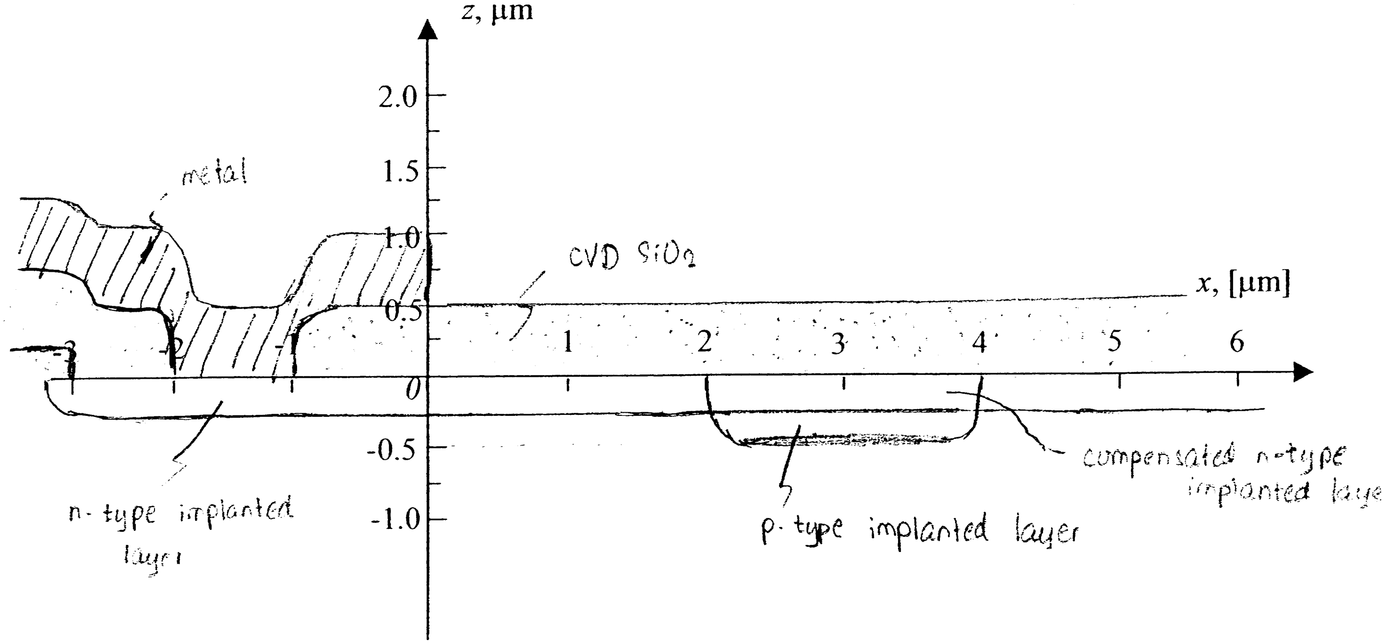
FALL 2001 Sample Midterm I solution (EE 105)

1 (a) [5 pts.] Sketch the cross section *A-A'* on the graph below **after step 8**. Identify all layers clearly.



(b) [4 pts.] What is the sheet resistance $R_{\square 1}$ of Region 1 (see the layout) in Ω/□?

$n = \bar{N}_d - N_{a,sub} = \frac{Q_d}{x_j} - N_{a,sub} = \frac{5\times10^{11}\,cm^{-2}}{.25\times10^{-4}\,cm} - 5\times10^{15}\,cm^{-3} = 1.5\times10^{16}\,cm^{-3}$

$R_{\square 1} = \frac{\rho}{t} = \left(\frac{1}{qn\mu_n}\right)\left(\frac{1}{x_j}\right) = \frac{1}{(1.6\times10^{-19})(1.5\times10^{16})(10^3)} \cdot \frac{1}{.25\times10^{-4}} = \boxed{16.7\,k\Omega/\square}$

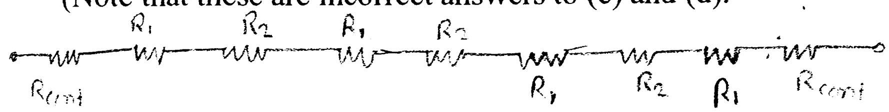
(c) [4 pts.] What is the sheet resistance $R_{\square 2}$ of Region 2 (see the layout) in Ω/□?

