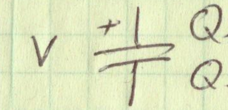
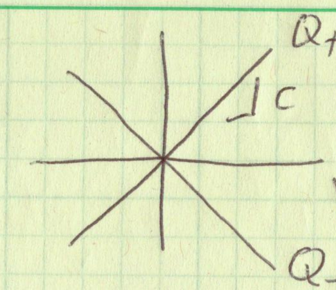
HW2 - Late Monday

MOS physics

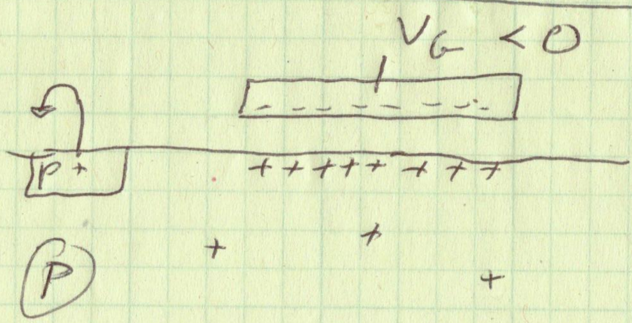
- Normal caps
- MOS caps
- triode
- saturation
- sub-threshold
- velocity sat.





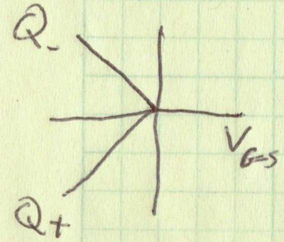
Keeping track of charge on normal caps will be important later (switched caps)

for now, it the MOS cap, and Q^-

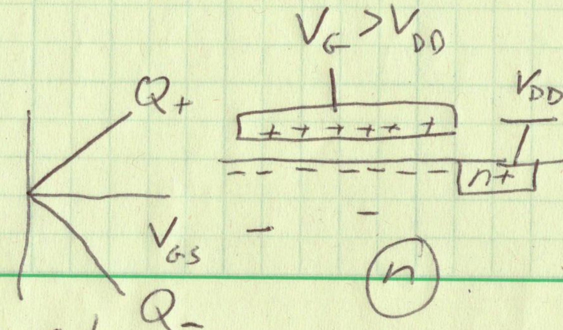


(technically should be flatband voltage)

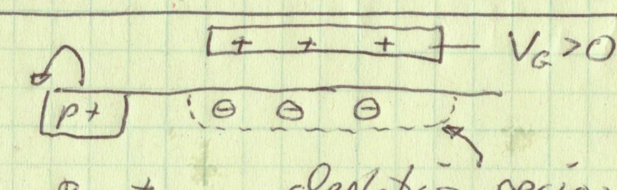
majority carriers accumulate. Looks "normal"



p-sub



n-sub



depletion

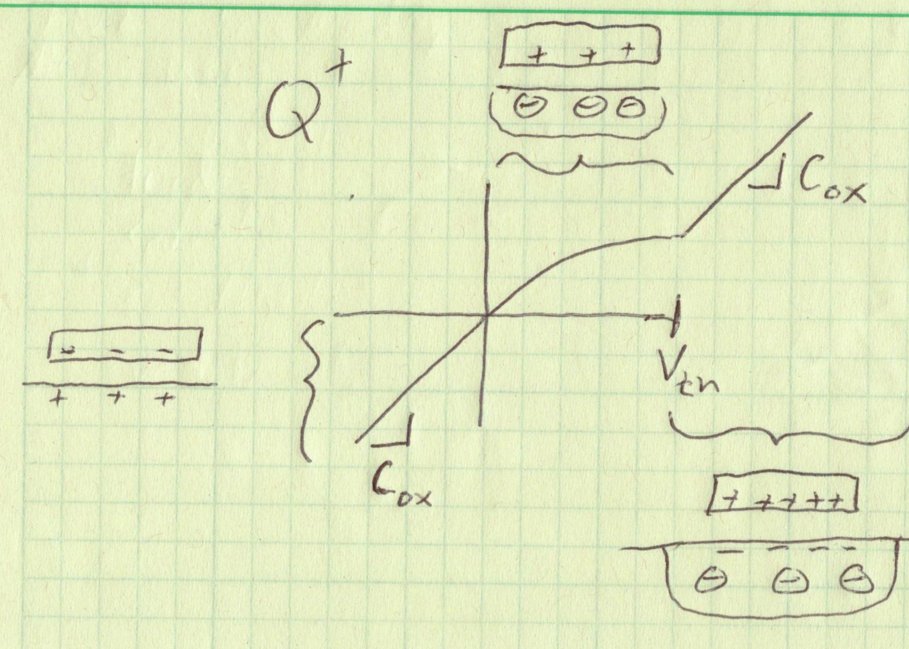
depletion region grows as $\sqrt{V_{GS}}$

