35 ns

A lot less stored charge in a short-base Junction.

3. GaAs $N_a = 10^{18}$ $N_d = 10^{17}$ $W_p = 0.4 \mu m$ $W_n = 100 \mu m$

$\tau_n = \tau_p = 0.01 \mu s$ $A = 0.25 cm^2$

$N_a = 10^{18} cm^{-3} \Rightarrow \mu_n = 275 cm^2 V^{-1} s^{-1} \Rightarrow D_n = 0.0256 V \times 275 cm^2 V^{-1} s^{-1}$

$= 7.04 cm^2 s^{-1}$

$\Rightarrow L_n = \sqrt{D_n \tau_n} = 2.65 \times 10^{-4} cm = 2.65 \mu m > W_p$ (Short diode at p side)

$N_d = 10^{17} cm^{-3} \Rightarrow \mu_p = 250 cm^2 V^{-1} s^{-1} \Rightarrow D_p = 6.4 cm^2 s^{-1} \Rightarrow L_p = 2.53 \mu m$ (long diode at n side)

a)

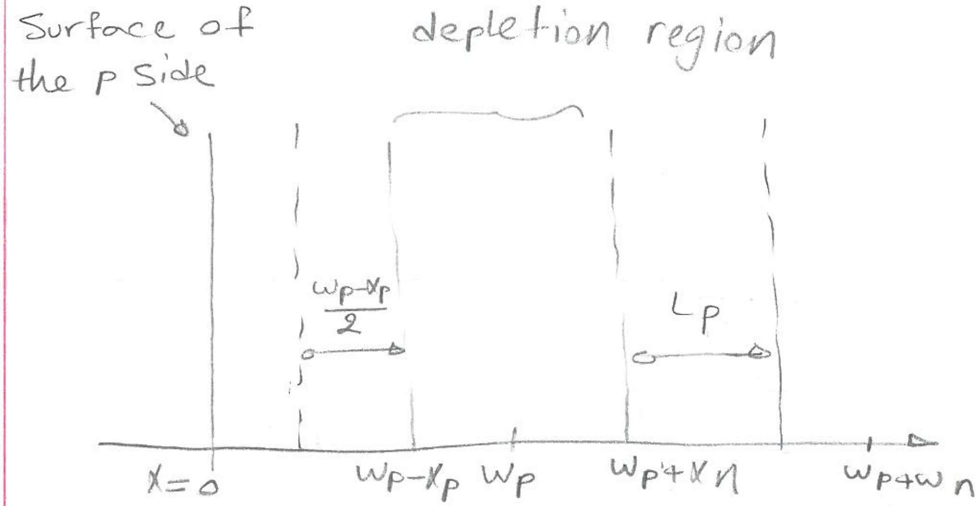
Need to know depletion region width:

$$X_n = \left[\frac{2k\epsilon_0}{q} \varphi_i \left(\frac{N_a}{N_d(N_a + N_d)} \right) \right]^{\frac{1}{2}}$$

$$\varphi_i = \frac{KT}{q} \ln\left(\frac{N_d N_a}{n_i^2} \right) = 1.31 V$$

$$\Rightarrow X_n = \left[\frac{2 \times 12.9 \times 8.85 \times 10^{-14}}{1.6 \times 10^{-19}} \times 1.31 \times \frac{10^{18}}{10^{18} \times (10^{17} + 10^{18})} \right]^{\frac{1}{2}} = 4.12 \times 10^{-6} cm = 0.0412 \mu m$$

$$X_p = \left[\frac{2k\epsilon_0}{q} \varphi_i \left(\frac{N_d}{N_a(N_d + N_a)} \right) \right]^{\frac{1}{2}} = 1.3 \times 10^{-6} cm = 0.013 \mu m$$



all the carriers generated form $\frac{w_p - x_p}{2}$ to $w_p + x_n + L_p$

are captured by depletion region and end up as

short circuit current $\Longrightarrow$

$$I_{ph} = qA \int_{\frac{w_p - x_p}{2}}^{w_p + x_n + L_p} g(x) = qA\varphi_o \eta \left[\exp\left(-\alpha\left(\frac{w_p - x_p}{2}\right)\right) - \exp(-\alpha(w_p + x_n + L_p)) \right]$$

