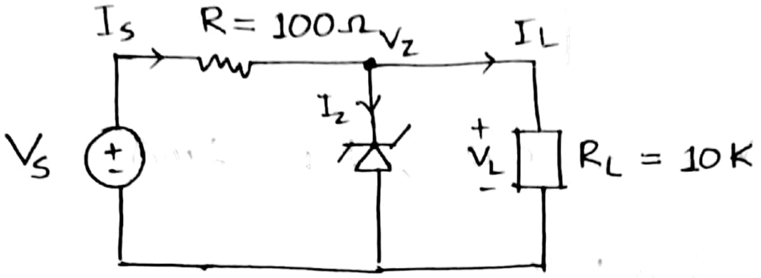
1. Week 6 Problem



Given, $V_{Z0} = 3V$, $r_Z = 0\Omega$, $I_{ZK} = 1\,mA$

worst case:

$$I_Z = I_{ZK} = 1\,mA$$

$$\therefore V_L = V_Z = V_{Z0} + I_Z r_Z$$
$$= 3 + 1 \times 0$$
$$= 3\,V$$

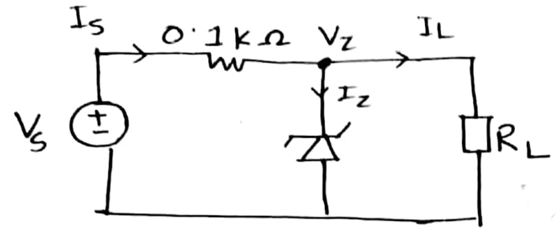
$$\therefore I_L = \frac{V_L}{R_L} = \frac{3}{10K} = 0.3\,mA$$

$$\therefore I_S = I_Z + I_L = (1 + 0.3)\,mA = 1.3\,mA$$

Now, $I_S = \dfrac{V_S - V_Z}{R}$ $\qquad R = 100\Omega = 0.1K\Omega$

$$\Rightarrow V_S = V_Z + I_S R$$
$$= 3 + 1.3 \times 0.1 = 3.13\,V$$

2.



Given, $V_{Zo} = 3V$, $r_Z = 0\Omega$, $I_{ZK} = 1mA$

$V_S = 5V \pm 5 \times 10\%$

$R_L = ?$ (worst case)

<u>Answer:</u> worst case sceneric,

$I_Z = I_{ZK} = 1mA$

$\therefore V_L = V_Z = V_{Zo} + I_Z r_Z = 3 + 1 \times 0 = 3V$

$V_S = V_S(min)$ [for worst case]

$= 5 - 5 \times 10\%$

$= 4.5V$

$\therefore I_S = \dfrac{V_S - V_Z}{0.1k\Omega} = \dfrac{4.5 - 3}{0.1} = 15\ mA$

$\therefore I_L = I_S - I_Z = 15 - 1 = 14\ mA$

$$\therefore R_L = \frac{V_L}{I_L} = \frac{V_Z}{I_L} = \frac{3\,V}{14\,mA}$$

$$= 0.214\ K\Omega \quad [\text{Ans}]$$

3. NAND gate truth Table:

A	B	OUT
0	0	1
0	1	1
1	0	1
1	1	0

When A = 0

B	OUT
0	1
1	1

When A = 1

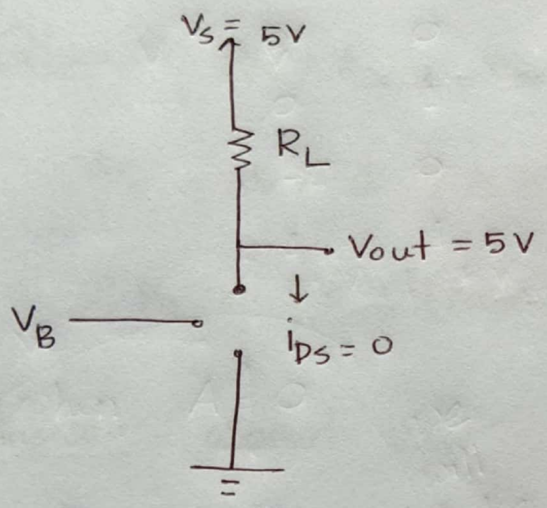
B	OUT
0	1
1	0

⟹ For this particular problem, we need this.

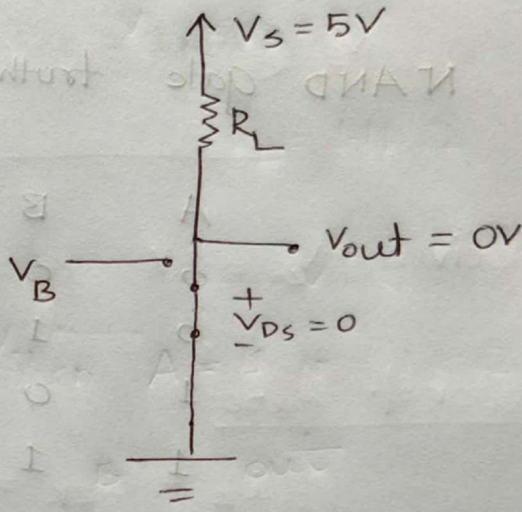
Because we can see, when one input is high, the gate will behave like an inverter

For S-Model: [Given, $V_T = 1V$]

