Answer to the Q. NO - 1(a)

ⓐ Given, $K' = 0.2 mA/V^2$; $V_t = 0.7V$; $\frac{W}{L} = 10$

ⓐ $V_{GS} = 5V$; $V_{DS} = 1V$

Here, $V_{GS} > V_T$

and $V_{GS} - V_t = 5 - 0.7 = 4.3V$

$\therefore V_{DS} < V_{GS} - V_t$ [Triode mode]

$\therefore I_D = K' \frac{W}{L} (V_{GS} - V_t - \frac{1}{2} V_{DS}) V_{DS}$

$= 0.2 \times 10 \times (4.3 - \frac{1}{2})$

$= 7.6 mA$ (Ans)

ⓑ $V_{GS} = 2$, $V_{DS} = 1.3 V$

Here, $V_{GS} > V_t$

and $V_{GS} - V_t = 2 - 0.7 = 1.3$

$\therefore V_{DS} \geq V_{GS} - V_t$ [saturation mode]

$\therefore I_D = \frac{K'}{2} \frac{W}{L} (V_{GS} - V_t)^2$

$= \frac{0.2}{2} \times 10 \times (1.3)^2 = 1.69 mA$ (Ans)

(c) $V_{GS} = 5V$, $V_{DS} = 0.2$ V

Here, $V_{GS} > V_t$

and $V_{GS} - V_t = 5 - 0.7 = 4.3$ V

$\therefore V_{DS} < V_{GS} - V_t$ [Triode mode]

$$\therefore I_D = K' \frac{W}{L} \left(V_{GS} - V_t - \frac{1}{2} V_{DS} \right) V_{DS}$$

$$= \cancel{5\times}\, 0.2 \times 10 \times \left(4.3 - \frac{0.2}{2} \right) \times 0.2$$

$$= 1.68 \text{ mA}$$ (Ans)

(d) $V_{GS} = V_{DS} = 5V$

Here, $V_{GS} > V_t$

and $V_{GS} - V_t = 4.3$

$\therefore V_{DS} \geq V_{GS} - V_t$

$$\therefore I_D = \frac{K'}{2} \frac{W}{L} \left(V_{GS} - V_t \right)^2$$

$$= \frac{0.2}{2} \times 10 \times (4.3)^2 = 18.49 \text{ mA}$$ (Ans)

Answer to the Q. NO - 1(b)

$V_{th} = 1\,V$

case	V_{GS}	V_{OV}	V_{DS}	Region of operation
a	0	-1	1	cutoff ; $V_{GS} < V_{th}$
b	1.5	0.5	1	saturation; $V_{GS} > V_{th}$ $V_{DS} \geq V_{OV}$
c	1.5	0.5	0.5	saturation; $V_{DS} \geq V_{OV}$
d Here, $V_D = 1\,V$ $V_S = 0\,V$	1.5	0.5	1	saturation;
e	2.5	1.5	1	Triode; $V_{GS} > V_{th}$ $V_{DS} < V_{OV}$

Answer to the Q. NO - 1(c)

1st Circuit,

$V_G = 2.2\,V$

$V_S = 0\,V$

$V_D = 2.2\,V$

$V_T = 0.4$

$\therefore V_{GS} = 2.2 - 0 = 2.2\,V$

$V_{OV} = 2.2 - 0.4 = 1.8\,V$

$V_{DS} = 2.2 - 0 = 2.2\,V$

$\therefore V_{DS} \geq V_{OV}$

$\therefore$ Region of operation is saturation. ~~mode~~

2nd circuit,

$V_G = 0V$

$V_S = -1V$

$V_D = -0.6V$

$V_T = 0.4V$

$\therefore V_{GS} = 0-(-1) = 1V$

$V_{OV} = \cancel{} 1-0.4 = 0.6V$

$V_{DS} = -0.6-(-1) = 0.4V$

$\therefore V_{DS} < V_{OV}$

$\therefore$ Region of operation is triode.