@ wavelength $= 0.65\mu m \Rightarrow \underline{\alpha = 2\times10^{4}\ cm^{-1}}$

$$\varphi_o = \frac{P\lambda}{hc} = \frac{10\ mW}{cm^2} \times \frac{1}{\frac{1.24}{0.65} \times 1.6\times10^{-19} J} = \underline{3.28\times10^{16}\ cm^{-2} s^{-1}}$$

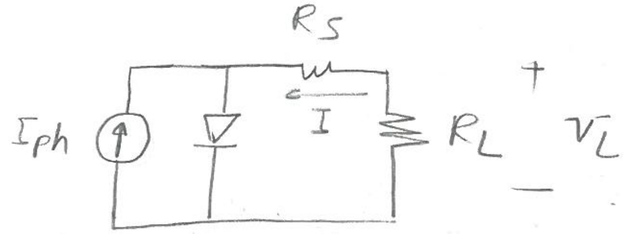
η

$$\Longrightarrow I_{ph} = (1.6\times10^{-19} C)(0.25 cm^2)(3.28\times10^{16} cm^{-2} s^{-1})(0.9) \times$$

$$\left[\exp(-10^{4} cm^{-1} \times 0.1935\times10^{-4}) - \exp(-2\times10^{4}(2.97\times10^{-4})) \right] =$$

$$= 9.7\times10^{-4} A = \underline{0.97\ mA}$$

3 b)



$$P = -\frac{kT}{q}\frac{R_L I}{R_S+R_L}\ln\left(\frac{I_{ph}+I}{I_o}+1\right)$$

need to know I and Rs:

$$\rho = \frac{1}{q n \mu_n} = \frac{1}{1.6\times10^{-14}\times10^{17}\times800} = 0.0781\,\Omega\,cm$$

$$W_n = 100\times10^{-4}\,cm \Rightarrow R_S = \rho\frac{L}{A} = 0.0781\times\frac{10^{-2}}{0.25} = 3.125\times10^{-3}\,\Omega$$
$$= \underline{\underline{3.125\,m\Omega}}$$

for I we need to solve this equation:

$$V_L = -IR_L \Rightarrow \frac{kT}{q}\frac{R_L}{R_S+R_L}\ln\left(\frac{I_{ph}+I}{I_o}+1\right) = -IR_L$$

$$I_o = qAn_i^2\left[\frac{D_p}{N_d L_p}+\frac{D_n}{N_a W_p}\right] = (1.6\times10^{-14}C)(0.25cm^2)(2.4\times10^{6}cm^{-3})^2$$

$$\times\left[\frac{6.4\,cm^2s^{-1}}{10^{17}cm^{-3}\times2.53\times10^{-4}cm}+\frac{7.04\,cm^2s^{-1}}{10^{18}cm^{-3}\times0.4\times10^{-4}cm}\right] = 9.82\times10^{-20}A \Rightarrow I \simeq -I_{ph}$$

$$\Rightarrow P = R_L I^2 = (0.97\times10^{-3}A)^2\times100\,\Omega = \underline{\underline{0.094\,mW}}$$

to find Pmax we need to slove (94 P.38)

$$\Rightarrow \begin{cases} P_{max} = 0.811\ mW \\ I_m = 9.42\times10^{-4}\ A \end{cases} \Rightarrow R_L = \frac{0.811}{(9.42\times10^{-4})^2} m\Omega = 913.95\Omega$$

$\Rightarrow$ If we increase R_L to 913.95Ω we get better Power and after that less power.

3c) E_g for GaAs $= 1.424\ eV$ (300 k)

$$E_g = h\frac{c}{\lambda} = \frac{1.24}{\lambda(\mu m)} eV \Rightarrow \lambda = \frac{1.24}{1.424}\mu m \simeq \underline{871 nm}$$

3d)

$$q_{out} = \int U dx = \int_{n-Side} U dx + \int_{P-Side\ (Short\ diode)} U dx$$

$$= \frac{n_{P_0}(e^{(\frac{qV_A}{U_T})} - 1)W_P}{2\tau_n} + \frac{L_p P_{no}}{\tau_p}(e^{\frac{qV_A}{U_T}} - 1)$$

$$= \frac{5.76\times10^{-6}\times3.73\times10^{13}\times0.4\times10^{-4}}{2\times0.01\times10^{-6}} cm^{-2}s^{-1} + \frac{2.53\times10^{-4}\times5.76\times10^{-5}\times3.73\times10^{1}}{0.01\times10^{-6}} cm^{-2}s^{-}$$

$$\simeq \underline{5.44\times10^{13}\ cm^{-2}s^{-1}}$$

The recombination takes place in two quasi-neutral n and p regions (Ignoring the recombination in the depletion region).