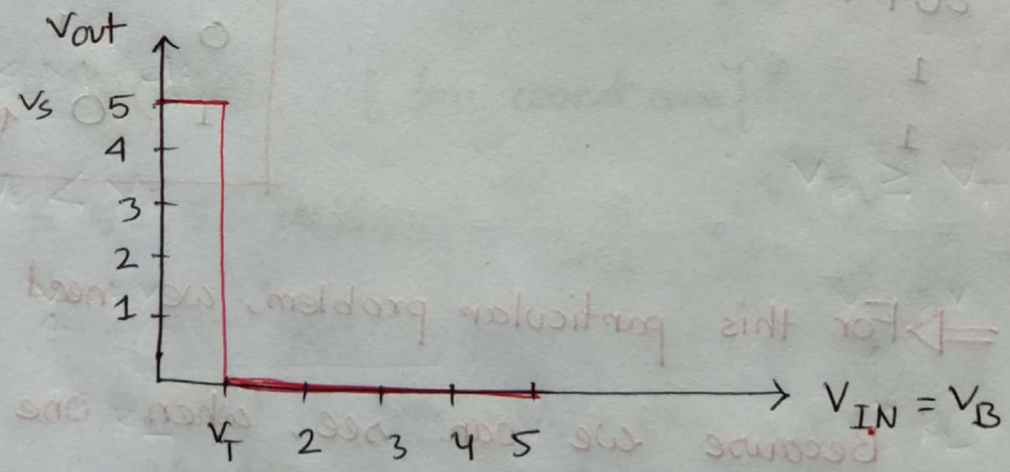
$V_B < V_T$



$V_B \geq V_T$

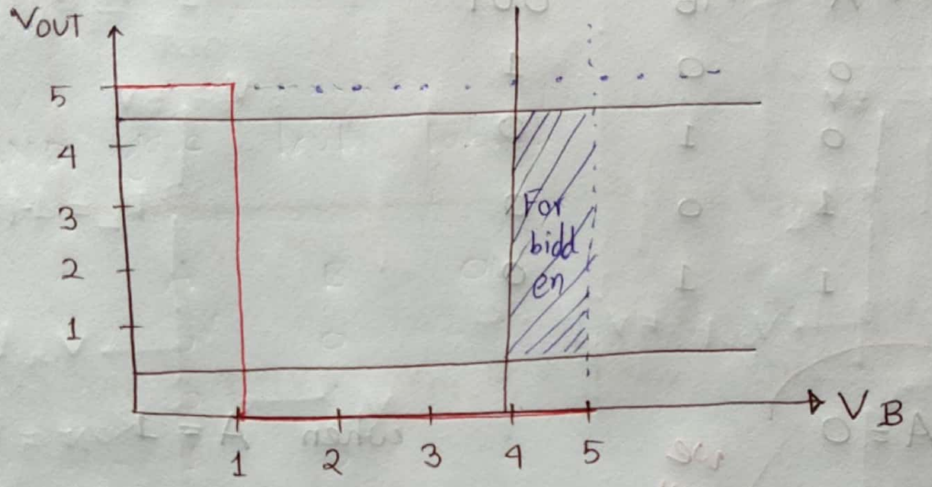


∴ Transfer characteristics graph:



Given,

$V_{OH} = 4.4V$, $V_{OL} = 0.5V$, $V_{IH} = 3.9V$



From the figure, we can clearly see, the maximum value of V_{IL} can be

$$V_{IL} \leq V_T$$

$$\Rightarrow V_{IL} \leq 1V$$

Also, for static discipline, we know, $V_{IL} > V_{OL}$.

$$\therefore V_{OL} < V_{IL} < V_T$$

$$\Rightarrow 0.5 < V_{IL} < 1V$$

4. NOR gate Truth Table:

A	B	OUT
0	0	1
0	1	0
1	0	0
1	1	0

when $A = 0$

B	OUT
0	1
1	0

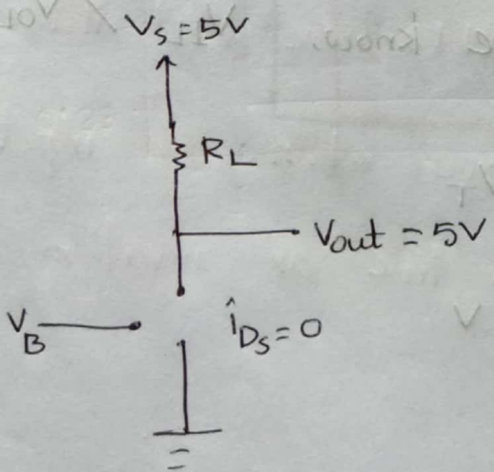
we will take this

when $A = 1$

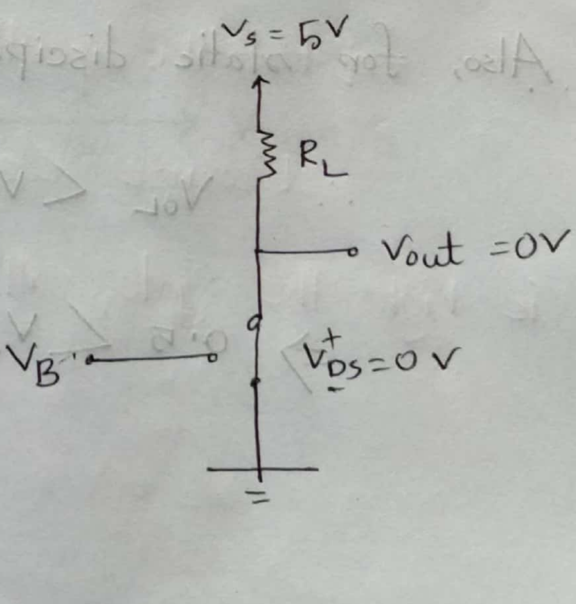
B	out
0	0
1	0

For S-Model:

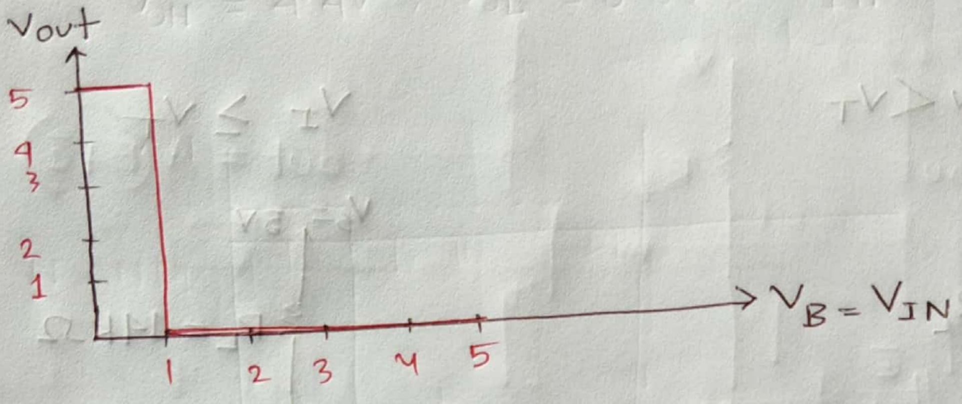
$V_B < V_T$



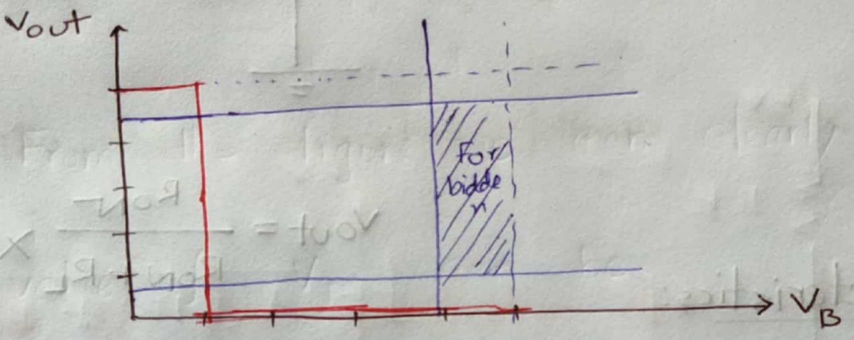
$V_B \geq V_T$



Transfer characteristics:



