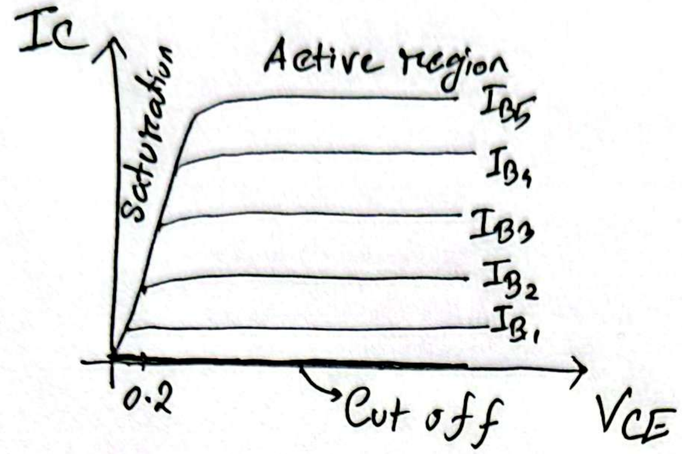
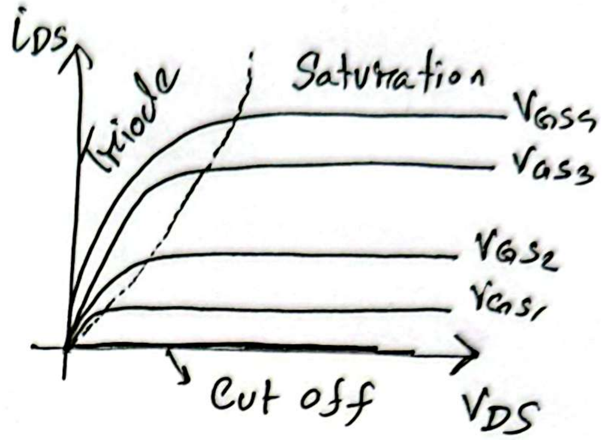
Q-1)

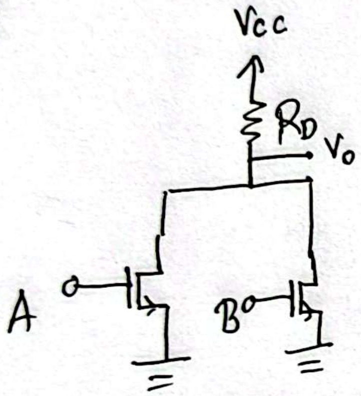
a) BJT



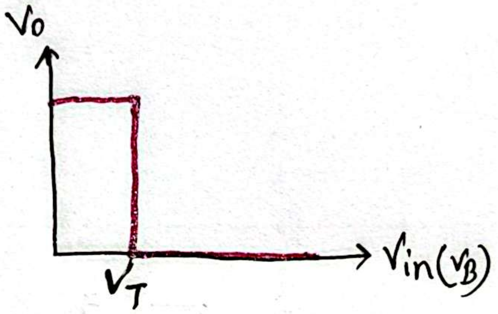
MOSFET

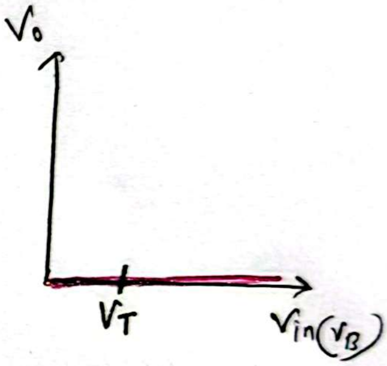


b)



