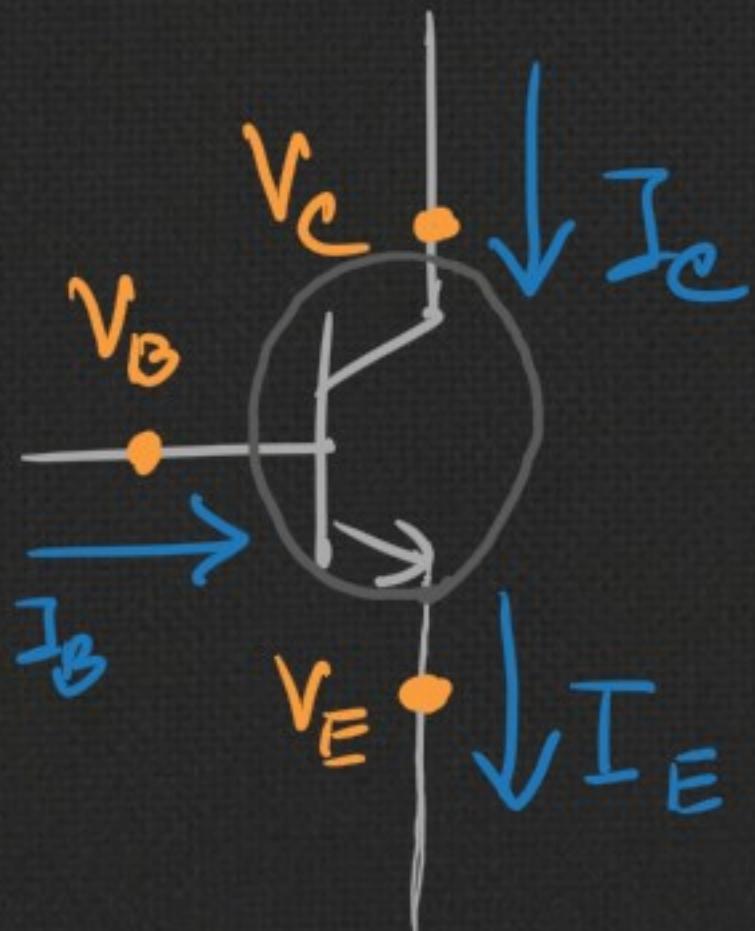


State	Bias	Condition	Equation
Active	BE - Forward Bias BC - Reverse Bias	$I_B, I_C, I_E > 0$ $V_{CE} > 0.2v$	$V_{BE} = 0.7v$ $I_C = \beta I_B$ $\beta = 50 \sim 200$ $\alpha = \frac{\beta}{\beta+1}$
Saturation	BE - Forward Bias BC - Forward Bias	$I_B, I_C, I_E > 0$ $\frac{I_C}{I_B} < \beta$	$V_{BE} = 0.8v$ $V_{CE} = 0.2v$
Cut-off	BE - Reverse Bias BC - Reverse Bias	$V_{BE} \leq 0.7v$ $V_{BC} \leq 0.6v$	$I_B, I_C, I_E = 0$

BJT in DC

KCL at supernode BCE \Rightarrow



$$I_E = I_C + I_B$$

\hookrightarrow True for any mode.

