Emau

Summary of laws for Sheet 5 BJT Trs

npn transistors

① active mode

→ $I_C = \alpha I_E$

→ $I_C = \beta I_B$ → Common emitter Current gain

→ $I_E = (1+\beta) I_B$

→ $I_B = \frac{I_E}{1+\beta} = \frac{I_C}{\beta}$

→ $I_E = I_B + I_C$

→ $\beta = \frac{\alpha}{1-\alpha} = \frac{I_C}{I_B}$

α → Common base Current gain

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

to check active mode

$V_{CE} > V_{BE}\ (0.7)$

② Saturation mode

$V_{CE} = 0.2$

$V_{BE} = 0.7$

نحسب التيارات بس ال circuit ملهاش قوانين

to check Saturation

$I_{B\,sat} > I_{B\,min}$ (active)

PnP transistors

① active mode

→ $I_C = \alpha I_E = \beta I_B$

→ $I_E = (1+\beta) I_B$

→ $I_E = I_B + I_C$

→ $I_B = \frac{I_E}{1+\beta} = \frac{I_C}{\beta}$

→ $\beta = \frac{\alpha}{1-\alpha} = \frac{I_C}{I_B}$

→ $\alpha = \frac{\beta}{1+\beta} = \frac{I_C}{I_E}$

to check active mode

$V_{EC} > V_{EB}\ (0.7)$

② Saturation mode

$V_{EC} = 0.2$

$V_{EB} = 0.7$

to check Saturation

$I_{B\,sat} > I_{B\,min}$ (active)

Cut off

V_{BE} or $V_{EB} < 0$ (-ve)

من الحالة دي نشتغل على انه off

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1

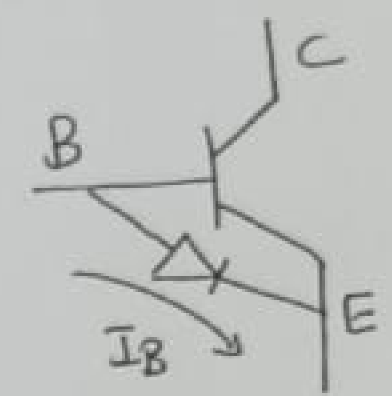
"Sheet 5"

1. Consider NPN transistor whose base–emitter voltage is 0.76 V at a collector current equals 10 mA. Determine:

(a) -The current will it conduct at $V_{BE} = 0.70$ V.

(b) - The base–emitter voltage for $I_C = 10\ \mu A$.

Sol:-



(a) $I_B = I_S \left(e^{\frac{V_{BE}}{\eta V_T}} - 1\right)$

assume Ge $\eta = 1$ $V_T = 0.026$

$I_C = \beta I_B$

$I_C = \beta I_S \left(e^{\frac{V_{BE}}{\eta V_T}} - 1\right)$

$I_{C1} = 10mA \longrightarrow V_{BE1} = 0.76$

$I_{C2} = ? \longrightarrow V_{BE2} = 0.7$

$$\frac{I_{C1}}{I_{C2}} = \frac{\cancel{\beta I_S}\left(e^{\frac{V_{BE1}}{\eta V_T}} - 1\right)}{\cancel{\beta I_S}\left(e^{\frac{V_{BE2}}{\eta V_T}} - 1\right)} = \frac{e^{\frac{0.76}{0.026}} - 1}{e^{\frac{0.7}{0.026}} - 1}$$

$$I_{C2} = \frac{(10^{-2})\left(e^{\frac{0.7}{0.026}} - 1\right)}{\left(e^{\frac{0.7}{0.026}} - 1\right)} = 0.995\,mA$$

(b)

$$\frac{I_{C1}}{I_{C2}} = \frac{e^{\frac{0.7}{0.026}} - 1}{e^{\frac{V_{BE2}}{0.026}} - 1}$$

$$\frac{10 \times 10^{-3}}{10 \times 10^{-6}} = \frac{e^{\frac{0.7}{0.026}} - 1}{e^{\frac{V_{BE2}}{0.026}} - 1}$$

$V_{BE2} = 0.52$ V

Eman
(2)

2. In a BJT, the base current is 10 μA, and the collector current is 600 μA. Find β and α for this transistor.

Sol:-

$i_B = 10\,\mu A \quad , \quad i_C = 600\,\mu A$

$$\beta = \frac{i_C}{i_B} = \frac{600}{10} = 60$$

$$\alpha = \frac{\beta}{1+\beta} = \frac{60}{61} \simeq 0.9836$$

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3. Measurement of npn BJT in a particular circuit shows the base current to be 14.46 μA, the emitter current to be 1.460 mA, and the base–emitter voltage to be 0.7 V. For these conditions, calculate α and β.

