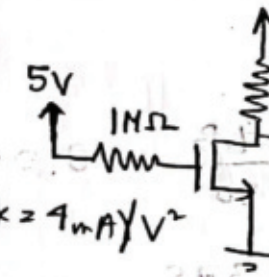
Q1 Set-A

(a)

Saturation: $V_{GS} \geq V_T$, $V_{DS} \geq V_{OV}$:

(b)



$V_T = 1, k = 4\,mA/V^2$

Saturation: $V_G = 5V, V_S = 0, V_D = x$

$V_{GS} = 5V$

$V_{OV} = 5 - 1 = 4V$

$I_D = \frac{4}{2}(V_{OV})^2 = 2 \times 16 = 32\,mA$

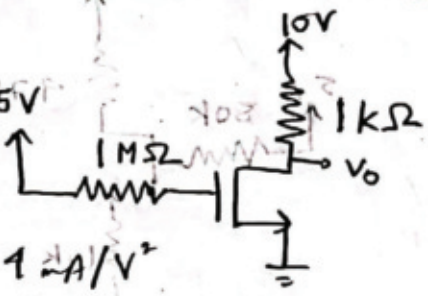
$V_o = 10 - 0.1 I_D = 10 - 3.2$

$\hookrightarrow V_o = 6.8\,V > 5\,V$

Thus, input HIGH gives output HIGH.

As the ckt is malfunctioning, Nirmol was correct

(c)



$V_T = 1, k = 4\,mA/V^2$

Saturation: $V_G = 5, V_S = 0, V_D = x$

$V_{DS} = x, V_{GS} = 5V, V_{OV} = 4V$

$I_D = 4\left[V_{DS}V_{OV} - \frac{1}{2}V_{DS}^2\right]$

$= 4\left[4x - \frac{1}{2}x^2\right]$

$I_D = \frac{k}{2}V_{OV}^2 = 2 \times 16 = 32\,mA$

$V_o = 10 - 32 = -22V$ ✗

Triode:

$I_D = 4\left[V_{DS}V_{OV} - \frac{1}{2}V_{DS}^2\right]$

$= 4\left[4x - \frac{1}{2}x^2\right]$

Also, $I_D = \frac{10 - V_D}{1} = 10 - x$

$\therefore 10 - x = 16x - 2x^2$ ($V_{DS} > V_{OV}$)

$\Rightarrow 2x^2 - 17x + 10 = 0 \Rightarrow x = 7.861V$ ✗

$\because V_{out} = 0.636V < 5V$

$\therefore$ output $\equiv$ LOW

So, it's working properly after modification

0.636 ✓ ($\hookrightarrow V_{DS} < V_{OV}$)

(d) $V_{DS} = V_D = V_{OV} = 4V$

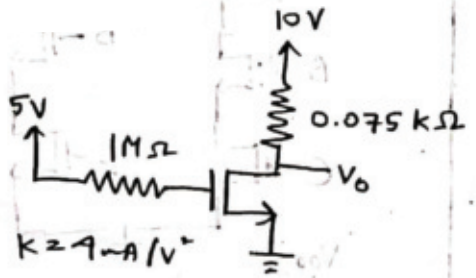
$I_D = \frac{10 - 4}{R_D} = \frac{k}{2}V_{OV}^2$

$\Rightarrow \frac{10 - 4}{\left(\frac{1}{2}\right) \cdot 4^2} = R_D \Rightarrow R_D = 0.1875\,k\Omega$

Q1 Set B

Saturation: $\frac{i_c}{i_b} < \beta$

(b)



$V_T = 1V$, $k = 4 mA/V^2$

$V_G = 5V$, $V_S = 0V$, $V_D = x$

$V_{GS} = 5V$, $V_{ov} = 4V$

Saturation: $I_D = \frac{4}{2}(4)^2$

$= 32 mA$

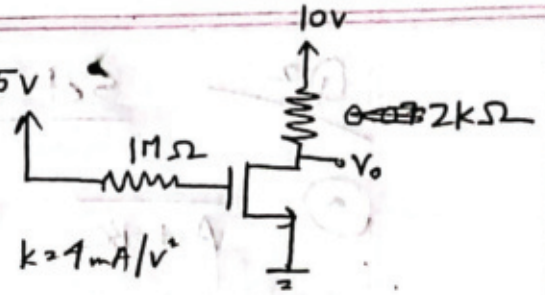
$V_o = 10 - 0.075 I_D = \boxed{7.6 V} > 5V$