In ACTIVE, $I_C = \beta I_B$ \rightarrow ONLY in ACTIVE

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

$$\therefore I_C = \frac{\beta}{1+\beta} I_E \rightarrow$$
 ONLY in ACTIVE

We define $\frac{\beta}{1+\beta}$ as α

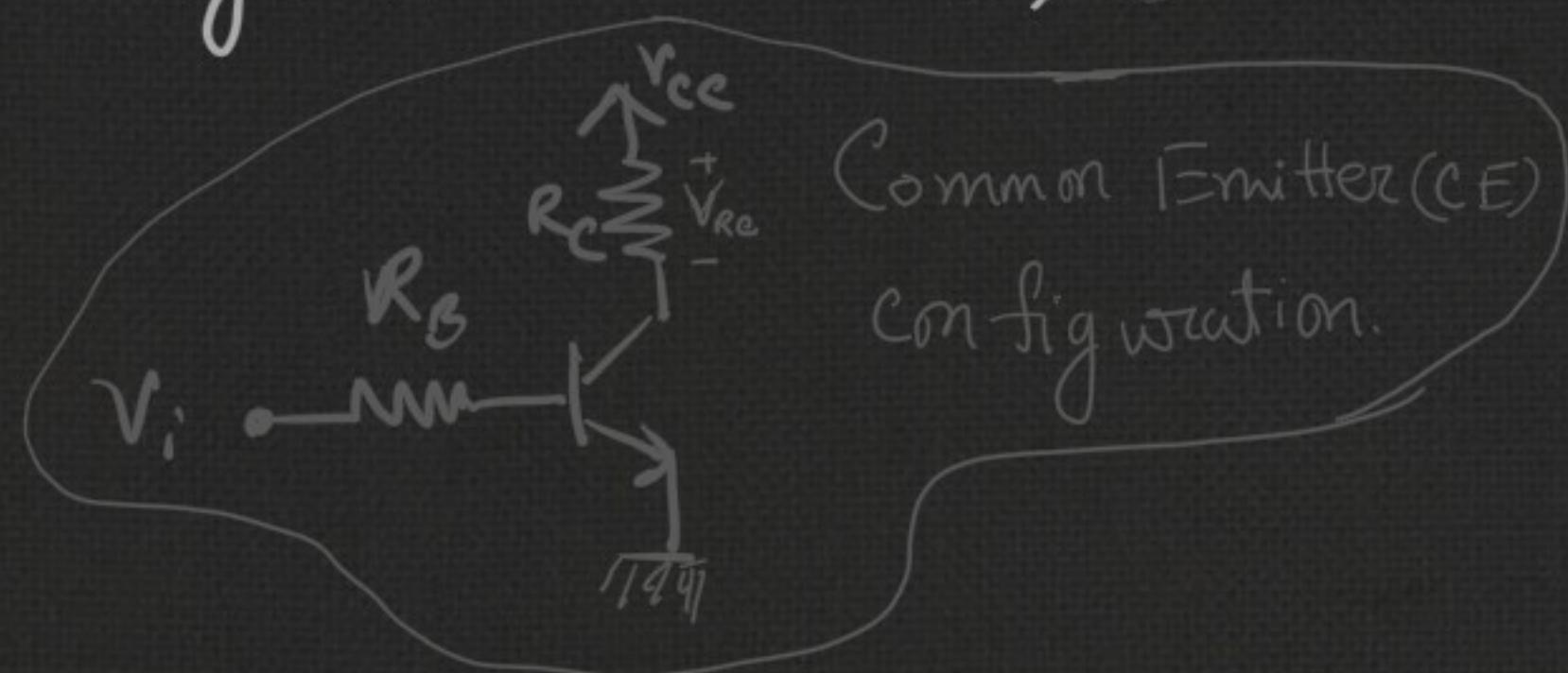
So, $I_C = \alpha I_E$

The typical value for $\beta = 100$. So, $\alpha \approx 0.99$ So, we can say, during ACTIVE region, $I_C \approx I_E$.

In SATURATION, $V_{CE} = V_{CE(sat)} = 0.2V$. This is the lowest possible value of V_{CE} . This implies that the voltage V_{RE} in the CE configuration can be, at

max, $V_{CC} - 0.2V$.

\hookrightarrow That is, 0.2V less than supply



How to solve Circuits with BJT?

⇒ Our old friend, Method of assumed state!

For BJT

① If assume in ACTIVE mode

$$V_{BE} = 0.7, I_C = \beta I_B \Rightarrow \text{Eqn true for ACTIVE}$$

You must show $V_{CE} > 0.2$

② If assume in SATURATION

$$V_{BE} = 0.8, V_{CE} = 0.2 \Rightarrow \text{Eqn true for SAT.}$$

You must show $I_C < \beta I_B$,
that is $\frac{I_C}{I_B} < \beta$

③ If assume in CUTOFF $\{ I_C = I_B = I_E = 0 \} \Rightarrow \text{Eqn true for CUTOFF}$