Sol:-

$I_B = 14.46 \mu A$

$I_E = 1.460\ mA$

$V_{BE} = 0.7 V$

$I_E = I_C + I_B$

$I_E = (1+\beta) I_B$

$1.460 = (1+\beta)\ 14.46 \times 10^{-3}$

$\beta \simeq 99.968$

$$\alpha = \frac{\beta}{1+\beta} = 0.99$$

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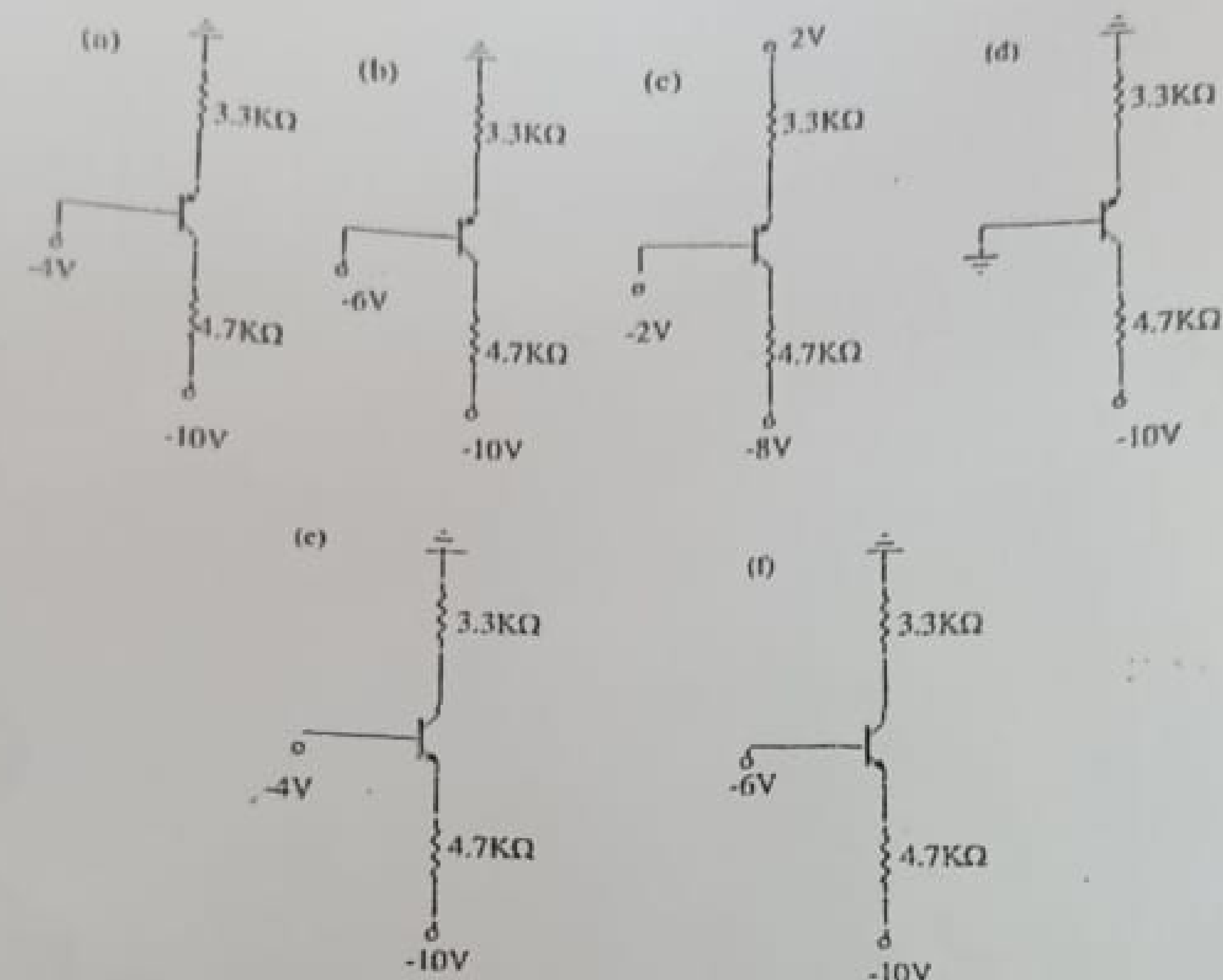
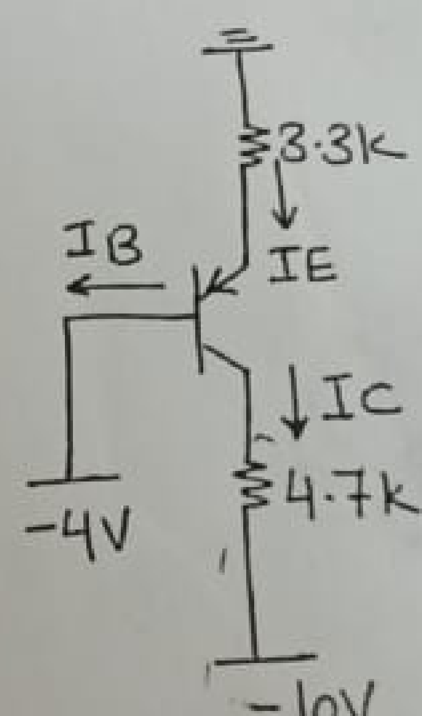
4. For the following circuits, find node voltages, V_E, V_C, and currents I_E, I_C, I_B. Use V_{BE} (or V_{EB} for PNP transistor) = 0.7 V and β=50.



Sol:-

a] assume the PNP transistor is active



$V_B = -4\ V$

$V_{EB} = V_E - V_B = 0.7V$

- $V_E = V_B + 0.7$
  $= -4 + 0.7 = -3.3V$

- $I_E = \dfrac{0 - V_E}{3.3k} = \dfrac{3.3}{3.3k} = 1mA$

- $I_B = \dfrac{I_E}{1+\beta} = \dfrac{1mA}{51} = 19.6\mu A$

- $I_C = \beta I_B = 50 * 19.6\ \mu A = 0.98mA$

- $V_C = 4.7k * I_C - 10 = -5.392V$

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$V_{EC} = V_E - V_C$
$V_{EC} = -3.3 + 5.392 = 2.1V$

$V_{EC} >$ ∴ V_{BE} assumption true
Tr active

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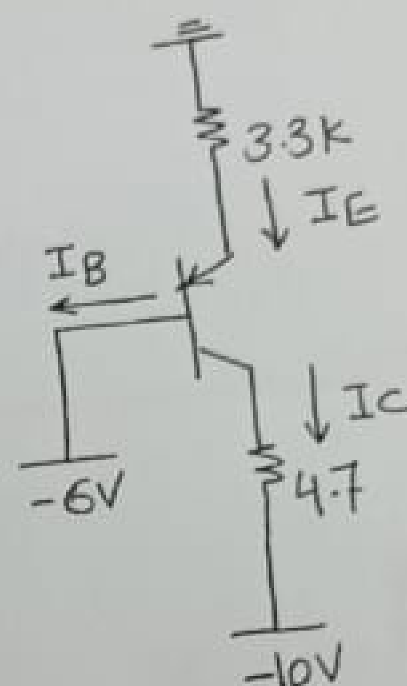
b] assume the PNP tr is active



$V_B = -6\,V$

$V_{EB} = V_E - V_B = 0.7V$

- $V_E = V_B + 0.7$
  $= -6 + 0.7 = -5.3V$

- $I_E = \frac{0 - V_E}{3.3k} = \frac{5.3}{3.3k} = 1.606\,mA \simeq 1.61\,mA$

- $I_B = \frac{I_E}{1+\beta} = \frac{1.61\,mA}{51} = 31.49\,\mu A$

- $I_C = \beta I_B = 50 * 31.49\,\mu A = 1.575\,mA$

- $V_C = 4.7\,k * I_C - 10 = -2.59\,V$

- $V_{EC} = V_E - V_C$
  $= -5.3 + 2.59 = -2.71\,V$

$V_{EC} < V_{BE}$ then assumption not true
Tr working in Saturation Region

∴ $V_{EC} = 0.2$

$V_C = V_E - 0.2 = -5.3 - 0.2 = -5.5\,V$

$I_C = \frac{V_C - (-10)}{4.7k} = \frac{-5.5 + 10}{4.7} = 0.957\,mA$

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$I_B = I_E - I_C = 0.648\, mA$