4. Using a polysilicon gate that acts as a metal.

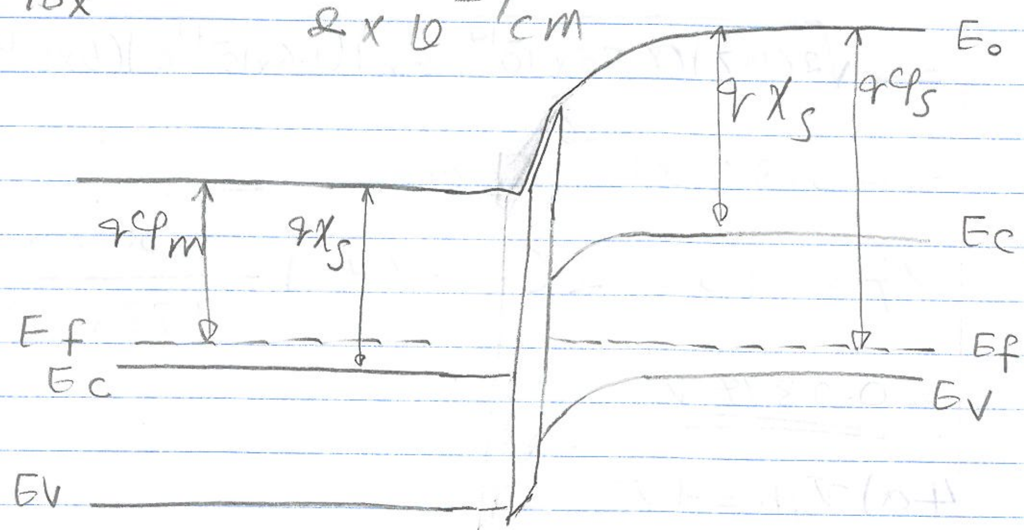
$E_f = E_c + 0.05 eV \Longrightarrow n^+$ degenerate

$t_{ox} = 2\times10^{-7} cm$; $N_a = 5\times10^{17} cm^{-3}$

In order to determine the mode of operation

we need to find V_T first.

$$C_{ox} = \frac{K_{ox}\varepsilon_o}{t_{ox}} = \frac{(3.9)(8.85\times10^{-14} F cm^{-1})}{2\times10^{-7} cm} = 1.73\times10^{-6} F cm^{-2}$$



$\chi_s = 4.05 V$

$\varphi_m = \chi_s - (E_f - E_c) = 4V$

$\varphi_s = \chi_s + E_g - (E_f - E_v)$

$E_f - E_v = \frac{kT}{q} \ln\left(\frac{N_v}{N_a}\right) = 25mV \ln\left(\frac{2.5\times10^{19}}{5\times10^{17}}\right) = 0.0978V$

$\varphi_s = (4.05 + 1.12 - 0.0978)V = 5.07V$

$\varphi_{ms} = \varphi_m - \varphi_s = 4.0 - 5.07V = -1.07V$

Since there are no oxide charges, $V_{FB} = \varphi_{ms} = -1.07V$

Threshold voltage V_T:

$$V_T = \varphi_{ms} - 2\varphi_F - \frac{Q_B'}{C_{ox}}$$ (need to find all the terms!)

$$\varphi_F = \frac{-kT}{q}\ln\left(\frac{N_a}{n_i}\right) = -25mV\ln\left(\frac{5\times10^{17}}{10^{10}}\right) = -0.443V$$

$$Q_B' = Q_{dmax}' = -\sqrt{2k_s\epsilon_0 q N_a|2\varphi_F|}$$

$$= -\sqrt{2(11.7)(8.85\times10^{-14}F/cm)(1.6\times10^{-19}C)(5\times10^{17}cm^{-3})2(0.443)}$$

$$= -0.383\times10^{-6}\ Ccm^{-2}$$

$$V_T = -1.07 - 2(-0.443) - \frac{(-0.383\times10^{-6}Ccm^{-2})}{1.73\times10^{-6}Fcm^{-2}}$$

$$= 0.0374V$$

4a) $V_{gb} = -1V$

$V_{FB} < V_{gb} < V_T \Longrightarrow$ depletion.