Input HIGH → Output HIGH

Statement verified

Nirmol was correct

(c)



$V_T = 1V$, $k = 4 mA/V^2$

$V_G = 5$, $V_S = 0$, $V_D = x$

$V_{GS} = 5$, $V_{ov} = 4$, $V_{DS} = x$

Saturation: $I_D = \frac{4}{2}(4)^2 = 32 mA$

$V_o = 10 - 2I_D = -54 V$ ∝

Triode: $I_D = 4\left[4x - \frac{1}{2}x^2\right]$

Also, $I_D = \frac{10-x}{2}$

$\therefore \frac{10-x}{2} = 16x - 2x^2$

$\Rightarrow 10 - x = 32x - 4x^2$

$\Rightarrow 4x^2 - 33x + 10 = 0$

$\Rightarrow x = 7.935 V$ ∝ $[V_{DS} > V_{ov}]$

or,

$0.315 V$ ✓

$\therefore V_{out} = 0.315V < 5V \equiv$ LOW

So, the ckt is working properly after the modification

(d) $V_{DS} = V_D = V_{ov} = 4V$

$I_D = \frac{10-4}{R_D} = \frac{4}{2}(4)^2$

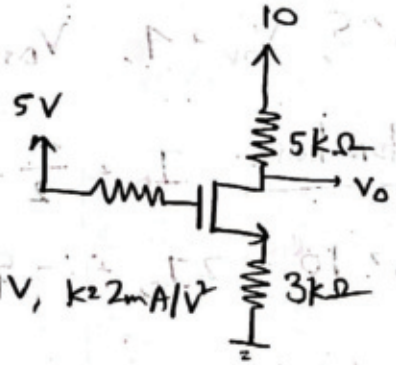
$\Rightarrow \boxed{R_D = 0.1875 k\Omega}$

Q3 Set A

(a)

$$\overline{A.(B+C) + D.E}$$

(b)



$V_t = 1V$, $k = 2mA/V^2$

$V_G = 5V$, $V_D = y$, $V_S = x$

$$I_D = \frac{10-y}{5} = \frac{x-0}{3}, \quad V_{GS} = 5-x$$

$$V_{OV} = 4-x$$

$$\Rightarrow y = 10 - \frac{5}{3}x$$

Saturation:

$$I_D = \frac{k}{2} V_{ov}^2$$

$$\Rightarrow \frac{x-0}{3} = \frac{2}{2} \times (4-x)^2$$

$$\Rightarrow x = 3(16 - 8x + x^2)$$

$$\Rightarrow 3x^2 - 25x + 48 = 0$$

$$\Rightarrow x = 5.33\,V, \; 3\,V$$

$V_{GS} = 5 - 5.33 = -0.33$ ✗

$V_{GS} = 5 - 3 = 2V$

$V_{ov} = 1V$

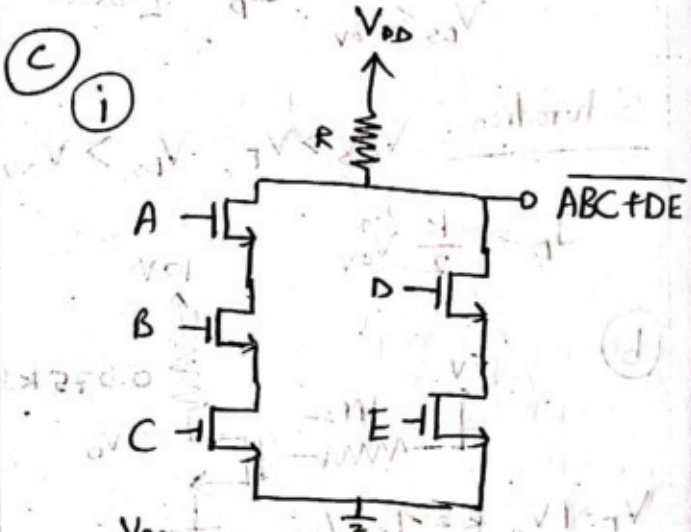
$V_{DS} = 10 - \frac{5}{3} \times 3$

$V_D = 10 - \frac{5}{3} \times 3 = 5\,V$

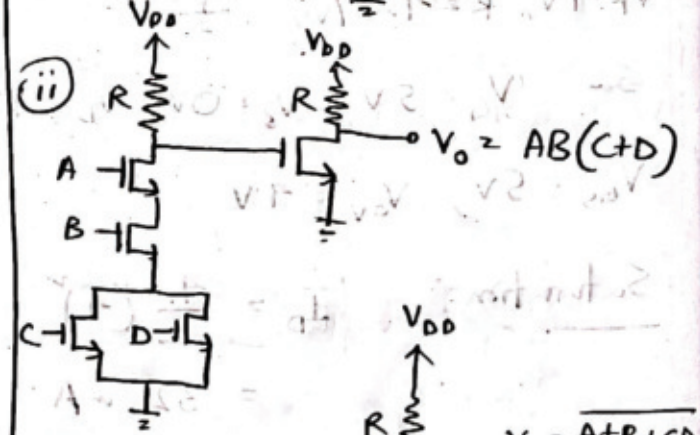
$V_{DS} = V_D - V_S = 5 - 3 = 2V$ ✓

$V_{DS} > V_{OV}$ ✓

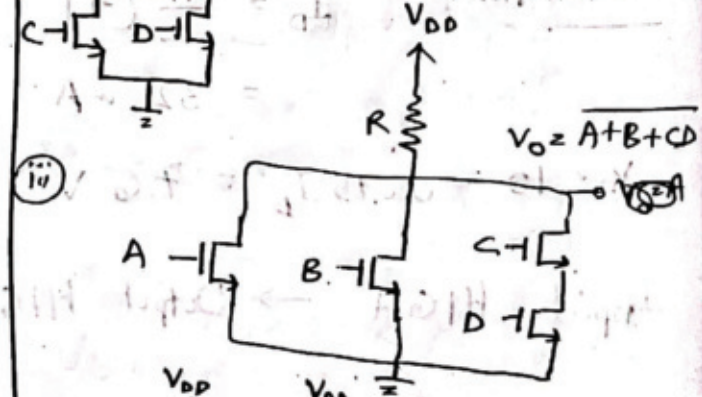
(c) (i)



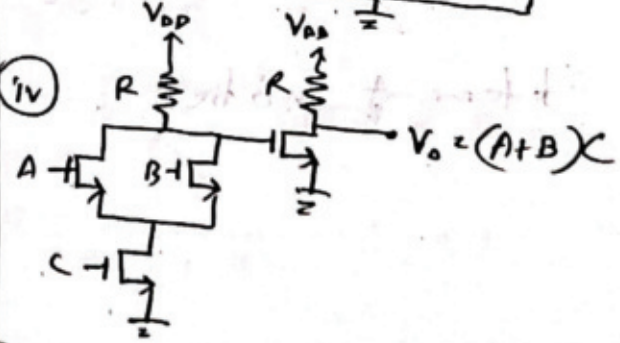
(ii)



(iii)



(iv)



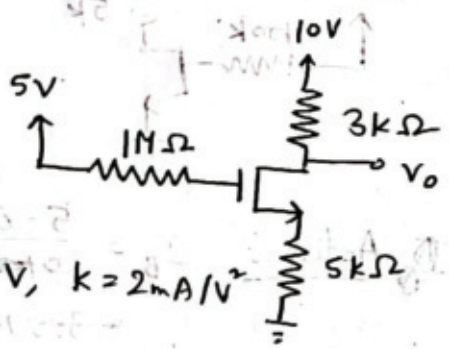
Q3

Set B

(a)

