In intrinsic $n_i = n_0 = p_0$ $\quad E_i = \left(\frac{E_c+E_v}{2}\right) + \frac{3}{4} k_B T \ln\left(\frac{m_{dsh}^*}{m_{dse}^*}\right)$

$$S(E) = \frac{1}{2\pi^2}\left(\frac{2m_{dse}^*}{\hbar^2}\right)^{3/2}\sqrt{E-E_c} \quad (2.43) \qquad E > E_c$$

$$S(E) = \frac{1}{2\pi^2}\left(\frac{2m_{dsh}^*}{\hbar^2}\right)^{3/2}\sqrt{E_v-E} \quad (2.44) \qquad E < E_v$$

$$f(E) = \frac{1}{1+\exp\left[\frac{E-E_F}{k_BT}\right]} \quad (2.51) \approx \exp\left[-\frac{(E-E_F)}{k_BT}\right] \quad (2.53) \quad \text{if} \quad \exp\left[\frac{E-E_F}{k_BT}\right] \gg 1$$

$$f_p(E) = 1 - f(E) = \frac{1}{1+\exp\left[\frac{E_F-E}{k_BT}\right]} \quad (2.52) \approx \exp\left[-\frac{(E_F-E)}{k_BT}\right] \quad (2.54) \quad \text{if} \quad \exp\left[\frac{E_F-E}{k_BT}\right] \gg 1$$

$E_c - E_F > 2.3k_BT$

$E_F - E_v > 2.3k_BT$

$$n_0 = N_c \exp\left[-\frac{(E_c-E_F)}{k_BT}\right] \quad (2.59) \qquad E_c - E_F = -k_BT\ln\left(\frac{n_0}{N_c}\right)$$

$$p_0 = N_v \exp\left[-\frac{(E_F-E_v)}{k_BT}\right] \quad (2.60) \qquad E_F - E_v = -k_BT\ln\left(\frac{p_0}{N_v}\right)$$

$$N_c = 2\left(\frac{m_{dse}^* k_BT}{2\pi\hbar^2}\right)^{3/2} \quad (2.61) \qquad N_v = 2\left(\frac{m_{dsh}^* k_BT}{2\pi\hbar^2}\right)^{3/2} \quad (2.62)$$

if non degenerate

$$N_c = 2.54\times10^{19}\left(\frac{m_{dse}^*}{m_0}\right)^{3/2}\left(\frac{T}{300}\right)^{3/2} \quad (2.63) \qquad N_v = 2.54\times10^{19}\left(\frac{m_{dsh}^*}{m_0}\right)^{3/2}\left(\frac{T}{300}\right)^{3/2} \quad (2.64)$$

$$n_0 p_0 = n_i^2 \quad (2.66)$$

$$n_i = \sqrt{N_c N_v}\exp\left[-\frac{E_g}{k_BT}\right] \quad (2.67)$$

$$E_i = \left(\frac{E_c+E_v}{2}\right) + \frac{k_BT}{2}\ln\left(\frac{N_v}{N_c}\right) = \left(\frac{E_c+E_v}{2}\right) + \frac{3}{4}k_BT\ln\left(\frac{m_{dsh}^*}{m_{dse}^*}\right) \quad (2.70 + 2.72)$$

E_{midgap} $\quad n_0$

$$N_c = n_i \exp\left[\frac{E_c-E_i}{k_BT}\right] \qquad N_v = n_i \exp\left[\frac{E_i-E_v}{k_BT}\right] \quad (2.74)$$

$$n_0 = n_i \exp\left[\frac{E_F-E_i}{k_BT}\right] \qquad p_0 = n_i \exp\left[\frac{E_i-E_F}{k_BT}\right] \quad 2.75$$

Doping $\quad n_0 \approx N_D$ when $N_D \gg n_i$ (2.77)
$\quad p_0 \approx N_A$ when $N_A \gg n_i$ (2.78)

Compensation doping $\quad$ if $N_D > N_A$ then $n_0 = N_D - N_A$
$\quad$ if $N_A > N_D$ then $n_0 = N_A - N_D$ $\Big\}$ only if $|N_D - N_A| \gg n_i$

else must solve quadratically along with $n_0 p_0 = n_i^2$ and

$$N_D^+ + p_0 = N_A^- + n_0$$