EE-4231 (Useful Equations)

$E = h\nu \qquad h\nu = E_2 - E_1$

Quantum Mechanics

$$p(x) \rightarrow \frac{\hbar}{j}\frac{\partial}{\partial x}; \quad \text{E} \rightarrow -\frac{\hbar}{j}\frac{\partial}{\partial t}$$

$$\langle f(x) \rangle = \frac{\int_{-\infty}^{\infty} f(x)P(x)dx}{\int_{-\infty}^{\infty} P(x)dx}$$

$$\varphi_n = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}; \quad E_n = \frac{n^2\pi^2\hbar^2}{2mL^2}$$

$$T = 16\left(\frac{E}{V_o}\right)\left(1-\frac{E}{V_o}\right)e^{-2ka}; \; k = \sqrt{\frac{2m(V_o - E)}{\hbar^2}}$$

Hydrogen Atom

$$r_n = \frac{Kn^2\hbar^2}{mq^2}; \; E_n = -\frac{mq^4}{2K^2n^2\hbar^2}; \; K = 4\pi\varepsilon_o\varepsilon_r$$

Semiconductors

$$m^* = \frac{\hbar^2}{d^2E/dk^2}$$

$$f(E) = \frac{1}{1 + e^{(E-E_f)/kT}}$$

$$n_0 = N_c e^{-(E_c - E_f)/KT}; \; p_0 = N_v e^{-(E_f - E_v)/KT}$$

$$N_c = 2\left[\frac{2\pi m_n^* kT}{h^2}\right]^{3/2} \qquad N_v = 2\left[\frac{2\pi m_p^* kT}{h^2}\right]^{3/2}$$

$$n_i = \sqrt{N_c N_v}\, e^{-E_g/2kT}$$

$$n_0 p_0 = n_i^2$$

$$n_0 = n_i e^{(E_f - E_i)/kT}; \; p_0 = n_i e^{(E_i - E_f)/kT}$$

$$p_0 + N_d^+ = n_0 + N_a^-$$

$$J_x = q(n\mu_n + p\mu_p)E_x = \sigma E_x$$

$$\mu_n = \frac{|v_d|}{E}$$

$$R = \frac{\rho L}{wt} = \frac{L}{wt}\frac{1}{\sigma}$$

Interaction of Photons & Semiconductors

$$I_t = I_0 e^{-\alpha\ell}$$

$$\tau_n = \frac{1}{\alpha_r(n_0 + p_0)}$$

$$\delta n = \tau_n g_{op}; \; \delta p = \tau_p g_{op}$$

$$n = n_i e^{(F_n - E_i)/kT}; \; p = n_i e^{(E_i - F_p)/kT}$$

$$\delta n(t) = \Delta n e^{-\alpha_r p_0 t} = \Delta n e^{-t/\tau_n}$$

$$g_{op} = \alpha_r n_0 \delta n + \alpha_r \delta n^2$$

Drift and Diffusion Currents

$$J_n(x) = q\mu_n n(x)E(x) + qD_n\frac{dn(x)}{dx}$$

$$J_p(x) = q\mu_p p(x)E(x) - qD_p\frac{dp(x)}{dx}$$

$$\frac{D}{\mu} = \frac{kT}{q}$$

PN Junctions

$$V_0 = \frac{kT}{q}\ln\frac{N_a N_d}{n_i^2}$$

$$W = \left[\frac{2\varepsilon V_0}{q}\left(\frac{1}{N_a} + \frac{1}{N_d}\right)\right]^{\frac{1}{2}}$$

$$E_0 = -\frac{q}{\varepsilon}N_d x_{n0} = -\frac{q}{\varepsilon}N_a x_{p0}$$

$$x_{p0} = \frac{WN_d}{N_a + N_d}; \; x_{n0} = \frac{WN_a}{N_a + N_d}$$

$$Q_+ = -Q_- = qAN_d x_{n0} = qAN_a x_{p0}$$

$$I = qA\left[\frac{D_p}{L_p}p_n + \frac{D_n}{L_n}n_p\right]\left(e^{qV/kT} - 1\right)$$

$$L_p = \sqrt{D_p\tau_p}; \qquad L_n = \sqrt{D_n\tau_n}$$

$$C_j = A\left[\frac{q\varepsilon}{2(V_o - V)}\left(\frac{N_d N_a}{N_d + N_a}\right)\right]^{\frac{1}{2}}$$

Constants (at 300 ^{o}K)

kT = 0.0259 eV
1 eV = 1.6 x 10^{-19} J
q = 1.6 x 10^{-19} C
m_o = 9.11 x 10^{-31} kg
h = 6.63 x 10^{-34} J-s
ε_o = 8.85 x 10^{-14} F/cm
Silicon: E_g = 1.11 eV; n_i = 1.5 x 10^{10}/cm^3
μ_n = 1350 cm^2/V-s; μ_p = 480 cm^2/V-s
ε_r = 11.8
GaAs: E_g = 1.43 eV; n_i = 10^6/cm^3
μ_n = 8500 cm^2/V-s; μ_p = 400 cm^2/V-s
ε_r = 13.2