Serie 11

Given constants

$kT/q = 25.9\,[mV] \quad @ \quad T = 300\,[K]$
$n_i(Si) = 1.5 \cdot 10^{10}\,[cm^{-3}] \quad @ \quad T = 300\,[K]$
$q = 1.60 \cdot 10^{-19}\,[C]$
$\epsilon_0 = 8.85 \cdot 10^{-14}\,[F/cm]$
$\epsilon_{Si} = 11.7 \cdot \epsilon_0$
$\epsilon_{SiO} = 3.9 \cdot \epsilon_0$

Exercise 01

You have access to the specifications of an industrial CMOS technology that we want to consider for the design of an IC operating at $T = 85\,[°C]$. For a long-channel NMOS transistor, we have: an off current $I_{off} = 1\,[nA/\mu m]$, a threshold voltage $V_{th} = 0.5\,[V]$, a subthreshold slope $SS = 70\,[mV/dec]$, all at $T = 25\,[°C]$. The current I_{off} is the current I_D at $V_{GS} = 0\,[V]$ and $V_{DS} = V_{DD}$, normalized by the channel width W. The subthreshold slope is defined as $SS = \frac{\partial V_{GS}}{\partial(log_{10} I_D)} = ln(10) \cdot \frac{kT}{q}(1 + \frac{C_d}{C_{ox}})$ (in subthreshold, of course). The following formula holds:

$$I_D(V_{th}) = I_{off} \cdot 10^{\frac{V_{th}}{SS}}$$

Extract I_{off} at $T = 85\,[°C]$. Assume that the threshold voltage of your MOSFET changes with temperature according to $\frac{dV_{th}}{dT} = -4\,[mV/°C]$, over the range of interest for your application.
Hint: exploit the fact that the current $I_D(V_{th})$ is defined constant, independently of V_{th}.

Exercise 02

Consider the output characteristic $I_D(V_D)$ (reported below) of a long-channel NMOS transistor, for the case where its body contact (B) is shorted with the source (S) to ground ($0\,[V]$). The channel length is $L = 1\,[\mu m]$ and the gate oxide thickness is $t_{ox} = 10\,[nm]$. Answer the following questions:

- Assuming that the MOSFET has quasi-ideal long-channel transistor behavior, estimate its threshold voltage V_{th}.
- Estimate the electron mobility μ_n of its inversion channel at low transverse field. How does this value compare with the volume electron mobility?

- Estimate its transconductance g_m at $V_{GS} = 3\,[V]$ and $V_{DS} = 3\,[V]$ for $W = 10\,[\mu m]$, under the same assumption of the first point. Comment on the possibility of choosing the transconductance value by design and compare it with the value of a bipolar transistor.

- Estimate the capacitance C_{GS} for the same V_{GS}, V_{DS} and W. In saturation: $C_{GS} \approx \frac{2}{3} W L C_{ox}$.