Columbia University
Department of Electrical Engineering
EE 3106. Problem Set #7
Due: December 6, 2000

1. P& N, Volume 4, Problem 2.7

2. P& N, Volume 4, Problem 2.8

3. Consider an Si/SiO₂ MOS diode at 300K with \( t_{oxide} = 30 \text{nm} \), \( N_A = 5 \times 10^{15} \text{cm}^{-3} \). Assume that the area of the diode is \( 5 \times 10^{-4} \text{cm}^2 \). \( \Phi_{MS} = 3eV \). There is a positive fixed charge at the Si/SiO₂ interface with \( Q_F/q = 10^{11} \text{cm}^{-2} \).

(a) What is the flatband voltage \( V_{FB} \)? What is the threshold voltage \( V_T \)?

(b) Sketch the charge density, electric field, and electric potential at \( V_G = V_T \). Sketch the band diagram at \( V_G = V_T \). What is the electric field in the oxide? What is the electric field in the silicon at the Si/SiO₂ interface? What is the potential dropped across the oxide? What is the potential dropped across the silicon? What is the thickness of the depletion region?

(c) Plot the capacitance as a function of \( V_G \) at \( f = 500kHz \).
4. An n-channel silicon MOSFET at $T = 300K$ has $W = 50\mu m$, $L = 5\mu m$, $t_{oxide} = 0.05\mu m$, $N_A = 10^{15} \text{cm}^{-3}$, $\mu_n = 800 \text{cm}^2\text{V}^{-1}\text{sec}^{-1}$. Assume $V_{FB} = 0$.

(a) Find $V_T$.

(b) Plot $I_D$ versus $V_{DS}$ for $V_{GS} = 1$, 2, 3 V. You may use the square-law theory.

(c) Assume that the transistor is used in the circuit shown below. Using the square law theory, plot $\sqrt{I_D}$ as a function of $V_D$. Explain how this technique might be used to experimentally determine $V_T$ and $W/\mu C_{ox}/L$.

(c) If this FET is used in the circuit shown below, find the DC operating point and the small signal equivalent circuit at this operating point. The only capacitors you need to include in your model are $C_{gs}$ and $C_{gd}$. You may assume that in the linear region, $C_{gs} \approx C_{gd} \approx C_{ox}WL/2$. In the saturation region, you may assume $C_{gs} = (2/3)C_{ox}WL$ and $C_{gd} = 0$. 

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2 V
1000 Ohms
5 V
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