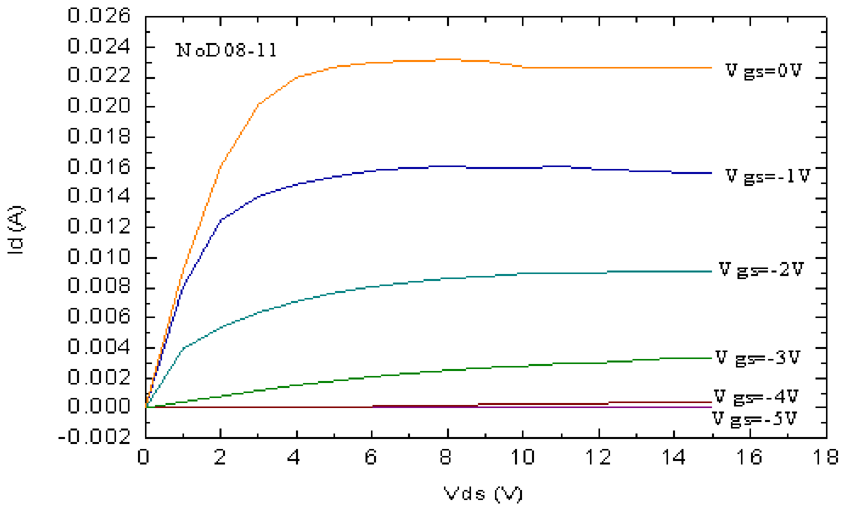
EEE118 Tutorial Questions – Sheet 6

l. A JFET has a channel resistivity of 0.15 Ωm. At zero drain bias, calculate the channel resistance for a gate length, *L*, of 1 μm a width, *Z*, of 1mm and a channel thickness of 2 μm assuming no gate bias and a negligible zero gate bias depletion in the channel. Using the expression for depletion thickness for a p+n junction in the notes, calculate the pinch off voltage assuming a negligible built-in potential and an electron mobility of 0.12 $m^2V^{-1}s^{-1}$ in the channel. Use $\varepsilon = \varepsilon_o\, \varepsilon_r = 8.85 \times 10^{-12} \times 12\ Fm^{-1}$.

What is the resistance of the channel when a gate voltage equal to half the pinch off voltage is applied?

(75 Ω, 1.05 V, 254 Ω)

4. The output characteristics of a depletion mode FET is shown in the figure. From this estimate the transconductance, g_m, and the channel resistance at zero gate bias and low drain bias (neglect any other resistances).



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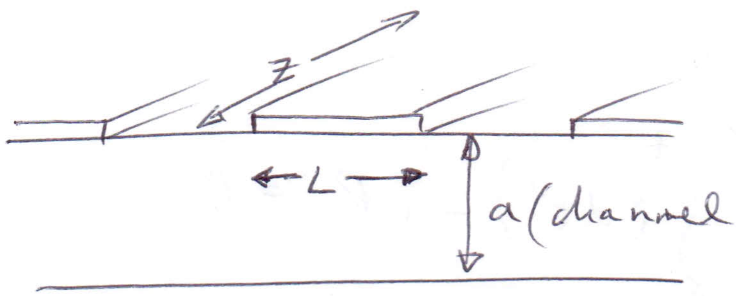
Solutions

① Channel resistance $R_{CH} = \dfrac{\rho L}{Z a}$



$$= \frac{0.15 \times 1\times10^{-6}}{1\times10^{-3} \times 2\times10^{-6}}$$

$$= \underline{\underline{75\,\Omega}}$$

From the notes
depletion thickness

$$W = \left[\frac{2(V_0+V)\epsilon}{e} \cdot \frac{N_a+N_d}{N_a \times N_d}\right]^{\frac{1}{2}} \Rightarrow \left[\frac{2V\epsilon}{e} \cdot \frac{1}{N_d}\right]^{\frac{1}{2}} \quad — ①$$

when $N_a \gg N_d$ and $V_0 \ll V$

when $W = a$, $V = V_p$ (pinch-off voltage)

We need N_d to get V_p ie. $N_d = \dfrac{1}{\rho e \mu}$

$$= \frac{1}{0.15 \times 1.6\times10^{-19} \times 0.12}$$

$$= 3.47\times10^{20}\ m^{-3}$$

From equation ① $V_p = \dfrac{a^2 e N_d}{2\epsilon}$

$$= \frac{(2\times10^{-6})^2 \times 1.6\times10^{-19} \times 3.47\times10^{20}}{2\times 8.85\times10^{-12} \times 12}$$

$$= \underline{\underline{1.05\,V}}$$

Deplion thickness $W \propto V_g^{\frac{1}{2}}$ (from equation 1)

At pinch-off $W = a = \text{const } V_p^{\frac{1}{2}}$

At $V_p/2$ $\quad W' = 2 \dfrac{(V_p/2)^{1/2}}{V_p^{\frac{1}{2}}} = \dfrac{2}{\sqrt{2}} = 1.4\mu m$

$\therefore$ Channel thickness $= 2 - 1.41 = 0.59\mu m$

$R_{CH} \propto W_{CH}$ (channel thickness)

hence $\quad R_{CH}$ at $V_p/2 = \dfrac{2}{0.59} \times 75\Omega$

$= \underline{254\,\Omega}$

2 $\quad g_m = \dfrac{\Delta I_D}{\Delta V_g} = \dfrac{0.023 - 0.016\text{ A}}{1\text{ V}} = \underline{\underline{7 \times 10^{-3} S}}$

$R_{CH} \approx \dfrac{3.2V}{0.026A} = \underline{\underline{123\,\Omega}}$

Note that gm reduces as V_g gets more negative