# Equations Governing P-N Junction and Diode Models

1. Built-in Potential ($V_{bi}$):

   $V_{bi} = (kT / q) * \ln(N_A * N_D / n_i^2)$

2. Depletion Region Width ($W$):

   $W = \sqrt{((2 * \epsilon / q) * ((N_A + N_D) / (N_A * N_D)) * (V_{bi} - V))}$

3. Depletion Width on Each Side:

   P-side: $W_p = W * (N_D / (N_A + N_D))$

   N-side: $W_n = W * (N_A / (N_A + N_D))$

4. Electric Field ($E$):

   $E_{max} = q * N_A * W_p / \epsilon = q * N_D * W_n / \epsilon$

5. Capacitance of the Junction ($C_j$):

   $C_j = \epsilon * A / W$

   For reverse bias: $C_j = C_0 / \sqrt{(1 + V_R / V_{bi})}$

6. Diode Current Equation:

   $I = I_S * (\exp(qV / kT) - 1)$

7. Continuity Equation:

   For holes: $(d(p)/d(t)) = (1/q) * \text{div}(J_p) + G - R$

   For electrons: $(d(n)/d(t)) = (1/q) * \text{div}(J_n) + G - R$

8. Diffusion Lengths:

L_p = sqrt(D_p * tau_p), L_n = sqrt(D_n * tau_n)

9. Diffusion Current and Drift Current:

Electron diffusion: J_n_diff = q * D_n * (d(n)/d(x))

Hole diffusion: J_p_diff = q * D_p * (d(p)/d(x))

Electron drift: J_n_drift = q * mu_n * n * E

Hole drift: J_p_drift = q * mu_p * p * E

10. Ideal Diode Equation:

I = I_S * (exp(qV / kT) - 1)

11. Dynamic Resistance (r_d):

r_d = n * V_T / I

Where V_T = kT / q (~26mV at room temperature)

12. Power Dissipation:

P = I * V