Given, $V_{OH} = 4.4V$, $V_{OL} = 0.5V$, $V_{IH} = 3.9V$



To avoid invalid region, $V_{IL} < V_T$

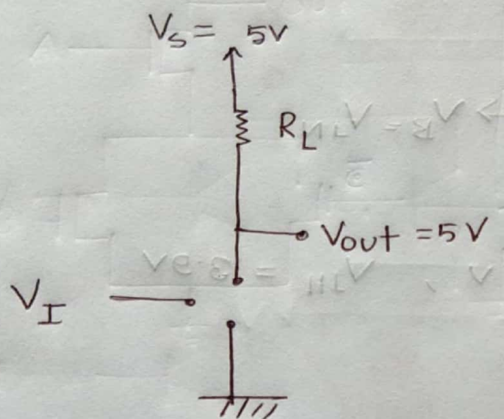
To meet tighter restrictions, $V_{IL} > V_{OL}$

$$\therefore \quad V_{OL} < V_{IL} < V_T$$

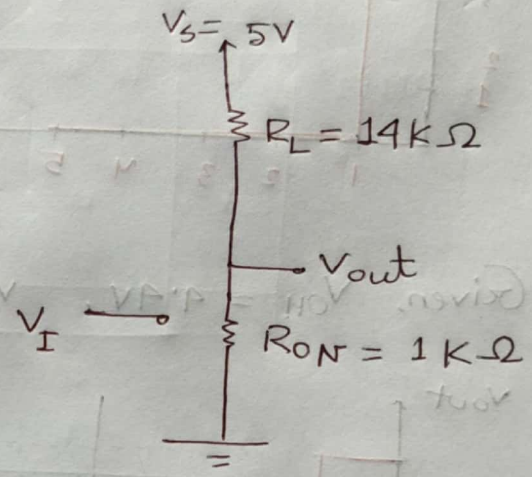
$$\Rightarrow \quad 0.5 < V_{IL} < 1$$

5. For SR model:

$V_I = LOW < V_T$



$V_I \geq V_T$

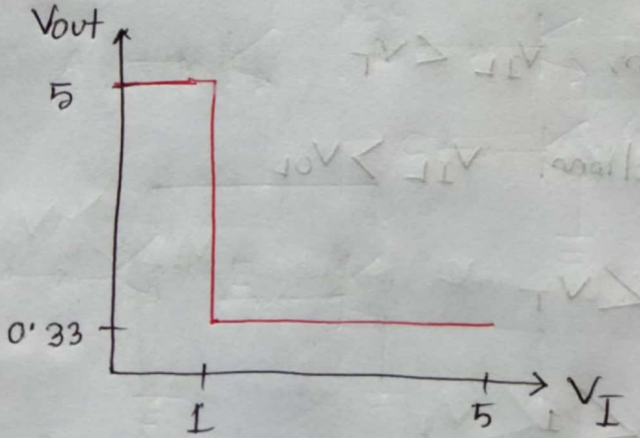


$$V_{out} = \frac{R_{ON}}{R_{ON} + R_L} \times V_S$$

$$= \frac{1}{1+14} \times V_S$$

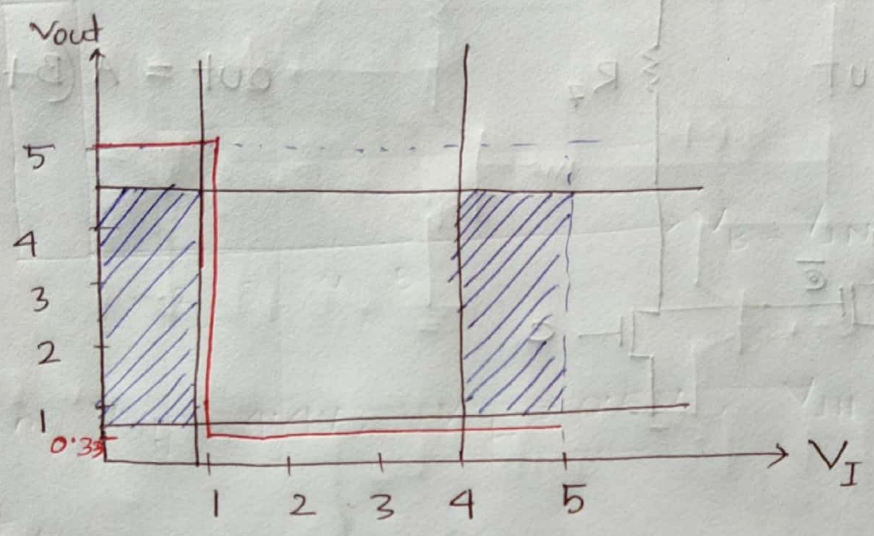
$$= 0.33V$$

<u>Transfer Characteristics:</u>



Given,

$V_{OH} = 4.5V$, $V_{OL} = 0.5V$, $V_{IH} = 4V$, $V_{IL} = 0.9V$



Yes, the specification follows static discipline.