$$V_{gb} - \varphi_{ms} = V_{ox} + V_S \quad ①$$

$$V_{ox} = \frac{-Q_d'}{C_{ox}'} \quad ②$$

Putting ② into ①

$$-1V - (-1.07V) = \frac{\sqrt{2k_s\epsilon_0 q N_a V_S}}{C_{ox}'} + V_S$$

$$0.07V = 0.235\sqrt{V_S} + V_S \Longrightarrow V_S = 0.0296V$$

4a) $V_{ox} = 0.235\sqrt{V_s} = \underline{\underline{0.0404\ V}}$

$Q_g' = C_{ox}' V_{ox} = \underline{\underline{0.694 \times 10^{-7}\ C\,cm^{-2}}}$

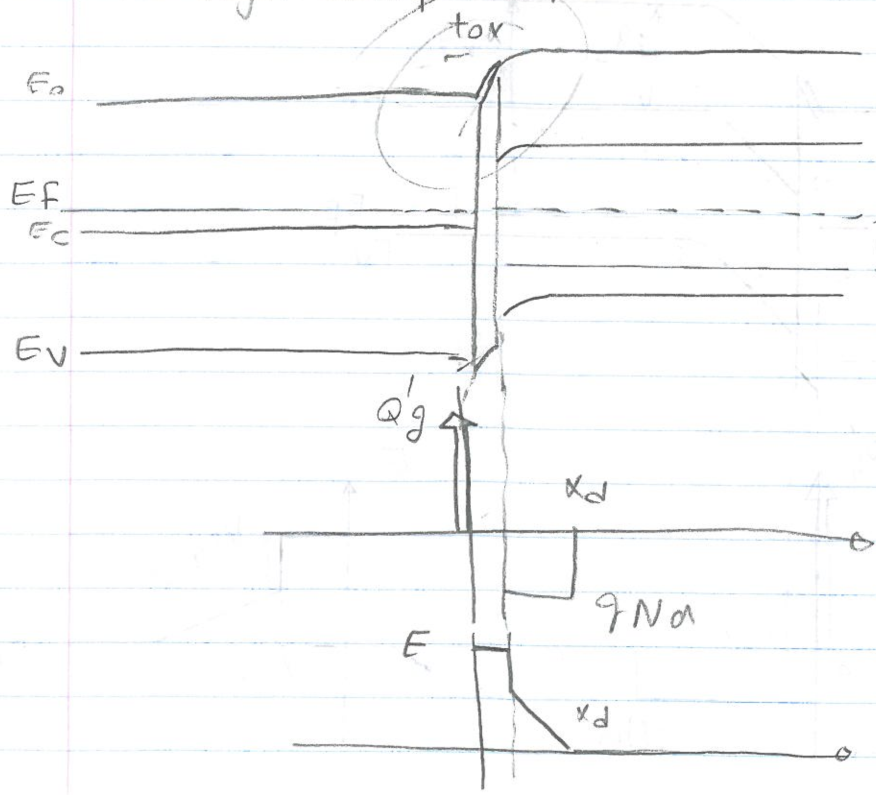
$$x_d = \frac{-Q_s}{qN_a} = \frac{Q_g}{qN_a} = \frac{0.694\times10^{-7}\ C\,cm^{-2}}{(1.6\times10^{-19}\ C)(5\times10^{17}\ cm^{-3})} = 8.74\times10^{-7}\ cm$$

$$= \underline{\underline{8.74\ nm}}$$

$$C_s' = C_d' = \frac{k_s\epsilon_0}{x_d} = \frac{(11.7)(8.85\times10^{-14}\ F\,cm^{-1})}{8.74\times10^{-7}\ cm} = \underline{\underline{1.18\times10^{-6}\ F\,cm^{-2}}}$$

$$C'_{total} = \frac{C'_{ox}C'_d}{C'_{ox}+C'_d} = \underline{\underline{0.703\times10^{-6}\ F\,cm^{-2}}}$$

Since depletion region width can be modulated rapidly, the capacitance is the same for low and high frequency.



4 b) $v_{gb} = 0\,\bar{V}$

$V_{FB} < V_{gb} < V_T \Longrightarrow$ depletion

Similar to (a) : $V_{gb} - \varphi_{ms} = V_{ox} + V_S$.