3rd circuit,

$V_G = 1V$

$V_S = 1V$

$V_D = 3V$

$V_T = 0.4$

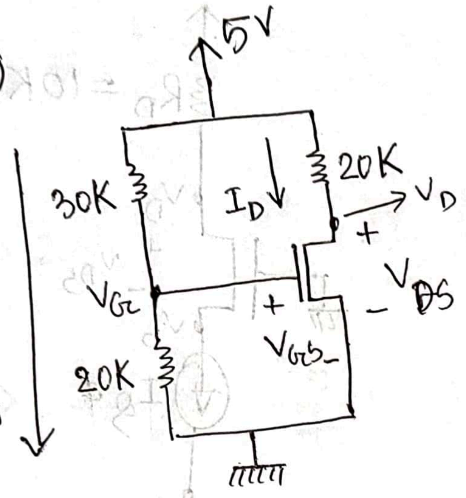
$\therefore V_{GS} = 1-1 = 0$

$\therefore V_{GS} < V_T$

$\therefore$ Region of operation is cutoff.

Answer to the Q. NO-2

(a)



Here, $V_{th} = 1V$

$K_n = 0.1 \, mA/V^2$

and $V_S = 0 \, V$

KVL in L_1,

$30I + 20I = 5 \Rightarrow 50I = 5 \Rightarrow I = 0.1 \, mA$

Now, $\dfrac{V_G - 0}{20} = 0.1$

$\Rightarrow V_G = 2 \, V$

Easier to do voltage division:

$V_G = \dfrac{20k}{20k + 30k} \times 5 = 2V.$

$\therefore V_{GS} = 2 - 0 = 2 \, V > V_{th}$

Let's assume ~~activ~~ saturation mode,

$\therefore I_D = \dfrac{K_n}{2} (V_{GS} - V_{th})^2$

$\Rightarrow I_D = \dfrac{0.1}{2} \times (2-1)^2$

$\Rightarrow I_D = 0.05 \, mA$

At V_D node,

$\dfrac{5 - V_D}{20} = 0.05$

$\Rightarrow V_D = 4 \, V$

$\therefore V_{DS} = 4 - 0 = 4 \, V$

$V_{OV} = 2 - 1 = 1 \, V$

$\therefore V_{DS} > V_{OV}$

Assumption correct!

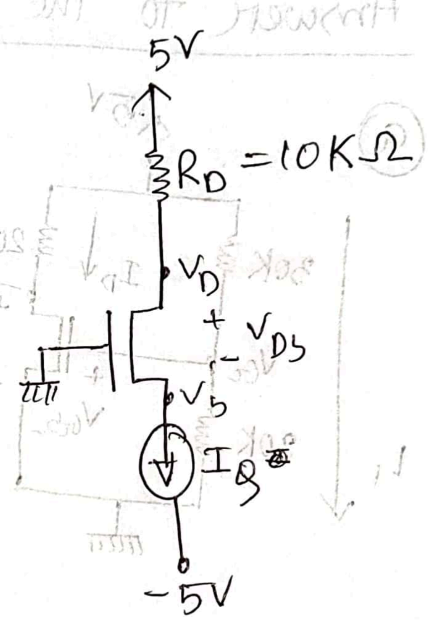
Answer to the Q. NO - 3

(a) Here, $V_D = 2.5\,V$

$V_{Th} = 0.8\,V$

$K'_n = 80\,\mu A/V^2$

$V_G = 0\,V$



$V_D = 2.5\,V > V_G$

$\therefore$ The mosfet is in saturation.

(V_s not needed)

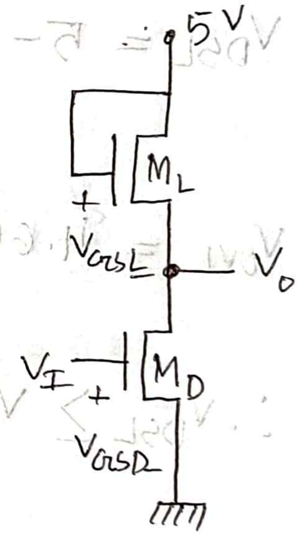
~~let's assume~~ & saturation,

$$I_D = \frac{K'_n}{2}\,\frac{W}{L}\,(V_{GS} - V_{Tn})^2$$

$$\Rightarrow 250 = \frac{80}{2}\,\frac{W}{L}\,(-V_S - 0.8)^2$$

$$\Rightarrow \frac{W}{L} = \frac{25}{4} \times \frac{1}{V_S^2 + 1.6V_S + 0.64}$$