$\overline{AB + C(D+E)}$

(b)



$V_T = 1V$, $k = 2mA/V^2$

$V_G = 5V$, $V_D = y$, $V_S = x$

$I_D = \frac{10-y}{3} = \frac{x-0}{5} \Rightarrow y = 10 - \frac{3}{5}x$

$V_{GS} = 5 - x$, $V_{OV} = 4 - x$

Saturation: $I_D = \frac{2}{2} \times (4-x)^2$

$\frac{x-0}{5} = 1 \times (16 - 8x + x^2)$

$\Rightarrow x = 80 - 40x + 5x^2$

$\Rightarrow 5x^2 - 41x + 80 = 0$

$\Rightarrow x = 5V, 3.2V$

$V_{GS} = 5 - 5 = 0 < V_T$ ✗

$V_{GS} = 5 - 3.2 = 1.8V$

$V_{GS} > V_T$ ✓

$V_D = 10 - \frac{3}{5} \times 3.2 = 8.08V$

$V_{DS} = 8.08 - 3.2 = 4.88V$

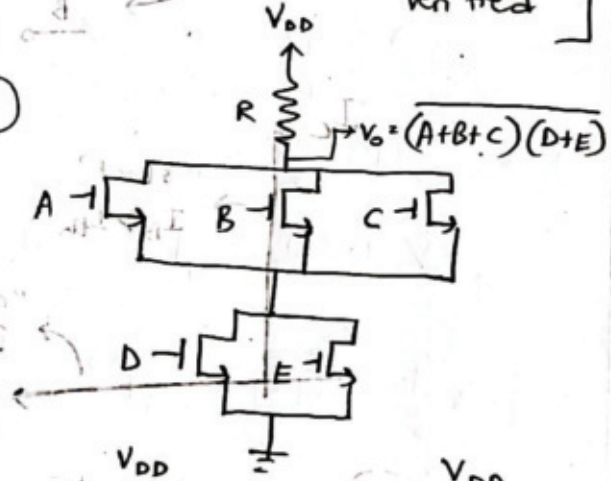
$\therefore V_D$

$V_{OV} = 4 - 3.2 = 0.8V$

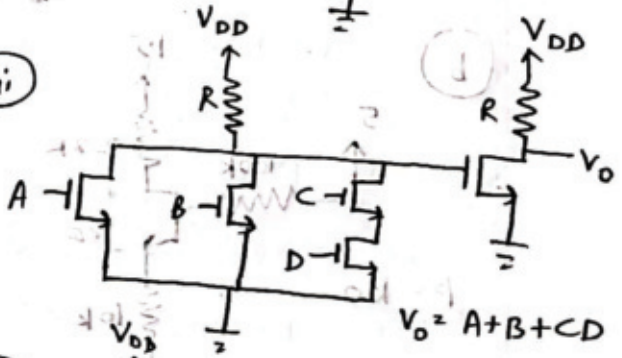
$\therefore V_{DS} > V_{OV}$ ✓ [saturation verified]

(c)

(i)

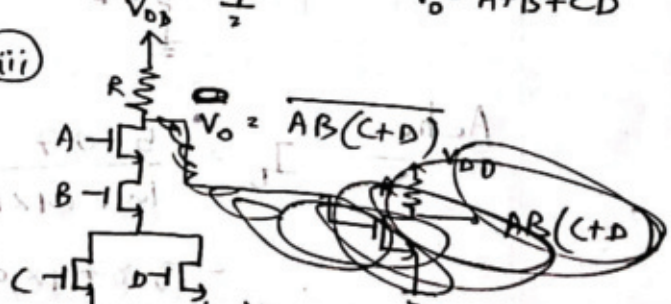


(ii)

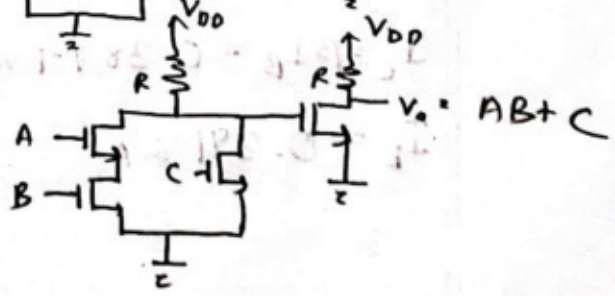


$V_o = A + B + CD$

(iii)