You must show $V_{BE} \leq 0.7V$ and $V_{CE} > 0.2$

3 steps

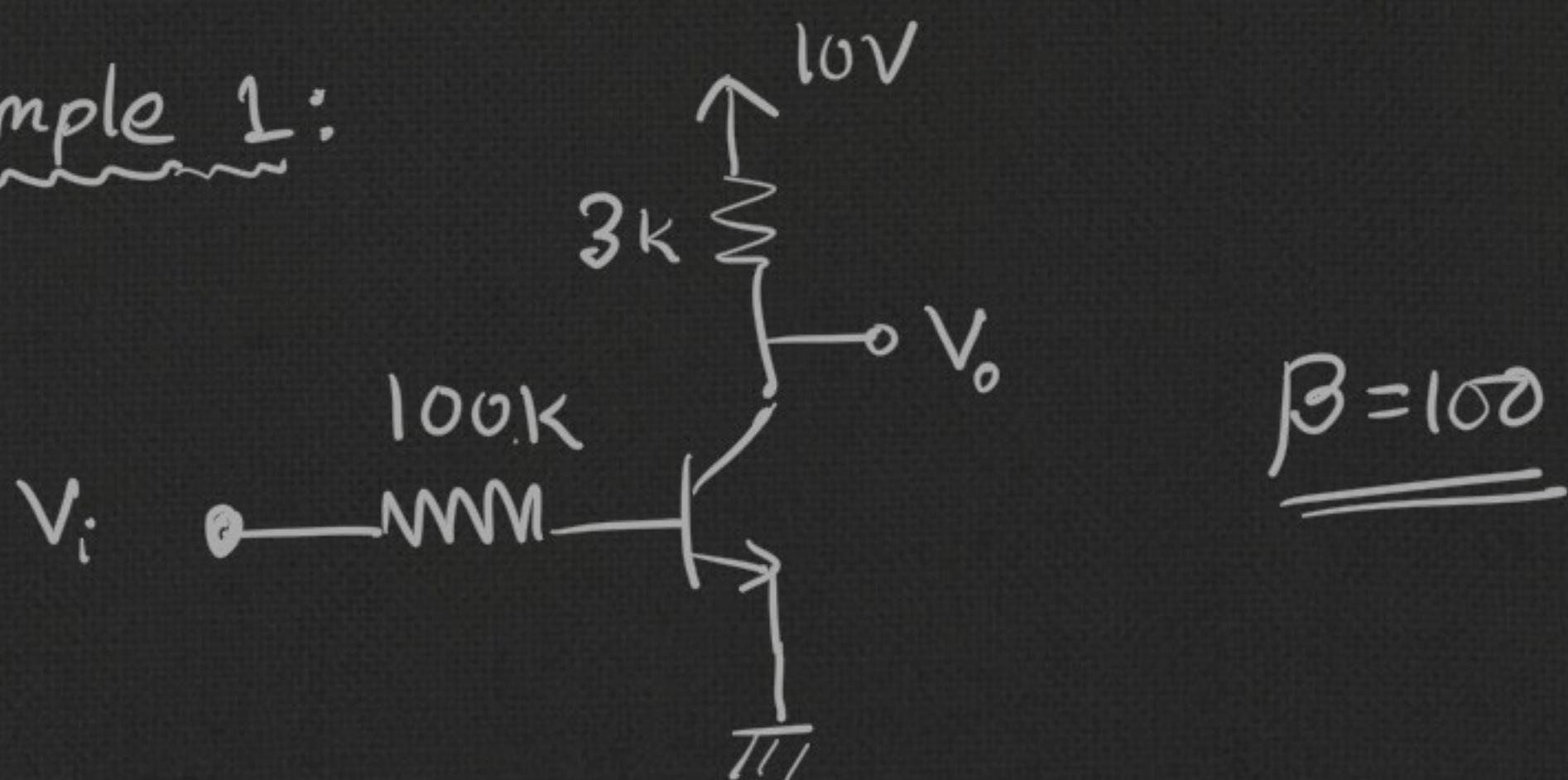
-① Assume a state. There are 3 possible states:
ACTIVE, SATURATION,
CUTOFF

