Formula Sheet (10-4-2017):

$$\rho = \frac{1}{en\mu}$$

$$D = D_o e^{-E_a / k_b T}$$

$$dU = TdS - PdV_o + \mu dN + \sum YdX$$

$$\frac{D}{\mu} = \frac{k_b T}{e}$$

$$n_\upsilon = n_o e^{-E_f / k_b T}$$

$$n_\upsilon = 4\pi N \left(\frac{m}{2\pi kT} \right)^{3/2} \upsilon^2 e^{-\frac{m\upsilon^2}{2kT}}$$

$$n_\varepsilon = \frac{2}{\sqrt{\pi}} N \left(\frac{1}{kT} \right)^{1/2} \varepsilon^{1/2} e^{-\frac{\varepsilon}{kT}}$$

$$x = \sqrt{Dt}$$

$$J_A = -C_A \mu_{mob}^A \sum_i \nabla Y_{i,A}$$

$$\frac{\partial C_A}{\partial t} = -\frac{\partial J_A}{\partial x} = D_A \frac{\partial^2 C_A}{\partial x^2}$$

$$C(x,t) = \frac{N_o}{\sqrt{\pi Dt}} \exp\left[-\left(\frac{x}{2\sqrt{Dt}} \right)^2 \right]$$
$$= C_o \exp\left(-\frac{x^2}{4Dt} \right)$$

$$C(x,t) = C_s - (C_s - C_o) erf\left(\frac{x}{2\sqrt{Dt}} \right)$$
$$= C_o + (C_s - C_o) erfc\left(\frac{x}{2\sqrt{Dt}} \right)$$

$$E = \frac{hc}{\lambda}$$

$$E = k_b T$$

$$p = \frac{h}{\lambda}$$

$$E = \frac{1}{2} m\upsilon^2$$

$$p = m\upsilon$$

$$E = \frac{e_1 e_2}{4\pi\varepsilon_o r}$$

$$\mu = \frac{e}{m_{eff}} \tau$$

$$J = en\upsilon_d$$

$$\upsilon_d = \mu \xi$$

$$\frac{1}{\mu_{total}} = \sum_i \frac{1}{\mu_i}$$

$$\rho = \rho_o \left[1 + \alpha_o (T - T_o) \right]$$

$$\alpha_o = \frac{1}{\rho_o} \left[\frac{\delta \rho}{\delta T} \right]_{T=T_o}$$

$$\rho = \rho_o \left[\frac{T}{T_o} \right]^n$$

$$\rho_I = CX(1 - X)$$

$$\rho_{alloy} = \rho_{matrix} + CX(1 - X)$$

$$Q' = -A\kappa \frac{\delta T}{\delta x}$$

$$C_{WFL} = \frac{\kappa}{\sigma T} = \frac{\pi^2 k_b^2}{3e^2} = 2.44 \times 10^{-8} \ \frac{\mathrm{W\Omega}}{\mathrm{K}^2}$$

$$I_{ph} = \Gamma_{ph} h\nu$$

$$\Gamma_{ph} = \frac{\Delta N_{ph}}{A \Delta t}$$

$$I(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \cdot \frac{1}{Exp\left(\frac{hc/\lambda}{k_b T} \right) - 1}$$

$$e^{i\phi} = \cos\phi + +i\sin\phi$$

$$\cos\phi = \frac{e^{i\phi} + e^{-i\phi}}{2}$$

$$E = h\nu$$

$$\sin\phi = \frac{e^{i\phi} - e^{-i\phi}}{2i}$$

$$KE = h\nu - \phi$$

$$E = \frac{h^2 n^2}{8ma^2}$$

$$\nu^{1/2} = B(Z - C)$$

$$\hat{\wp} = \frac{\hbar}{i}\nabla$$

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

$$\hat{J}(x,t) = \frac{\hbar}{2mi}\left[\psi^*(\nabla\psi) - (\nabla\psi^*)\psi\right]$$

$$H\Psi = E\Psi$$

$$\hat{J}(x,t) = \frac{1}{2m}\left[\psi^*(\hat{p}\psi) - (\hat{p}\psi^*)\psi\right]$$

$$H = -\frac{\hbar^2}{2m}\nabla^2 + V(x)$$

$$T = \frac{|J_{transmitted}|}{|J_{incident}|}$$

$$i\hbar\frac{\partial}{\partial t}\Psi(r,t) = H\Psi(r,t)$$

$$R = \frac{|J_{reflected}|}{|J_{incident}|}$$

$$2d\sin\theta = n\lambda$$

$$T + R = 1$$

$$\int \Psi^*\Psi dV = \langle\Psi|\Psi\rangle = 1$$

$$\langle o\rangle = \frac{\int \Psi^*\hat{O}\Psi dV}{\int \Psi^*\Psi dV} = \frac{\langle\Psi|\hat{O}|\Psi\rangle}{\langle\Psi|\Psi\rangle}$$

$$E = 13.6eV\left(\frac{m^*}{m_e}\right)\frac{1}{\varepsilon^2}$$

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$r = 0.5\,\mathring{A}\,\frac{m_e}{m^*}\varepsilon$$

