Assume silicon, room temperature, complete ionization.

\( q = 1.6 \times 10^{-19} \, \text{C} \), \( \varepsilon_{\text{ox}} = 3.9 \times 8.85 \times 10^{-14} \, \text{F/cm} \), \( \varepsilon_{\text{si}} = 11.7 \times 8.85 \times 10^{-14} \, \text{F/cm} \), \( kT/q = 0.0259 \, \text{V} \), 
\( E_g = 1.12 \, \text{eV} \), electron affinity \( \chi = 4.0 \, \text{eV} \), \( n_i = 10^{10} \, \text{cm}^{-3} \)

1. For an nMOSFET with \( t_{\text{ox}} = 20 \, \text{nm} \), \( \mu_n = 500 \, \text{cm}^2/\text{V-s} \), \( W = 10 \, \mu\text{m} \), \( L = 5 \, \mu\text{m} \), \( V_T = 0.5 \, \text{V} \), biased at \( V_{\text{gs}} = 3 \, \text{V} \) and \( V_{\text{ds}} = 0.1 \, \text{V} \).
   (a) Calculate the drain current and the transconductance.
   (b) What is the electron areal density and the electron velocity in the channel?

2. An MOS device has the following high-frequency C-V curve. The oxide is 15 nm thick. The silicon doping is \( 3 \times 10^{17} \, \text{cm}^{-3} \) (which type?). Neglect interface charge.
   (a) Draw the band diagram (include the gate electrode and the gate oxide, label the Fermi levels) at bias point A (\( V_{\text{g}} = 0 \)).
   (b) If the capacitance \( C \) at point A is half of the oxide capacitance, what is the surface potential (band bending) at A?

3. Consider an nMOSFET with a gate oxide thickness of 15 nm and p-type substrate doping of \( 5 \times 10^{16} / \text{cm}^3 \). The interface charge is negligible. The gate work function is 4.5 eV.
   (a) What is the threshold voltage?
   (b) Calculate the total charge per area in silicon at a gate voltage 1.0 V above the threshold voltage (assume zero source-drain voltage).
   (c) If a 2.0 V reverse bias is applied to the substrate, what will the threshold voltage be?