6.3  
(a) Consider n-type silicon in an MOS structure. Let $T = 300K$. Determine the semiconductor doping so that $\left| Q'_{SD} \right|_{\text{max}} = 7.5 \times 10^{-9} \text{ C/cm}^2$  
(b) Determine the surface potential that results in the maximum space charge width.

6.5  
Consider an MOS structure with n-type silicon. A metal-semiconductor work function difference of $\phi_{ms} = -0.35 \text{ V}$ is required. Determine the silicon doping required to meet this specification when the gate is (a) $n^+$ polysilicon, (b) $p^+$ polysilicon, and (c) aluminum. If a particular gate cannot meet this requirement, explain why.

6.7  
Consider an aluminum gate-silicon dioxide-p-type silicon MOS structure with $t_ox = 450 \text{ Å}$. The silicon doping is $N_a = 2 \times 10^{16} \text{ cm}^{-3}$ and the flat-band voltage is $V_{FB} = -1.0 \text{ V}$. Determine the fixed oxide charge $Q'_{SS}$.

6.10  
A 400Å oxide is grown on p-type silicon with $N_a = 5 \times 10^{15} \text{ cm}^{-3}$. The flat-band voltage is -0.9 V. Calculate the surface potential at the threshold inversion point as well as the threshold voltage assuming negligible oxide charge. Also find the maximum space charge width for this device.
6.11 An MOS transistor with an aluminum gate is fabricated on a p-type silicon substrate. The oxide thickness is \( t_{ox} = 450 \, \text{Å} \), and the equivalent fixed oxide charge is \( Q_{ss}' = 8 \times 10^{10} \, \text{cm}^{-2} \). The measured threshold voltage is \( V_T = +0.80 \, \text{V} \). Determine the p-type doping concentration.

6.16 The threshold voltage of an n-channel MOSFET is given by Equation (6.34a). Plot \( V_T \) versus temperature over the range \( 200 \leq T \leq 480 \, \text{K} \). Consider both an aluminum gate and an \( n^+ \) polysilicon gate. Assume the work function are independent of temperature and use device parameters similar to those in Example 6.5.

6.19 Consider an NMOS device with the parameters given in Problem 6.10. Plot \( V_T \) versus \( t_{ox} \) over the range \( 20 \leq t_{ox} \leq 500 \, \text{Å} \).

6.20 An ideal MOS capacitor with an aluminum gate has a silicon dioxide thickness of \( t_{ox} = 400 \, \text{Å} \) on a p-type silicon substrate doped with an acceptor concentration of \( N_a = 10^{16} \, \text{cm}^{-3} \). Determine the capacitances \( C_{ox} \), \( C'_{FB} \), \( C'_{\text{min}} \), and \( C'_{\text{inv}} \) at (a) \( f = 1 \, \text{Hz} \) and (b) \( f = 1 \, \text{MHz} \). (c) Determine \( V_{FB} \) and \( V_T \). Sketch \( C'/C_{ox} \) versus \( V_G \) for parts (a) and (b).
6.27 The high-frequency $C$-$V$ characteristic curve of an MOS capacitor is shown in Figure P6.27. The area of the device is $2 \times 10^{-3}$ cm$^2$. The metal-semiconductor work function difference is $\phi_{ms} = -0.50$ V, the oxide is SiO$_2$, the semiconductor is silicon, and the semiconductor doping concentration is $2 \times 10^{16}$ cm$^{-3}$. (a) Is the semiconductor n or p type? (b) What is the oxide thickness? (c) What is the equivalent trapped oxide charge density? (d) Determine the flat-band capacitance.

![Figure P6.27](image)

6.38 One curve of an n-channel MOSFET is characterized by the following parameters: $I_D(sat) = 2 \times 10^{-4}$ A, $V_{DS}(sat) = 4$ V, and $V_T = 0.8$ V. (a) What is the gate voltage? (b) What is the value of the conduction parameter? (c) If $V_G = 2$ V and $V_D = 2$ V, determine $I_D$. (d) If $V_G = 3$ V and $V_D = 1$ V, determine $I_D$. (e) For each of the conditions given in (c) and (d), sketch the inversion charge density and depletion region through the channel.
6.39 (a) An ideal n-channel MOSFET has an inversion carrier mobility \( \mu_n = 525 \text{ cm}^2/\text{V} \cdot \text{s} \), a threshold voltage \( V_T = +0.75 \text{ V} \), and an oxide thickness \( t_{ox} = 400 \text{ Å} \). When biased in the saturation region, the required rated current is \( I_D(sat) = 6 \text{ mA} \) when \( V_{GS} = 5 \text{ V} \). Determine the required \( W/L \) ratio. (b) A p-channel MOSFET has the same requirements when \( V_{GS} = 5 \text{ V} \) and has the same parameters as part (a) except \( \mu_p = 300 \text{ cm}^2/\text{V} \cdot \text{s} \) and \( V_T = -0.75 \text{ V} \). Determine the \( W/L \) ratio.

6.43 Consider a p-channel MOSFET with \( t_{ox} = 400 \text{ Å} \) and \( N_d = 5 \times 10^{15} \text{ cm}^{-3} \). Determine the body-to source voltage, \( V_{BS} \), such that the shift in threshold voltage, \( \Delta V_T \), from the \( V_{BS} = 0 \) curve is \( \Delta V_T = -1.5 \text{ V} \).

6.47 An n-channel MOSFET has the following parameters:

\[
\mu_n = 400 \text{ cm}^2/\text{V} \cdot \text{s} \quad t_{ox} = 500 \text{ Å} \quad L = 2 \mu\text{m} \quad W = 20 \mu\text{m} \quad V_T = +0.75 \text{ V}
\]

Assume the transistor is biased in the saturation region at \( V_{GS} = 4 \text{ V} \). (a) Calculate the ideal cutoff frequency. (b) Assume that the gate oxide overlaps both the source and drain contacts by \( 0.75 \mu\text{m} \). If a load resistance of \( R_L = 10 \text{ k\Omega} \) is connected to the output, calculate the cutoff frequency.
Design an ideal silicon n-channel MOSFET with a polysilicon gate to have a threshold voltage of $V_T = +0.65 \, \text{V}$. Assume an oxide thickness of $t_{ox} = 300 \, \text{Å}$, a channel length $L = 1.25 \, \text{μm}$, and a nominal value of $Q_{ss}' = 1.5 \times 10^{11} \, \text{cm}^{-2}$. It is desired to have a drain current of $I_D = 50 \, \text{μA}$ at $V_{GS} = 2.5 \, \text{V}$ and $V_{DS} = 0.1 \, \text{V}$. Determine the substrate doping concentration, channel width and type of gate required.

Please submit your homework to R514, EE-II