# Tutorial 6

General Notation

$n_e = n$

$n_p = p$

**Q.1** Given: $n_i = 1.5 \times 10^{10} \ /cm^3$

$\mu_e = 1300 \ cm^2/V\text{-}s$

$\mu_p = 500 \ cm^2/V\text{-}s$

$\rho = \frac{1}{\sigma} = ?$

In intrinsic Si $\rightarrow$ $n_e = n_p = n_i$ $\quad (n_e = n_p = n_i)$

$\sigma = n_e q \mu_e + n_p q \mu_p$

$= q n_i (\mu_e + \mu_p)$

$= 1.6 \times 10^{-19} \times 1.5 \times 10^{10} \times (1300 + 500)$

$= 1.6 \times 10^{-19} \times 1.5 \times 10^{10} \times 1800$ $\quad$ Coulomb $\times \frac{1}{cm^2} \times \frac{cm^2}{V\text{-}sec}$

$= 4.320 \times 10^{-6}$ $\quad$ Coulomb $\times \frac{1}{cm} \times \frac{}{V\text{-}sec}$

$= 4.320 \times 10^{-6}$ $\quad \frac{Amp}{cm} \times sec$

$= 4.320 \times 10^{-6}$ $\quad \frac{Coulomb}{cm \ V \ sec}$

$= 4.320 \times 10^{-6}$ $\quad \frac{Amp}{cm \ (volt)}$

$= 4.320 \times 10^{-6}$ $\quad \frac{1}{cm \ \Omega}$

$= 4.320 \times 10^{-6} \ \Omega^{-1} cm^{-1}$

$\rho = \frac{1}{\sigma} = \frac{1}{4.320 \times 10^{-6}} \ \Omega \ cm = 0.2314 \times 10^{6} \ \Omega \ cm$

Q.2 Given: $n_i = 1.5 \times 10^{10} / cm^3$

Concentration of Si atoms = $5 \times 10^{22}$ atoms$/cm^3$

$N_D$ (conc. of dopants which ≈ phosphorus here) $= (5 \times 10^{22}) \left(\frac{4}{10^8}\right) = 20 \times 10^{14} / cm^3$

$= 2 \times 10^{15} / cm^3$

$n \approx N_D = 2 \times 10^{15} / cm^3$ ← $e^-$ conc.

$p \approx \frac{n_i^2}{N_D} = \frac{(1.5 \times 10^{10})^2}{2 \times 10^{15}} = 1.125 \times 10^5 / cm^3$ ← hole conc.

Assuming mobilities are same as in ques. (1) –

$\sigma = n q \mu_n + p q \mu_p$

$= q(n\mu_n + p\mu_p)$

$= 1.6 \times 10^{-19} \left(2 \times 10^{15} \times 1300 + 1.125 \times 10^5 \times 500\right)$

$= 1.6 \times 10^{-19} \left(260 \times 10^{16} + 562.5 \times 10^5\right)$

$\approx 1.6 \times 10^{-19} \times 260 \times 10^{16}$

$= 416 \times 10^{-3} \ \Omega^{-1} cm^{-1}$

$\rho = \frac{1}{416 \times 10^{-3}} \ \Omega$ cm [redacted]

Q.3 Given: $N_A = 10^{15}/cm^3$

$N_D = 10^{16}/cm^3$

$$V_T = \frac{KT}{q} \ln \frac{N_A N_D}{n_i^2} = (25mV) \ln \left( \frac{10^{15} \times 10^{16}}{(1.5 \times 10^{10})^2} \right)$$

$\frac{KT}{q}$ @ 300K ≈ 25mV

KT @ 300K ≈ 25 meV

$= (25mv) \ln (0.45 \times 10^{11})$

$= (25mv)(24.529)$

$= 613.248\ mV$