** If the specification does not work: ⟹

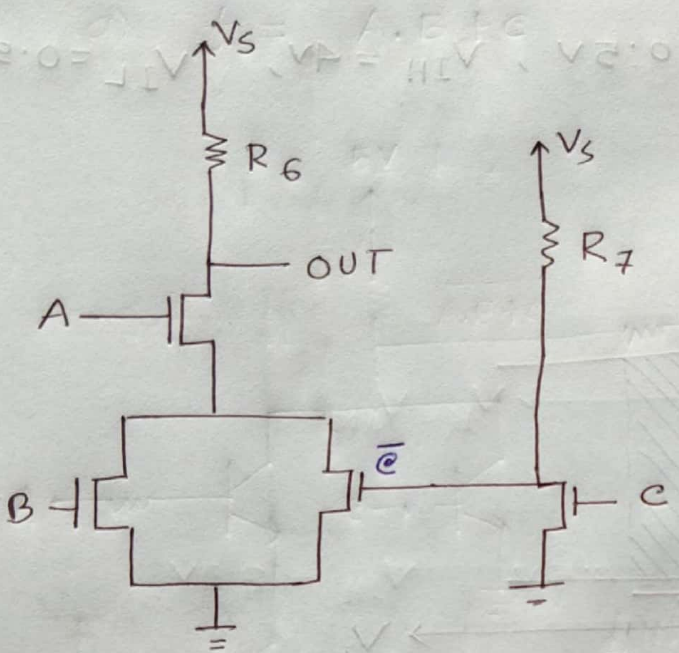
design condition:

$$\frac{R_{ON}}{R_L + R_{ON}} \times V_S < V_{OL}$$

If for R_L : ⟹ $R_L > \frac{V_S}{V_{OL}} \times R_{ON} - R_{ON}$

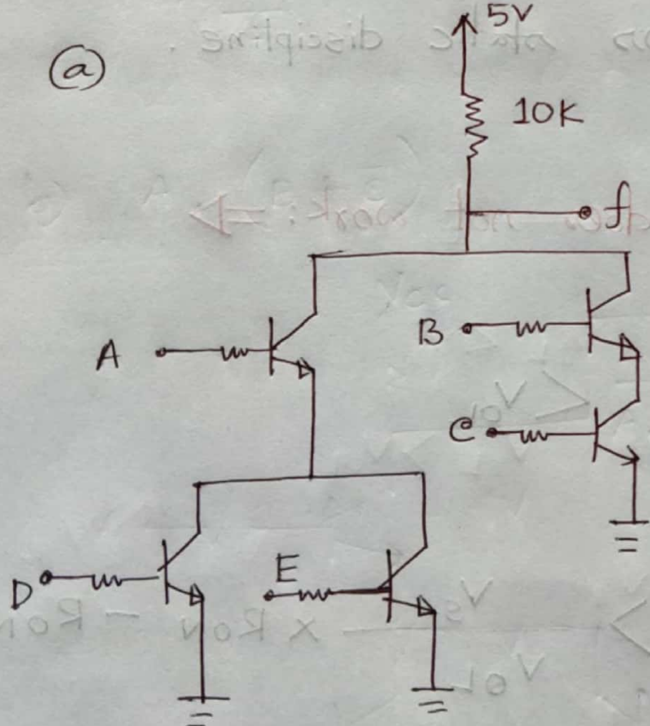
If for R_{ON} ⟹ $R_{ON} < \frac{V_{OL}}{V_S - V_{OL}} \times R_L$

6.



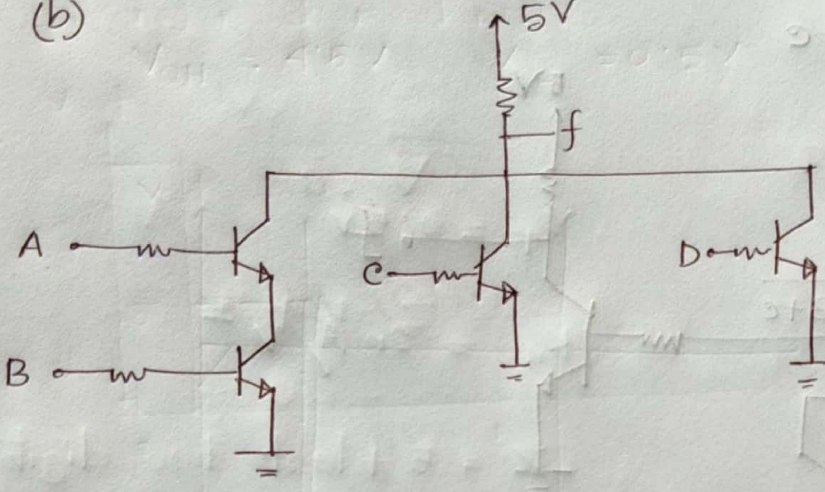
$$out = A(B+\bar{C})$$

7. (a)



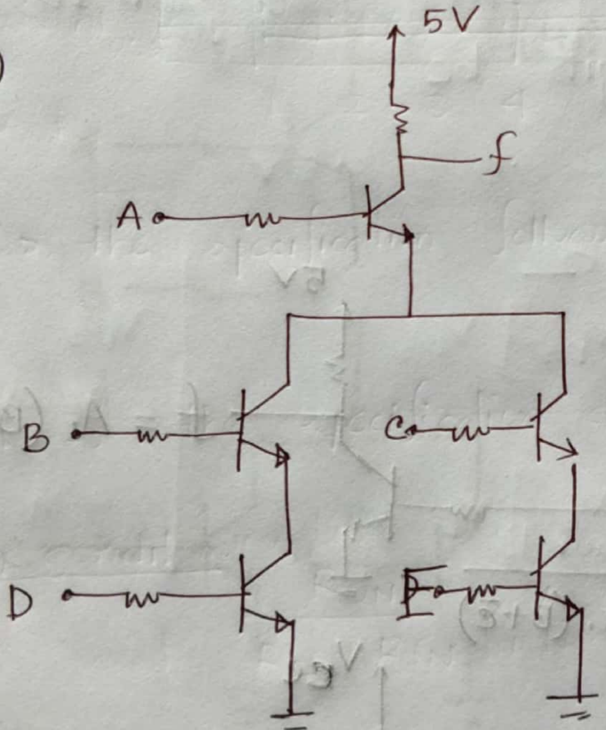
$$f = \overline{A(D+E) + BC}$$

(b)



