ECSE-2210 Microelectronics Technology
Homework 9 – Solution

1. An ideal MOS-C has $x_{ox} = 0.1$ μm, $N_D = 10^{15}$ cm^{-3}, and an area $A = 10^{-3}$ cm^2.
   a. Calculate ϕ_F in units of kT/q and in Volts.
   $\phi_F = (1/q)\,(E_i - E_F) = (1/q) \times kT \ln (10^{15} / n_i) = 11.5\ kT/q = -0.298$ V

   b. Calculate W when $\phi_S = 2\phi_F$.

   If $\phi_S = 2\phi_F$ then $W = W_T$. $W_T = 0.86$ μm using equation 16.16.

   c. Calculate $\mathcal{E}_S$ when $\phi_S = 2\phi_F$.

   $\mathcal{E}_S = -q\ N_D\ W/\varepsilon_s = -13760$ V/cm

   d. Calculate $V_G = V_T$ when $\phi_S = 2\phi_F$.

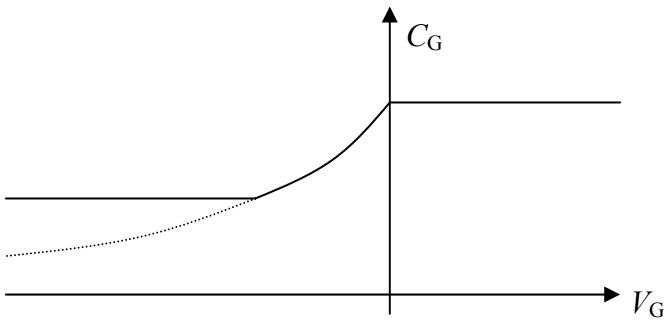
   If $\mathcal{E}_S = -13760$ V/cm in semiconductor, then $\mathcal{E}_{ox} = 3\ \mathcal{E}_S$
   $\mathcal{E}_{ox} = 41280$ V/cm

   Hence the total voltage is $V_G = V_T = 41280$ V/cm $\times\ 0.1 \times 10^{-4}$ cm $+ 2 \times (-0.298$ V)

   $V_G = V_T = -0.183$ V

   Or use equation 16.28 by properly using the signs (Make sure both parts are negative values. Think of physical reasons to remember this).

   e. Sketch the general shape (qualitative) of the high frequency C_G-V_G characteristic to be expected from this device.



f. Defining C_{max} to be the maximum high-frequency capacitance, determine C_{max}.

$C_{max} = C_{ox} = \varepsilon_{ox} A / x_{ox} = (1/3) \times 10^{-12}$ F/cm $\times 10^{-3}$ cm^2 / (0.1×10^{-4} cm) = 34.5 pF

g. Defining C_{min} to be the minimum high-frequency capacitance, determine C_{min}.

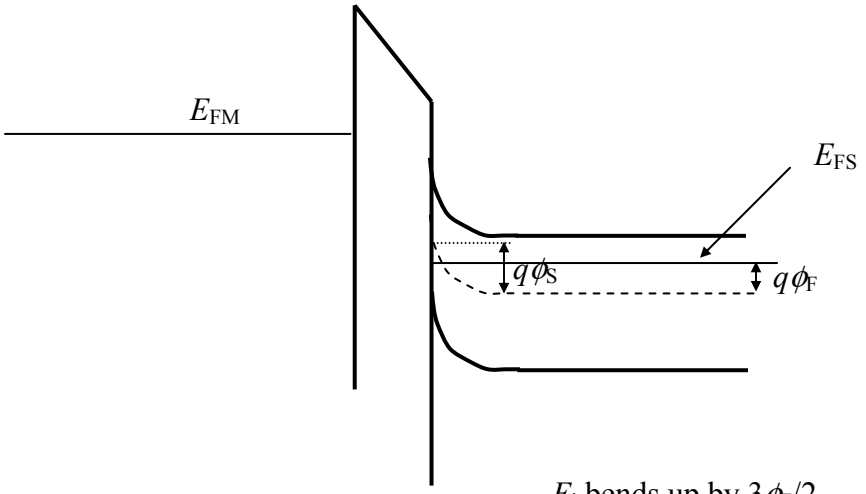
$\phi_F = -0.0259$ V ln [$10^{15} / 10^{10}$] = – 0.298 V

$W_T = [2\varepsilon_{Si} / (q\, N_D) \times 2 \times 0.298 \text{ V}]^{1/2} = 8.6 \times 10^{-5}$ cm (calculated earlier)

C_S = semiconductor capacitance = $\varepsilon_{Si} A / W_T$ = 11.6 pF

Therefore, $C_{min} = C_{ox}\, C_S / (C_{ox} + C_S)$ = 8.6 pF

h. Suppose the gate bias is such that $\phi_S = 3\phi_F / 2$. Draw the MOC-capacitor energy band diagram corresponding to the specified gate bias. (be sure to include the diagrams for all three components of the MOS- capacitor, show the proper band bending in both the oxide and the semiconductor, and properly position the Fermi level in the metal and the semiconductor.)



E_i bends up by $3\phi_F/2$.

i. The *C-V* characteristic of the device is measured as the dc bias is **rapidly** swept from accumulation into inversion. Using a dashed line, sketch the expected form of the resulting *C-V* characteristic on the same set of coordinates as in the part (e) answer. See graph in problem e.