$\therefore I_C < \beta I_B$

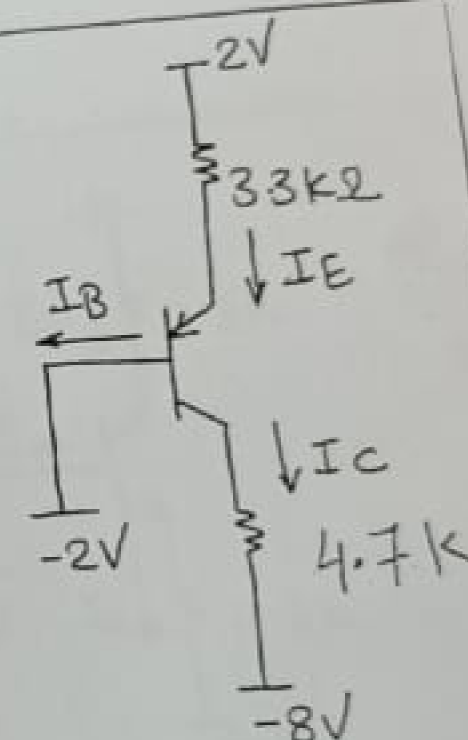
$0.957\, mA < \underset{\nearrow 50 * 0.648}{32.4\, mA}$ assumPtion true

or

$I_{B_{Sat}} > I_{B_{act}}$

$0.648\, mA > 31.49\, \mu A$

C] assume PNP Tr is active



$V_B = -2V$

$V_{EB} = V_E - V_B = 0.7V$

- $V_E = V_B + 0.7 = -2 + 0.7 = -1.3V$
- $I_E = \dfrac{2 - V_E}{3.3k} = \dfrac{2 + 1.3}{3.3} = 1 mA$
- $I_B = \dfrac{I_E}{1 + \beta} = \dfrac{1 mA}{51} = 19.6\, \mu A$
- $I_C = \beta I_B = 50 * 19.6\, \mu A = 0.98\, mA$
- $V_C = 4.7\, k\, I_C - 8 = -3.394V$

$V_{EC} = V_E - V_C = -1.3 + 3.394 = 2.094V$

$V_{EC} > V_{BE}$

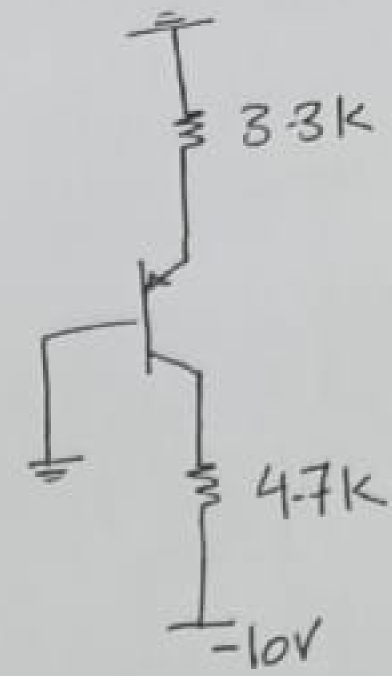
assumPtion true Tr in active mode

d] $V_B = 0V$

V_E is negative

then EB and CB junction will be off thus the transistor will operate in off mode

- $I_E = 0A$
- $I_B = 0A$
- $I_C = 0A$
- $V_C = -10V$
- $V_E = 0V$



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e] Assume NPN Tr is active

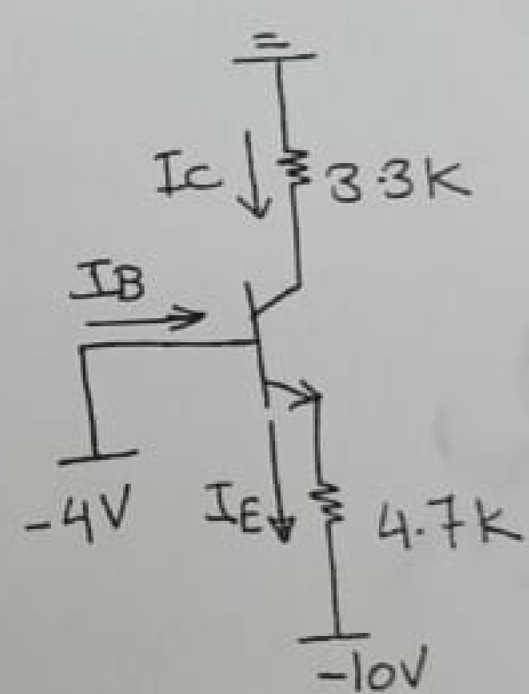
$V_B = -4V$

$V_{BE} = V_B - V_E = 0.7V$

- $V_E = V_B - 0.7 = -4 - 0.7 = -4.7V$
- $I_E = \dfrac{-4.7 + 10}{4.7k} = 1.128mA$
- $I_B = \dfrac{I_E}{1+\beta} = \dfrac{1.128}{51} = 22.11\mu A$
- $I_C = \beta I_B = 50 * 22.11\mu A = 1.106mA$
- $V_C = -3.3K * I_C = -3.65V$

$V_{CE} = -3.65 + 4.7 = 1.05V > V_{BE}$

assumption true Tr active



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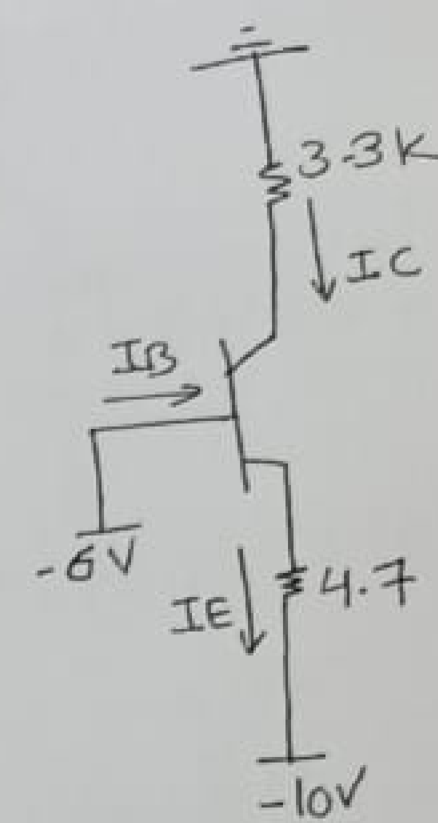
f) assume NPN transistor is active



$V_B = -6V$

$V_{BE} = V_B - V_E = 0.7V$

- $V_E = V_B - 0.7 = -6 - 0.7 = -6.7V$
- $I_E = \frac{-6.7+10}{4.7K} = 0.702\,mA$
- $I_B = \frac{I_E}{1+\beta} = \frac{0.702mA}{51} = 13.77\,\mu A$
- $I_C = \beta I_B = 50 * 13.77 = 0.688\,mA$
- $V_C = -3.3k * I_C = -2.272V$