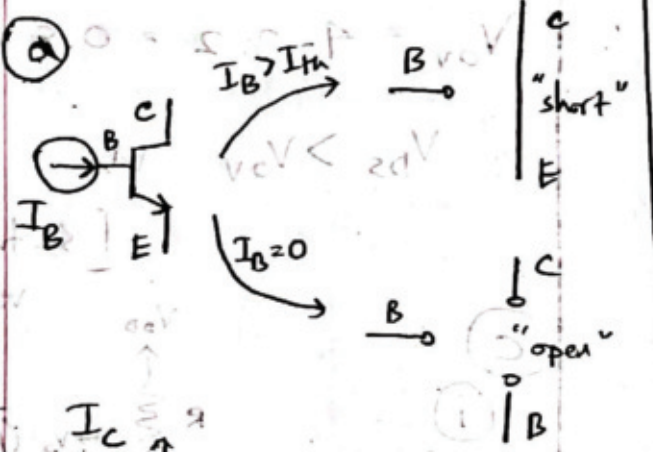


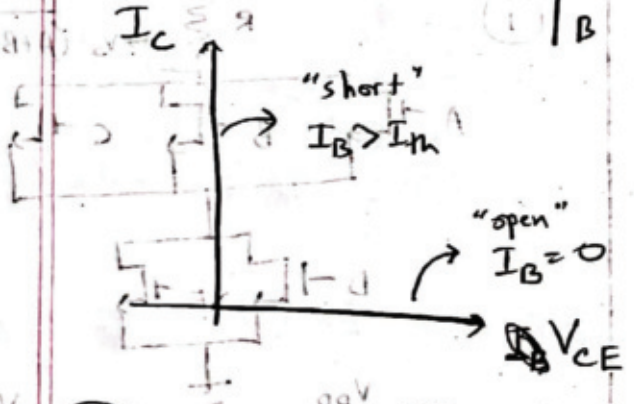
(iv)



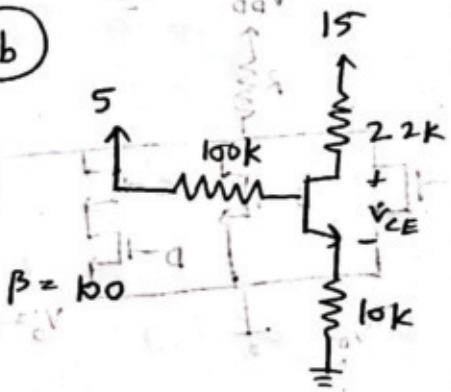
Q2 Set A

(a)





(b)



Active: $I_B = \frac{5 + 0.7}{100 + 101 \times 10}$

$= 3.879 \times 10^{-3}$ mA

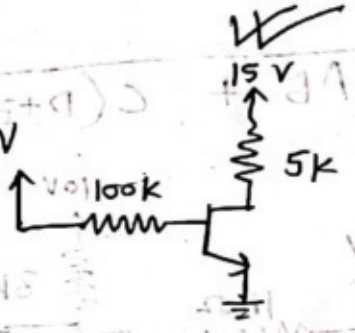
$I_C = \beta I_B = 0.3879$ mA

$I_E = 0.391$ mA

$V_{CE} = 15 - 2.2I_C - 10I_E$

$= 10.235 > 0.2$

(c)



Active: $I_B = \frac{5 - 0.7}{100 + 101 \times 10}$

$= 0.043$ mA

$I_C = 4.3$ mA

$V_{CE} = 15 - 5I_C = -6.5$ V

∴ Saturation

Saturation: $I_B = \frac{5 - 0.8}{100}$

$= 0.042$ mA

$I_C = \frac{15 - 0.2}{5} = 2.96$ mA

$\frac{I_C}{I_B} = 70.476 < \beta$

$I_E = 3.002$ mA

2c ==> Wrong solution. Correct solution is in the next page.