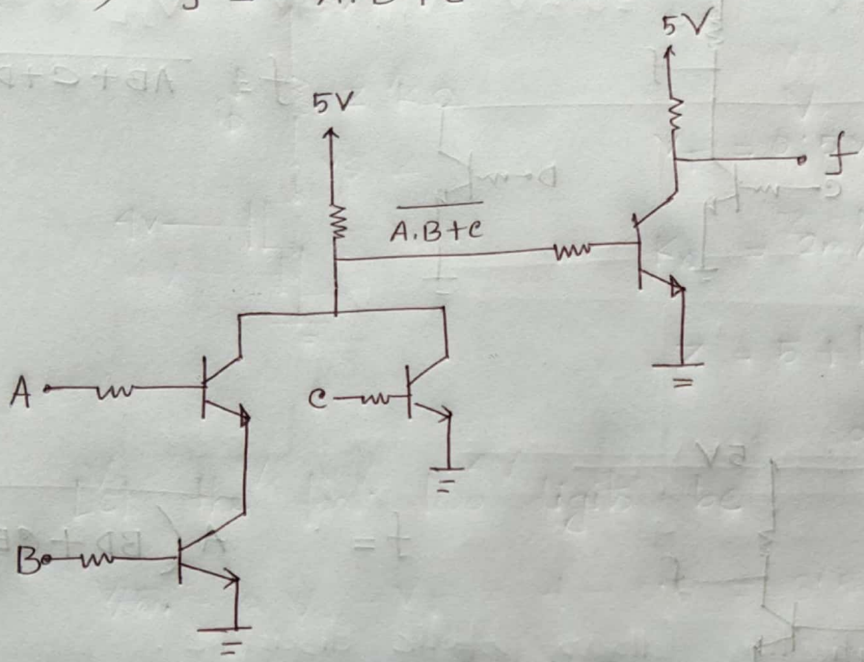
$f = \overline{AB + C + D}$

(c)

