Cheat Sheet

Constants

$$\begin{split} N_A &= 6.02 \times 10^{23} \; \text{molecules/mole} \\ k &= 1.38 \times 10^{-23} \; \text{J/K} \\ &= 8.62 \times 10^{-5} \; \text{ev/K} \\ q &= 1.60 \times 10^{-19} \; \text{C} \\ m_0 &= 9.11 \times 10^{-31} \; \text{kg} \\ \epsilon_0 &= 8.85 \times 10^{-14} \; \text{F/cm} \\ \text{Si: } \epsilon_r &= 11.8 \\ \text{SiO2: } \epsilon_r &= 3.9 \\ \text{Si: } n_i &= 1.5 \times 10^{10} \; cm^{-3} \end{split}$$

$$h=6.63 imes 10^{-34} ext{ Js}$$
 $=4.14 imes 10^{-15} ext{ eVs}$ $kT=0.0259 ext{ eV}$ $c=2.998 imes 10^{10} ext{ cm/s}$ $ext{Å}=10^{-8} ext{ cm}$ $1 ext{ eV}=1.6 imes 10^{-19} ext{ J}$ Si: $E_g=1.12 ext{ eV}$ Si: $\phi_m pprox \chi=4.05 ext{ eV}$ Si: $\mu_n=1350 ext{ } cm^2/Vs, \ \mu_p=480 ext{ } cm^2/Vs$

Formulas

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

$$egin{align*} p = mv = \hbar ec{k} = rac{\hbar}{\lambda} \ E = hv = \hbar \omega \ E = rac{1}{2} m v^2 = rac{1}{2} rac{p^2}{m} = rac{\hbar}{2m^*} ec{k}^2 \ m^* = rac{\hbar^2}{rac{d^2E}{dec{k}^2}} \ f(E) = rac{1}{e^{(E-E_F)/kT} + 1} pprox e^{(E_F-E)/kT} \ n_0 = N_c f(E_C) \ N_c = 2 (rac{2\pi m_p^* kT}{h^2})^{3/2} \ N_v = 2 (rac{2\pi m_p^* kT}{h^2})^{3/2} \ p_0 = N_v f(E_v) \ n_i = N_c e^{-(E_C-E_i)/kT} = \sqrt{N_c N_v} e^{-E_g/2kT} \ p_i = N_v e^{-(E_i-E_C)/kT} \ E = rac{mq^4}{2K^2\hbar^2} \end{aligned}$$

Equilibrium

$$egin{aligned} n_0 &= n_i e^{(E_F - E_i)/kT} \ p_0 &= n_i e^{(E_i - E_F)/kT} \ n_0 p_0 &= n_i^2 \end{aligned}$$

$$egin{aligned} E_N &= KE + PE = E_c + E(k) = -rac{mq^4}{K^2n^2\hbar^2} \ \langle Q
angle &= \int\limits_{-\infty}^{\infty} \psi^* Q_{op} \psi \ dec{x} \ Eg(x) &= \int\limits_{-\infty}^{\infty} g(x) P(x) dx \ L &= \sqrt{D au} \
ho &= rac{1}{\sigma} \ R &= rac{
ho L}{wt} \ J &= rac{I}{A} \ J &= J_n + J_p + Crac{dV}{dt} = \sigma arepsilon \ J_n(x) &= q \mu_n n(x) arepsilon(x) + q D_n rac{dn(x)}{dx} \ J_p(x) &= q \mu_p p(x) arepsilon(x) - q D_p rac{dp(x)}{dx} \ rac{kT}{q} &= rac{D}{\mu} \end{aligned}$$

