

Cheat Sheet

Constants

$$N_A = 6.02 \times 10^{23} \text{ molecules/mole}$$

$$k = 1.38 \times 10^{-23} \text{ J/K}$$

$$= 8.62 \times 10^{-5} \text{ eV/K}$$

$$q = 1.60 \times 10^{-19} \text{ C}$$

$$m_0 = 9.11 \times 10^{-31} \text{ kg}$$

$$\epsilon_0 = 8.85 \times 10^{-14} \text{ F/cm}$$

$$\text{Si: } \epsilon_r = 11.8$$

$$\text{SiO}_2: \epsilon_r = 3.9$$

$$\text{Si: } n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$= 4.14 \times 10^{-15} \text{ eVs}$$

$$kT = 0.0259 \text{ eV}$$

$$c = 2.998 \times 10^{10} \text{ cm/s}$$

$$\text{\AA} = 10^{-8} \text{ cm}$$

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

$$\text{Si: } E_g = 1.12 \text{ eV}$$

$$\text{Si: } \phi_m \approx \chi = 4.05 \text{ eV}$$

$$\text{Si: } \mu_n = 1350 \text{ cm}^2/\text{Vs}, \mu_p = 480 \text{ cm}^2/\text{Vs}$$

Formulas

	Classical Mechanics	Quantum Mechanics
Position	x	x
Momentum	$p = mv$	$\frac{\hbar}{j} \frac{\partial}{\partial x}$
Energy	$E = KE + PE = \frac{1}{2}mv^2 + PE$	$-\frac{\hbar}{j} \frac{\partial}{\partial t}$

$$p = mv = \hbar k = \frac{h}{\lambda}$$

$$E = hv = \hbar \omega$$

$$E = \frac{1}{2}mv^2 = \frac{1}{2} \frac{p^2}{m} = \frac{\hbar^2}{2m^*} k^2$$

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

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

$$n_0 = N_c f(E_C)$$

$$N_c = 2 \left(\frac{2\pi m_n^* kT}{h^2} \right)^{3/2}$$

$$N_v = 2 \left(\frac{2\pi m_p^* kT}{h^2} \right)^{3/2}$$

$$p_0 = N_v f(E_v)$$

$$n_i = N_c e^{-(E_C-E_i)/kT} = \sqrt{N_c N_v} e^{-E_g/2kT}$$

$$p_i = N_v e^{-(E_i-E_C)/kT}$$

$$E = \frac{mq^4}{2K^2 \hbar^2}$$

Equilibrium

$$n_0 = n_i e^{(E_F-E_i)/kT}$$

$$p_0 = n_i e^{(E_i-E_F)/kT}$$

$$n_0 p_0 = n_i^2$$

$$E_N = KE + PE = E_c + E(k) = -\frac{mq^4}{K^2 n^2 \hbar^2}$$

$$\langle Q \rangle = \int_{-\infty}^{\infty} \psi^* Q_{op} \psi d\vec{x}$$

$$Eg(x) = \int_{-\infty}^{\infty} g(x) P(x) dx$$

$$L = \sqrt{D\tau}$$

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

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

$$J = \frac{I}{A}$$

$$J = J_n + J_p + C \frac{dV}{dt} = \sigma \varepsilon$$

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

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

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

Potential Well

$$\psi = A \sin Kx$$

$$K = \frac{\sqrt{2mE}}{\hbar}$$

Steady State

$$n = N_c e^{-(E_C - E_n)/kT} = n_i e^{(F_n - E_i)/kT}$$

$$p = N_v e^{-(E_p - E_v)/kT} = n_i e^{(E_i - F_p)/kT}$$

$$np = n_i^2 e^{(F_n - F_p)/kT}$$

p-n

$$V_0 = \frac{kT}{q} \ln \left(\frac{N_a N_d}{n_i^2} \right)$$

$$\frac{p_p}{p_n} = \frac{n_n}{n_p} = e^{qV_0/kT}$$

$$W = \sqrt{\frac{2\epsilon(V_0 - V)}{q} \left(\frac{N_a + N_d}{N_a N_d} \right)}$$