-② Solve the ckt and find I_C, I_B, V_{CE}, V_{BE}

-③ Verify your assumption.
If wrong, repeat ①, ②, ③

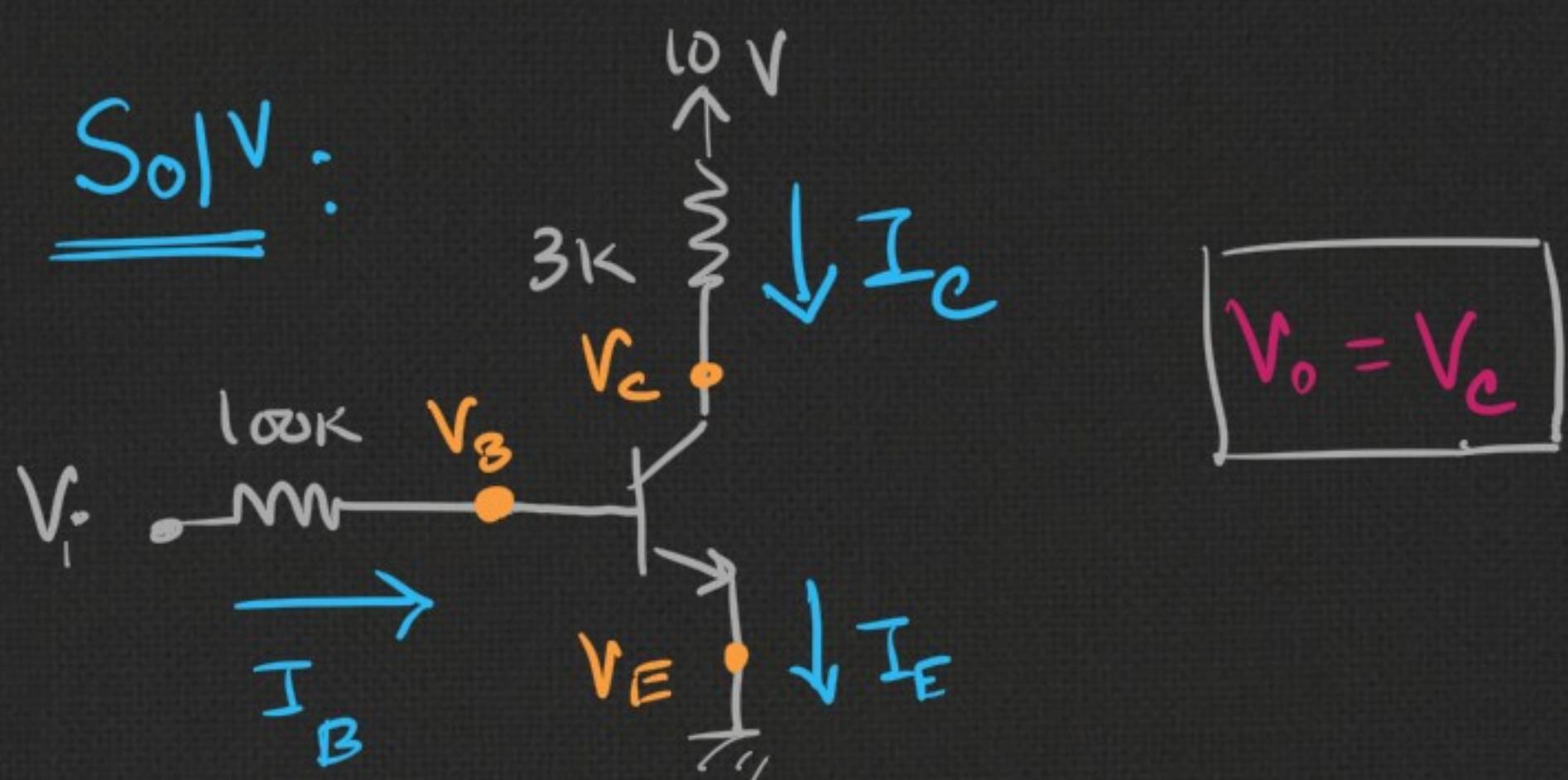
*must show ⇒ condition

Example 1:



Find V_o for ① $V_i = 1V$ ② $V_i = 5V$

Soln:



Since $V_i > 0.2V$ in both ① and ②, it will

be either in ACTIVE OR SATURATION

$$BE = ON \Rightarrow V_{BE} = 0.2V$$

$$\text{since } V_E = 0V \Rightarrow V_B - V_E = 0.2V =$$

$$\Rightarrow V_B = 0.2V$$

④ Assume BJT in ACTIVE

$$\therefore I_B = \frac{V_i - V_B}{R_B} = \frac{1 - 0.7}{100} = 0.003 \text{ mA} \\ = 3 \mu\text{A}$$

Since active, $I_C = \beta I_B = 100 \times 0.003 = 0.3 \text{ mA}$

from the circuit,

$$I_C = \frac{10 - V_C}{R_C}$$

$$\Rightarrow V_C = 10 - R_C I_C = 10 - 3 \times 0.3$$

$$\Rightarrow \boxed{V_o = V_C = 9.1 \text{ V}}$$

VERIFICATION: Since we assumed ACTIVE, we

need to check if $V_{CE} > 0.2 \text{ V}$

Since $V_i = 0 \Rightarrow V_{CE} = V_C - V_E = 9.1 \text{ V}$. \Rightarrow Assumption Correct (yay!)

⑤ Assume BJT in ACTIVE

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

$$\Rightarrow I_C = \beta I_B = 4.3 \text{ mA}$$

$$\Rightarrow V_o = V_C = 10 - I_C R_C = 10 - 3 \times 4.3 = -2.9 \text{ V}$$

VERIFICATION: $V_{CE} = -2.9V \therefore V_{CE} < 0.2V$

\Rightarrow Assumption WRONG! :-)