Set A

2c) Assume Q_2 is active,

$V_{BE} = 0.7V$

$V_E = 0V$

$5 - I_B(100) - 0.7 = 0$

$\therefore I_B = 0.043\ mA$

$I_C = \beta I_B = 100 \times 0.043 = 4.3\ mA$

$$I_C = \frac{V_{CC} - V_C}{R_C}$$

$$\Rightarrow 4.3\ mA = \frac{15 - V_C}{2.2k\Omega}$$

$\therefore V_C = 5.54V$

$\therefore V_{CE} = 5.54V$

$V_{CE} > 0.2V$

$\Rightarrow 5.54V > 0.2V$

$\therefore Q_2$ is in active mode.

Rahim was correct.

Set B

Q2

(a) Same as set A

(b) Active :

$I_B = 3.945 \times 10^{-3}$ mA

$I_C = 0.3945$ mA

$I_E = 0.398$ mA

$V_{CE} = 9.16 > 0.2$ V

[same as set A]

(c) Active :

$I_B = 0.05375$ mA

$I_C = 7.375$

$V_{CE} = 15 - 3.7 = -1.125$

∴ Must be saturation

Saturation :

$I_B = 0.0525$ mA

$I_C = 2.96$ mA

$I_E = 3.0125$ mA

$\frac{I_C}{I_B} = 56.38 < 100$

2c ==> Wrong solution. Correct solution is in the next page.

Set B

THR

2c) Assume active mode,

$V_{BE} = 0.7V$

$5 - 80I_B - V_{BE} = 0$

$\therefore I_B = 0.05375\ mA$

$I_C = \beta I_B = 100 \times 0.05375 = 5.375\ mA$

$I_C = \dfrac{V_{CC} - V_C}{R_C}$

$\Rightarrow 5.375 = \dfrac{15 - V_C}{3k}$

$\therefore V_C = -1.125$

$V_{CE} < 0.2$, so not active.

Assume saturation,

$5 - 80I_B - 0.8 = 0$

$\therefore I_B = 0.0525\ mA$

$V_{CE} = 0.2V = V_C$

$I_C = \dfrac{15 - 0.2}{3} = 4.93\ mA$

$I_E = I_B + I_C = 4.9825\ mA$

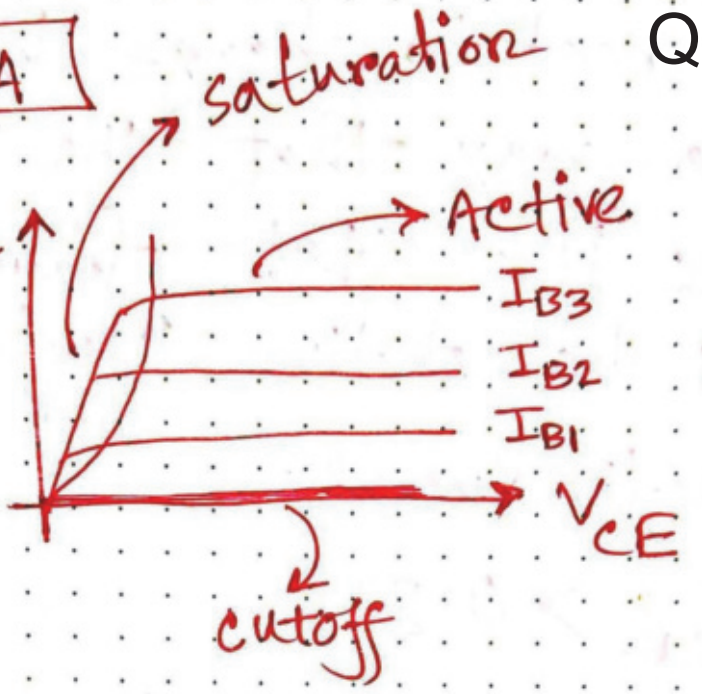
$\dfrac{I_C}{I_B} = \dfrac{4.93}{0.0525} = 93.904 < \beta$

So, in saturation mode.

