Equation Sheet (tear off and keep with you)

General Semiconductor:

$E = \frac{\hbar^2 k^2}{2m^*}$ $\quad v = \frac{1}{\hbar}\frac{dE}{dk}$ $\quad m^* = \hbar^2\left(\frac{d^2E}{dk^2}\right)^{-1}$ $\quad n_0 = \frac{N_d - N_a}{2} + \sqrt{\left(\frac{N_d - N_a}{2}\right)^2 + n_i^2}$ $\quad p_0 = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a - N_d}{2}\right)^2 + n_i^2}$ $\quad f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{kT}\right)}}$

$n_0 = n_i e^{\left(\frac{(E_F - E_{Fi})}{kT}\right)}$ $\quad p_0 = n_i e^{\left(\frac{(E_{Fi} - E_F)}{kT}\right)}$ $\quad n_i^2 = N_C N_V e^{\left(\frac{-E_g}{kT}\right)} = n_0 p_0$ $\quad V = IR$ $\quad L_{n,p} = \sqrt{D_{n,p}\tau_{n,p}}$ $\quad h = \frac{na}{A}, k = \frac{na}{B}, l = \frac{na}{C}$

$J_{drift} = \sigma E$ $\quad \sigma = e(\mu_n n + \mu_p p) = \frac{1}{\rho}$ $\quad J_{diff} = eD_n\frac{dn}{dx} - eD_p\frac{dp}{dx}$ $\quad J = \frac{I}{A}$ $\quad \frac{D}{\mu} = \frac{kT}{e}$ $\quad \mu = \frac{e\tau_c}{m_c^*} = \frac{g_m L^2}{V_{DS} C_{ox}}$

pn Junctions:

$V_{bi} = \frac{kT}{e}\ln\left(\frac{N_a N_d}{n_i^2}\right)$ $\quad x_n = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_a}{N_d(N_a + N_d)}V_{bi}\right]^{1/2}$ $\quad x_p = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_d}{N_a(N_a + N_d)}V_{bi}\right]^{1/2}$

$W = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_a + N_d}{N_a N_d}V_{bi}\right]^{1/2}$ $\quad W_{RB} = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_a + N_d}{N_a N_d}(V_{bi} + V_R)\right]^{1/2}$ $\quad n_p(-x_p) = n_{p0}e^{\left(\frac{eV_a}{kT}\right)}$ $\quad p_n(x_n) = p_{n0}e^{\left(\frac{eV_a}{kT}\right)}$

$\delta n_p(x) = n_{p0}\left[e^{\left(\frac{eV_a}{kT}\right)} - 1\right]e^{\left(\frac{x_p + x}{L_n}\right)}$ $\quad \delta p_n(x) = p_{n0}\left[e^{\left(\frac{eV_a}{kT}\right)} - 1\right]e^{\left(\frac{x_n - x}{L_p}\right)}$ $\quad E_{Fn} = E_{Fi} + kT\ln\left(\frac{n}{n_i}\right)$ $\quad E_{Fp} = E_{Fi} - kT\ln\left(\frac{p}{n_i}\right)$

$J_{ID} = J_S\left(e^{\left(\frac{eV_a}{kT}\right)} - 1\right)$ $\quad J_S = \frac{eD_p p_{n0}}{L_p} + \frac{eD_n n_{p0}}{L_n}$ $\quad J_{rec} = \frac{eWn_i}{2\tau_0}e^{\left(\frac{eV_a}{2kT}\right)}$ $\quad g_d = \frac{1}{r_d} = \frac{I_{DQ}}{V_t}$ $\quad C_d = \frac{1}{2V_t}\left(I_{p0}\tau_{p0} + I_{n0}\tau_{n0}\right)$

MOS Capacitors:

