1. In a forward biased pn junction diode, $L_{n,p} << $ device length.
   
   (a) Write down the expression for stored charge on both sides of the pn junction, $Q_n$ and $Q_p$, in terms of device parameters such as $N_D$, $N_A$, $V_A$, etc. (3 points)

   (b) Rewrite the expression of current density in terms of $Q_n$ and $Q_p$. (3 points)

   (c) Interpret the physical meaning of the expression you derived in part (b). (2 points)

   (d) How does the current change (increase or decrease) at a given forward bias as temperature increase? Demonstrate your answer with equations (use the back of this sheet if necessary). (4 points)
2. A silicon step function has \(N_A = 5 \times 10^{15} \text{ cm}^{-3}\) and \(N_D = 10^{15} \text{ cm}^{-3}\), \(D_N = 34 \text{ cm}^2/\text{sec}\), \(D_P = 12 \text{ cm}^2/\text{sec}\), \(n_i = 10^{10} \text{ cm}^{-3}\), \(kT = 0.026 \text{ eV}\), \(A = 10^{-4} \text{ cm}^2\), \(\tau_p = 0.4 \mu\text{s}\), and \(\tau_n = 0.1 \mu\text{s}\). Calculate.

(a) the reverse saturation current due to holes. (3 points)

(b) the reverse saturation current due to electrons. (3 points)

(c) reverse saturation current, \(I_0\). (2 points)

(d) If \(V_A = \phi/2\), calculate the
   i. hole concentration at \(x_n\) and injected hold concentration at \(x_n\). (3 points)
   
   ii. Hole concentration at \(x' = L_p/2\).

   iii. Electron concentration at \(-x_p\) and injected electron concentration at \(-x_p\).
       (3 points)

   iv. Electron concentration at \(x'' = L_n/2\). (3 points)

(e) Calculate the total injected hole charge for \(V_A = \phi/2\). (3 points)