FINAL EXAM SOLUTIONS

EE 3161

SPRING 2008

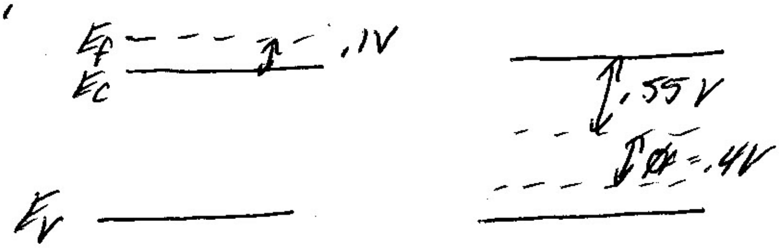
1. a.) $V_t = V_{FB} + \Delta V_{ox} + 2\phi_f + \frac{t_{ox}}{\epsilon_{ox}}\sqrt{2q\epsilon_{si}N_a 2\phi_f}$

$\phi_f = \frac{kT}{q}\ln\frac{N_a}{n_i} = .4V \quad 2\phi_f = .8V$

$\Delta V_{ox} = \frac{-Q_{ox}}{C_A} = \frac{-Q_{ox}X_f}{\epsilon_{ox}} = \frac{-(-1.4\times10^{-7}\frac{C}{cm^2})(75Å)}{(3.9)(8.854\times10^{-14}F/cm)}$

$\Delta V_{ox} \approx .3V$

<u>VFB:</u>



$V_{FB} \approx -.1 + .55 + .4 \approx -1.05V$

$V_t \approx -1.05 + .3 + .8 + .5$

$\boxed{V_t \approx .55V}$

If $V_{sub} = -3V$ then

$\frac{t_{ox}}{\epsilon_{ox}}\sqrt{2q\epsilon_{si}N_a(2\phi_f + |V_{sub}|)} \approx 1.34$

$\boxed{V_t \approx 1.39V}$

$$V_{FB} = V_{FB0} + \Delta V_{ox} - |V_{sub}|$$

$$\boxed{V_{FB} \approx -3.75V}$$

$$\boxed{C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} \approx 2.3\times10^{-7}\ F/cm^2}$$

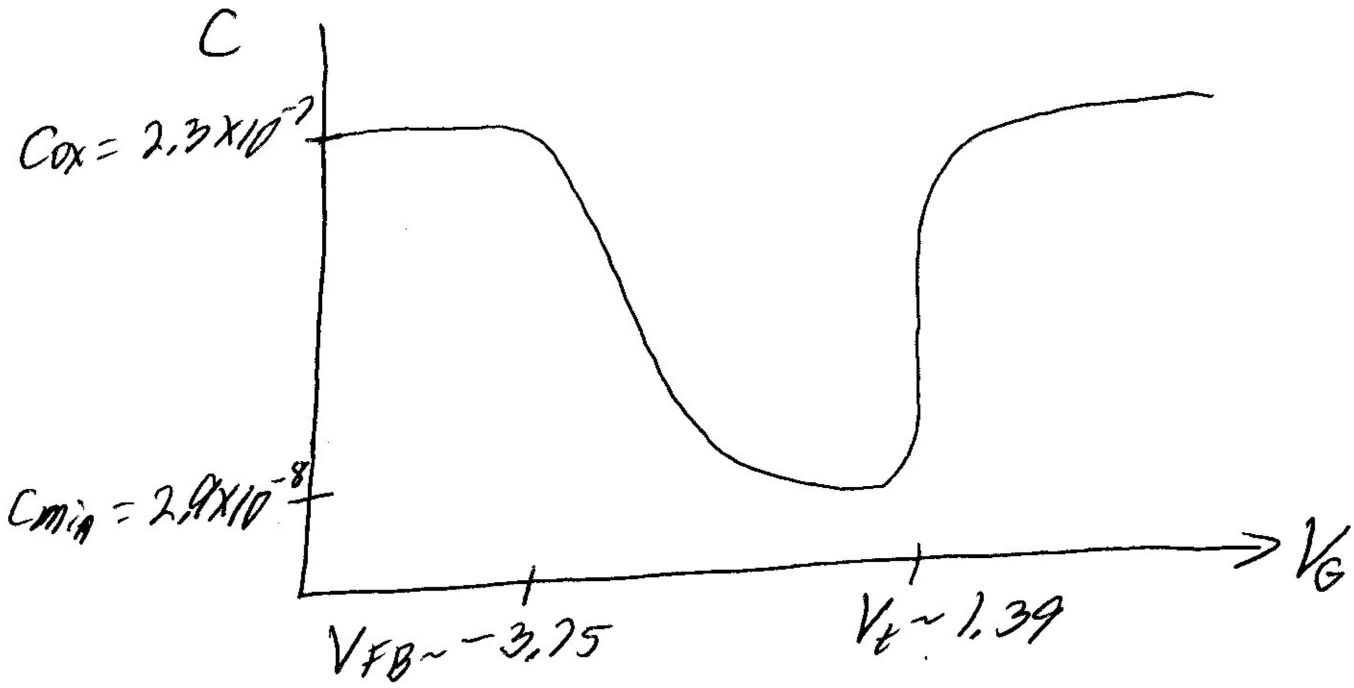
$$C_{si} = \frac{\epsilon_{si}}{W_{max}} \qquad W_{max} = \sqrt{\frac{2\epsilon_{si}}{qN_a}(2\phi_f + |V_{sub}|)}$$