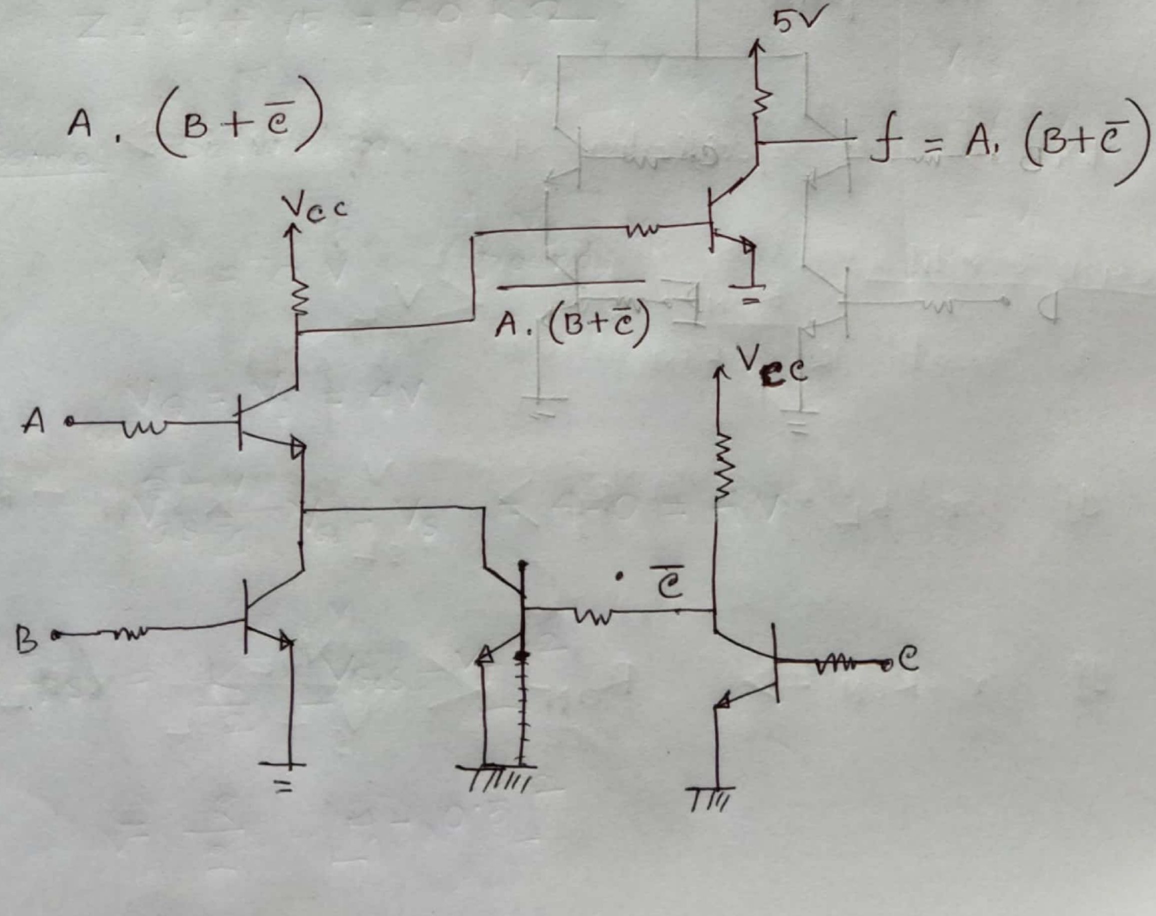


$f = \overline{A(BD + CE)}$

8. a) $f = A.B+C$



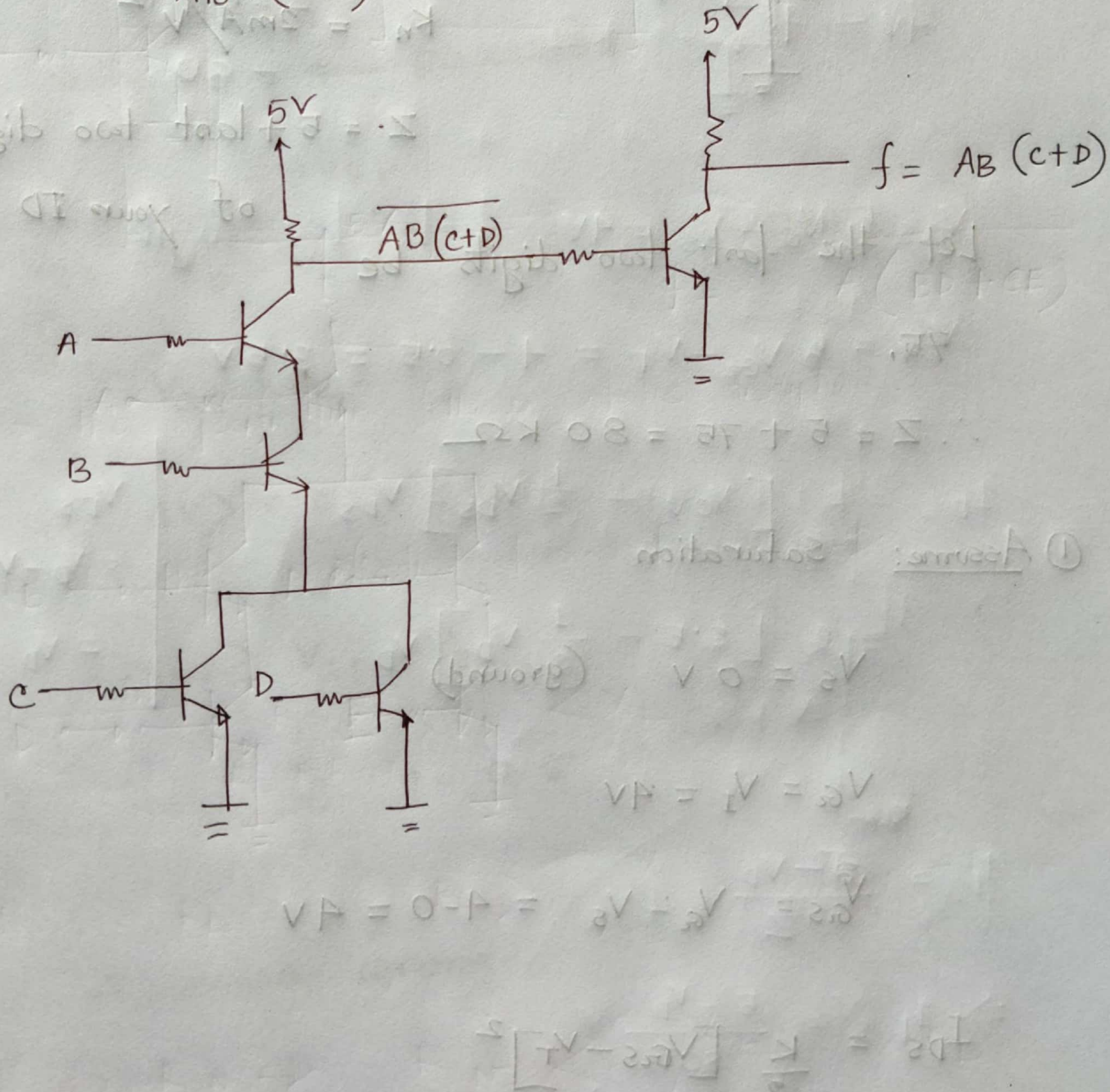
b) $A.(B+\overline{C})$



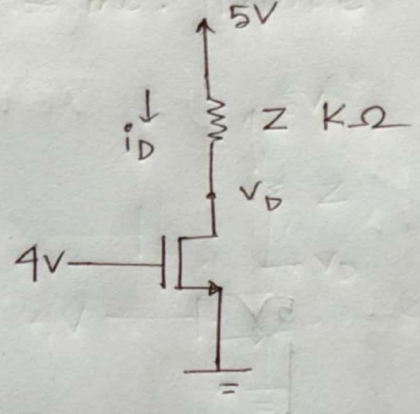
c) $f = \overline{\overline{AB} + \overline{C+D}}$

$= \overline{\overline{AB}} \cdot \overline{\overline{C+D}}$

$= AB\,(C+D)$



9.



$V_T = 0{\cdot}5\,V$

$K_n = 2mA/V^2$

Z = 5 + last two digits of your ID

Let the last two digits be 75.

$\therefore Z = 5 + 75 = 80\ K\Omega$

① Assume: Saturation

$V_S = 0\ V$ (ground)

$V_G = V_I = 4V$

$V_{GS} = V_G - V_S = 4 - 0 = 4V$

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

$$= \frac{2}{2}\left[4 - 0{\cdot}5\right]^2$$

$$= 12{\cdot}25\ mA$$

$$I_{DS} = \frac{5 - V_D}{Z}$$

$$\Rightarrow 12.25 = \frac{5 - V_D}{80}$$

$$\Rightarrow V_D = 5 \cancel{4} - 80 \times 12.25$$

$$= -975 V$$

$$V_{DS} = V_D - V_S = -975 - 0 = -975$$

Verify:

$$V_{GS} \geq V_T$$

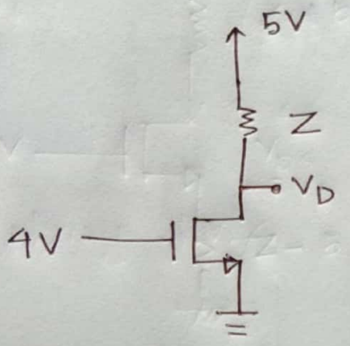
$$\Rightarrow 4V > 0.5$$

$$V_{DS} \geq V_{GS} - V_T$$

$$\Rightarrow -9075 \ngeq 4 - 0.5$$

$\therefore$ Assumtion wrong

(11) Assume : Triode



$V_T = 0.5V$

$V_S = 0$

$Z = 5 + 75 = 80$

$V_{GS} = V_G - V_S = 4V$

$V_{OV} = V_G - V_T = 4 - 0.5 = 3.5V$

$I_{DS} = k\left[V_{OV} - \frac{1}{2}V_{DS}\right]V_{DS}$

$V_{DS} = V_D - V_S = V_D$

$= 2\left[3.5 - \frac{1}{2}V_D\right]V_D$

$I_{DS} = \frac{5 - V_D}{Z}$

$\Rightarrow I_{DS} = \frac{5 - V_D}{80}$

$\Rightarrow V_D = 5 - I_{DS} \times 80$

$$\Rightarrow V_D = 5 - 2\left[3.5 - \tfrac{1}{2}V_D\right]V_D \quad \times 80$$

$$\Rightarrow V_D = 5 - 560 V_D + 80 V_D^2$$

$$\Rightarrow 80V_D^2 - V_D - 560V_D + 5 = 0$$

$$\Rightarrow 80V_D^2 - 561 V_D + 5 = 0$$

$$\Rightarrow V_D = 7.02\,V$$

$$= 0.009\,V$$

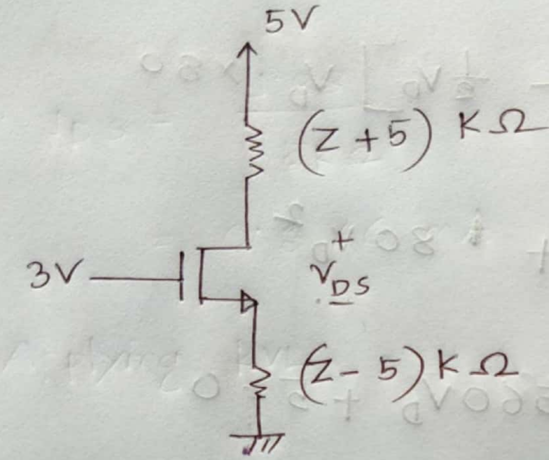
Taking the smaller root $V_D = 0.009\,V$