$V_{CE} = -2.272 + 6.7 = 4.428V$

$V_{CE} > V_{BE}$ assumption true

Tr active

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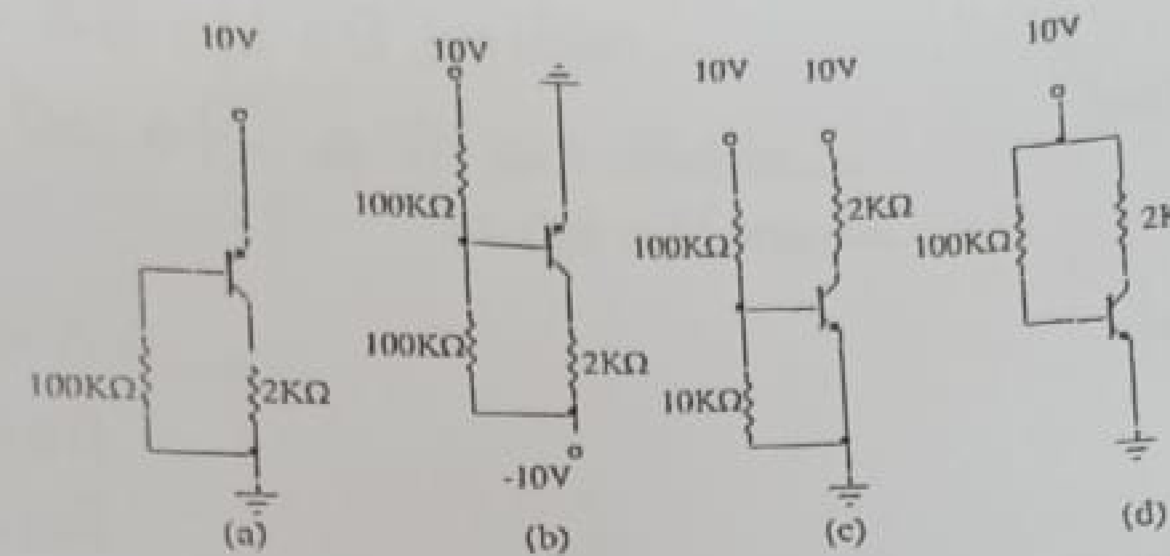
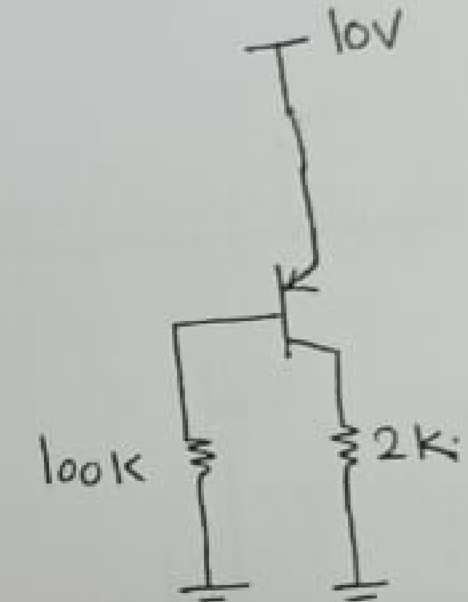
5. For the following circuits in which V_{BE} (V_{EB} for PNP transistor) = 0.7 V and β=10. Find the transistor's DC operating point?



Sol:-

a] assume PNP Tr is active



$V_E = 10V$

$V_{EB} = V_E - V_B = 0.7V$

- $V_B = V_E - 0.7 = 10 - 0.7 = 9.3V$
- $I_B = \dfrac{9.3}{100K} = 93\mu A$
- $I_C = \beta I_B = 10 * 93\mu A = 0.93mA$
- $I_E = I_B(1+\beta) = 93\mu A * 11 = 1.023mA$
- $V_C = 2K * I_C = 1.86\ V$

$V_{EC} = 10 - 1.86 = 8.14V > V_{BE}$

assumption true Tr active

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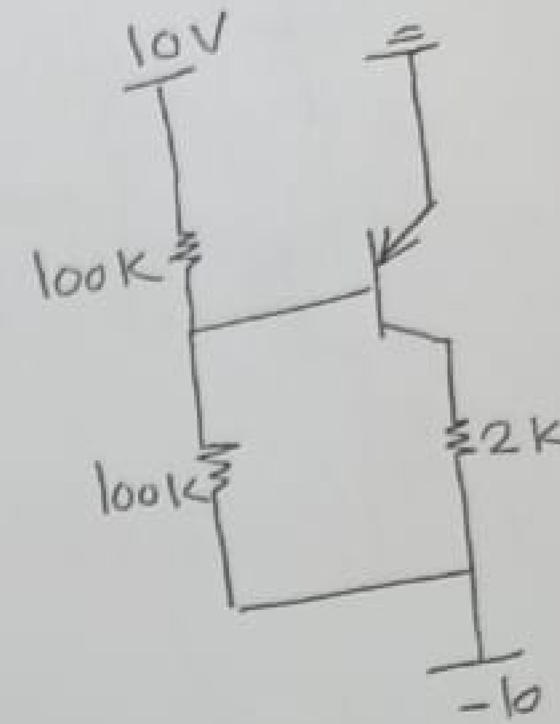
b] $V_E = 0V$

V_B is +ve

the EB and CB junction will be off ∴ Tr will operate in cut off mode



- $I_E = 0A$
- $I_B = 0A$
- $I_C = 0A$
- $V_C = -10V$
- $V_E = 0V$

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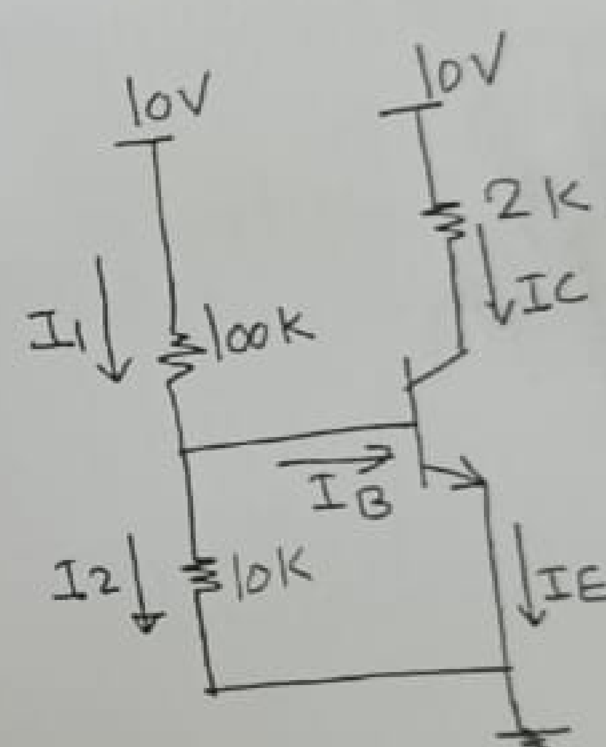
c] assume the NPN Tr is active