(b) Here,



$V_{thL} = V_{thD} = 1V$

$K_{nD} = 50\,\mu A/V^2$

$K_{nL} = 10\,\mu A/V^2$

$V_{DD} = 5V$

No need to assume. we know this.

let's assume M_L in saturation and M_D in triode,

Here, $I_{DL} = I_{DD}$

$$\Rightarrow \frac{K_{nL}}{2}(V_{GSL} - V_{thL})^2 = K_{nD} \times \left(V_{GSD} - V_{thD} - \frac{1}{2}V_{DSD}\right)V_{DSD}$$

$$\Rightarrow \frac{10}{2}(5 - V_0 - 1)^2 = 50 \times \left(5 - 0 - 1 - \frac{1}{2}V_0\right)V_0$$

$$\Rightarrow 5 \times (4 - V_0)^2 = 50 \times \left(4 - \frac{1}{2}V_0\right)V_0$$

$\Rightarrow 16 - 8V_0 + V_0^2 = 40V_0 - 5V_0^2$

$\Rightarrow 6V_0^2 - 48V_0 + 16 = 0$

$\therefore V_0 = \underset{X}{\underline{7.65}},\ 0.35$ ✓

$\therefore V_{GSL} = 5 - V_0 = 5 - 0.35$
$= 4.65\ V$

$V_{DSL} = 5 - V_0 = 5 - 0.35$
$= 4.65V$

$V_{OVL} = 4.65 - 1 = 3.65V$

$\therefore V_{DSL} \geq V_{OVL}$ [saturation mode]

$\therefore$ assumption correct!

$V_{GSD} = 5 - 0 = 5V$

$V_{DSD} = 0.35 - 0 = 0.35V$

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

$\therefore V_{DSD} < V_{OVD}$ [triode mode]

$\therefore$ assumption correct!

(c) Given,

$V_G = 5V$

$V_S = 0V$

$V_{GS} = 5 - 0 = 5V$

$V_{DS} = 0.15\ V$

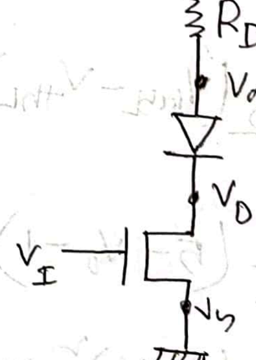
$V_{Th} = 0.6\ V$

$V_{ov} = 5 - 0.6 = 4.4V$

$I_D = 12\ mA$

$\because V_{DS} < V_{ov}$

$\therefore$ Region of operation is triode.



$$I_D = K_n' \frac{W}{L}\left(V_{GS} - V_{Th} - \frac{1}{2}V_{DS}\right)V_{DS}$$

$$\Rightarrow \frac{W}{L} = \frac{I_D}{K_n'\left(V_{OV} - \frac{1}{2}V_{DS}\right)V_{DS}}$$

$$\Rightarrow \frac{W}{L} = \frac{12\times10^{-3}}{80\times10^{-6}\times\left(4.4 - \frac{0.15}{2}\right)0.15}$$

$$\Rightarrow \frac{W}{L} = 231.21 \cong 231 \quad \text{(Ans)}$$

Now, $V_a - V_D = 1.6V$

$$\Rightarrow V_a = 1.6 + 0.15$$

$$\left[\begin{aligned} V_{DS} &= V_D - V_S \\ \Rightarrow 0.15 &= V_D - 0 \\ \Rightarrow V_D &= 0.15 \end{aligned}\right]$$

$$\Rightarrow V_a = 1.75$$

$$\therefore \frac{5 - V_a}{R_D} = I_D$$

$$\Rightarrow \frac{5 - 1.75}{R_D} = 12\times10^{-3}$$

$$\Rightarrow R_D = 270.83\ \Omega \cong 271\ \Omega$$

(Ans)

Answer to the Q; NO - 4

Lets $V_{CE(sat)} = 0.2\ V$ [For active mode]

case - 1 :

$V_{BE} = 0.7\ V$

$V_{CE} = 0.7\ V$

$\therefore V_{CE} > V_{CE(sat)}$

$\therefore$ Mode of operation is Active.

case - 2 :

$V_{BE} = 0.8\ V$

$V_{CE} = 0.1\ V$

$\therefore$ Mode of operation is Saturation.

case - 3 :

$V_{BE} = 0.7\ V$

$V_{CE} = 1.4\ V$

$\therefore$ Mode of operation is Active.