Question-04

Set-A

(a)



$I_{B3} > I_{B2} > I_{B1}$

(b) $I_B = 0.04\ mA$ **Sat. Mode**

$$5 - R_C I_C - V_{CE} - R_E I_E = 0$$

$$\hookrightarrow 5 - (1K) I_C - 0.2 - (1K)(I_B + I_C) = 0$$

$$\hookrightarrow I_C = 2.38\ mA.$$

$$\therefore I_E = (0.04 + 2.38)\ mA = 2.42\ mA$$

Verification

$$\frac{I_C}{I_B} < \beta$$

$$\hookrightarrow \frac{2.38}{0.04} < 90 \rightarrow 59.5 < 90 \rightarrow \text{True.}$$

$I_B = 0.04\ mA$
$I_C = 2.38\ mA$
$I_E = 2.42\ mA$
$V_{CE} = 0.2\ V$

© We need to change V_{cc} in such a way that the BJT changes it's state from Sat. mode to Active Mode.

In active mode,

$$V_{CE} > 0.2$$

Applying KVL we get,

$$V_{cc} - R_c I_c - V_{CE} - I_E R_E = 0$$

$$\hookrightarrow V_{CE} = V_{cc} - R_c I_c - R_E I_E .$$

We need to make sure that,

$$V_{cc} - I_c R_c - I_E R_E > 0.2$$

$$\hookrightarrow V_{cc} > I_c R_c + I_E R_E + 0.2$$

In active mode,

$$I_c = \beta I_B$$

$$\therefore V_{cc} > \beta I_B R_c + (I_c + I_B) R_E + 0.2$$

$$\rightarrow V_{cc} > \beta I_B R_c + (\beta I_B + I_B) R_E + 0.2$$

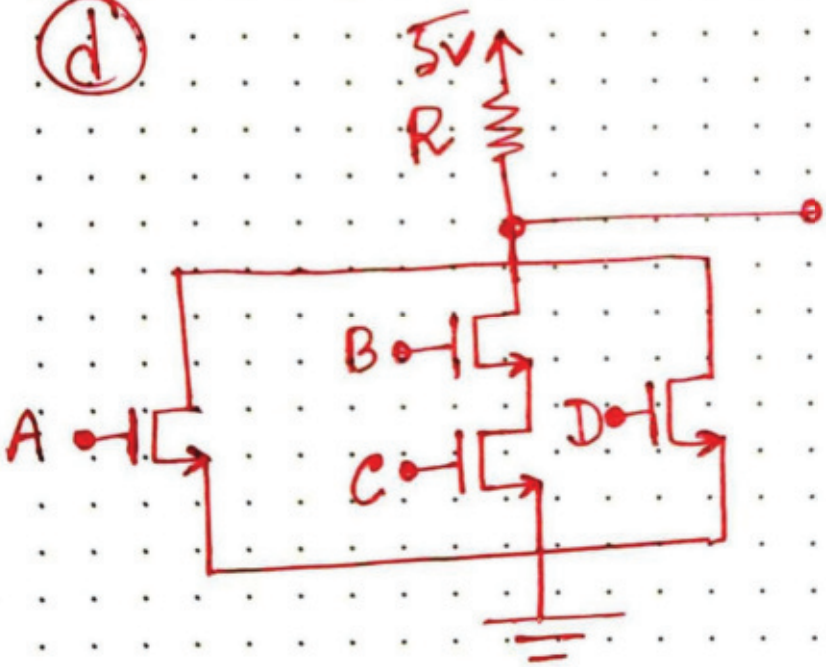
$\rightarrow V_{cc} > 90 \times 0.04 \times 1 + \underbrace{\left(90 \times 0.04\right)}_{+0.04} \times 1$

$+0.2$

$\rightarrow V_{cc} > 7.44.$

So, We need to increase V_{cc} from 5v to more than 7.44v in order to change the operating state of the BJT from Sat. mode to active mode.