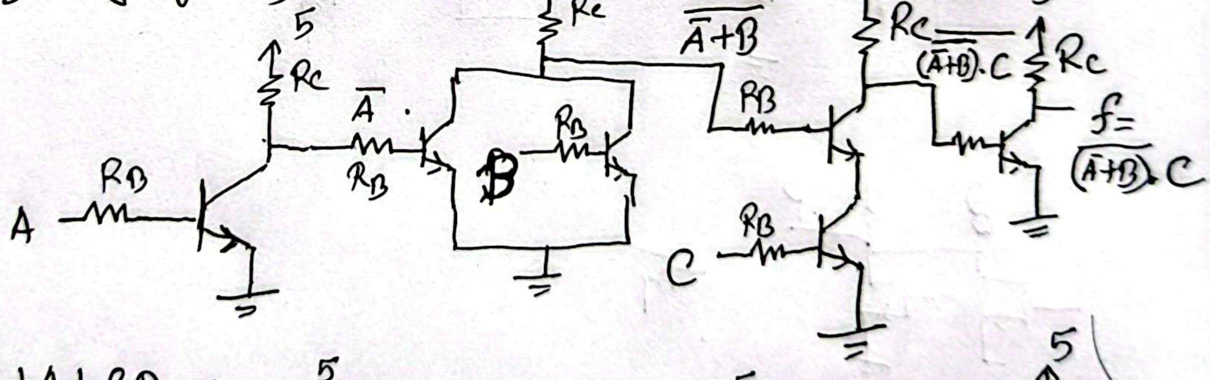
$V_A = 0$



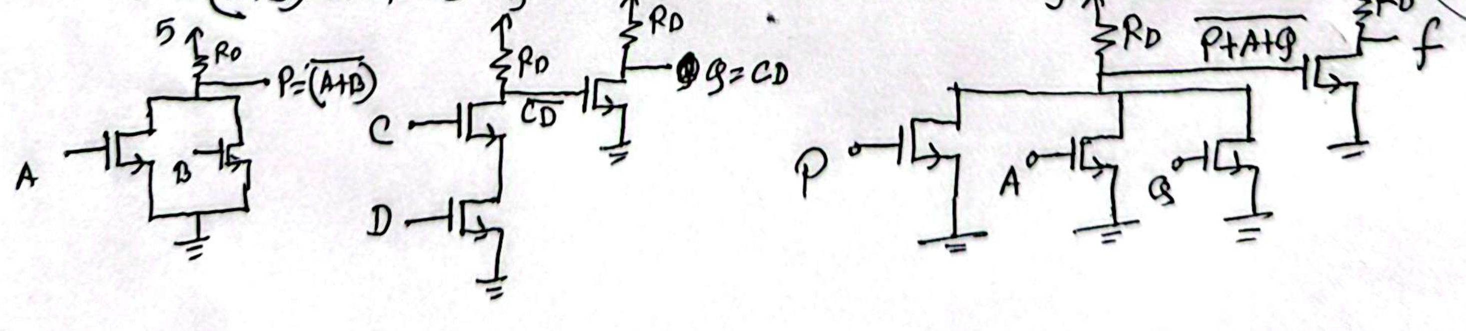


Q2

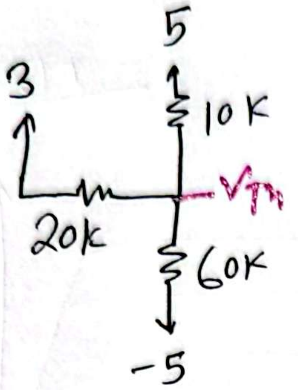
a) $f = \overline{(\bar{A}+B)}.C$ (using BJT)