$\therefore V_{CE} > V_{CE(sat)}$

case - 4 :

$V_{BE} = 0.7\ V$

$V_{CE} = 2.7\ V$

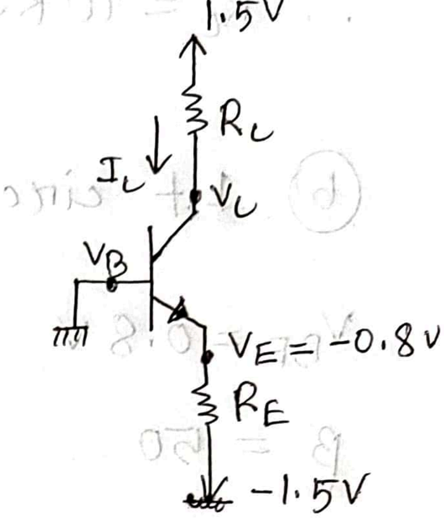
$\therefore$ Mode of operation is Active.

$\therefore V_{CE} > V_{CE(sat)}$

Answer to the Q. NO-5

(a) Here, $V_{BE} = 0.8\,V$, $V_C = 0.5\,V$

$\beta = 100$



$V_B = 0\,V$

$\therefore V_E = -0.8\,V$ $\quad \therefore V_{CE} = 0.5 + 0.8$
$= 1.3 > V_{CE(sat)}$

$\therefore$ Operation mode is active mode,

$i_C = 1\,mA$

$i_C = \beta I_B$

$\Rightarrow I_B = \frac{1}{100} = 0.01\,mA$

Now, $I_C = 0.1\,mA$

$\frac{1.5 - V_C}{R_C} = I_C$

$\Rightarrow R_C = \frac{1.5 - 0.5}{0.1} = 10\,K\Omega$

$I_E = I_B + I_C$

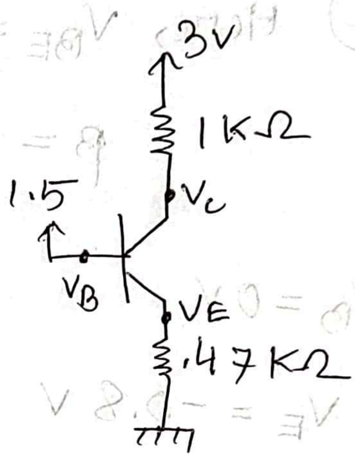
$\Rightarrow I_E = 0.01 + 0.1$
$= 0.11$

Again, $\frac{V_E - (-1.5)}{R_E} = I_E$

$\Rightarrow R_E = \frac{-0.8 + 1.5}{0.11} = 6.36\,K\Omega$

$\therefore R_C = 10\,K\Omega$ and $R_E = 6.36\,K\Omega$ (Ans)

(b) 1st circuit,



$V_{BE} = 0.8\,V$

$\beta = 50$

Here, $V_B = 1.5\,V$

$\therefore V_E = V_B - V_{BE}$
$= 0.7\,V$

let's assume active mode,

$\therefore V_{BE} = 0.7$

and $V_{CE} > 0.2$

At V_E Node,

$\frac{V_E - 0}{0.47} = I_E \Rightarrow I_E = \frac{0.7}{0.47} \Rightarrow I_E = 1.489\,mA$

$I_C = \alpha I_E \Rightarrow I_C = \frac{\beta}{\beta+1} I_E \Rightarrow I_C = \frac{50}{50+1} \times 1.489$
$= 1.46\,mA$

$\therefore I_B = I_E - I_C$
$= 1.489 - 1.46$
$= 0.03\,mA$

At V_c node,

$$\frac{3-V_c}{1} = 1.46$$

$\Rightarrow V_c = 1.54\,V$

$\therefore V_{CE} = 1.54 - 0.7 = 0.84 > 0.2$

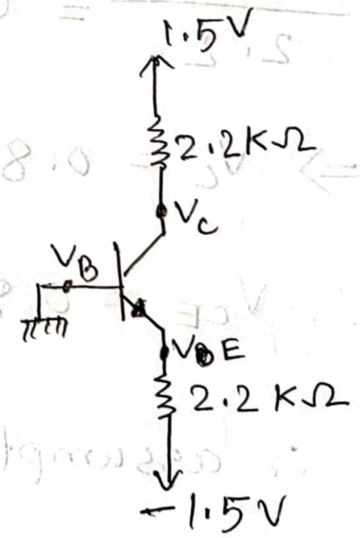
$\therefore$ assumption correct!