<u>Verify:</u> $V_{GS} \geq V_T$ $\qquad$ $V_{DS} < V_{GS} - V_T$

$\Rightarrow 4V > 0.5V$ ✓ $\qquad$ $\Rightarrow 0.009 < 3.5V$ ✓

∴ Assumtion right

10.

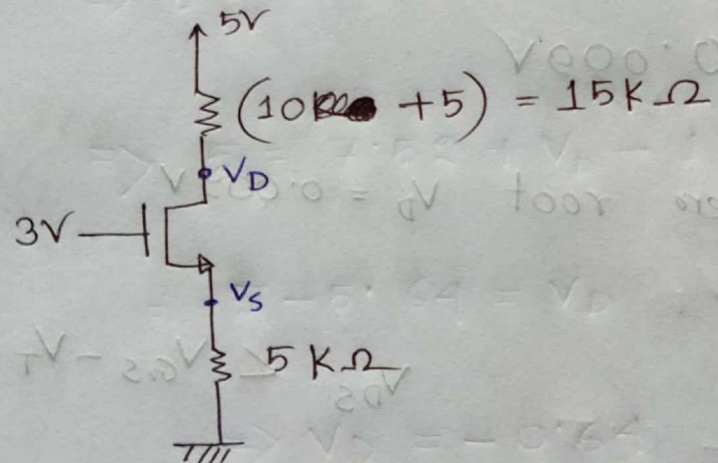


$V_T = 0'5V$

$k_n = 2mA/V^2$

$Z = 5 + 05 \longrightarrow$ last two digits

$= 10\ k\Omega$



Assume: Saturation

$V_{GS} = V_G - V_S$

$= 3 - V_S$

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

$$= \frac{2}{2}\left[3 - V_S - 0.5\right]^2$$

$$= \left[2.5 - V_S\right]^2$$

$$I_{DS} = \frac{V_S - 0}{5}$$

$$\Rightarrow V_S = I_{DS} \times 5$$

$$\Rightarrow V_S = \left[2.5 - V_S\right]^2 \times 5$$

$$\Rightarrow V_S = \left[6.25 - 5V_S + V_S^2\right] 5$$

$$\Rightarrow V_S = 31.25 - 25V_S + 5V_S^2$$

$$\Rightarrow V_S + 5V_S^2 + 25V_S + 31.25 = 0$$

$$\Rightarrow 5V_S^2 - 26V_S + 31.25 = 0$$

$$\therefore V_S = 3.31\text{ V}$$

$$1.88\text{ V}$$ smaller root

$$\therefore I_{DS} = \frac{1.88}{5k\Omega}$$

$$= 0.376 \text{ mA}$$

Applying KVL

$$5 = 15 \times I_{DS} + V_{DS} + 5 \times I_{DS}$$

$$\Rightarrow 5 = 20 I_{DS} + V_D - V_S$$

$$\Rightarrow 5 = 20 \times 0.376 + V_D - 1.88$$

$$\Rightarrow 5 = 7.52 + V_D - 1.88$$

$$\Rightarrow 5 - 5.64 = V_D$$

$$\Rightarrow V_D = -0.64$$

$$\therefore V_{DS} = V_D - V_S$$

$$= -0.64 - 1.88$$

$$= -2.52$$

Verify:

$V_{GS} > V_T$

$\Rightarrow V_G - V_S > V_T$

$\Rightarrow 3 - 1.88 > 0.5$

$\Rightarrow 1.12 > 0.5$ ✓

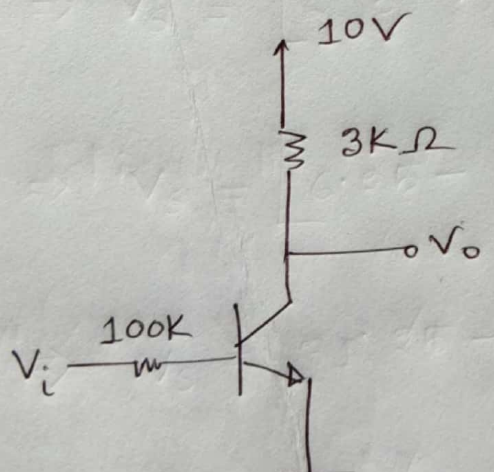
$V_{DS} \geq V_{GS} - V_T$

$\Rightarrow -2.52 \not> 1.12 - 0.5$

✗

∴ Assumption wrong

11.



$\beta = 100$

① $V_i = 1V$

Assume: Active

$\rightarrow V_{BE} = 0.7V$

$\rightarrow I_c = \beta I_B$

$V_{BE} = 0.7$

$\Rightarrow V_B - V_E = 0.7$

$\Rightarrow V_B = 0.7$

$$I_B = \frac{V_i - V_B}{R_B} = \frac{1 - 0.7}{100} = 0.003 mA$$

$I_c = \beta I_B$

$= 100 \times 0.003$

$= 0.3 mA$

$$I_c = \frac{V_{cc} - V_c}{R_c} = \frac{10 - V_c}{3}.$$

$\Rightarrow V_c = 9.1V$

$I_E = I_c + I_B = 0.3 + 0.003 = 0.303 mA$

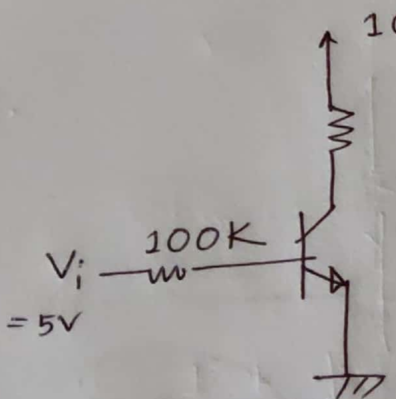
Verify:

