

EE121 Equation Sheet

Boltzmann's constant:	$k = 1.381 \times 10^{-23} \text{ J/K} = 8.618 \times 10^{-5} \text{ eV/K}$		
Planck's constant	$h = 4.136 \times 10^{-15} \text{ eV-sec} = 6.626 \times 10^{-34} \text{ J-sec}$		
Electronic charge:	$q = 1.602 \times 10^{-19} \text{ C}$		
kT at 300 K	$kT = 0.0259 \text{ eV}$		
eV-J conversion	$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$		
Free-space permittivity	$\epsilon_0 = 8.854 \times 10^{-14} \text{ F/cm}$		
Speed of Light	$c = 2.998 \times 10^{10} \text{ cm/s}$		
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

Periodic Table

						<i>VIII</i>
						He
	<i>IIB</i>	<i>IVB</i>	<i>VB</i>	<i>VIB</i>	<i>VIIB</i>	
	B	C	N	O	F	Ne
	Al	Si	P	S	Cl	Ar
<i>IIB</i>	Zn	Ga	Ge	As	Se	Br
	Cd	In	Sn	Sb	Te	I
	Hg	Tl	Pb	Bi	Po	At
						Rn

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

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

$$n_0 p_0 = n_i^2$$

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

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

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

$$J = qD_n \frac{dn}{dx} - qD_p \frac{dp}{dx}$$

$$J = q(n_0 \mu_n + p_0 \mu_p)E = \sigma E$$

$$\frac{D_n}{\mu_n} = \frac{kT}{q}$$

$$\frac{D_p}{\mu_p} = \frac{kT}{q}$$

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

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

$$p_0 = n_i e^{\frac{-(E_F - E_i)}{kT}}$$

$$V_0 = \frac{kT}{q} \ln \left[\frac{(N_{ap}^- - N_{dp}^+)(N_{dn}^+ - N_{an}^-)}{n_i^2} \right]$$

$$qV_0 = (E_F - E_{in}) - (E_F - E_{ip})$$

$$(N_{ap}^-)_{\text{Eff}} x_{p0} = (N_{dn}^+)_{\text{Eff}} x_{n0}$$

$$I = I_0 \left[e^{\left(\frac{qV}{kT}\right)} - 1 \right]$$

BJT Relationships

$$i_B = \frac{1}{\beta} i_C$$

$$i_E = i_B + i_C$$

$$\alpha_0 = \frac{\beta}{\beta + 1}$$

$$\alpha_F = \frac{i_{Cn}}{i_{En}} \quad \text{OR} \quad \alpha_F = \frac{i_{Cp}}{i_{Ep}}$$

$$\gamma = \frac{i_{En}}{i_{En} + i_{Ep}} \quad \text{OR} \quad \gamma = \frac{i_{Ep}}{i_{En} + i_{Ep}}$$

Saturation Conditions

$$v_{DG} = v_{DS} - v_{GS} \geq V_{po}$$

$$v_{GD} = v_{SD} - v_{SG} \geq V_{po}$$

FET Relationships

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

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

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

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

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

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

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

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

$$f = \frac{c}{\lambda}$$

$$I = I_0 e^{-\alpha_L x}$$

$$I = I_0 \left[e^{\frac{qV_d}{kT}} - 1 \right] - I_{\text{light}}$$

$$E_p = hf = \frac{hc}{\lambda}$$

$$v_p = \frac{c}{n}$$

$$I_{\text{light}} = \frac{\eta q P \lambda}{hc}$$