BCC: $h + k + l$=even; FCC: h, k, l all odd OR all even

$$n = \frac{1}{2}(N_D + \Theta_n - N)\left\{\sqrt{1 + \frac{4\Theta_n N}{(N_D + \Theta_n - N)^2}} - 1\right\}$$

$$\Theta_n = \mathrm{N_C} g_D e^{|E_D|/kT} \;\&\; \Theta_p = \mathrm{N_v} g_A e^{-E_A/kT}$$

$$p = \frac{1}{2}(N_A + \Theta_p - N)\left\{\sqrt{1 + \frac{4\Theta_p N}{(N_A + \Theta_p - N)^2}} - 1\right\}$$

$$N = |N_D - N_A|$$

$$N^* = N_D \cdot F(E_D) = \frac{N_D}{1 + g_D e^{(E_D - E_f)/kT}}$$

$$n = n_i e^{-\frac{(E_f - E_i)}{kT}}$$

$$p = n_i e^{-\frac{(E_i - E_f)}{kT}}$$

$$n = p = n_i = \sqrt{N_C N_V}\, e^{-E_g/2kT}$$

$$N_C = 2\left(\frac{2\pi m_{eff,e} m_e kT}{h^2}\right)^{\frac{3}{2}}$$

$$N_V = 2\left(\frac{2\pi m_{eff,h} m_e kT}{h^2}\right)^{\frac{3}{2}}$$

$0 < \xi < 1$:

$$\frac{1-2\xi}{2\sqrt{\xi(1-\xi)}}Sin\left[\alpha_0 a\sqrt{\xi}\right]Sinh\left[\alpha_0 b\sqrt{1-\xi}\right] + Cos\left[\alpha_0 a\sqrt{\xi}\right]Cosh\left[\alpha_0 b\sqrt{1-\xi}\right] = Cos\left[k(a+b)\right]$$

$\xi > 1$:

$$\frac{1-2\xi}{2\sqrt{\xi(\xi-1)}}Sin\left[\alpha_0 a\sqrt{\xi}\right]Sin\left[\alpha_0 b\sqrt{\xi-1}\right] + Cos\left[\alpha_0 a\sqrt{\xi}\right]Cos\left[\alpha_0 b\sqrt{\xi-1}\right] = Cos\left[k(a+b)\right]$$

$$E_f = \frac{E_g}{2} + \frac{3}{4} kTLn\left(\frac{m_{eff}^{h^+}}{m_{eff}^{e^-}}\right)$$

$$g(E) = 8\pi\sqrt{2}\left(\frac{m_{eff}}{h^2}\right)^{\frac{3}{2}}\sqrt{E}$$

$$m = \frac{\hbar^2}{\left(\frac{\partial^2 E}{\partial k^2}\right)} = \frac{\hbar}{\left(\frac{\partial \upsilon_g}{\partial k}\right)}$$

$$\upsilon_g = \frac{\partial \omega}{\partial k} = \frac{1}{\hbar}\left(\frac{\partial E}{\partial k}\right)$$

$$I_{D,Linear} = \pm\mu C_{ox}\frac{W}{L}\left[\left(V_{GS} - V_T\right)V_{DS} - \frac{V_{DS}^2}{2}\right]$$

(+ = nMOS; - = pMOS)

$$I_{Dsat} = \pm\mu C_{ox}\frac{W}{2L}\left(V_{GS} - V_T\right)^2$$

(+ = nMOS; - = pMOS)

$$C = \frac{\partial Q}{\partial V}$$

$$C_{ox} = \frac{\varepsilon_o k}{t_{ox}} A_{ox}$$

$$J \propto \int \upsilon_g(k) T(k)\left[f_{leftSide}\left(E_f\right) - f_{rightSide}\left(E_f\right)\right]dk$$

$$where\ p = m\upsilon_g \ \ \&\ \ \upsilon_g = \frac{\hat{p}}{m} \ \ \&\ \ \upsilon_g = \frac{1}{\hbar}\frac{\partial E}{\partial k}$$

