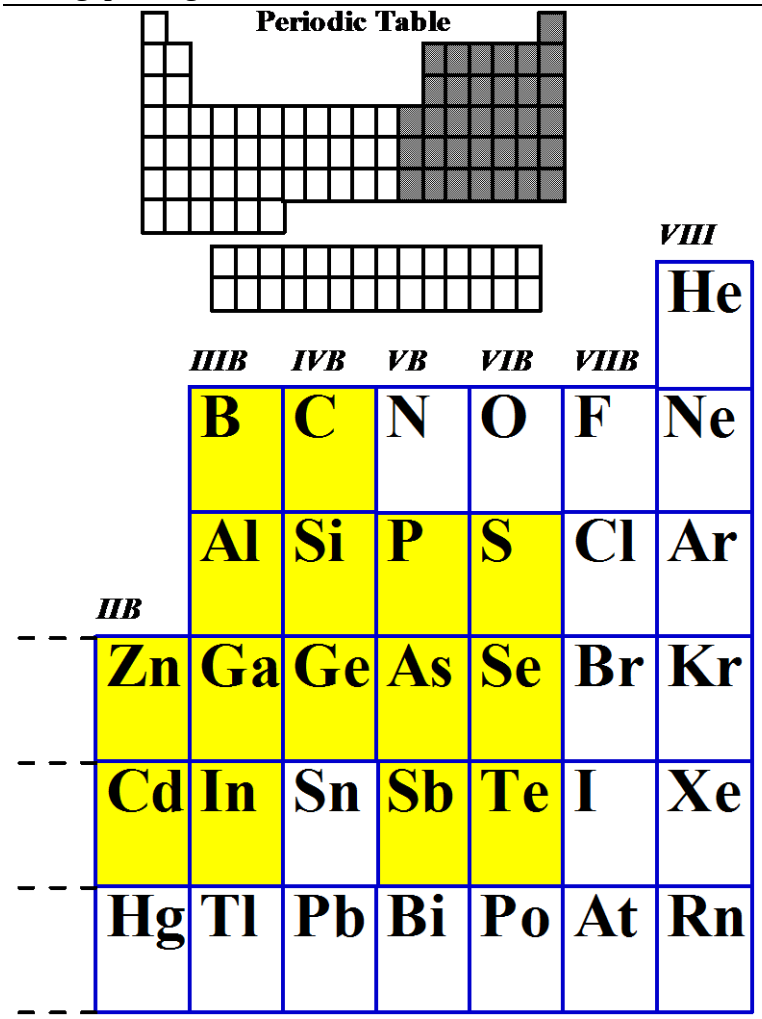
EE 2200 Equation Sheet

Boltzmann's constant:	$k = 1.381 \times 10^{-23}$ J/K $= 8.618 \times 10^{-5}$ eV/K			
Planck's constant	$h = 4.136 \times 10^{-15}$ eV-sec $= 6.626 \times 10^{-34}$ J-sec			
Electronic charge:	$q = 1.602 \times 10^{-19}$ C			
kT at 300 K	kT = 0.0259 eV			
eV-J conversion	1 eV $= 1.602 \times 10^{-19}$ J			
Free-space permittivity	$\varepsilon_0 = 8.854 \times 10^{-14}$ F/cm			
Speed of Light	$c = 2.998 \times 10^{10}$ cm/s			
Relative permittivity	Si: 11.9	Ge: 16.0	GaAs: 13.1	
Bandgap energies	Si: 1.12 eV	Ge: 0.67 eV	GaAs: 1.42 eV	



$$\rho(T) = \rho_{20}[1 + \alpha_{20}(T - 20)]$$

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

$$n_0 p_0 = n_i^2$$

$$(E_F - E_i) = kT \ln\left(\frac{n_0}{n_i}\right)$$

$$(E_F - E_i) = -kT \ln\left(\frac{p_0}{n_i}\right)$$

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

$$J = qD_n \frac{dn}{dx} - qD_p \frac{dp}{dx} \qquad p_0 = n_i e^{\frac{-(E_F - E_i)}{kT}}$$