surface charge

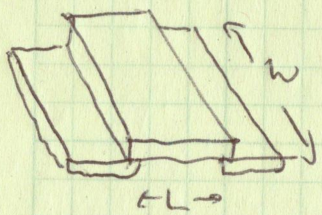
magic!

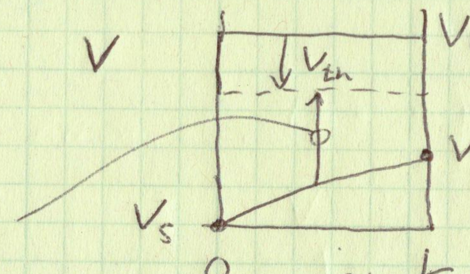
fixed ions in depletion region

Lillienfield 1927 field effect



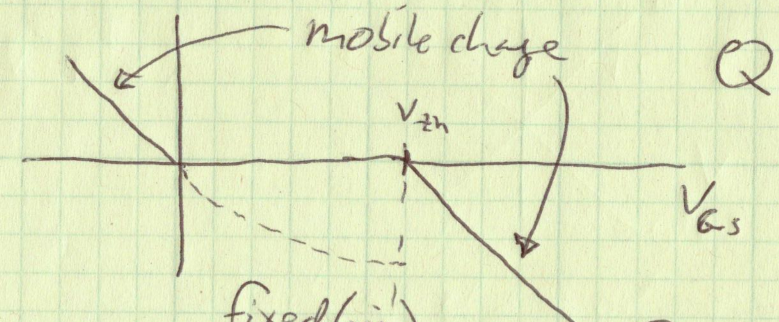
add contacts to the edges



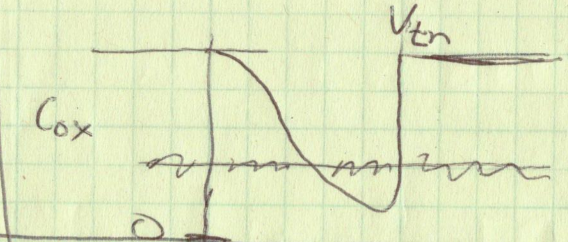


$V_{GC}(x)$

$$\sigma_{ch}(x) = C_{ox}\left(V_{G} - V_t - V_{CL}(x)\right)$$

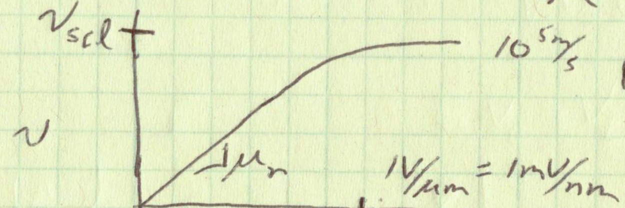


$$\sigma_{ch} = C_{ox}(V_{GS} - V_{tn})$$



I_D = (avg. charge per length)(velocity)

$$W C_{ox}\left(V_{GS} - V_{tn} - \tfrac{1}{2}V_{DS}\right)\left(\mu_n \frac{V_{DS}}{L}\right)$$