Now assume in SATURATION

$$\therefore V_{CE} = 0.2V$$

since $V_E = 0V$ and $V_{CE} = V_C - V_E$

$$\therefore V_C = V_o = 0.2V.$$

Because SAT $\Rightarrow V_{BE} = 0.8V$

$$I_B = \frac{V_i - V_B}{R_B} = \frac{5 - 0.8}{100} = 0.043mA$$

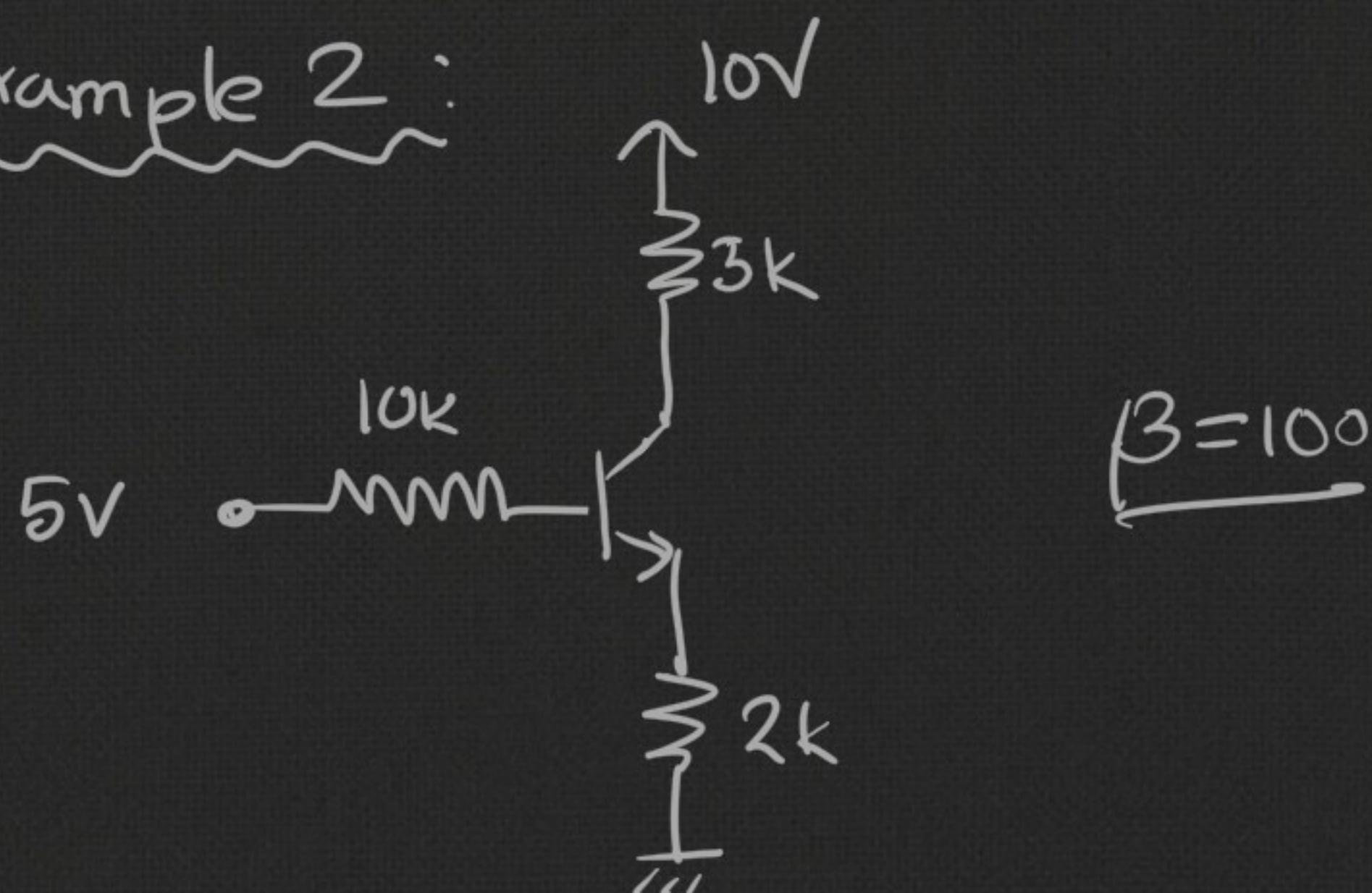
$$I_C = \frac{10 - V_C}{R_C} = \frac{10 - 0.2}{3} = 3.2mA$$

VERIFICATION: Since we've assumed saturation,

we need to show $\frac{I_C}{I_B} < \beta$. Now, $\frac{I_C}{I_B} = \frac{3.2}{0.043} = 76$

$\frac{I_C}{I_B} < 100 \Rightarrow$ Assumption CORRECT. :-)

Example 2:



Find I_B , I_C , I_E and V_{CE} .

