1. A semiconductor is nonuniformly doped with donor impurity atoms $N_D(x)$. Please show that the electric field induced in the semiconductor under thermal equilibrium condition can be expressed as

$$\mathscr{E}(x) = -\left(\frac{kT}{q}\right)\frac{1}{N_D(x)}\frac{dN_D(x)}{dx} \quad (15\%)$$

2. For the compressively strained $Si_{1-x}Ge_x$ grown on unstrained silicon, that is, an n-type Si/p-type $Si_{0.9}Ge_{0.1}$ heterojunction at room temperature, the valence band offset $\Delta E_V = 0.073$ eV. The bandgap of $Si_{1-x}Ge_x$ is given by $1.17 - 0.96x + 0.43x^2 - 0.17x^3$, and the dielectric constant is given by $\varepsilon(x) = 11.9(1 + 0.35x)$. Find the total depletion width at thermal equilibrium when n-Si and p-$Si_{0.9}Ge_{0.1}$ have impurity concentrations of 1×10^{16} and 1×10^{17} cm^{-3}, respectively. (Hint: N_C (Si) $= 2.8 \times 10^{19}$ cm^{-3} and N_V ($Si_{0.9}Ge_{0.1}$) $= 3.328 \times 10^{18}$ cm^{-3}) (15%)

3. A GaAs is doped with 10^{18} P atoms/cm^3. What would be the resultant equilibrium hole concentration p_o at 300 K? Where is the position of E_F relative to E_i? (Hint: n_i for GaAs at 300 K is 2.25×10^6 cm^{-3}) (10%)

4. An ideal Si p-n junction has $N_D = 10^{19}$ cm^{-3}, $N_A = 10^{17}$ cm^{-3}, $\tau_p = \tau_n = 10^{-6}$ s, and with a device area of 1.0×10^{-6} cm^2.
   (a) Determine the theoretical saturation current at 300 K. (5%)
   (b) What would be the forward and reverse currents at ±1 V. (5%)

5. Assume the distribution of volume charge density, $\rho_{ot}(x)$, for oxide-trapped charge Q_{ot} in an oxide layer of a MOS diode is $(10^{17} - 4 \times 10^{22} \times x)$ cm^{-3}, where x is the distance from the location to the metal-oxide interface. If the thickness of the oxide layer is 25 nm, find the change in the flat-band voltage due to Q_{ot}. The dielectric constant of oxide is 3.9 and permittivity ε_0 is 8.85×10^{-14} F/cm. (10%)

（背面仍有題目,請繼續作答）

6. A MOSFET has a threshold voltage of V_T = 0.4 V, a subthreshold swing of 80 mV/dec, and a drain current of 1 μA at V_T. Find the subthreshold leakage current at gate voltage is 0 V. (8%)

7. For a tungsten-silicon Schottky diode with donor concentration $N_D = 10^{16}$ cm^{-3} at 300 K, find the following from forward current density vs. applied voltage characteristics shown in Fig. 1. The dielectric constant of silicon is 11.9, effective Richardson constant A* is 110 A/K^2-cm^2, and effective density of states in the conduction band N_C is 2.8×10^{19} cm^{-3}.
(a) barrier height (8%)
(b) depletion layer width (8%)

8. A single crystal silicon sample 0.5 μm thick (absorption coefficient $\alpha = 10^4$ cm^{-1}) is illuminated with a monochromatic light having wavelength of 496 nm. The incident power is 1 mW. The energy gap of silicon is 1.1 eV. Find the following:
(a) The total energy absorbed by the silicon per second. (8%)
(b) The number of photons per second given off from recombination by intrinsic transitions. (8%)

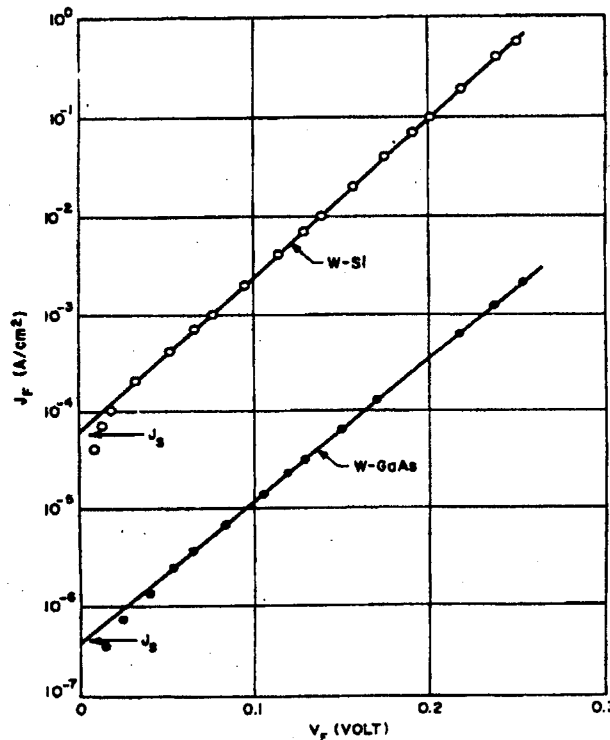

Fig. 1