Module 2 Unit 1

SEMICONDUCTORS – FORMULA SHEET

Parameter	Formula
1. Number of atoms per unit volume	$n = \frac{D \times N_0}{M}$
2. Effective mass	$m^* = \frac{\hbar^2}{\left(\frac{d^2E}{dk^2}\right)}$
3. Intrinsic carrier concentration	$n = p = n_i = \sqrt{N_C N_V} \exp\left(-\frac{E_g}{2kT}\right)$
4. Extrinsic carrier concentration	N-type: • Majority carriers: $n_n \approx N_D$ at RT • Minority carriers: $p_n \approx \frac{n_i^2}{N_D}$ at RT • $n = N_C \exp\left(-\frac{E_C - E_F}{kT}\right)$ at moderate temperatures N-type: • Majority carriers: $p_p \approx N_A$ at RT • Minority carriers: $n_p \approx \frac{n_i^2}{N_A}$ at RT • $p = N_V \exp\left(-\frac{E_F - E_V}{kT}\right)$ at moderate temperatures
5. Conductivity and resistivity	Conductivity: Intrinsic: $\sigma_i = qn_i(\mu_n + \mu_p)$ N-type: $\sigma_n = qn\mu_n$ P-type: $\sigma_p = qp\mu_p$ Resistivity: $\rho = \frac{1}{\sigma}$
6. Drift velocity and mobility	Drift velocity: $v_d = \mu\varepsilon$ Mobility: $\mu = \frac{q\langle\tau\rangle}{m^*}$; $\langle\tau\rangle$: average charge carrier lifetime

7. Drift current density	Electrons: $J_n(\text{drift}) = qn\mu_n\varepsilon = \sigma_n\varepsilon$ Holes: $J_p(\text{drift}) = qp\mu_p\varepsilon = \sigma_p\varepsilon$
8. Diffusion current density	Electrons: $J_n(\text{diffusion}) = qD_n\frac{dn}{dx}$ Holes: $J_p(\text{diffusion}) = -qD_p\frac{dp}{dx}$
9. Einstein's relation	$\frac{D}{\mu} = \frac{kT}{q} = \text{constant at a given temperature}$
10. Probability factor for occupation of energy level E (Fermi-Dirac function)	Electrons: $F(E) = \frac{1}{1 + \exp\left(\frac{E - E_F}{kT}\right)}$ Holes: $1 - F(E)$
11. Position of Fermi level in intrinsic semiconductors	$E_F = E_i = \frac{E_C + E_V}{2} + \frac{3}{4}kT\ln\frac{m_h^*}{m_e^*} \approx \frac{E_g}{2}$
12. Fermi level shift due to doping	N-type: $E_F - E_i = kT\ln\left(\frac{n}{n_i}\right)$; $p \approx N_A$ at RT P-type: $E_F - E_i = -kT\ln\left(\frac{p}{n_i}\right)$; $n \approx N_D$ at RT