Potential Well

$$\psi = A \sin K x$$
 $K = \frac{\sqrt{2mE}}{\hbar}$

Steady State

$$egin{aligned} n &= N_c e^{-(E_C - F_n)/kT} = n_i e^{(F_n - E_i)/kT} \ p &= N_v e^{-(F_p - E_v)/kT} = n_i e^{(E_i - F_p)/kT} \ np &= n_i^2 e^{(F_n - F_p)/kT} \end{aligned}$$

$$\psi_H = \sqrt{rac{2}{L}} \sin rac{nm}{L} x \ \psi_K(X) = U(k_x,x) e^{jKxX}$$

p-n

$$egin{aligned} V_0 &= rac{kT}{q} \mathrm{ln} \left(rac{N_a N_d}{n_i^2}
ight) \ rac{p_p}{p_n} &= rac{n_n}{n_p} = e^{qV_0/kT} \ W &= \sqrt{rac{2\epsilon(V_0 - V)}{q} \left(rac{N_a + N_d}{N_a N_d}
ight)} \ n &= n_0 + \delta_n \ p &= p_0 + \delta_p \ \delta_p(x_n) &= \Delta p_n e^{-x_n/L_p} \ \delta_n(x_p) &= \Delta n_p e^{-x_p/L_n} \end{aligned}$$

One sided

$$x_{p0} = W rac{N_d}{N_a + N_d} \ x_{n0} = W rac{N_a}{N_a + N_d}$$

BJT pnp

$$egin{aligned} B &= rac{I_C}{I_{E_p}} = \mathrm{sech}\left(rac{W_b}{L_p}
ight) \ \gamma &= rac{I_{E_p}}{I_{E_n} + I_{E_p}} = \left(1 + rac{L_p^n n_n \mu_n^p}{L_p^n p_p \mu_p^n} \mathrm{tanh}\left(rac{W_b}{L_p^n}
ight)
ight)^{-1} \ lpha &= B \gamma \ eta &= rac{lpha}{1 - lpha} \ I_{E_p} &= q A rac{D_p}{L_p} \left(\Delta p_E \coth rac{W_b}{L_p} - \Delta p_C \coth rac{W_b}{L_p}
ight) \ I_C &= q A rac{D_p}{L_p} \left(\Delta p_E \operatorname{csch}rac{W_b}{L_p} - \Delta p_C \coth rac{W_b}{L_p}
ight) \ I_B &= q A rac{D_p}{L_p} \left((\Delta p_E + \Delta p_C) anh rac{W_b}{2L_p}
ight) \ \Delta p_E &= p_n (e^{qV_{EB}/kT} - 1) \ \Delta p_C &= p_n (e^{qV_{CB}/kT} - 1) \ I_C/I_E &= lpha \ I_C/I_B &= eta \end{aligned}$$

$$egin{aligned} Q_+ &= qAx_{n0}N_d = qAx_{p0}N_a \ arepsilon_0 &= -rac{q}{arepsilon}x_{n0}N_d = -rac{q}{arepsilon}x_{p0}N_a \ I_p &= qArac{D_p}{L_p}p_n(e^{qV/kT}-1) \ I_n &= qArac{D_n}{L_n}n_p(e^{qV/kT}-1) \ I_{op} &= qAg_{op}(L_p+L_n+W) \ \Delta\sigma &= qg_{op}(au_n\mu_n+ au_p\mu_p) \ C_j &= rac{\epsilon A}{W} \end{aligned}$$

MOS

$$egin{aligned} rac{1}{2}\phi_s &= \phi_F = rac{kT}{q}\ln\left(rac{N_a}{n_i}
ight) = E_F - E_i \ W_{min} &= W igg|_{V_0 - V = \phi_s} \ C_i &= rac{\epsilon_i}{d} \ C_d &= rac{\epsilon_s}{W} \ C &= rac{C_iC_d}{C_i + C_d} \ V_{FB} &= \phi_{ms} - rac{Q_i}{C_i} \ Q_d &= -qN_aW_m = -2(\epsilon_sqN_a\phi_F)^{1/2} \ V_T &= V_{FB} - rac{Q_d}{C_i} + \phi_s \ \Phi_s &= \chi + rac{E_g}{2} - \phi_F \ I_D &= rac{ar{\mu_n}ZC_i}{L}((V_G - V_T)V_D - rac{1}{2}V_D^2) \ I_{Dsat} &= rac{Z}{2L}ar{\mu_n}C_iV_D^2 \end{aligned}$$