$$W_{max} \approx .31\mu m$$

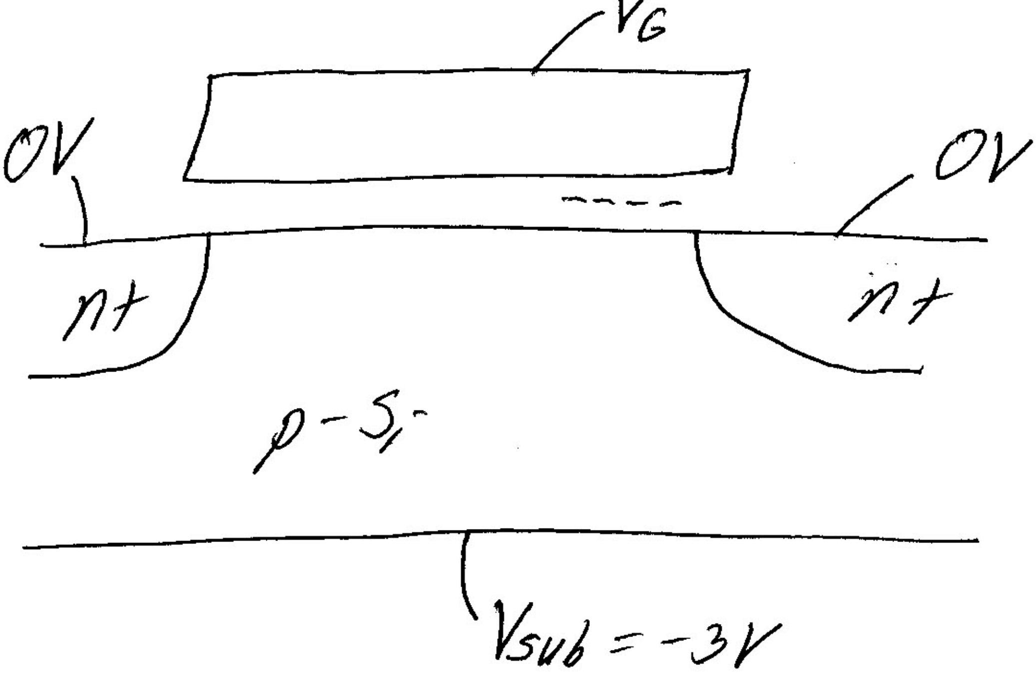
$$C_{si} \approx 3.3\times10^{-8}\ F/cm^2$$