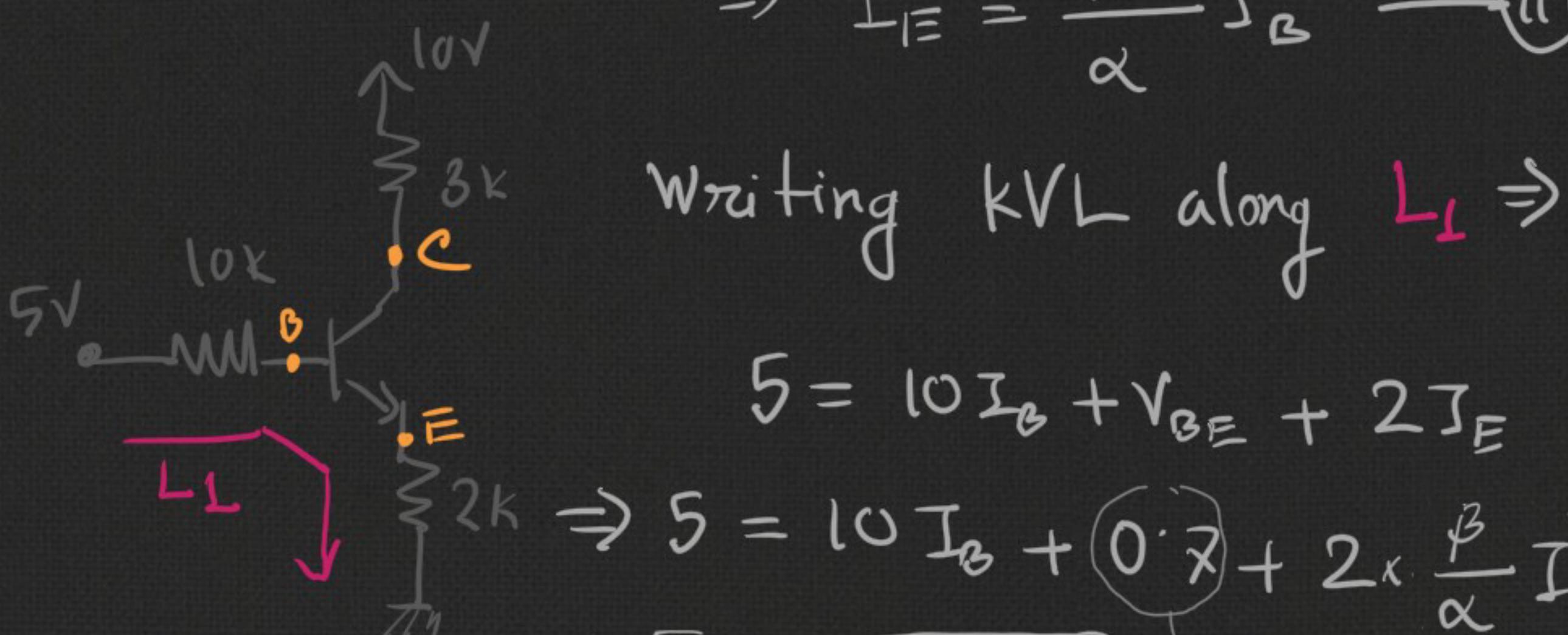
Sol'n: Assume in ACTIVE

$$\Rightarrow I_C = \alpha I_E \quad \text{--- (i)}$$

$$I_C = \beta I_B \quad \text{--- (ii)}$$

from (i) and (ii), $\beta I_B = \alpha I_E$

$$\Rightarrow I_E = \frac{\beta}{\alpha} I_B \quad \text{--- (iii)}$$



Writing KVL along $L_1 \Rightarrow$

$$5 = 10 I_B + V_{BE} + 2 I_E$$

$$\Rightarrow 5 = 10 I_B + 0 \quad \xrightarrow{\text{from (iii)}} + 2 \times \frac{\beta}{\alpha} I_B$$

