ECSE-2210 Microelectronics Technology
Homework 4 – Solution

1. a) $\dfrac{D_n}{\mu_n} = \dfrac{kT}{q}$ ➔ $D_n = (kT/q)\,\mu_n = 0.025\text{ V} \times 1000\text{ cm}^2/\text{Vs} = 25\text{ cm}^2/\text{s}$

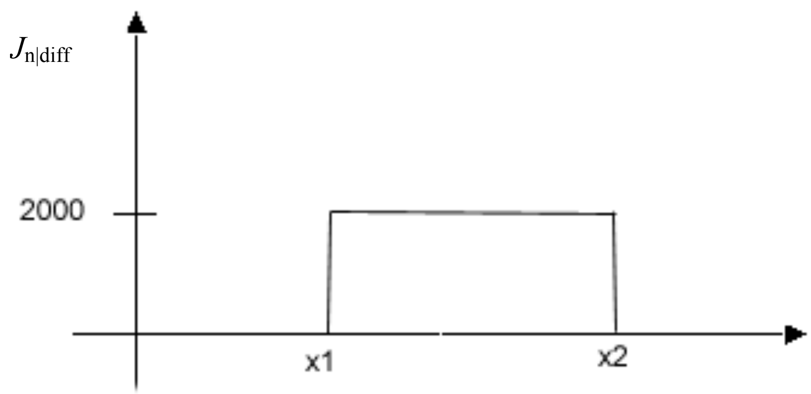
Note: $kT = 0.025\text{ eV} = 0.025 \times 1.6 \times 10^{-19}\text{ CV} = 0.025 \times 1.6 \times 10^{-19}\text{ J}$

$kT/q = (0.025 \times 1.6 \times 10^{-19}\text{ J}) / 1.6 \times 10^{-19}\text{ C} = 0.025\text{ V}$

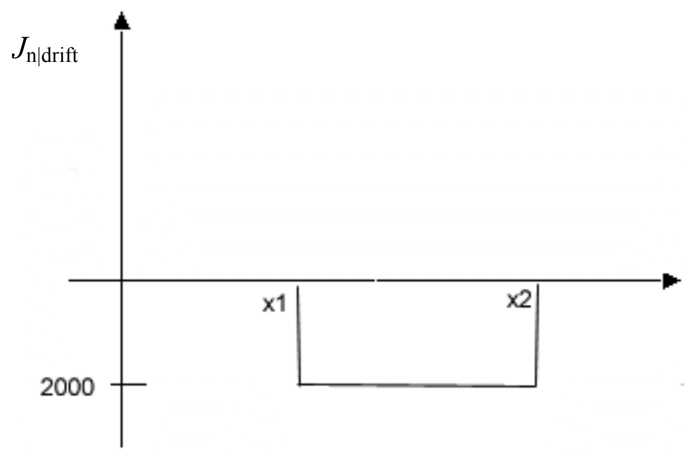
b) Internally generated $\mathcal{E}$-field prevents diffusion of electrons in this case.

c) $J_{n|diff} = q\, D_n \dfrac{dn}{dx} = 1.6 \times 10^{-19}\text{ C} \times 25\text{ cm}^2/\text{s} \times (5\times10^{17} - 10^{12})\text{ cm}^{-3} / (10 \times 10^{-4}\text{ cm})$

$= 2000\text{ A/cm}^2$



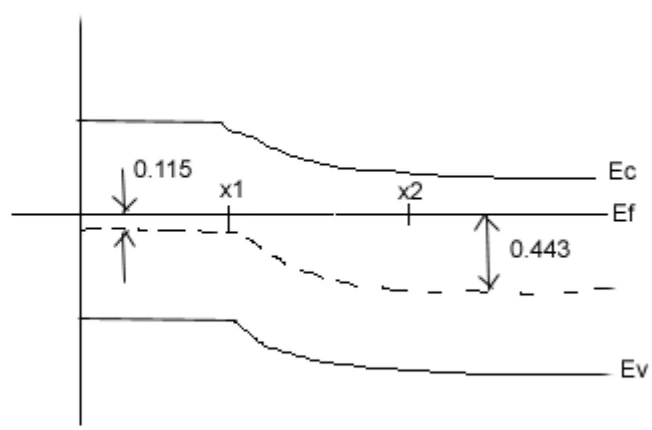
d) *Total current density* = 0 (under equilibrium), therefore: $J_{n|drift} = -J_{n|diff}$



e) $n = n_i \exp\left(\frac{E_F - E_i}{kT}\right) \Rightarrow E_F - E_i = \frac{kT}{q} \ln\left(\frac{n}{n_i}\right)$

$n = 1 \times 10^{12}\ \text{cm}^{-3} \Rightarrow E_F - E_i = 0.115$ eV

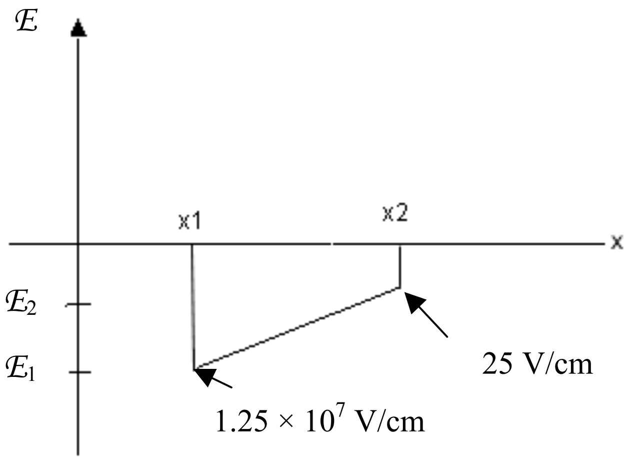
$n = 5 \times 10^{17}\ \text{cm}^{-3} \Rightarrow E_F - E_i = 0.443$ eV



f) *Potential difference* = 0.328 V (Right side is at a higher potential. Plot the band diagram "upside down" to get potential)

g) Note: $J_{n|drift} = q\, n\, \mu_n\, \mathcal{E}$ = constant (see above).

Since n increases linearly with x, and $J_{n|drift}$ is constant, $\mathcal{E}$ field will decrease linearly as shown between x_1 and x_2.



2. a) $R = \rho \times l / A$

$l = R\,A / \rho$

The electron mobility for $N_A + N_D = 9 \times 10^{17}$ cm^{-3} is about $\mu_n = 300$ cm^2/Vs.

$n = 10^{17}$ cm^{-3} since $N_D - N_A = 10^{17}$ cm^{-3}.

$\rho = (q\,\mu_n\,n)^{-1} = 0.208\ \Omega$ cm

$l = R\,A / \rho = 5\ \Omega \times 10^{-2}$ cm^2 / 0.208 Ω cm = 0.24 cm (approximate value)