IDEAL DIODE EQUATION – 1

$$n(x_n)p(x_n) = p(x_n)N_D = n_i^2\, e^{qV_A/kT}$$

$$p(x_n) = \frac{n_i^2}{N_D} e^{qV_A/kT}$$

$$\boxed{\Delta p_n(x_n) = \frac{n_i^2}{N_D}\left(e^{qV_A/kT} - 1\right)}$$

$$0 = D_P \frac{d^2 \Delta p_n}{dx'^2} - \frac{\Delta p_n}{\tau_p} \qquad \ldots x' \geq 0$$

$$\Delta p_n(x' \rightarrow \infty) = 0$$

$$\Delta p_n(x'{=}0) = \frac{n_i^2}{N_D}\left(e^{qV_A/kT} - 1\right)$$

IDEAL DIODE EQUATION – 2

$$\Delta p_n(x') = A_1 e^{-x'/L_P} + A_2 e^{x'/L_P} \qquad \ldots x' \geq 0$$

$$L_P = \sqrt{D_P \tau_p}$$

$$\boxed{\Delta p_n(x') = \frac{n_i^2}{N_D}\left(e^{qV_A/kT} - 1\right) e^{-x'/L_P}} \qquad \ldots x' \geq 0$$

$$\boxed{J_P(x') = -qD_P \frac{d\Delta p_n}{dx'} = q\frac{D_P}{L_P}\frac{n_i^2}{N_D}\left(e^{qV_A/kT} - 1\right) e^{-x'/L_P}} \qquad \ldots x' \geq 0$$

$$\boxed{\Delta n_p(x'') = \frac{n_i^2}{N_A}\left(e^{qV_A/kT} - 1\right) e^{-x''/L_N}} \qquad \ldots x'' \geq 0$$

IDEAL DIODE EQ. – 3

$$\boxed{J_N(x'') = -qD_N \frac{d\Delta n_p}{dx''} = q\frac{D_N}{L_N}\frac{n_i^2}{N_A}\left(e^{qV_A/kT} - 1\right) e^{-x''/L_N}} \qquad \ldots x'' \geq 0$$

$$J_N(x{=}{-x_p}) = J_N(x''{=}0) = q\frac{D_N}{L_N}\frac{n_i^2}{N_A}\left(e^{qV_A/kT} - 1\right)$$

$$J_P(x{=}x_n) = J_P(x'{=}0) = q\frac{D_P}{L_P}\frac{n_i^2}{N_D}\left(e^{qV_A/kT} - 1\right)$$

$$I = AJ = qA\left(\frac{D_N}{L_N}\frac{n_i^2}{N_A} + \frac{D_P}{L_P}\frac{n_i^2}{N_D}\right)\left(e^{qV_A/kT} - 1\right)$$

$$\boxed{I = I_0\left(e^{qV_A/kT} - 1\right)}$$

$$\boxed{I_0 \equiv qA\left(\frac{D_N}{L_N}\frac{n_i^2}{N_A} + \frac{D_P}{L_P}\frac{n_i^2}{N_D}\right)}$$

JUNCTION CAPACITANCE

$$Y = G + j\omega C$$

$$\boxed{C_J = \frac{K_S \varepsilon_0 A}{W}}$$

$$W = \left[\frac{2K_S\varepsilon_0}{qN_B}(V_{bi}-V_A)\right]^{1/2} \quad \text{... asymmetrical step junction}$$

$$W = \left[\frac{12K_S\varepsilon_0}{qa}(V_{bi}-V_A)\right]^{1/3} \quad \text{... linearly-graded junction}$$

$$N_B(x) = bx^m \quad \text{... } x > 0$$

SCHOTTKY I–V

$$I_{M\bullet\to S}(V_A) = I_{M\bullet\to S}(V_A = 0)$$

$$I_{M\bullet\to S}(V_A{=}0) = -I_{S\bullet\to M}(V_A{=}0) = -Aa^*T^2 e^{-\Phi_B/kT}$$

$$I = I_{S\bullet\to M} + I_{M\bullet\to S} = I_{S\bullet\to M} + I_{M\bullet\to S}(V_A{=}0)$$

$$\boxed{\begin{aligned} I &= I_s\,(e^{qV_A/kT} - 1) \\ I_s &\equiv Aa^*T^2 e^{-\Phi_B/kT} \end{aligned}}$$

DIODES

BUILT-IN VOLTAGE

$$J_N = q\mu_n n\mathcal{E} + qD_N \frac{dn}{dx} = 0$$

$$\mathcal{E} = -\frac{D_N}{\mu_n}\frac{dn/dx}{n} = -\frac{kT}{q}\frac{dn/dx}{n}$$

$$V_{bi} = -\int_{-x_p}^{x_n} \mathcal{E}\, dx = \frac{kT}{q}\int_{n(-x_p)}^{n(x_n)} \frac{dn}{n} = \frac{kT}{q}\ln\left[\frac{n(x_n)}{n(-x_p)}\right]$$

$$n(x_n) = N_D$$

$$n(-x_p) = n_i^2/N_A$$

$$\boxed{V_{bi} = \frac{kT}{q}\ln\left(\frac{N_A N_D}{n_i^2}\right)}$$

STEP JUNCTION

For $-x_p \le x \le 0 \ldots$

$$\mathcal{E}(x) = -\frac{qN_A}{K_S\varepsilon_0}(x_p + x)$$

$$V(x) = \frac{qN_A}{2K_S\varepsilon_0}(x_p + x)^2$$

$$x_p = \left[\frac{2K_S\varepsilon_0}{q}\frac{N_D}{N_A(N_A + N_D)}(V_{bi} - V_A)\right]^{1/2}$$

For $0 \le x \le x_n \ldots$

$$\mathcal{E}(x) = -\frac{qN_D}{K_S\varepsilon_0}(x_n - x)$$

$$V(x) = V_{bi} - V_A - \frac{qN_D}{2K_S\varepsilon_0}(x_n - x)^2$$

$$x_n = \left[\frac{2K_S\varepsilon_0}{q}\frac{N_A}{N_D(N_A + N_D)}(V_{bi} - V_A)\right]^{1/2}$$

and

$$\boxed{W = \left[\frac{2K_S\varepsilon_0}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)(V_{bi} - V_A)\right]^{1/2}}$$

LINEARLY GRADED JUNCTION

$$\rho(x) = \begin{cases} qax & \ldots -W/2 \le x \le W/2 \\ 0 & \ldots x \le -W/2 \text{ and } x \ge W/2 \end{cases}$$

$$x_p = x_n = \frac{W}{2}$$

$$\mathcal{E}(x) = \frac{qa}{2K_S\varepsilon_0}\left[x^2 - \left(\frac{W}{2}\right)^2\right] \qquad \ldots -\frac{W}{2} \le x \le \frac{W}{2}$$

$$V(x) = \frac{qa}{6K_S\varepsilon_0}\left[2\left(\frac{W}{2}\right)^3 + 3\left(\frac{W}{2}\right)^2 x - x^3\right] \qquad \ldots -\frac{W}{2} \le x \le \frac{W}{2}$$

$$\boxed{W = \left[\frac{12K_S\varepsilon_0}{qa}(V_{bi} - V_A)\right]^{1/3}}$$