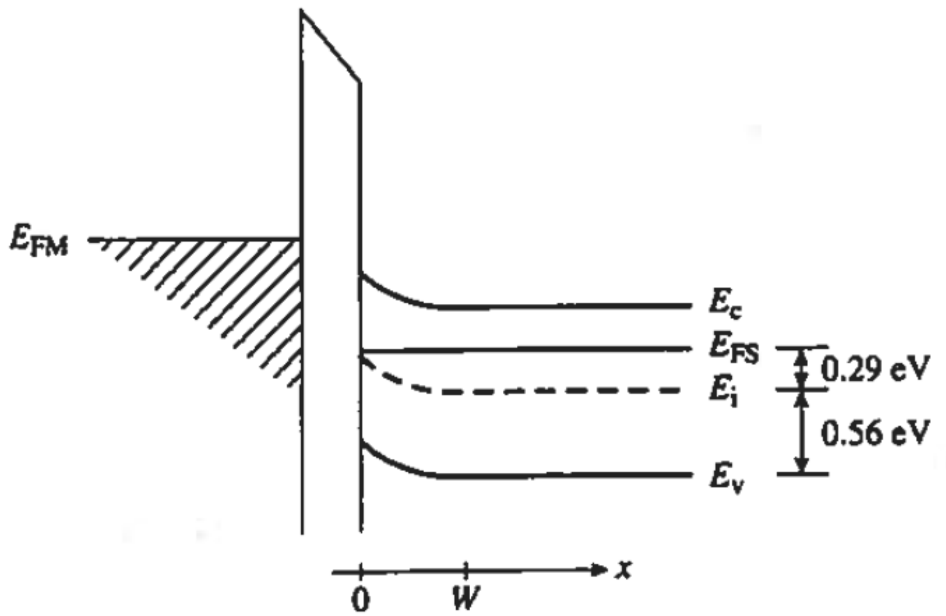
ECE 305 – Spring 2018

Homework 9 – Due Tuesday, April 3, 2018 at 12:00 PM in class (or in EE 326B)

1. Consider an ideal MOS capacitor made of crystalline silicon and silicon dioxide described by the band diagram below (may not be drawn to scale). Assume $\mathcal{E}_{ox} = 2 \cdot 10^4$ V/cm, $t_{ox} = 200$ nm, $K_{ox} = 4$, $K_{Si} = 12$, and $E_g = 1.12$ eV.



   a. Sketch the electrostatic field as a function of position x.

   b. Sketch the electron density as a function of position x.

   c. What is the level of n-type doping N_D in the semiconductor?

   d. What is the numerical value of the surface potential ϕ_s?

   e. What is the voltage drop across the oxide ΔV_{ox}?

   f. What is the electrostatic potential voltage of the gate electrode V_G', assuming that the right-hand side of the semiconductor is grounded?

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2. Consider a metal-oxide-semiconductor (MOS) capacitor with an oxide thickness t_{ox}, oxide dielectric constant K_{ox}, semiconductor dielectric constant K_{Si}, and semiconductor doping N_A. Assume that operation is at room temperature ($T = 300$ K).

   a. Using the delta-depletion approximation, show that the depletion width W as a function of gate bias goes as $W = \frac{K_{si}}{K_{ox}} t_{ox} \left[\sqrt{1 + \frac{V_G'}{V_\delta}} - 1\right]$. Write down the expression for V_δ in terms of K_{ox}, K_{Si}, N_A, t_{ox}, and basic constants. **Hint**: use $V_G' = \phi_S + \frac{K_{si}}{K_{ox}} t_{ox} \sqrt{\frac{2qN_A}{K_{si}\epsilon_o}\phi_S}$ and $W = \sqrt{\frac{2K_{si}\epsilon_o}{qN_A}\phi_S}$.

   b. Now assume that $t_{ox} = 0.1\ \mu\text{m}$, $N_A = 10^{15}\ \text{cm}^{-3}$, $K_{ox} = 4$, and $K_{Si} = 12$. Calculate the threshold voltage V_T'. Quantify how the depletion width and capacitance change as one goes from $V_G' = 0$ to $V_G' = V_T'$. **Hint:** Use $C = \frac{C_o}{\sqrt{1+V_G'/V_\delta}}$.