$0 - (-1.07) = 0.235\sqrt{V_S} + V_S \Longrightarrow \underline{V_S = 0.853\,V}$

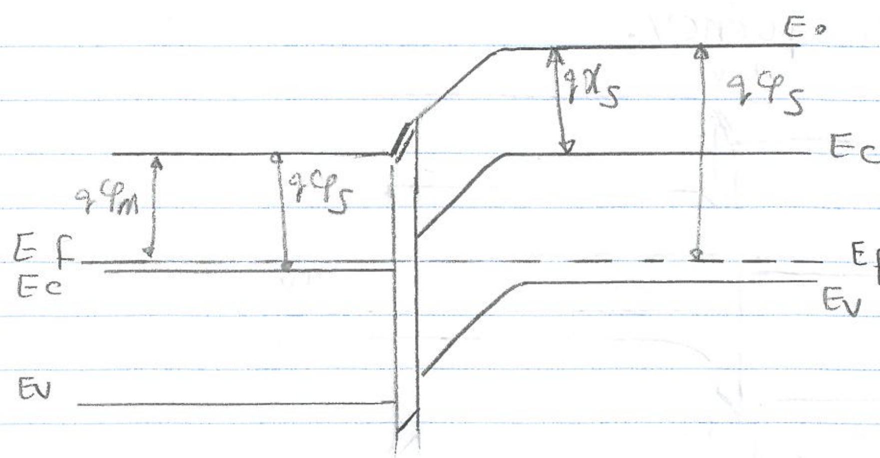
$V_{ox} = 0.235\sqrt{0.853}\ V = \underline{0.217\,V}$

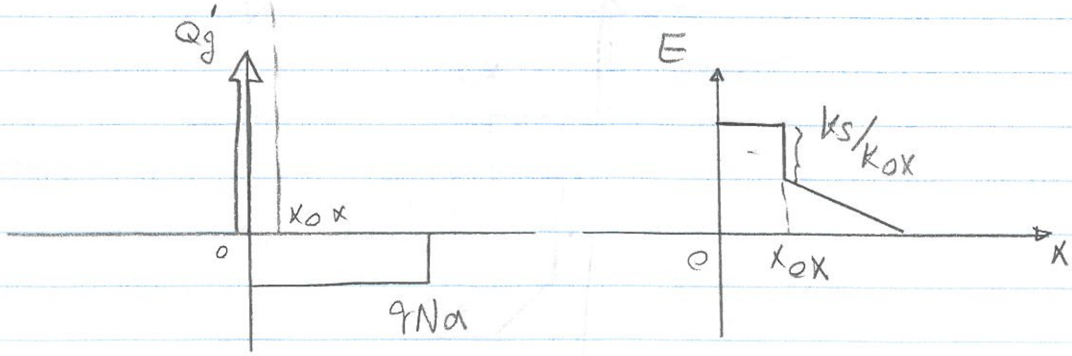
$Q_g' = C_{ox}' V_{ox} = \underline{3.75\times10^{-7}\ C\,cm^{-2}}$ $x_d = \frac{Q_g}{qN_a} = 46.9\times10^{-7}\ cm$

$= \underline{46.9\,nm}$

$C_s' = C_d' = \frac{K_S \epsilon_0}{x_d} = 2.21\times10^{-7}\ F\,cm^{-2}$

$C'_{total} = C_d' \parallel C_{ox}' = \underline{1.96\times10^{-7}}\ F\,cm^{-2}$ for both low and high frequecy





4c) $v_{gb} = 1V \quad v_{gb} > V_T \Rightarrow$ inversion

$V_S \cong \varphi_{surface} = |2\varphi_F| = 2(0.433) = 0.886V$

$v_{gb} - \varphi_{ms} = V_{ox} + V_S \Rightarrow 1 - (-1.07)V = V_{ox} + 0.866V$

$\Rightarrow V_{ox} = 1.204V$

$V_{ox} = \dfrac{-Q_S'}{C_{ox}} \Rightarrow Q_S' = -(1.204V)(1.73\times10^{-6}\,Fcm^{-2})$

$= -2.08\times10^{-6}\,Ccm^{-2} = -Q_m' = -Q_g'$

$Q_i' = Q_m' - Q_{dmax}' = 2.08\times10^{-6} - (+0.383\times10^{-6})\,Ccm^{-2}$

$= 1.68\times10^{-6}\,Ccm^{-2}$ or $\left(Q_i' = C_{ox}'(V_{gb} - V_T) = 1.66\times10^{-6}\,Ccm^{-2}\right)$