$$h = 6.626\times10^{-34} J\cdot s = 4.136\times10^{-15} eV\cdot s$$

$$m_e = 9.11\times10^{-31} kg$$

$$c = 2.9979\times10^8 m/s$$

$$1eV = 1.602x10^{-19} J$$

$$\varepsilon_o = 8.85\times10^{-12}\frac{F}{m}$$

$$\hbar = \frac{h}{2\pi} \ \ \&\ \ \nu = \frac{\omega}{2\pi}$$

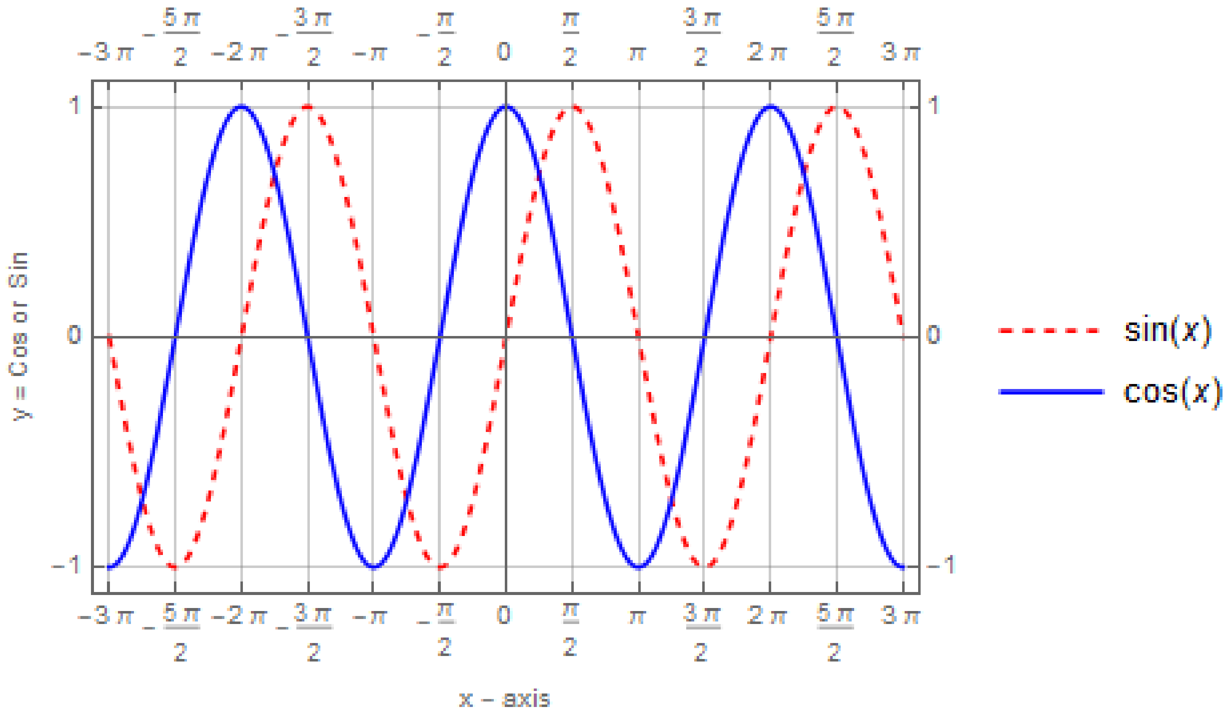
$$k_B = 1.381\times10^{-23}\frac{J}{K} = 8.6173\times10^{-5}\frac{eV}{K}$$

$$e = 1.602x10^{-19} C$$

$$C_{WFL} = \frac{\pi k_B^2}{3e} \sim 2.44\times10^{-8}\frac{W\Omega}{K^2}$$

Additional Equations:

$\Gamma_{ph} = \frac{\Delta N_{ph}}{A\Delta t}$	$I = \Gamma_{ph} h\nu$
$I_\lambda = \frac{2\pi hc^2}{\lambda^5\left[\exp\left(\frac{hc}{\lambda kT}\right) - 1\right]}$	$\sigma = \frac{1}{C_{WFL}T}\kappa$
$\rho_{eff} = \chi_\alpha\rho_\alpha + \chi_\beta\rho_\beta$	$\sigma_{eff} = \chi_\alpha\sigma_\alpha + \chi_\beta\sigma_\beta$
$\frac{\sigma_{eff} - \sigma_c}{\sigma_{eff} + 2\sigma_c} = \chi_d\frac{\sigma_d - \sigma_c}{\sigma_d + 2\sigma_c}$	$\sigma = \frac{1}{\theta}\frac{L}{AC_{WFL}T}$
$\int_0^\infty r^2 dr\int_0^\pi Sin\theta d\theta\int_0^{2\pi} d\varphi$	$f_{MB}(E) = \frac{1}{e^{\frac{E-\mu}{kT}}}$
$f_{BE}(E) = \frac{1}{e^{\frac{E-\mu}{kT}} - 1}$	$f_{FD}(E) = \frac{1}{e^{\frac{E-\mu}{kT}} + 1}$


y = Cos or Sin
x – axis
sin(x)
cos(x)
−3π
−5π/2
−2π
−3π/2
−π
−π/2
0
π/2
π
3π/2
2π
5π/2
3π
1
0
−1