(d)



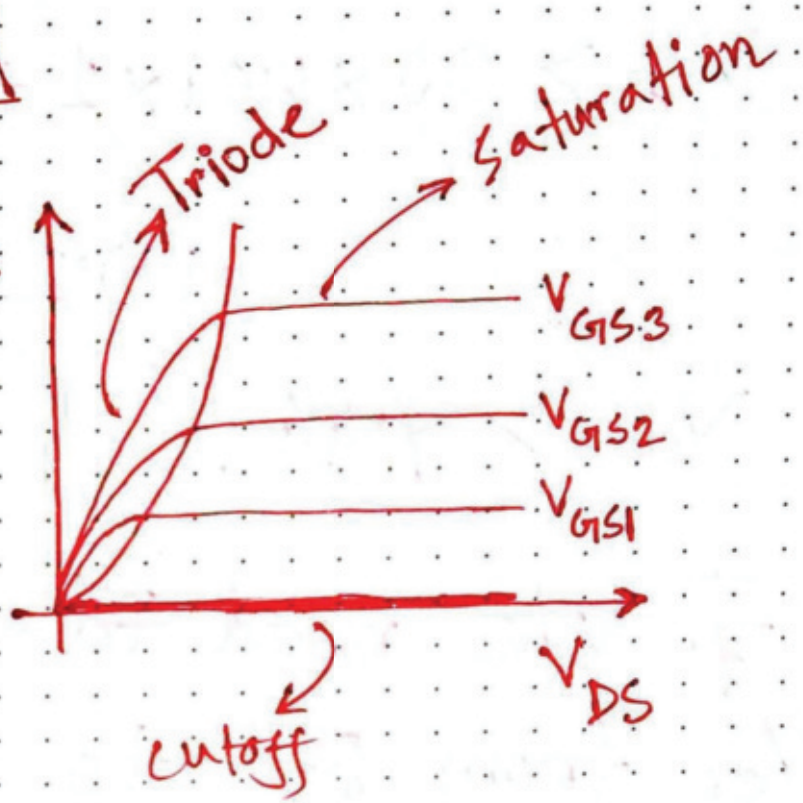
$f = \overline{A + B.C + D}$

I mistakenly drew this logic ckt using MOSFETs instead of BJTs.

The correct ckt will look similar to this one. Each MOSFET will be replaced by a BJT with a resistor in the Base Terminal.

Set-B

(a) i_{DS}



$V_{GS3} > V_{GS2} > V_{GS1}$

(b) **Sat. Mode**

$I_B = 0.05$ mA

$I_C = 2.375$ mA

$I_E = 2.425$ mA

$V_{CE} = 0.2$ V.

Verification

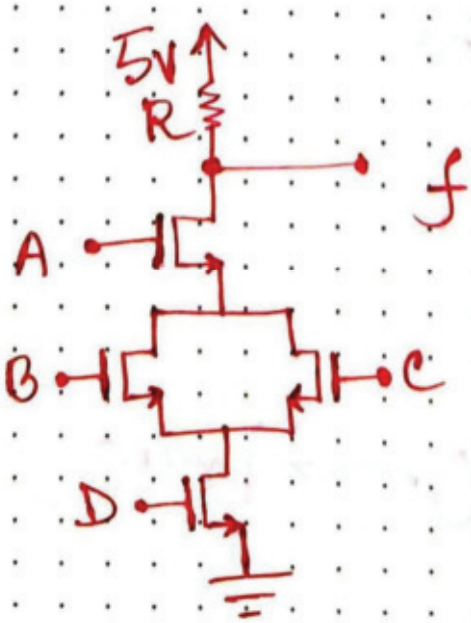
$\frac{I_C}{I_B} < \beta$

↳ $47.5 < 110 \rightarrow$ True

(c) Procedure → Similar to Set-A.

$V_{cc} > 11.25\,v$.

(d)



$$f = \overline{A.(B+C).D}$$

I mistakenly drew this logic ckt using MOSFETs instead of BJTs.

The correct ckt will look similar to this one. Each MOSFET will be replaced by a BJT with a resistor in the Base Terminal.