$$n = n_0 + \delta_n$$

$$p = p_0 + \delta_p$$

$$\delta_p(x_n) = \Delta p_n e^{-x_n/L_p}$$

$$\delta_n(x_p) = \Delta n_p e^{-x_p/L_n}$$

One sided

$$x_{p0} = W \frac{N_d}{N_a + N_d}$$

$$x_{n0} = W \frac{N_a}{N_a + N_d}$$

BJT pnp

$$B = \frac{I_C}{I_{E_p}} = \text{sech} \left(\frac{W_b}{L_p} \right)$$

$$\gamma = \frac{I_{E_p}}{I_{E_n} + I_{E_p}} = \left(1 + \frac{L_p^n n_n \mu_n^p}{L_n^p p_p \mu_p^n} \tanh \left(\frac{W_b}{L_p^n} \right) \right)^{-1}$$

$$\alpha = B\gamma$$

$$\beta = \frac{\alpha}{1 - \alpha}$$

$$I_{E_p} = qA \frac{D_p}{L_p} \left(\Delta p_E \text{ctnh} \frac{W_b}{L_p} - \Delta p_C \text{csch} \frac{W_b}{L_p} \right)$$

$$I_C = qA \frac{D_p}{L_p} \left(\Delta p_E \text{csch} \frac{W_b}{L_p} - \Delta p_C \text{ctnh} \frac{W_b}{L_p} \right)$$

$$I_B = qA \frac{D_p}{L_p} \left((\Delta p_E + \Delta p_C) \tanh \frac{W_b}{2L_p} \right)$$

$$\Delta p_E = p_n (e^{qV_{EB}/kT} - 1)$$

$$\Delta p_C = p_n (e^{qV_{CB}/kT} - 1)$$

$$I_C/I_E = \alpha$$

$$I_C/I_B = \beta$$

$$\psi_H = \sqrt{\frac{2}{L}} \sin \frac{nm}{L} x$$

$$\psi_K(X) = U(k_x, x) e^{jKxX}$$

$$Q_+ = qAx_{n0}N_d = qAx_{p0}N_a$$

$$\varepsilon_0 = -\frac{q}{\varepsilon} x_{n0}N_d = -\frac{q}{\varepsilon} x_{p0}N_a$$

$$I_p = qA \frac{D_p}{L_p} p_n (e^{qV/kT} - 1)$$

$$I_n = qA \frac{D_n}{L_n} n_p (e^{qV/kT} - 1)$$

$$I_{op} = qAg_{op}(L_p + L_n + W)$$

$$\Delta\sigma = qg_{op}(\tau_n \mu_n + \tau_p \mu_p)$$

$$C_j = \frac{\epsilon A}{W}$$

MOS

$$\frac{1}{2}\phi_s = \phi_F = \frac{kT}{q} \ln \left(\frac{N_a}{n_i} \right) = E_F - E_i$$

$$W_{min} = W \Big|_{V_0 - V = \phi_s}$$

$$C_i = \frac{\epsilon_i}{d}$$

$$C_d = \frac{\epsilon_s}{W}$$

$$C = \frac{C_i C_d}{C_i + C_d}$$

$$V_{FB} = \phi_{ms} - \frac{Q_i}{C_i}$$

$$Q_d = -qN_a W_m = -2(\epsilon_s q N_a \phi_F)^{1/2}$$

$$V_T = V_{FB} - \frac{Q_d}{C_i} + \phi_s$$

$$\Phi_s = \chi + \frac{E_g}{2} - \phi_F$$

$$I_D = \frac{\mu_n Z C_i}{L} ((V_G - V_T)V_D - \frac{1}{2}V_D^2)$$

$$I_{Dsat} = \frac{Z}{2L} \mu_n C_i V_D^2$$