10.42 An n-channel MOSFET has the same parameters as given in Problem 10.37. The gate terminal is connected to the drain terminal. Plot I_D versus V_{DS} for $0 \le V_{DS} \le 5$ V. Determine the range of V_{DS} over which the transistor is biased in the nonsaturation and saturation regions.

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10.37 An ideal n-channel MOSFET has the following parameters: $V_T = 0.45$ V, $\mu_n = 425$ cm^2/V-s, $t_{ox} = 11$ nm $= 110$ Å, $W = 20$ μm, and $L = 1.2$ μm.

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Gate & drain connected $\Rightarrow V_{GD} = 0 \Rightarrow V_{GS} = V_{DS}$

Per (10.43b), $V_{DS}(sat) = V_{GS} - V_T = V_{DS} - V_T$

$\hookrightarrow V_{DS} = V_{DS}(sat) + \overset{0.45}{V_T} > V_{DS}(sat)$

$\Rightarrow$ Always in saturation mode for $0 \le V_{DS} \le 5V$

Use (10.45a), $I_D = \frac{W \mu_n C_{ox}}{2L} \left(V_{GS} - V_T\right)^2$

Per (10.35), $C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.9(8.8541878 \times 10^{-12} F/m)}{11 \times 10^{-9} m}$ ← Table B.6 SiO_2

$= 3.13921 \times 10^{-3} F/m^2$

use MKS

$I_D = \frac{20 \times 10^{-6}(425 \times 10^{-4}) 3.1392 \times 10^{-3}}{2(1.2 \times 10^{-6})} (V_{DS} - 0.45)^2$

$I_D = 0.0011111804 (V_{DS} - 0.45)^2 \quad (A)$

Plot for $0 \le V_{DS} \le 5V$

Plot I_D versus V_{DS} using MathCAD

Given $T := 300\ K$ $VT := 0.45\ V$ $\mu n := 425 \cdot 10^{-4}\ m^2/V\text{-}s$

$tox := 11 \cdot 10^{-9}\ m$ $W := 20 \cdot 10^{-6}\ m$ $L := 1.2 \cdot 10^{-6}\ m$

Table B.6 SiO_2 at 300 K $\varepsilon rox := 3.9$ $\varepsilon 0 := 8.8541878 \cdot 10^{-12}\ F/m$

(10.35) $Cox := \frac{\varepsilon rox \cdot \varepsilon 0}{tox}$ $Cox = 3.139212 \times 10^{-3}\ F/m^2$

Saturation mode (10.45a) drain current with $V_{DS} = V_{GS}$ $ID(VGS) := \frac{W \cdot \mu n \cdot Cox}{2 \cdot L} \cdot (VGS - VT)^2 \cdot 1000\ mA$

$n := 0 .. 50$ $VDS_n := n \cdot 0.1$