1. (15%)
   It is well known that the diffusion of electrons from a region of high concentration to a region of low concentration produces current density due to a flux of electrons. D_n is the electron diffusion coefficient, and \( \mu_n \) is electron mobility. Consider diffusion of electrons due to a density gradient shown as:

   ![Graph](image)

   (a) Please write the electron diffusion current density for this one-dimensional case. Please also specify the direction of electron flux and diffusion current.

   (b) For a silicon with a certain concentration of electron, \( n_s \), under applied electric field, what is the current density?

   (c) What is the total current density for this one-dimensional case? For normal device operation, is the drive current dominated by the current in (a) or (b)? Why?

2. (20%)
   Consider a compensated silicon at \( T = 300 \) K contains an acceptor impurity concentration of \( N_A = 5 \times 10^{15}/\text{cm}^3 \). Now certain concentration of donor impurity atoms, \( N_D \), are added so that the silicon is n-type material and the Fermi energy is 0.2 eV below the conduction band edge.
   (a) Assume all dopant atoms are completely ionized, what is the charge neutrality equation?
   (b) Find the concentration of \( N_D \) that must be added.

3. (15%)
   Electrons are incident from the left on a one dimension barrier at Si/SiO_2 interface as shown below. Assume that the potential barrier extends to infinity.

   ![Diagram](image)

   The electrons energy is less than \( V_0 \), i.e., \( E < V_0 \).
(a) Please solve Schrodinger’s equation.
(b) Find the transmission and reflection probabilities.

4. Consider a forward-biased silicon PN junction diode at 300K. Assume that the ideal reverse-saturation current density is \( J_s = 10^{-41} A/cm^2 \) and the recombination current density is \( J_r = 10^{-7} A/cm^2 \). Calculate the forward-bias voltage at which the ideal diffusion current is equal to the recombination current. (15%) 

5. Consider an n-MOSFET with \( W=15\mu m \), \( L=2\mu m \), and \( C_{ox} = 69 \times 10^{-8} F/cm^2 \). Assume that the drain current in the linear region for \( V_{ds} = 0.1V \), \( I_d = 35\mu A \) at \( V_{gs} = 1.5V \), and \( I_d = 75\mu A \) at \( V_{gs} = 2.5V \). Please determine the carrier mobility from experimental results. (15%) 

6. Sketch capacitance-voltage curve of the MOS structures shown in the below figures. The capacitance was measured at 100kHz. In all cases, the gate DC bias is varied slowly. Meanwhile, explain why? (20%)