1. A silicon $pn$ junction has very high doping on the $p$-side ($x < 0$, assume $E_{F_p} = E_V$ in $p$-region), $n$-type doping of $N_{d1}$ for $0 < x < x_1$ and $N_{d2}$ for $x > x_1$. Assume that all of the dopants are fully ionized and use the depletion approximation.

   (a) If $N_{d1} = 10^{18}$ cm$^{-3}$, $N_{d2} = 10^{17}$ cm$^{-3}$, $x_1 = 0.02\mu$m, and $x_n = 0.05\mu$m, sketch the charge density, electric field and potential as a function of distance from the surface. What is the applied bias?

   (b) Assuming that $x_n > x_1$ and $N_a \gg N_{d1}, N_{d2}$, determine expressions for the depletion region width, total depletion charge and depletion capacitance as function of applied voltage.

2. Consider a contact between aluminum ($\Phi_M = 4.1$ V) and silicon ($\chi_S = 4.05$ V) doped with $N_d = 10^{18}$ cm$^{-3}$. Assume that the silicon surface states have a neutrality level of $E_v + 0.5$ eV. Determine the barrier (if any) for electrons from the semiconductor to the metal if there are:

   (a) No surface states.

   (b) An infinite density of surface states.

   (c) A large (but not infinite density) of surface states equal to $N_{ss}(E) = 7 \times 10^{14}$ cm$^{-2}$eV$^{-1}$. Assume that the surface states are located an average distance of 0.1 nm into the silicon and the electrons in the aluminum located an average distance of 0.1 nm into the metal. Use the silicon dielectric constant for all materials. (Hint: As for pn-junction, assume a value for the depletion region width and determine expression for voltage drop across junction which equals built-in voltage.)