$$C_{min} = \frac{C_{si}C_{ox}}{C_{si}+C_{ox}}$$

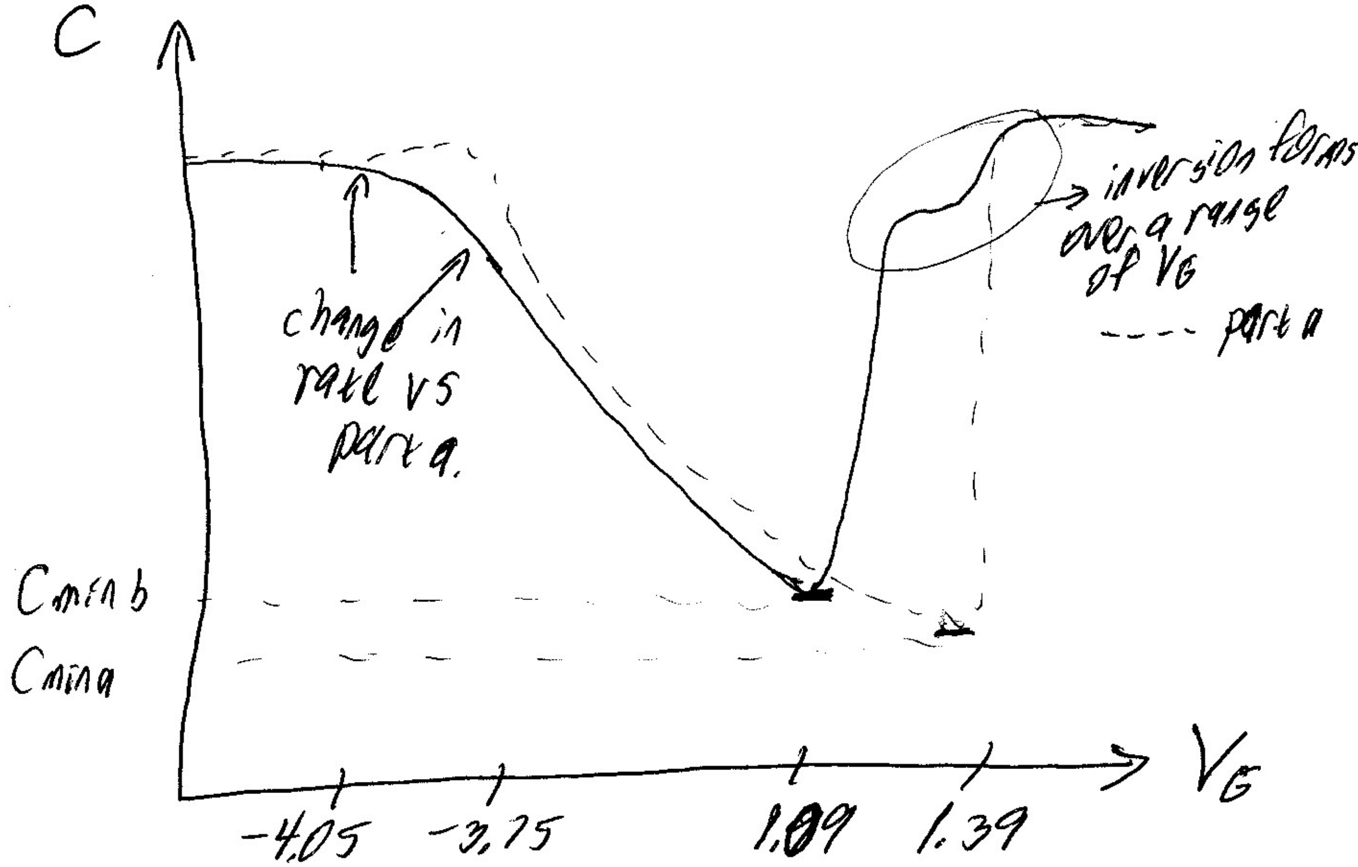
$$\boxed{C_{min} \approx 2.9\times10^{-8}\ F/cm^2}$$



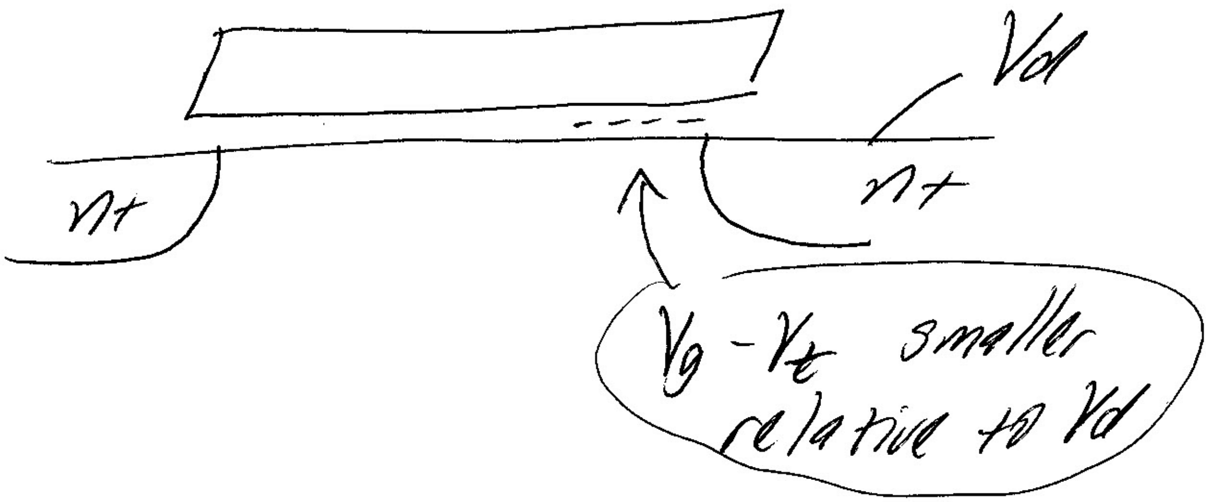
b.)