$$J = q(n_o \mu_n + p_0 \mu_p)E = \sigma E \qquad V_0 = \frac{kT}{q} \ln\left[\frac{(N_{ap}^- - N_{dp}^+)(N_{dn}^+ - N_{an}^-)}{n_i^2}\right]$$

$$\frac{D_n}{\mu_n} = \frac{kT}{q} \qquad qV_0 = (E_F - E_{in}) - (E_F - E_{ip})$$

$$\frac{D_p}{\mu_p} = \frac{kT}{q} \qquad (N_{ap}^-)_{Eff} x_{p0} = (N_{dn}^+)_{Eff} x_{n0}$$

$$W_0 = \left\{\frac{2\varepsilon_0 \varepsilon_r V_0}{q}\left[\frac{(N_{ap}^-)_{Eff} + (N_{dn}^+)_{Eff}}{(N_{ap}^-)_{Eff}(N_{dn}^+)_{Eff}}\right]\right\}^{1/2} \qquad I = I_0\left[e^{\left(\frac{qV}{kT}\right)} - 1\right]$$

$$W = \left\{\frac{2\varepsilon_0 \varepsilon_r (V_0 - V_A)}{q}\left[\frac{(N_{ap}^-)_{Eff} + (N_{dn}^+)_{Eff}}{(N_{ap}^-)_{Eff}(N_{dn}^+)_{Eff}}\right]\right\}^{1/2}$$

BJT Relationships

$$i_B = \frac{1}{\beta} i_C \qquad i_E = i_B + i_C \qquad \alpha_0 = \frac{\beta}{\beta + 1}$$

$$\alpha_F = \frac{i_{Cn}}{i_{En}} \quad \text{or} \quad \alpha_F = \frac{i_{Cp}}{i_{Ep}} \qquad \gamma = \frac{i_{En}}{i_{En} + i_{Ep}} \quad \text{or} \quad \gamma = \frac{i_{Ep}}{i_{En} + i_{Ep}}$$

Saturation Conditions

$$v_{DG} = v_{DS} - v_{GS} \geq V_{po} \qquad v_{GD} = v_{SD} - v_{SG} \geq V_{po}$$

$$v_{DS} - v_{GS} \geq -V_{on} \qquad v_{SD} - v_{SG} \geq -V_{on}$$

FET Relationships

$$i_{DS} = I_{DSS}\left[2\left(1 + \frac{v_{GS}}{V_{po}}\right)\left(\frac{v_{DS}}{V_{po}}\right) - \left(\frac{v_{DS}}{V_{po}}\right)^2\right] \qquad i_{DS} = I_{DSS}\left(1 + \frac{v_{GS}}{V_{po}}\right)^2$$

$$i_{SD} = I_{SDS}\left[2\left(1 + \frac{v_{SG}}{V_{po}}\right)\left(\frac{v_{SD}}{V_{po}}\right) - \left(\frac{v_{SD}}{V_{po}}\right)^2\right] \qquad i_{SD} = I_{SDS}\left(1 + \frac{v_{SG}}{V_{po}}\right)^2$$

$$i_{DS} = KV_{on}{}^2\left[2\left(\frac{v_{GS}}{V_{on}} - 1\right)\left(\frac{v_{DS}}{V_{on}}\right) - \left(\frac{v_{DS}}{V_{on}}\right)^2\right] \qquad i_{DS} = KV_{on}{}^2\left(\frac{v_{GS}}{V_{on}} - 1\right)^2$$

$$i_{SD} = KV_{on}{}^2\left[2\left(\frac{v_{SG}}{V_{on}} - 1\right)\left(\frac{v_{SD}}{V_{on}}\right) - \left(\frac{v_{SD}}{V_{on}}\right)^2\right] \qquad i_{SD} = KV_{on}{}^2\left(\frac{v_{SG}}{V_{on}} - 1\right)^2$$

$$f = \frac{c}{\lambda} \qquad E_p = hf = \frac{hc}{\lambda}$$

$$I = I_0 e^{-\alpha_L x} \qquad v_p = \frac{c}{n}$$

$$I = I_0\left[e^{\frac{qV_d}{kT}} - 1\right] - I_{light} \qquad I_{light} = \frac{\eta q P \lambda}{hc}$$