$V_E = 0.7\,V$ $\quad$ $I_E = 1.489\ mA$

$V_B = 1.5\,V$ $\quad$ $I_B = 0.03\ mA$

$V_c = 1.54\,V$ $\quad$ $I_c = 1.46\ mA$ $\quad$ (Ans)

2nd circuit,



let's assume active mode,

$V_{BE} = 0.8\,V$, $\beta = 50$

$V_{CE} > 0.2$

$V_B = 0\,V$

$\therefore V_E = -0.8\,V$

$$\therefore I_E = \frac{V_E - (-1.5)}{2.2}$$

$$\Rightarrow I_E = \frac{-0.8+1.5}{2.2} = 0.318 \text{ mA}$$

$$I_C = \frac{\beta}{\beta+1} \times I_E$$

$$= \frac{50}{50+1} \times 0.318 = 0.312 \text{ mA}$$

$$I_B = I_E - I_C = 0.318 - 0.312$$

$$= 0.006 \text{ mA}$$

At V_C node,

$$\frac{1.5 - V_C}{2.2} = 0.318$$

$$\Rightarrow V_C = 0.8$$

$$\therefore V_{CE} = 0.8 - (-0.8) = 1.6 > 0.2$$

$\therefore$ assumption correct!

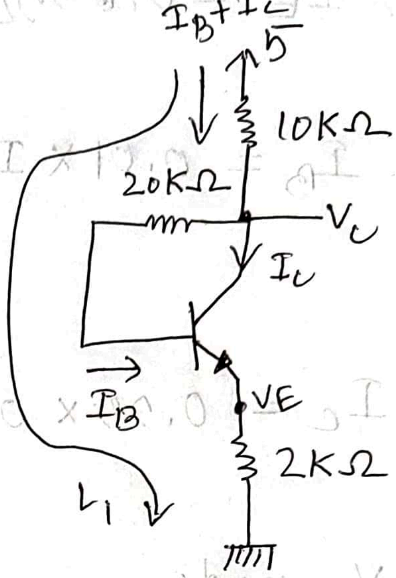
$V_E = -0.8$ V $\qquad I_E = 0.318$ mA

$V_B = 0$ V $\qquad I_B = 0.006$ mA

$V_C = 0.8$ V $\qquad I_C = 0.312$ mA

(Ans)

Answer to the Q.NO - 6



ⓐ Circuit-1 :

Let's assume active mode,

$V_{BE} = 0.7\,V$

$V_{CE} > 0.2\,V$

$\beta = \cancel{75}$ 100

KVL in L_1,

$10(I_B + I_C) + 20 I_B + 2 I_E = 5 - 0.7$ —— (1)

$I_E = I_B + I_C$ —— (11)

and, $I_C = \frac{\beta}{\beta+1} I_E = \boxed{0.99} I_E$

Here $\beta = 100$ was used.