$$\Rightarrow I_B = 0.02 \text{ mA}$$

Since assumed AC V_E , $V_{BE} = 0$

$$\therefore I_C = \beta I_B = 100 \times 0.02 = 2 \text{ mA}$$

$$\therefore \boxed{I_C = 2 \text{ mA}}$$

$$\therefore I_E = I_C + I_B \Rightarrow \boxed{I_E = 2.02 \text{ mA}}$$

From the ckt, $V_E - 0 = I_E \times 2$

$$\Rightarrow V_E = 4.04 \text{ V}$$

Again, from the ckt, $10 - V_C = I_C \times 3$

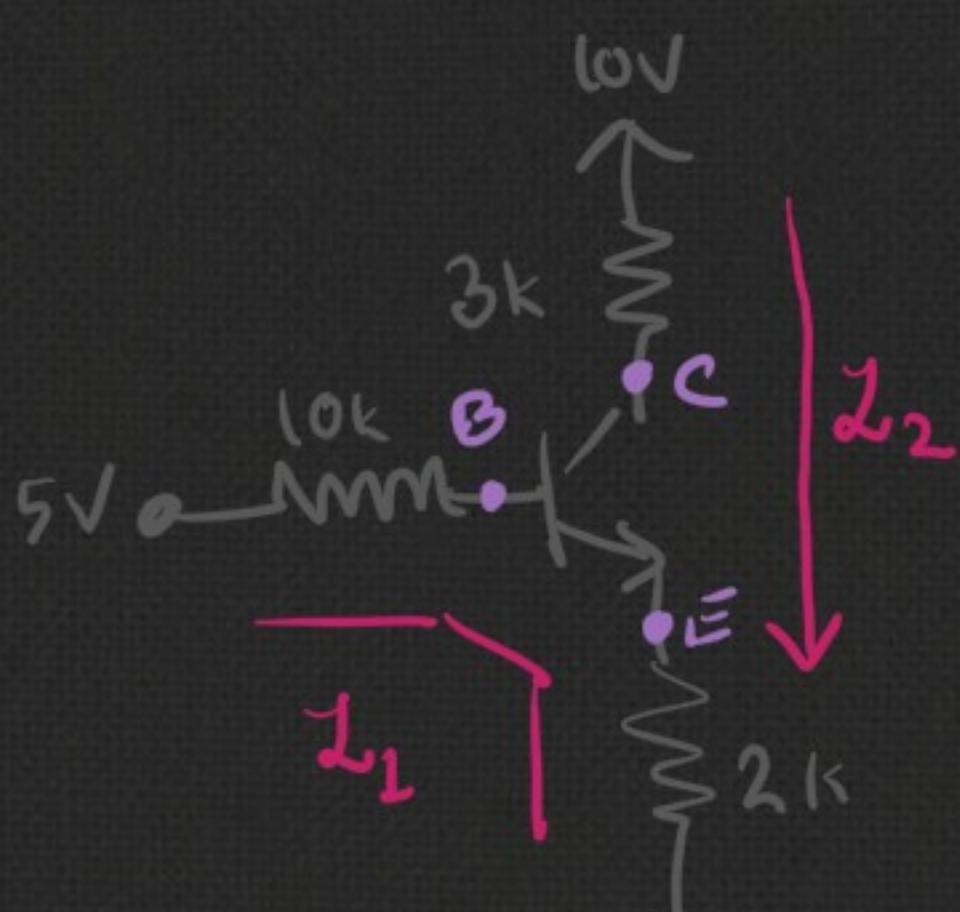
$$\Rightarrow V_C = 4 \text{ V}$$

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

$$\Rightarrow \boxed{V_{CE} = 0.04 \text{ V}}$$

Assumed ACTIVE, found
 $V_{CE} < 0.2 \text{ V}$. So assumption
WRONG!! (- -)

Assume in SATURATION $\Rightarrow \boxed{\therefore V_{CE} = 0.2 \text{ V}}$



KVL along L_1

$$5 = 10I_B + V_{BE} + 2I_E$$

$$\Rightarrow 5 = 10I_B + 0.8 + 2I_E \quad \text{--- (i)}$$

KVL along L_2

$$10 = 3I_C + V_{CE} + 2I_E$$

$$\Rightarrow 10 = 3I_C + 0.2 + 2I_E \quad \text{--- (ii)}$$

PTO

From KCL \Rightarrow

$$I_E = I_B + I_C \quad \text{--- (iii)}$$

Solving (i), (ii) and (iii)