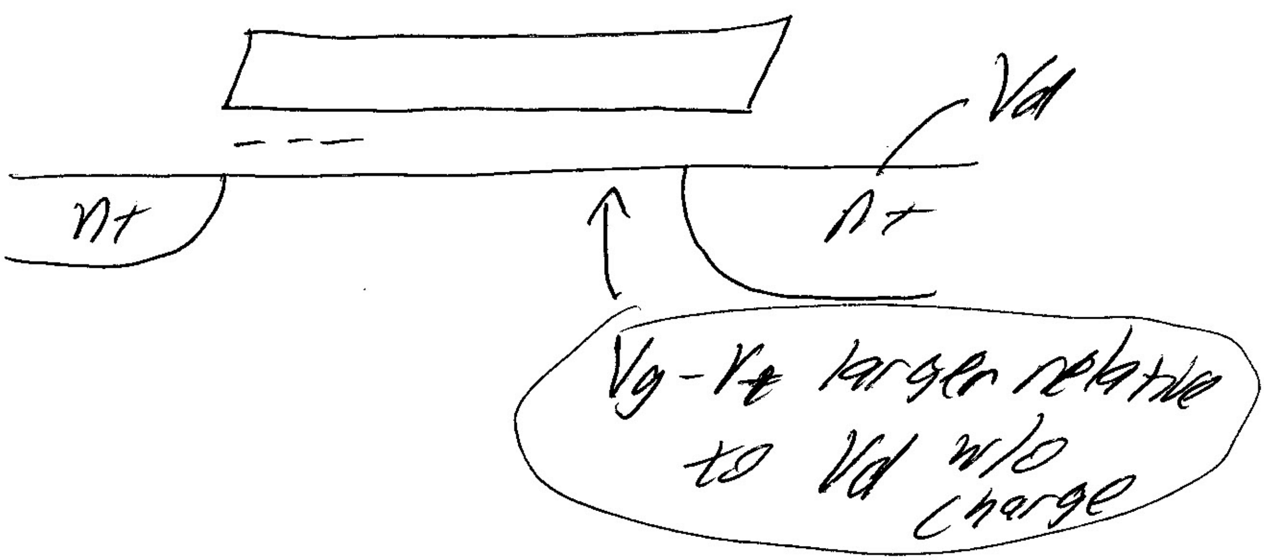


→ near drain has $V_t \sim 1.39V$
→ most of channel has $V_t \sim 1.09V$
→ near drain has $V_{FB} \sim -3.75V$
→ most of channel has $V_{FB} \sim -4.05$



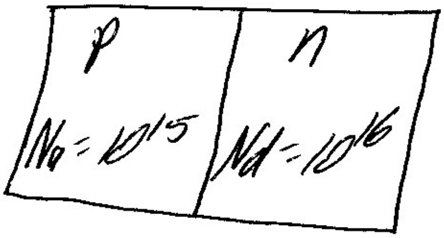
Id begins to flow in significant quantities only when all of the channel is inverted (at least with what we have learned in class.). However, the magnitude of Id will change.





(2.)

$$I_{RB} = qAG_L(L_n + L_p + W) + qA\frac{n_i}{2\tau_0}W$$



$\tau = .3\mu s$

$$V_{bi} = \frac{kT}{q}\ln\frac{N_a N_d}{n_i^2} = .65V$$

$$V_{bi} - V_A = 5.65V$$

$$\underline{W \approx 2.8\mu m}$$

$$L_n = \sqrt{D_n \tau_n} = \sqrt{\frac{kT}{q}\mu_n(N_a = 10^{15}cm^{-3})\,\tau}$$

$$L_n = \sqrt{(.026)(1345)(.3\mu s)}$$

$$\underline{L_n \approx 32\mu m}$$

$$L_p = \sqrt{D_p \tau_p} = \sqrt{\frac{kT}{q}\mu_p(N_d = 10^{16}cm^{-3})\,\tau}$$

$$L_p \approx \sqrt{(.026)(437)(.3\mu s)}$$

$$\underline{L_p \approx 18\mu m}$$

$$I_{RB} = (1.6\times10^{-19})(.01cm^2)\frac{1.1\times10^{10}cm^{-3}}{2(.3\mu s)}(2.8\times10^{-4}cm)$$