Putting $I_C = 0.99 I_E$ in eqn (11),

$I_E = I_B + 0.99 I_E$

$\Rightarrow I_B = 0.01 I_E$

Putting $I_B = 0.01 I_E$ in eqn (1),

$10 I_E + 20 \times 0.01 I_E + 2 I_E = 4.3$

$\Rightarrow 12.2 I_E = 4.3$

$\Rightarrow I_E = 0.0352 \, mA$

$\therefore I_B = 0.01 \times I_E = 0.01 \times 0.0352 \, mA$

$= 0.00352 \, mA$

$I_C = 0.99 \times 0.0352 = 0.348 \, mA$

At V_c node,

$$\frac{5 - V_c}{10} = I_c + I_B$$

$\Rightarrow V_c = 5 - 10(0.00352 + 0.348)$

$\Rightarrow V_c = \boxed{1.48} \, V$

At ~~node~~ V_E node,

$$\frac{V_E}{2} = I_E$$

$\Rightarrow V_E = 0.704 \, V$

$\therefore V_{CE} = \boxed{1.48} - 0.704 = \boxed{0.776} > 0.2$

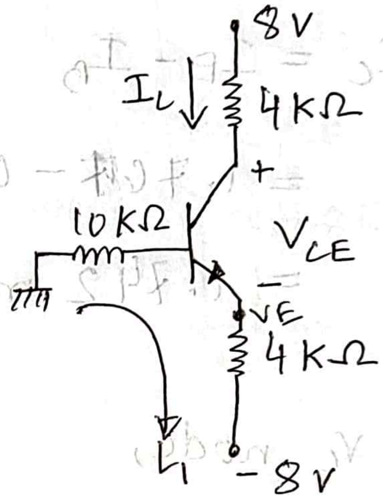
[Active mode]

$\therefore$ assumption correct!

$\therefore V_C = \boxed{1.48}$ V

$I_B = 0.00352$ mA (Ans)

Circuit-2 :



Let's assume active mode,

$V_{BE} = 0.7$ V

$V_{CE} > 0.2$ V

$\beta = 75$

KVL on L_1,

$10 I_B + 4 I_E = 0 - 0.7 + 8$

$\Rightarrow 10 I_B + 4 I_E = 7.3$ —— (i)

we know, $I_E = I_B + I_C$ and, $I_E = \frac{\beta}{\alpha} I_B$

$= \frac{75}{\boxed{0.99}} I_B$ —— (ii)

$\frac{75}{76} = 0.986$

Putting eqn (ii) values on eqn (i),

$10 I_B + 4 \times \frac{75}{0.99} I_B = 7.3$

$\Rightarrow 313.03 I_B = 7.3$

$\Rightarrow I_B = 0.0233 \text{ mA}$

$$\therefore I_E = \frac{075}{0.99} \times 0.0233 = 1.765 \text{ mA}$$

and,

$$I_C = I_E - I_B$$

$$= 1.765 - 0.0233$$

$$= 1.742 \text{ mA}$$

At V_C node,

$$\frac{8 - V_C}{4} = 1.742$$

$$\Rightarrow V_C = 1.032 \text{ V}$$

At V_E node,

$$\frac{V_E + 8}{4} = 1.765$$

$$\Rightarrow V_E = -0.94 \text{ V}$$

$$\therefore V_{CE} = 1.032 + 0.94 = 1.972 > 0.2$$

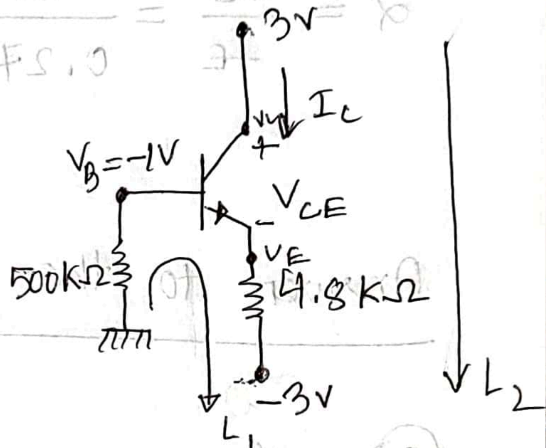
$\boxed{\text{Active mode}}$

$\therefore$ assumption correct!

$\therefore I_c = 1.742\ mA$

$V_{CE} = 1.972\ \cancel{m}V$ (Ans)

ⓑ Let's assume active mode,



$V_{BE} = 0.7\ V$

$V_{CE} > 0.2$

Here, $V_B = -1V$

$\therefore V_E = -1 - 0.7 = -1.7\ V$

At V_E node,

$$\frac{V_E + 3}{4.8} = I_E$$

$$\Rightarrow I_E = \frac{-1.7+3}{4.8}$$

$\Rightarrow I_E = 0.271\ mA$

Now, KVL on L_1,

$500 I_B + 4.8 I_E = -0.7 + 3$

$\Rightarrow 500 I_B + 4.8 \times 0.271 = -0.7 + 3$

$\Rightarrow I_B = 0.002\ mA$

$\therefore I_c = I_E - I_B$

$= 0.271 - 0.002$

$= 0.269\ mA$

KVL on L_2,

$4.8 I_E = 3 - V_{CE} + 3$

$\Rightarrow V_{CE} = 6 - (4.8 \times 0.271)$

$\Rightarrow V_{CE} = 4.7 > 0.2$

$\therefore$ assumption correct!