- $V_E = 0V$

$V_{BE} = V_B - V_E = 0.7V$

- $V_B = 0.7V$

$I_2 = \frac{0.7}{10k} = 0.07mA$

$I_1 = \frac{10-0.7}{100k} = 0.093mA$

- $I_B = I_1 - I_2 = 0.093 - 0.07 = 23\mu A$
- $I_C = \beta I_B$

$= 10 * 23\mu A = 0.023mA$

$V_C = 10 - 2k * I_C = 9.54V$

$V_{CE} = 9.54 - 0 = 9.54V > V_{BE}$

assumption true

Eman

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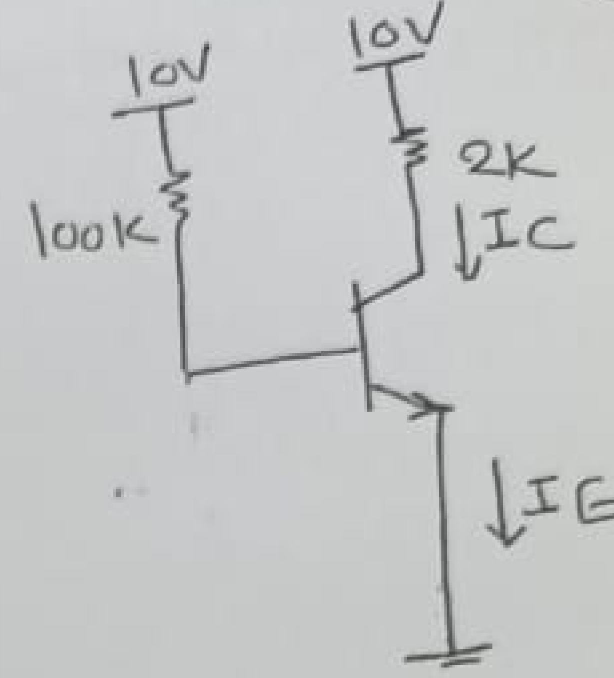
d] assume NPN Tr is active



$V_E = 0\,V$

$V_{BE} = V_B - V_E = 0.7V$

$V_B = 0.7V$

$I_B = \dfrac{10 - 0.7}{100k} = 93\mu A$

$I_C = \beta I_B = 0.93\,mA$

$I_E = (1+\beta) I_B = 1.023\,mA$

$V_C = 10 - 2k * I_C = 8.14\,V$

$V_{CE} = 8.14 - 0 = 8.14\,V > V_{BE}$

assumPtion true Tr active

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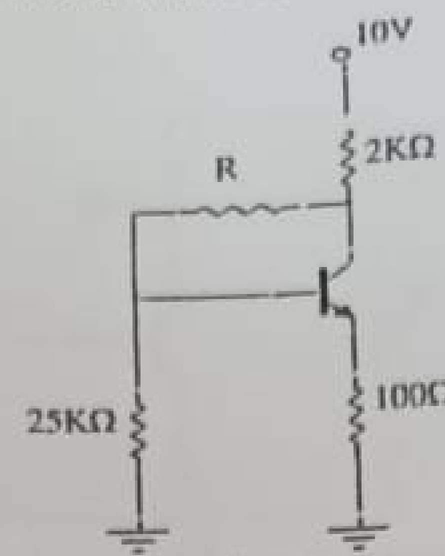
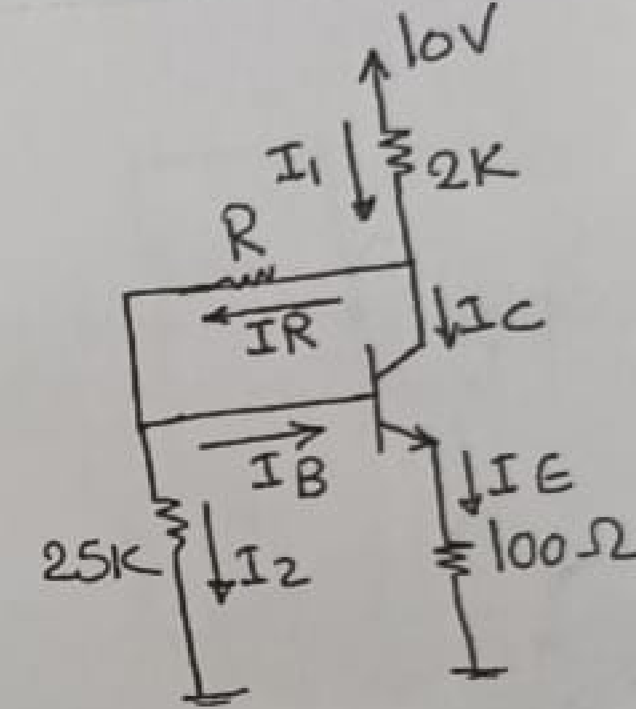
6. If $\alpha=0.97$ and $V_{BE}=0.7V$, find R in the circuit shown if $I_E=2mA$.



Sol:-

x assume tr in active mode



$I_C = \alpha I_E = 0.97 * 2 = 1.94 mA$

$I_B = I_E - I_C = 2 - 1.94 = 0.06 mA$

$V_E = I_E R_E = 100 * 2 \times 10^{-3} = 0.2V$

$V_B = V_{BE} + V_E = 0.7 + 0.2 = 0.9V$

$I_2 = \frac{V_B}{25K\Omega} = 0.036 mA$

$I_R = I_B + I_2 = 0.06 + 0.036 = 0.096 mA$

$I_1 = I_R + I_C = 0.096 + 1.94 = 2.036 mA$

$V_C = V_{CC} - I_1(2) = 10 - (2.036 \times 2) = 5.928V$

$V_{CE} = V_C - V_E = 5.928 - 0.2 = 5.728V > V_{BE}$

assumption true

$R = \frac{V_C - V_B}{I_R} = \frac{5.028}{0.096} = 52.375 K\Omega$

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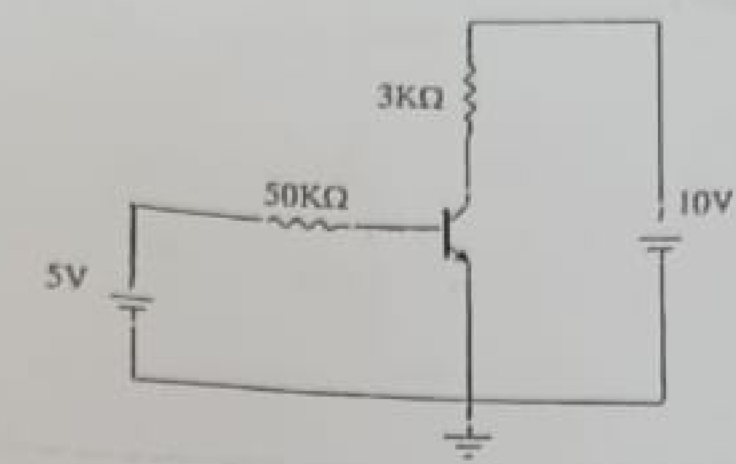
7. In the figure show below, if β=100, determine whether or not the silicon transistor is insaturation and find I_B, and I_C. Repeat with the 2KΩ emitter resistance is added.