$$+ (1.6\times10^{-19})(.01cm^2)\, G_L\, (52.8\times10^{-4}cm)$$

$$I_{RB} = 8.2\,nA + (8.45\times10^{-24})(G_L)$$

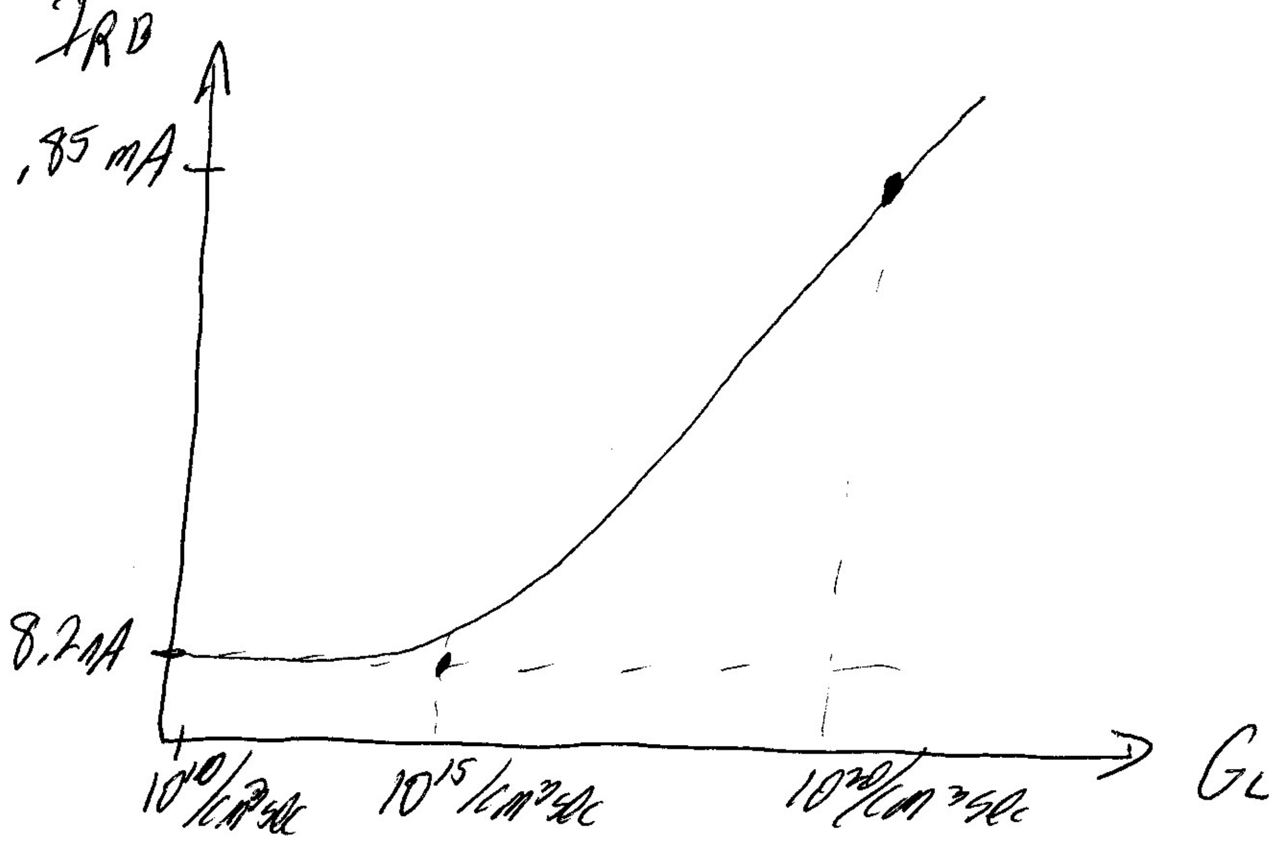
The two terms are equal at

$G_L \sim 9.7\times10^{14}/cm^3sec$

$G_L \sim 10^{15}/cm^3sec$

$G_L \sim \frac{\Delta p}{\tau}$, $\Delta p \sim 3\times10^{8}\,\frac{carriers}{cm^3}$

$\Delta n \sim$ "



(3.) $I_{Dsat} \sim Z C_{ox} v_{sat} (V_G - V_t)$

a.) v_{sat} begins to be approached when $\frac{V_{DS}}{L} \sim \mathcal{E}_c = 1.1 \times 10^4 V/cm$

$$V_{DS} \sim \mathcal{E}_c L$$

$$\boxed{V_{DS} \sim 1.1V}$$

b.) There are several effects here including gradual punchthrough, decreased channel resistance (as L decreases), but the one we covered in class was V_t lowering which would directly affect our equation.