Use the following formulae in your solutions

Mathematical Model of the pn junction

$$i_D = I_S\left\{\exp\left(\frac{v_D}{V_T}\right)-1\right\}$$

Mathematical Model of a finite gain OpAmp

$V_o=0.5A_{cm}(V_+ + V_-)+A_d(V_+ - V_-)$

$CMRR=A_d/A_{cm}$

NMOS Transistor Mathematical Model

$v_{GS} \le V_{TN}$	$i_{DS}=0$	Cutoff
$v_{GS} \ge V_{TN}$ $0 \le v_{DS} \le (v_{GS}-V_{TN})$	$i_{DS}=K_n\left\{(v_{GS}-V_{TN})v_{DS}-\frac{v_{DS}^2}{2}\right\}$	Linear
$v_{GS} \ge V_{TN}$ $v_{DS} \ge (v_{GS}-V_{TN}) \ge 0$	$i_{DS}=\frac{K_n}{2}(v_{GS}-V_{TN})^2(1+\lambda v_{DS})$	Saturation

PMOS Transistor Mathematical Model

$v_{SG} \le -V_{TP}$	$i_{SD}=0$	Cutoff
$v_{SG} \ge -V_{TP}$ $0 \le v_{SD} \le (v_{SG}+V_{TP})$	$i_{SD}=K_p\left\{(v_{SG}+V_{TP})v_{SD}-\frac{v_{SD}^2}{2}\right\}$	Linear
$v_{SG} \ge -V_{TP}$ $v_{SD} \ge (v_{SG}+V_{TP}) \ge 0$	$i_{SD}=\frac{K_p}{2}(v_{SG}+V_{TP})^2(1+\lambda v_{SD})$	Saturation

Small signal Model Parameters of NMOS Transistors

$$g_m=\sqrt{2K_n I_{DS}(1+\lambda V_{DS})}$$

$$r_o=\frac{\frac{1}{\lambda}+V_{DS}}{I_{DS}}$$ Valid for $v_{gs} \le 0.2(V_{GS}-V_T)$

Common source amplifier

$$\boldsymbol{A_v} \approx -\frac{\boldsymbol{R_{IN}}}{\boldsymbol{R_{IN}}+\boldsymbol{R_S}}\boldsymbol{g_m}(\boldsymbol{R_D} \parallel \boldsymbol{r_o} \parallel \boldsymbol{R_L}) \qquad R_{IN}=R_G$$

Propagation delays for reference CMOS inverter with V_{DD}=5V, V_{TN}=1V and V_{TP}=-1V

$$\tau_{PHL} = 0.322\frac{C}{K_n} \qquad \tau_{PLH} = 0.322\frac{C}{K_p}$$

Full Transport Model of npn transistors

$$i_C = I_s\left[\exp(\frac{v_{BE}}{V_T}) - \exp(\frac{v_{BC}}{V_T})\right] - \frac{I_s}{\beta_R}\left[\exp(\frac{v_{BC}}{V_T}) - 1\right]$$
$$i_E = I_s\left[\exp(\frac{v_{BE}}{V_T}) - \exp(\frac{v_{BC}}{V_T})\right] + \frac{I_s}{\beta_F}\left[\exp(\frac{v_{BE}}{V_T}) - 1\right]$$
$$i_B = \frac{I_s}{\beta_F}\left[\exp(\frac{v_{BE}}{V_T}) - 1\right] + \frac{I_s}{\beta_R}\left[\exp(\frac{v_{BC}}{V_T}) - 1\right]$$

Simplifications of the Transport Model of npn Transistors

Forward active region: $i_C = I_s \exp(\frac{v_{BE}}{V_T})$, $i_B = \frac{i_C}{\beta_F}$ and $i_E = \frac{i_C}{\alpha_F}$

Saturation Region: v_{CESAT}=0.2 V

Cut-off region: $i_B = i_C = i_E = 0$

Full Transport Model of pnp transistors

$$i_C = I_s\left[\exp(\frac{v_{EB}}{V_T}) - \exp(\frac{v_{CB}}{V_T})\right] - \frac{I_s}{\beta_R}\left[\exp(\frac{v_{CB}}{V_T}) - 1\right]$$
$$i_E = I_s\left[\exp(\frac{v_{EB}}{V_T}) - \exp(\frac{v_{CB}}{V_T})\right] + \frac{I_s}{\beta_F}\left[\exp(\frac{v_{EB}}{V_T}) - 1\right]$$
$$i_B = \frac{I_s}{\beta_F}\left[\exp(\frac{v_{EB}}{V_T}) - 1\right] + \frac{I_s}{\beta_R}\left[\exp(\frac{v_{CB}}{V_T}) - 1\right]$$

Simplifications of the Transport Model of pnp Transistors

Forward active region: $i_C = I_s \exp(\frac{v_{EB}}{V_T})$, $i_B = \frac{i_C}{\beta_F}$ and $i_E = \frac{i_C}{\alpha_F}$

Saturation Region: v_{ECSAT}=0.2 V

Cut-off region: $i_B = i_C = i_E = 0$

Small signal model for the BJT

$$g_m = \frac{I_C}{V_T} \qquad r_\pi = \frac{\beta}{g_m} \qquad r_e = \frac{\alpha}{g_m}$$

$r_o = \frac{V_A}{I_C}$ Valid for $v_{be} \le 0.005V$

Common emitter amplifier

$$A_v = -\frac{R_{IN}}{R_{IN} + R_S} g_m \left(R_C \parallel r_o \parallel R_L\right) \qquad R_{IN} = R_{BB} \parallel r_\pi$$

2-Port Network Parameters

$$v_1 = z_{11} i_1 + z_{12} i_2$$
$$v_2 = z_{21} i_1 + z_{22} i_2$$

$$i_1 = y_{11} v_1 + y_{12} v_2$$
$$i_2 = y_{21} v_1 + y_{22} v_2$$

$$v_1 = h_{11} i_1 + h_{12} v_2$$
$$i_2 = h_{21} i_1 + h_{22} v_2$$

$$i_1 = g_{11} v_1 + g_{12} i_2$$
$$v_2 = g_{21} v_1 + g_{22} i_2$$