$n = \bar{N}_d - \bar{N}_{a,implant} - N_{a,sub} = \frac{Q_d}{x_j} - \frac{Q_a}{t} - N_{a,sub} = \frac{5\times10^{11}}{.25\times10^{-4}} - \frac{5\times10^{11}}{0.5\times10^{-4}} - 5\times10^{15}$

$= 5\times10^{15}\,cm^{-3}$

$\therefore R_{\square 2} = 3R_{\square 1} = \boxed{50\,k\Omega/\square}$

(c) [4 pts.] What is the resistance $R_{1\text{-}2}$ between terminals 1 and 2 in Ω? Make judicious approximations to find the effective width of the resistor. If you couldn't solve parts (c) and (d), use $R_{\square 1}$ = 200 Ω and $R_{\square 2}$ = 175 Ω in this part. (Note that these are incorrect answers to (c) and (d).



in each $R_{\square 1}$ & $R_{\square 2}$ region. # of □'s $= \frac{2\,\mu m}{1\,\mu m} = 2\square$

$\therefore R = 2(0.65\square) R_{\square 1} + 4R_{\square 1}(2\square) + 3R_{\square 2}(2\square) = \boxed{455.3\,k\Omega}$

(contacts)

(2) mos capacitor

a) $V_{FB} = -0.8V$

b) $V_{Tn} = 0.5V$

c) $C = C_{ox} \cdot Area = \frac{\varepsilon_{ox}}{t_{ox}}(225\mu m^2) = \left(\frac{3.45\times10^{-13}\ F/cm}{172.5\times10^{-8}\ cm}\right)(225\times10^{-8}\ cm^2)$

$\therefore C = 45\ pF$

d) $Q_N = -C_{ox}(V_{GB} - V_{Tn}) = -\frac{\varepsilon_{ox}}{t_{ox}}(1-0.5) = -10\ \mu C/cm^2$

e) $i_{gb}(t) = C\frac{d\,v_{gb}(t)}{dt} = C\frac{d}{dt}\{10mV \cos(2\pi \cdot 100\times10^6 t)\}$

How do we know what C is? Operating point (DC) voltage $V_{GB} = -0.5V$

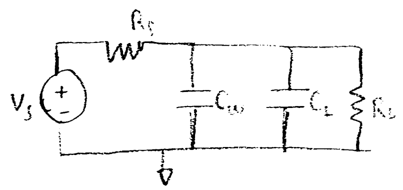
$C(V_{GB} = -0.5V) \approx 0.875\ C_{ox}\,Area \approx 0.875\,(45pF)$

(Area: from part ©)

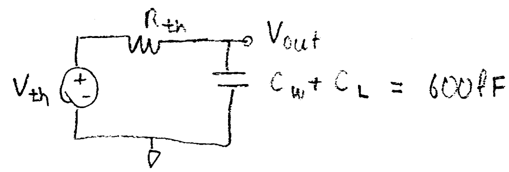
$\therefore i_{gb}(t) = -0.875\,(45pF)(10mV)(2\pi\times100\times10^6)\sin(2\pi\times100\times10^6 t)$

$= \boxed{-0.25\ mA\ \sin(2\pi\times100\times10^6 t)}$

(3) a)



$\Rightarrow$ Thevénin



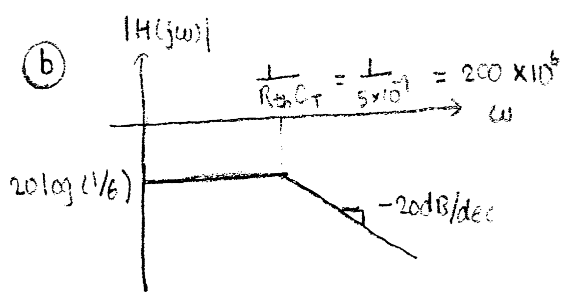
∴ Low-pass

$V_{th} = V_s\left(\frac{R_L}{R_L + R_s}\right) = \frac{1}{6}V_s$

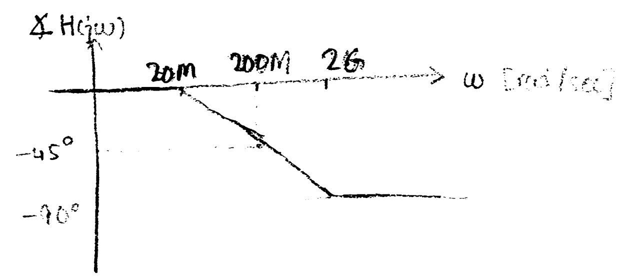
$R_{th} = R_L \| R_s = 50/6\ k\Omega$

$\therefore H(j\omega) = \frac{V_{out}}{V_s} = \frac{(1/6)}{1 + j\omega R_{th} C_T} = \frac{(1/6)}{1 + j\omega\, 5\times10^{-9}}$

(b)



(c)



(d) $V_{out} = V_s\,H(j\omega') = \frac{(1/6)V_s}{1 + j\omega' R_{th} C_T} = \frac{(1/6)V_s}{1 + j0.785} = \frac{\left(\frac{25mV}{6}\right)\angle 0^\circ}{\sqrt{1^2 + (0.785)^2}\,\angle \tan^{-1}(0.785)}$

($\omega' = 2\pi\times25MHz$, $R_{th}C_T = 5\times10^{-9}$)

$\approx 3.3\ mV\ \angle 0 - 38.1^\circ$

$= 3.3\ mV\ \angle -38.1^\circ$

$\therefore \boxed{v_{out}(t) = 3.3mV\ \cos(2\pi(25MHz)t - 38.1^\circ)}$