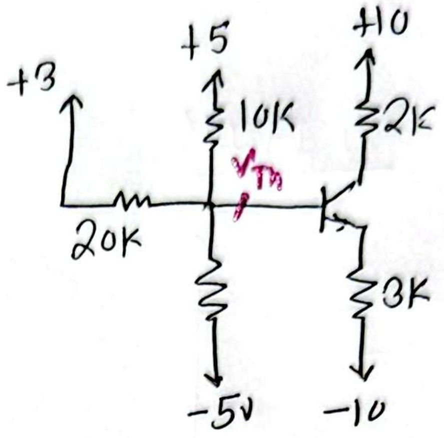


b) $f = \overline{(A+B)} + A + CD$



Q3

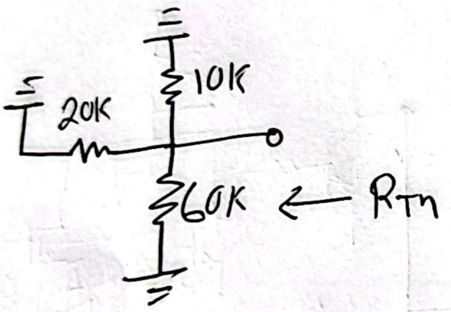




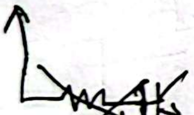
Thevenin's Theorem

KCL
$$\frac{V_{Th}-5}{10}+\frac{V_{Th}+5}{60}+\frac{V_{Th}-3}{20}=0$$
$$V_{Th}=3.4$$

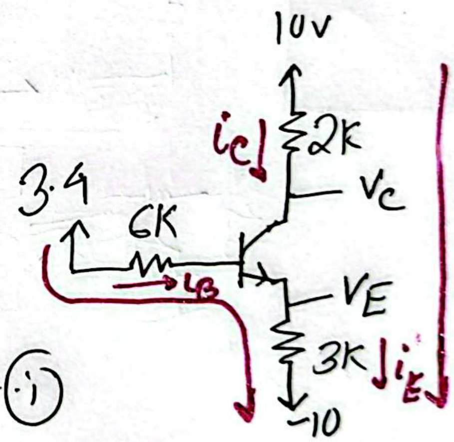
R_{Th}



$$R_{Th}=20\,\|\,60\,\|\,10$$
$$=6K$$



Assuming Saturation Mode



KVL $3.4=6i_B+0.8+3i_E-10$

$\Rightarrow 6i_B+3i_E=12.6$ --- (i)

KVL $10=2i_C+0.2+3i_E-10$

$\Rightarrow 2i_C+3i_E=19.8$ --- (ii)

KCL $i_E=i_C+i_B$

$\Rightarrow i_B+i_C-i_E=0$ --- (iii)