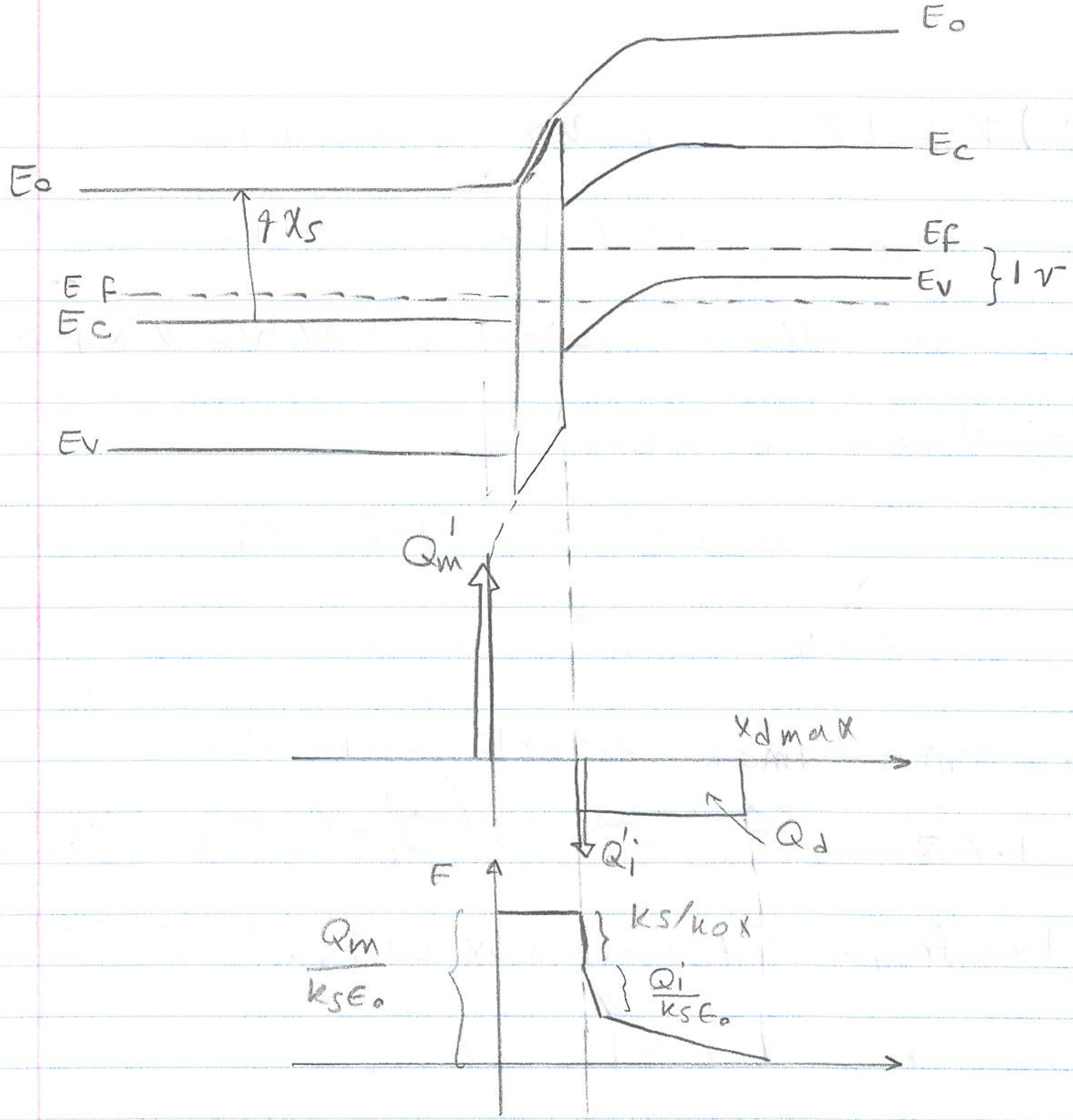
@ low freq. $C_{total} = C_{ox} = 1.73\times10^{-6}\,Fcm^{-2}$

@ high freq $C_{total} = C_{ox} \parallel C_{S,min}$

$$C_{Smin} = \frac{K_S\epsilon_0}{X_d} \quad \text{and} \quad X_d = \frac{Q_i}{qN_a}$$

$\Rightarrow C_{Smin} = 3.37\times10^{-8}\,Ccm^{-2}$

$C_{Smin} = 3.31\times10^{-8}\,Ccm^{-2}$ for HF.



E₀
Ec
Ef
Ev
1v
E₀
qχs
E F
E c
Ev
Q'm
xd max
Q'i
Qd
F
Ks/Kox
Qm / KsE₀
Q'i / KsE₀