Easier to just:

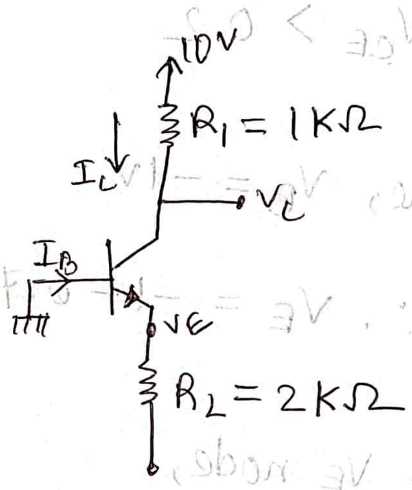
$V_{CE} = 3 - (-1.7) > 0.2$

$$\therefore \beta = \frac{I_C}{I_B} = \frac{0.269}{0.002} = 134.5$$

$$\alpha = \frac{I_C}{I_E} = \frac{0.269}{0.271} = 0.99$$

(Ans)

Answer to the Q. NO-7



(a) let's assume active mode,

$\beta = 100$, $V_{BE} = 0.7$ V

$\alpha = 0.99$, $V_{CE} > 0.2$

Here, $V_B = 0V$

$\therefore V_E = 0 - 0.7 = -0.7V$

we know,

$I_E = I_B + I_C$

$\Rightarrow I_B + I_C - I_E = 0$ —— (i)

$I_C = \beta I_B$

$\Rightarrow 100 I_B - I_C = 0$ —— (ii)

$I_C = \alpha I_E$

$\Rightarrow I_C - 0.99 I_E = 0$ —— (iii)

Solving eqⁿ (i), (ii), (iii) we get,

$I_B = I_C = I_E = 0 \text{ mA}$

$\therefore V_C = 10 \text{ V}$

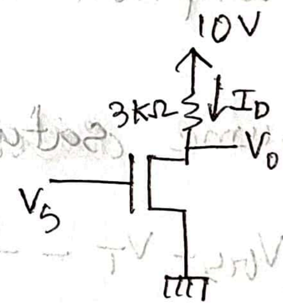
$\therefore V_{CE} = 10 + 0.7 = 10.7 > 0.2$ [active mode]

$\therefore$ assumption correct !

$I_C = I_B = I_E = 0 \text{ mA}$

and $V_C = 10 \text{ V}$ (Ans)

(b) Here,



$V_G = 10 \text{ V}$

$V_S = 0 \text{ V}$

$V_T = 1 \text{ V}$

$K = 5 \text{ mA}/\text{V}^2$

$\therefore V_{GS} = 10 - 0 = 10 > V_T$

let's assume saturation mode,

$I_D = \frac{K}{2} (V_{GS} - V_T)^2$

$\Rightarrow I_D = \frac{5}{2}(10-1)^2$

$\Rightarrow I_D = 202.5 \ mA$

$V_{ov} = 10 - 1$
$= 9V$

At node V_0,

$\frac{10 - V_0}{3} = 202.5$

$\Rightarrow V_0 = -597.5 = V_D$

$\therefore V_{DS} = -597.5 \not> V_{ov}$

$\therefore$ assumption wrong.

let's assume active mode,

$I_D = K(V_{GS} - V_T - \frac{1}{2}V_0)V_0$

$\Rightarrow \frac{10 - V_0}{3} = 5(10 - 1 - \frac{1}{2}V_0)V_0 = 5V_0(9 - \frac{1}{2}V_0)$

$\Rightarrow \frac{10 - V_0}{3} = 45V_0 - \frac{5}{2}V_0^2$

$\Rightarrow 10 - V_0 = 135V_0 - 7.5V_0^2$

$\Rightarrow 7.5V_0^2 - 136V_0 + 10 = 0$

$\therefore V_0 = \underset{\times}{\underline{18.06}}, \ 0.074$ ✓

$\therefore V_{DS} = 0.074 < V_{ov}$

$\therefore$ assumption correct!

$$\therefore I_{DS_2} = \frac{10-0.074}{3} = \cancel{3.3090}\ \cancel{mA}\ 3.309\ mA$$

and $V_0 = 0.074V$ (Ans)