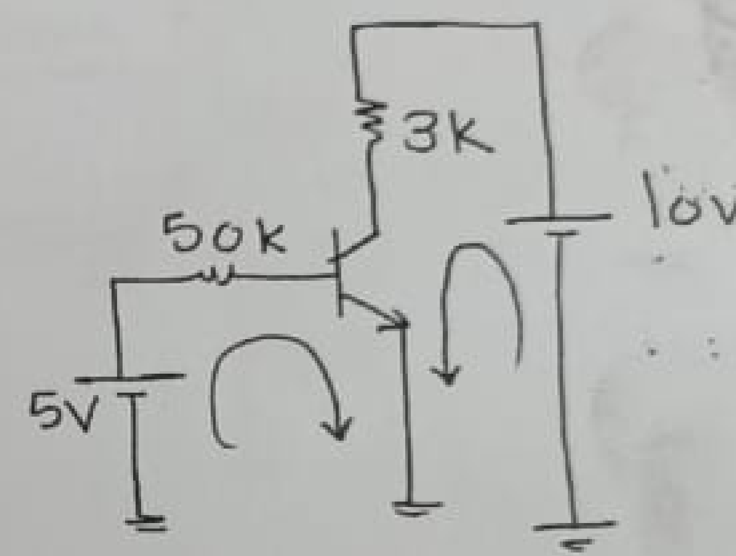


Sol:-

assume Tr in saturation

$V_{CE} = 0.2V$

$V_{BE} = 0.7V$



i/P loop

$$5 = I_B(50) + \underset{}{\overset{V_{BE}}{0.7}}$$

$$I_{B_{sat}} = \frac{5-0.7}{50\times10^3} = 8.6\times10^{-5} A = 86 \mu A = 0.086 mA$$

o/P loop

$$10 - I_C(3) - \overset{V_{CE}}{0.2} = 0$$

$$I_C = \frac{10-0.2}{3\times10^3} = 3.26\times10^{-3} = 3.26 mA$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta} = \frac{3.26}{100} = 0.0326 mA$$

$\underset{active}{I_{B(min)}} < I_{B(sat)}$ assumption true Tr in saturation

اقل تيار
بدخليه sat
واي تيار ش act

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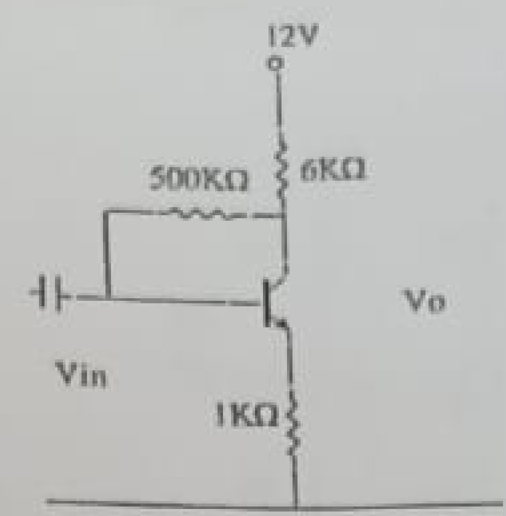
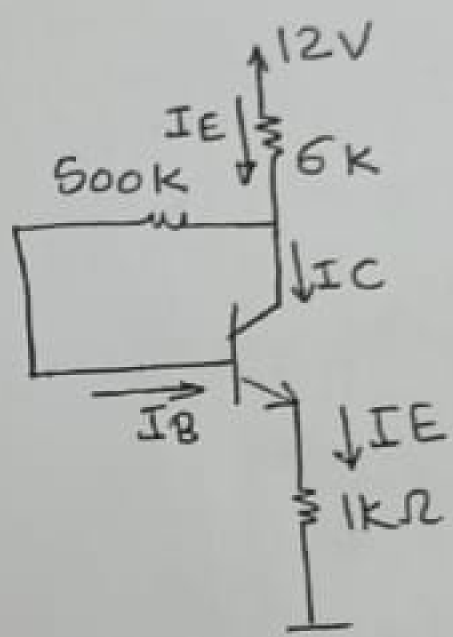
8. In the collector base bias circuit shown in figure, calculate the quiescent collector voltagewhen $\beta=100$.



Sol:-

assume tr active

i/P loop



$12 - 6\,I_E - 500\,I_B - 0.7 - 1\,I_E = 0$

$12 - 0.7 = 7\,I_E + 500\,I_B$

$= 7(1+\beta)I_B + 500\,I_B$

$11.3 = [7(101) + 500]\,I_B$

$I_B = 9.36\ \mu A$

$I_C = \beta I_B = 100 \times 9.36 = 0.936\,mA$

$I_E = (1+\beta)I_B = 0.946\,mA$

o/P loop

$12 - (6+1)I_E = V_{CE}$

$= 5.38V > V_{BE}$ assumption true

$V_C = V_{CE} + I_E R_E = 5.38 + 0.946 = 6.32V$

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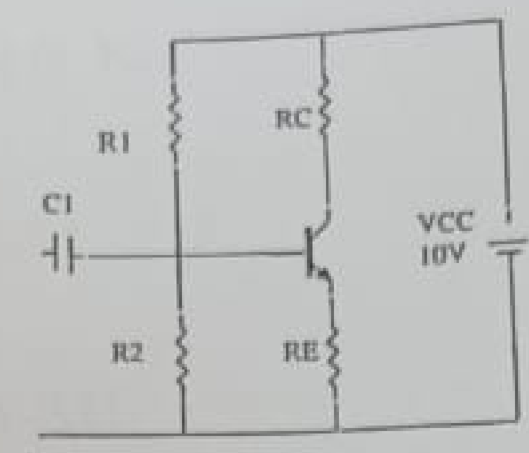
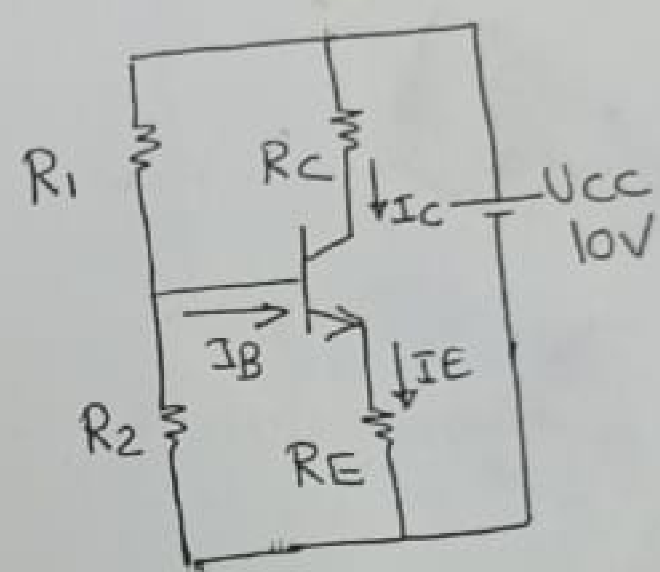
9. In the circuit shown in figure, determine the unknown parameters that satisfy the bias condition to be V_{CE}=5V and I_C= 1mA with β =50.