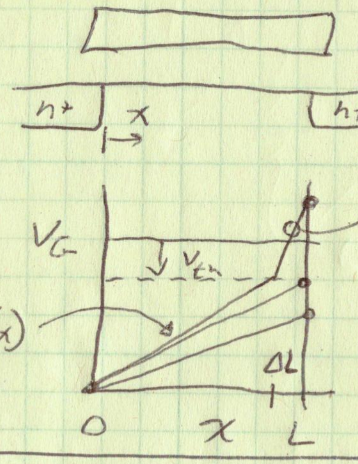
(compare $c = 3\times10^8$ m/s)

$$E = \frac{V_{DS}}{L}$$

$$I_D = \mu_n C_{ox} \frac{W}{L}\left(V_{GS} - V_{tn} - \tfrac{1}{2}V_{DS}\right) V_{DS}$$

"triode" or "linear"

As V_{DS} increases, the drain side of channel loses charge density



slope $\approx E_{BD} = 30\,V/\mu m$

channel field $= \dfrac{V}{d}$

$$= \frac{V_{GS}-V_{tn}}{L-\Delta L}$$

$$I_D = (\text{avg charge density per length})(\text{velocity})$$

$$= \left(W C_{ox} \frac{V_{GS}-V_{tn}}{2}\right)\left(\mu_n \frac{(V_{GS}-V_{tn})}{L-\Delta L}\right)$$

$$= \frac{\mu_n C_{ox}}{2}\frac{W}{L}(V_{GS}-V_{tn})^2(1+\lambda V_{DS})$$

$$\frac{1}{1-\Delta L/L} \simeq 1+\lambda V_{DS}$$

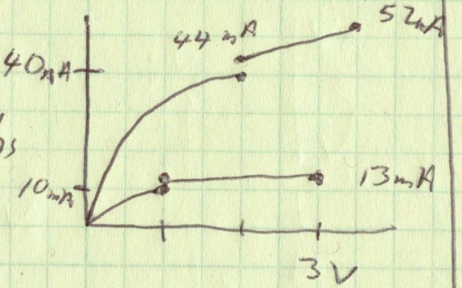
$$\Delta L = \frac{V_{DS}}{E_{BD}} \quad \text{-ish}$$

saturation

$\mu_n C_{ox} = 200\,\frac{\mu A}{V^2}$ $\quad V_{tn} = 1V$ $\quad L = 1\mu m$ $\quad W = 100\mu m$

$\mu_n C_{ox}\frac{W}{L} = \frac{20\,mA}{V^2}$ $\quad \lambda = 0.1\,\frac{1}{V} = \frac{1}{10V}$

$V_G = 2V$



triode: $I_D = 20\frac{mA}{V^2}\left(1-\frac{1}{2}V_{DS}\right)V_{DS}$

max at $V_D = V_{Dsat} = V_{GS}-V_{th}$

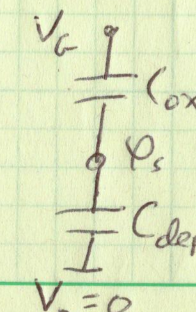
sat: $I_D = \left(10\frac{mA}{V^2}\right)(1)\left(1+\frac{V_{DS}}{10V}\right)$

discontinuity! Soln? Add $(1+\lambda V_{DS})$ to triode equation. Totally non-physical.

Sub-threshold

Surface potential near source, φ_s or $V_C(0)$

$$\varphi_s = \frac{1}{n}V_{GB}$$



$$\varphi_s = \underbrace{\frac{C_{ox}}{C_{ox}+C_{depl}}}_{\frac{1}{n}} V_G$$

$$I_D \simeq I_s\, e^{\varphi_s/V_{TH}}$$

$$= I_s\, e^{V_{GB}/nV_{TH}}$$