$i_B=0.1mA$

$i_C=3.9mA$

$i_E=4mA$

$$\frac{i_C}{i_B}=\frac{3.9}{0.1}=39<100$$

Correct Assumption

$\boxed{\text{Saturation}}$

Q3

Given,

$V_G = 4V \qquad V_T = 1V$

$I_{DS} = 2mA \qquad K = 4mA/V^2$

Assuming the MOSFET is in Saturation region

$$I_{DS} = \frac{1}{2}K\left[V_{GS} - V_T\right]^2$$

$$\Rightarrow 2 = \frac{1}{2} \times 4\left[4 - V_S - 1\right]^2$$

$$\Rightarrow 1 = (3 - V_S)^2$$

$$\Rightarrow 9 - 6V_S + V_S^2 = 1$$

$$\Rightarrow V_S^2 - 6V_S + 8 = 0$$

$$\Rightarrow V_S = 4 \text{ or } 2V$$

if $V_S = 4 \quad V_{GS} = 0 < V_T$ ✗

if $V_S = 2 \quad V_{GS} = 2V > V_T$ ✓

$\therefore V_S = 2$

$$2 = \frac{10 - V_D}{1} \qquad \therefore V_D = 8V$$

$V_{DS} = 8-2 = 6V$

$V_{ov} = V_{GS} - V_T = 2-1 = 1$

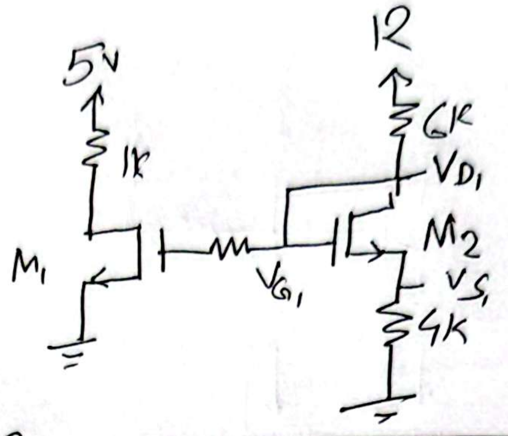
$\therefore \; V_{GS} > V_T$

$V_{DS} \geq V_{ov}$

Assumption is correct

$\therefore \; \boxed{V_D = 8V}$

Q5



M_2 — Saturation

$V_{G_1} = V_{D_1}$

$$I_{D_1} = \frac{K_n}{2}\left[V_{GS_1} - V_T\right]^2$$

$$= \frac{2}{2}\left[V_{G_1} - V_{S_1} - V_T\right]^2$$

$$= \left[V_{D_1} - V_{S_1} - V_T\right]^2$$

$$\boxed{I_D = \frac{12 - V_{D_1}}{6} = \frac{V_{S_1}}{4} \Rightarrow V_{D_1} = 12 - \frac{3}{2}V_{S_1} \quad \text{— (i)}}$$

$$\Rightarrow \frac{V_{S_1}}{4} = \cancel{\left[12 - \frac{3}{2}V_{S_1} - 1\right]^2} = \left[12 - \frac{3}{2}V_{S_1} - V_{S_1} - 1\right]^2$$

$$\Rightarrow \frac{V_{S_1}}{4} = \left[11 - \frac{5}{2}V_{S_1}\right]^2$$

$$\Rightarrow \frac{V_{S_1}}{4} = 121 - 55V_{S_1} + \frac{25}{4}V_{S_1}^2$$

$$\Rightarrow \frac{25}{4}V_{S_1}^2 - \frac{221}{4}V_{S_1} + 121 = 0$$

$$\Rightarrow 25V_{S_1}^2 - 221V_{S_1} + 484 = 0$$

$V_{S_1} = 4$ or 4.84

if $V_{S_1} = 4V$

$V_{D_1} = 6$

$\therefore V_{G_1} = 6$

$V_{GS_1} = 2V > V_T$ ✓

if $V_{S_1} = \cancel{4V}\ 4.84V$

$V_{D_1} = 4.74$

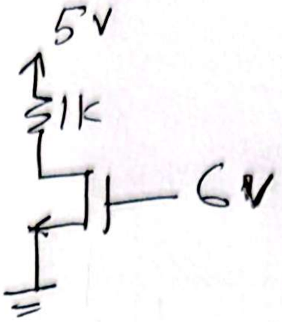
$V_{G_1} = 4.74$

$V_{GS_1} < V_T$ ✗

$\therefore V_{S_1} = 4$

$\therefore I_{RD_1} = \frac{12-6}{6} = 1\,mA$

Assuming Triode Mode



$V_{S2} = 0$

$V_{G2} = 6V$

$$I_D = K\left[V_{GS_2} - V_T - \frac{1}{2}V_{DS_2}\right]V_{DS_2}$$

$$\Rightarrow \frac{5 - V_{D_2}}{1} = \frac{1}{2}\left[V_{G2} - V_T - \frac{1}{2}V_{D_2}\right]V_{D2}$$

$$\Rightarrow 5 - V_{D_2} = \frac{1}{2}\left[6 - 1 - \frac{1}{2}V_{D2}\right]V_{D2}$$

$$\Rightarrow 10 - 2V_{D_2} = 5V_{D_2} - \frac{1}{2}V_{D_2}^2$$

$$\Rightarrow V_{D_2}^2 - 14V_{D2} + 20 = 0$$

$$\Rightarrow V_{D_2} = 12.385 \quad , \quad 1.615\,V \checkmark$$

$V_{ov} = V_{GS_2} - V_T$

$= 6 - 1$

$= 5V$

12.385: ✓ ✗ $V_{DS} > V_{ov}$

1.615: ~~$V_{DS} > V_o$~~ $V_{DS} < V_{ov}$

$$I_{RD_2} = \frac{5 - 1.615}{1}$$

$$= 3.385\,mA$$

$$\boxed{\begin{aligned} V_o &= V_{D_2} = 1.615\,V \\ I_{RD_1} &= 1\,mA \\ I_{RD_2} &= 3.385\,mA \end{aligned}}$$