Sol:-

$I_B = \frac{I_C}{\beta} = \frac{1mA}{50} = 0.02mA$

$I_E = I_B + I_C = 1.02mA$

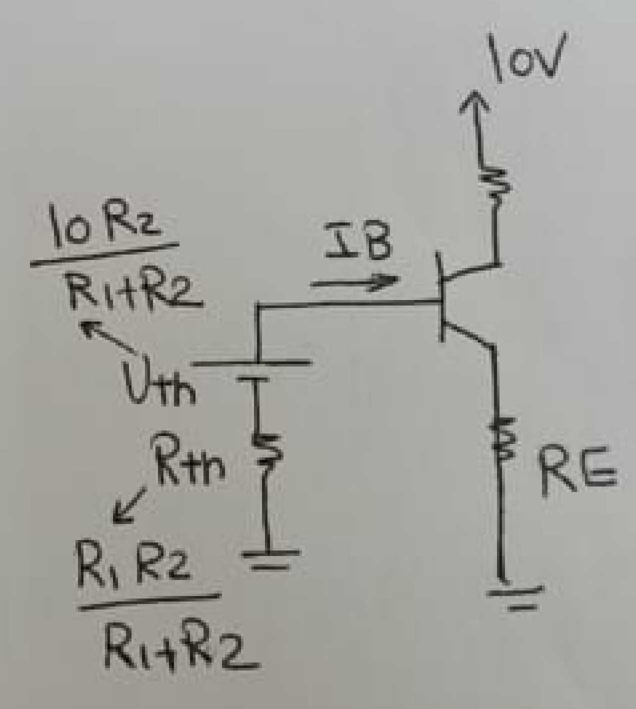


o/p loop

$10 - 5 - I_C R_C - I_E R_E = 0$

$5 = R_C + 1.02 R_E$

i/p loop



$V_{th} - 0.7 = R_{th}(0.02) + R_E(1.02)$

$R_E = 0.5k$

$R_{th} = 100k$

o/p loop

$5 = R_C + 1.02 * 0.5$

$R_C = 4.5k\Omega$

i/P loop

$$\frac{10 R_2}{R_1+R_2} - 0.7 = 100 * 0.02 + 0.5 * 1.02$$

$$R_{th} = \frac{R_1 R_2}{R_1+R_2} = 100\text{ K}$$

$$V_{th} = \frac{10 R_2}{R_1+R_2} = 3.21 \text{ V}$$

$$\frac{R_2}{R_1+R_2} = 0.321$$

$$R_{th} = 0.321 R_1 = 100\text{k}$$

$$R_1 = 311.5 \text{ k}\Omega$$

$$0.321(R_1 + R_2) = R_2$$

$$0.321(311.5 + R_2) = R_2$$

$$R_2 = 147.3 \text{ k}\Omega$$

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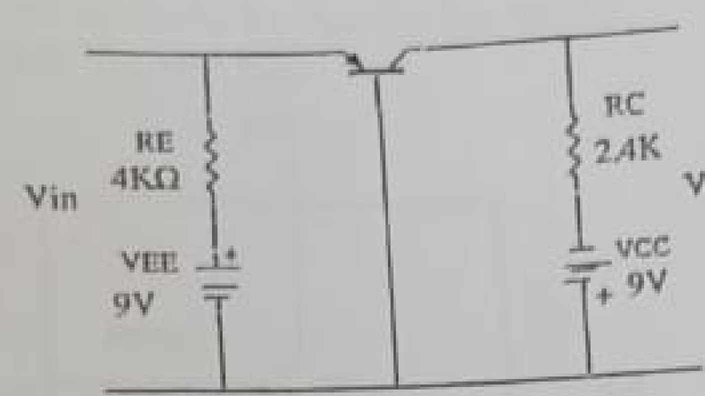
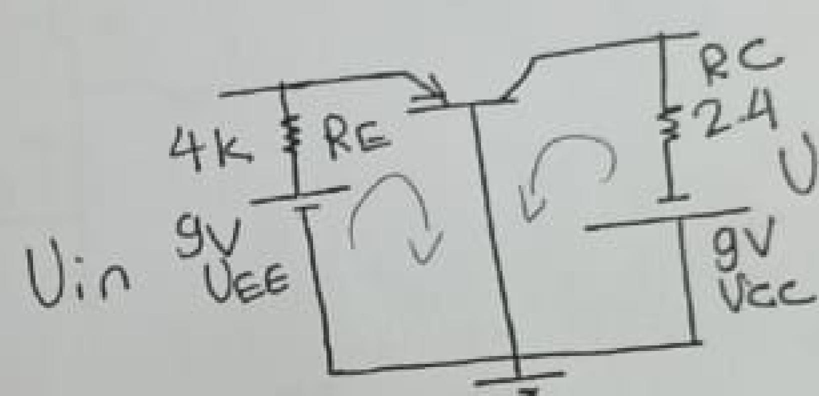
(17)