$C'(acc) = C_{ox} = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox}}$ $\quad C'(depl) = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox} + \left(\frac{\varepsilon_{ox}}{\varepsilon_s}\right)x_d}$ $\quad C'_{\min} = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox} + \left(\frac{\varepsilon_{ox}}{\varepsilon_s}\right)x_{dT}}$ $\quad C'_{FB} = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox} + \left(\frac{\varepsilon_{ox}}{\varepsilon_s}\right)\sqrt{V_t\left(\frac{\varepsilon_s\varepsilon_0}{eN_{a,d}}\right)}}$

$V_{FB} = \phi_{ms} - \frac{Q'_{ss}}{C_{ox}}$ $\quad e\phi_s = E_{Fi}\big|_{bulk} - E_{Fi}\big|_{surf}$ $\quad V_{TN} = \frac{\left|Q'_{SD}(\max)\right|}{C_{ox}} + V_{FB} + 2\phi_{fp}$ $\quad V_{TP} = \frac{-\left|Q'_{SD}(\max)\right|}{C_{ox}} + V_{FB} - 2\phi_{fn}$

p-type: $\phi_{ms} = \phi'_m - \left(\chi' + \frac{E_g}{2e} + \phi_{fp}\right)$ $\quad \phi_{fp} = V_t\ln\left(\frac{N_a}{n_i}\right)$ $\quad x_d = \left(\frac{2\varepsilon_s\varepsilon_0\phi_s}{eN_a}\right)^{1/2}$ $\quad x_{dT} = \left(\frac{4\varepsilon_s\varepsilon_0\phi_{fp}}{eN_a}\right)^{1/2}$ $\quad \left|Q'_{SD}(\max)\right| = eN_a x_{dT}$

n-type: $\phi_{ms} = \phi'_m - \left(\chi' + \frac{E_g}{2e} - \phi_{fn}\right)$ $\quad \phi_{fn} = V_t\ln\left(\frac{N_d}{n_i}\right)$ $\quad x_d = \left(\frac{2\varepsilon_s\varepsilon_0\phi_s}{eN_d}\right)^{1/2}$ $\quad x_{dT} = \left(\frac{4\varepsilon_s\varepsilon_0\phi_{fn}}{eN_d}\right)^{1/2}$ $\quad \left|Q'_{SD}(\max)\right| = eN_d x_{dT}$

MOSFETs:

$g_m = \frac{\delta I_D}{\delta V_{GS}}$ $\quad SS = \left(\frac{\delta(\log(I_D))}{\delta V_{GS}}\right)^{-1}$ $\quad f_T = \frac{g_m}{2\pi(C_{gsT} + C_M)} = \frac{g_m}{2\pi C_G}$ $\quad C_M = C_{gdT}(1 + g_m R_L)$

p-type: $I_D = \frac{W\mu_p C_{ox}}{2L}\left[2(V_{SG} + V_T)V_{SD} - V_{SD}^2\right]$ $\quad I_D(sat) = \frac{W\mu_p C_{ox}}{2L}(V_{SG} + V_T)^2$ $\quad K_p = \frac{W\mu_p C_{ox}}{2L}$ $\quad k'_p = \mu_p C_{ox}$

n-type: $I_D = \frac{W\mu_n C_{ox}}{2L}\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right]$ $\quad I_D(sat) = \frac{W\mu_n C_{ox}}{2L}(V_{GS} - V_T)^2$ $\quad K_n = \frac{W\mu_n C_{ox}}{2L}$ $\quad k'_n = \mu_n C_{ox}$

$k = 8.62x10^{-5} eV/K = 1.38x10^{-23} J/K$ $\quad h = 4.14x10^{-15} eV \cdot s = 6.63x10^{-34} J \cdot s$ $\quad \hbar = \frac{h}{2\pi}$

$q = 1.602x10^{-19} C$ Si at T = 300 K: n_i = 1.5x10^{10} cm^{-3}, E_g = 1.12 eV, ε_s = 11.7 $\quad SiO_2$: ε_{ox} = 3.9

*k*T = 0.026 eV at room temperature $\quad \varepsilon_0$ = 8.85x10^{-14} F/cm