$$V_{CE} = V_C - V_E$$
$$= 9.1 - 0$$
$$= 9.1$$

$V_{CE} > 0.2V$

∴ Assumtion right

(ii) $V_i = 5V$



Assume: Active $\longrightarrow$ $V_{BE} = 0.7V$, $I_C = \beta I_B$

$V_{BE} = 0.7$

$\Rightarrow V_B = 0.7V$

$$I_B = \frac{V_i - V_B}{R_B}$$
$$= \frac{5 - 0.7}{100}$$
$$= 0.043 mA$$

$I_c = \beta I_B$

$= 100 \times 0.043$

$= 4.3\ mA$

$$I_c = \frac{10 - V_c}{3}$$

$\Rightarrow V_c = -2.9V$

Verify: $V_{CE} = V_c - V_E$

$= -2.9\ V \ngtr 0.2V$

$\therefore$ Assumption wrong

Assume: Saturation —— $V_{BE} = 0.8V$

$V_{CE} = 0.2V$

$V_{BE} = 0.8$

$\Rightarrow V_B = 0.8$

$V_{CE} = 0.2$

$\Rightarrow V_c = 0.2V = V_o$

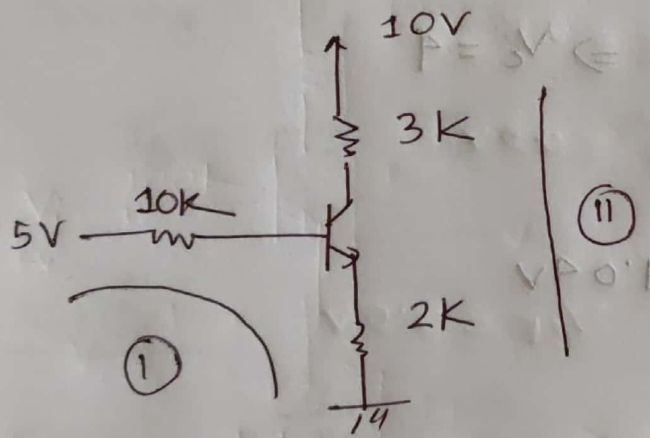
$$I_B = \frac{5 - 0.8}{100} = 0.042\,mA$$

$$I_c = \frac{10 - V_c}{R_c} = \frac{10 - 0.2}{3} = \frac{9.8}{3} = 3.29\,mA$$

$$\frac{I_c}{I_B} = \frac{3.29}{0.042} = 78.33 < \beta \checkmark$$

∴ Assumption right.

12.



Assume: Active $\longrightarrow$ $V_{BE} = 0.7\,V$

$I_c = \beta I_B$ —— (1)

$I_C = \alpha I_E$ —— (11)

(1) ÷ (11)

$$I_E = \frac{\beta}{\alpha} I_B$$

Scanned with CamScanner

KVL $\longrightarrow$ (1) line

$$5 = 10 I_B + 0.7 + 2 I_E$$

$$\Rightarrow 5 = 10 I_B + 0.7 + 2 \frac{\beta}{\alpha} I_B$$

$$\Rightarrow I_B = 0.02 \, mA$$

$$I_c = \beta I_B = 100 \times 0.02 = 2mA$$

$$I_E = I_c + I_B = 2.02 \, mA$$

$$I_c = \frac{V_{cc} - V_c}{R_c} = \frac{10 - V_c}{3} \Rightarrow V_c = 4$$

$$I_E = \frac{V_E - 0}{2} \Rightarrow V_E = 4.04V$$

$$\therefore V_{CE} = V_c - V_E$$

$$= 4 - 4.04$$

$$= -0.04 \not> 0.2$$

$\therefore$ wrong

Assume: Saturation: $V_{BE} = 0.8V$ $V_{CE} = 0.2V$

KCL: $I_E = I_C + I_B$ —— (I)

KVL Line (I): $5 = 10I_B + V_{BE} + 2I_E$

$= 10I_B + 0.8 + 2I_E$ —— (II)

line (II): $10 = 3I_C + V_{CE} + 2I_E$

$= 3I_C + 0.2 + 2I_E$ —— (III)

Solving (I), (II), (III)

$I_B = .03$ $I_C = 1.95$ $I_E = 1.98$

Verify:

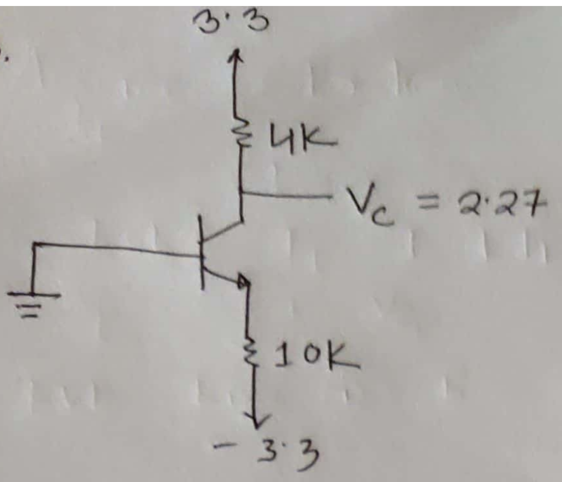
$\frac{I_C}{I_B} < \beta$

$\Rightarrow \frac{1.95}{.03} < \beta$

$\Rightarrow 65 < 100$

$\therefore$ right

13.



Assume: Active

$V_{BE} = 0.7$

$I_C = \beta I_B$

$I_C = \alpha I_E$

$$I_C = \frac{3.3 - 2.27}{4} = 0.257$$

$V_{BE} = 0.7 \Rightarrow V_E = -0.7$

$$I_E = \frac{-0.7 - (-3.3)}{10} = 0.26$$

$I_B = I_E - I_C = 0.26 - 0.257 = 0.0025 \text{ mA}$

$$\beta = \frac{I_C}{I_B} = 103$$

$$\alpha = \frac{I_C}{I_E} = 0.99$$

Verification:

$$V_{CE} = V_C - V_E$$

$$= 2.27 - (-0.7)$$

$$= 2.97 > 0.2V$$

$\therefore$ right