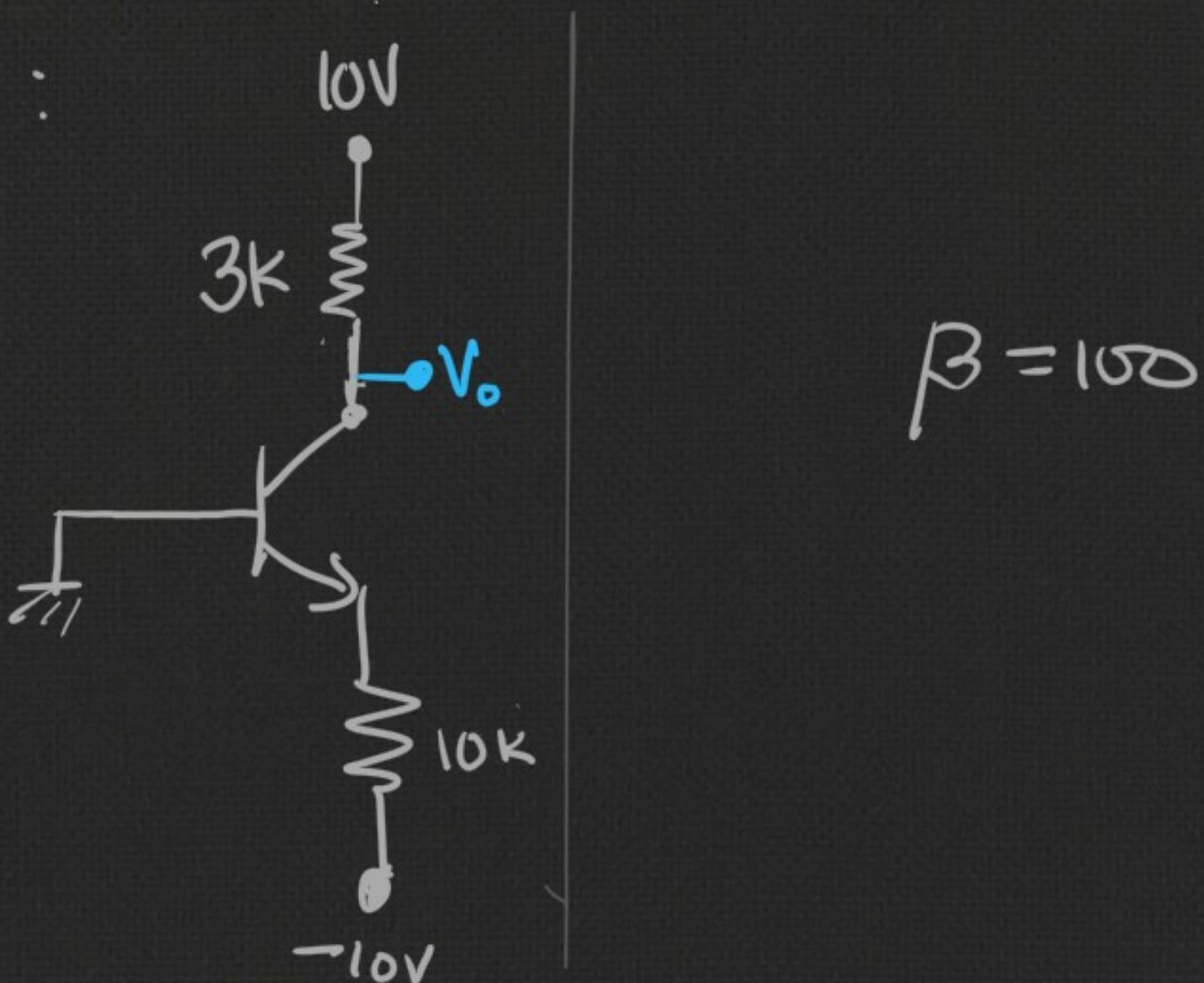
$$I_B = 0.03 \text{ mA}$$

$$I_C = 1.95 \text{ mA}$$

$$I_E = 1.98 \text{ mA}$$

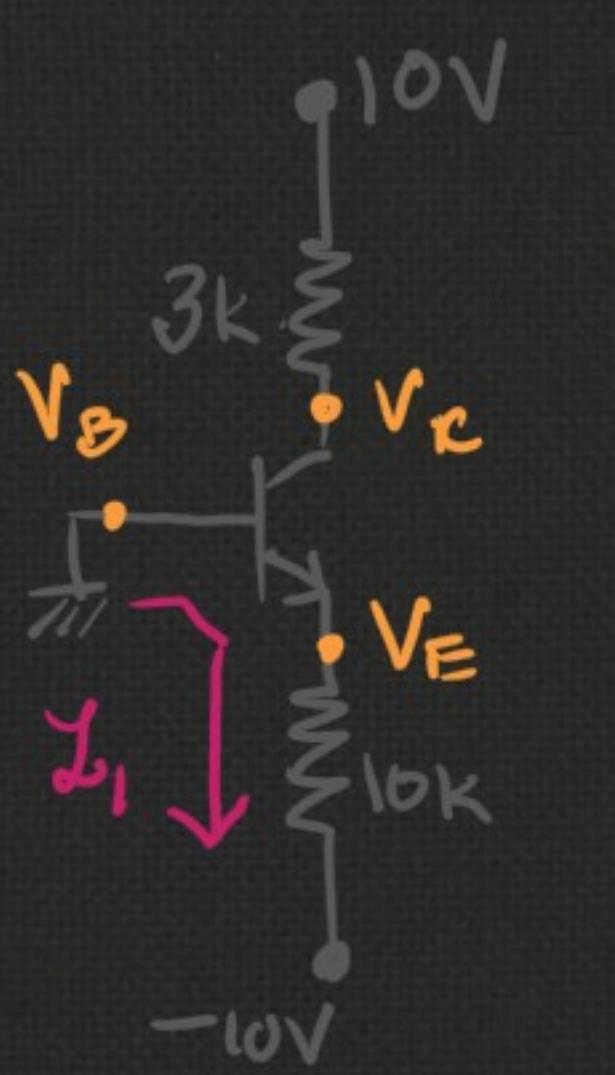
Since $\frac{I_C}{I_B} = \frac{1.95}{0.03} < \beta$, so assumption CORRECT!

Example 3 :



find I_B , I_c , I_E and V_o

Soln :



Base connected to GND

$$\therefore V_B = 0V$$

Assume BJT ACTIVE

$$\therefore V_{BE} = 0.7V$$

$$\Rightarrow V_B - V_E = 0.7V$$

$$\Rightarrow V_E = -0.7V$$

$$\boxed{\begin{aligned} \beta &= 100 \\ \therefore \alpha &= \frac{1+\beta}{\beta} \\ &= 0.99 \end{aligned}}$$

KVL along \mathcal{Z}_2 : $0 = V_{BE} + 10I_E + (-10)$

$$\Rightarrow 0 = 0.7 + 10I_E - 10$$

$$\Rightarrow \underline{I_E = 0.93mA}$$

$$\therefore \underline{I_c = \alpha I_E = 0.99 \times 0.93 \Rightarrow I_c = 0.92mA}$$

$$\therefore \underline{I_B = I_E - I_c \Rightarrow I_B = 0.01mA}$$

From CKT, $10 - V_C = 3I_C$

$$\Rightarrow \underline{\underline{V_C = 7.24V}}$$

Check: $V_{CE} = V_C - V_E = 7.24 - (-0.2)$

$$\Rightarrow V_{CE} = 7.44V$$

$\therefore V_{CE} > 0.2 \Rightarrow \underline{\underline{\text{Assumption Correct!}}}$