10. Calculate the currents I_E and I_C for the circuit shown in figure, if $\beta = 150$.



Sol:-

assume Tr active



I/P loop

$9 - 0.7 = 4 I_E$

$I_E = 2.075 \, mA$

$I_B = \dfrac{I_E}{1+\beta} = 0.014 \, mA$

$I_C = \beta I_B = 2.061 \, mA$

O/P loop

$9 - 2.4 I_C = V_{CB}$

$V_{CB} = 4.053 > V_{BE}$ active

$\therefore I_C = 2.061$, $I_E = 2.075 \, mA$

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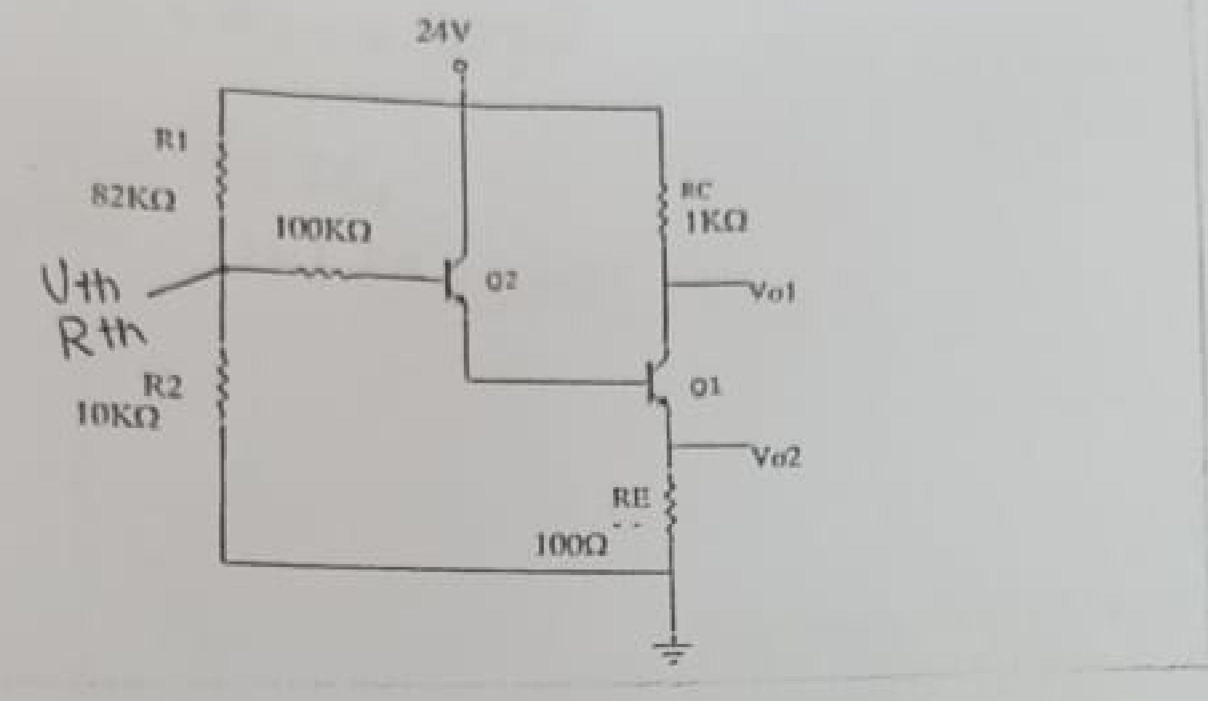
11. For the circuit shown, transistor Q1 and Q2 operate in the active region with $V_{BE1}=V_{BE2}=0.7V$, $\beta 1=100$, $\beta 2=50$.

a) Find the currents I_{B2}, I_1, I_2, I_{C2}, I_{B1}, I_{C1}, I_{E1}, and I_{E2}.

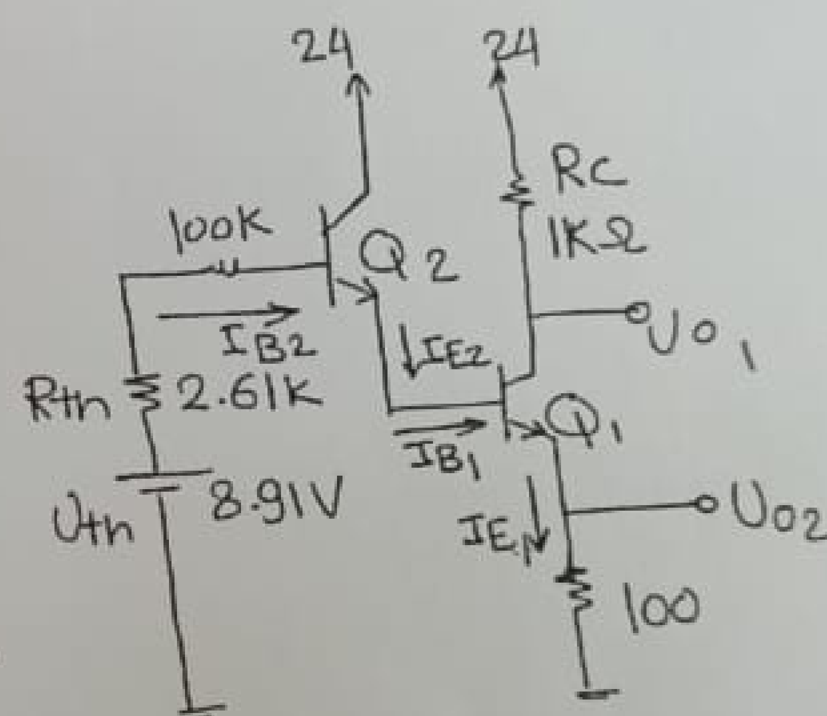
b) Find the voltages V_{O1} and V_{O2}.



Sol:-

$$V_{th} = \frac{24 * 10}{10 + 82} = 2.61V$$

$$R_{th} = \frac{82 * 10}{82 + 10} = 8.91k$$



i/P loop

$$V_{th} - I_{B2}(100 + 8.91) - 0.7 - 0.7$$
$$- 101 * 51 * 0.1 * I_{B2} = 0$$

$$I_{B2} = 1.94 \mu A$$

$$I_{C2} = \beta_2 I_{B2} = 0.097 mA$$

$$I_{E2} = (1+\beta_2) I_{B2} = 0.099 mA$$

$$(1+\beta_1) I_{B1} = I_{E1}$$
$$(1+\beta_1)(1+\beta_2) I_{B2} = (1+\beta_1) I_{E2}$$
$$I_{E2} = I_{B1} = 0.099 mA$$

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$I_{C_1} = \beta_1 I_{B_1} = 9.89\ mA$

$I_{E_1} = (1+\beta_1) I_{B_1} = 9.99\ mA$

$V_{o2} = I_{E_1} * 100 = 0.999V$

$V_{o1} = 24 - R_C I_{C_1}$

$= 24 - (1k)(9.89\ mA) = 14.11\ V$

Eman

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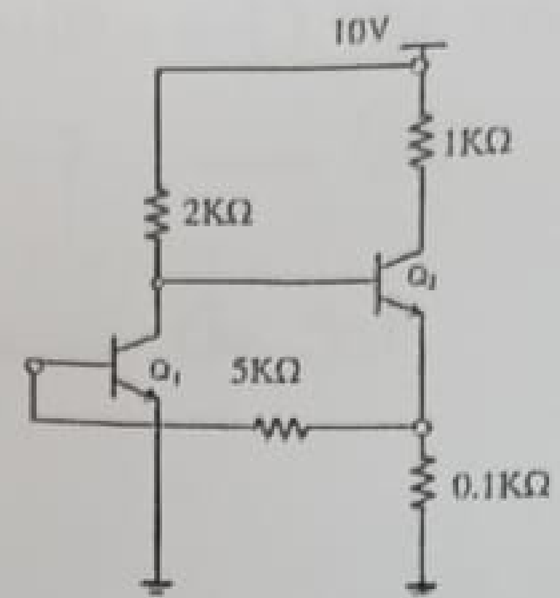
12. Evaluate the voltages at all nodes and the currents through all branches. What is the DCmode of operation for the transistors? Assume: $V_{BE} = 0.7$ V β=50.



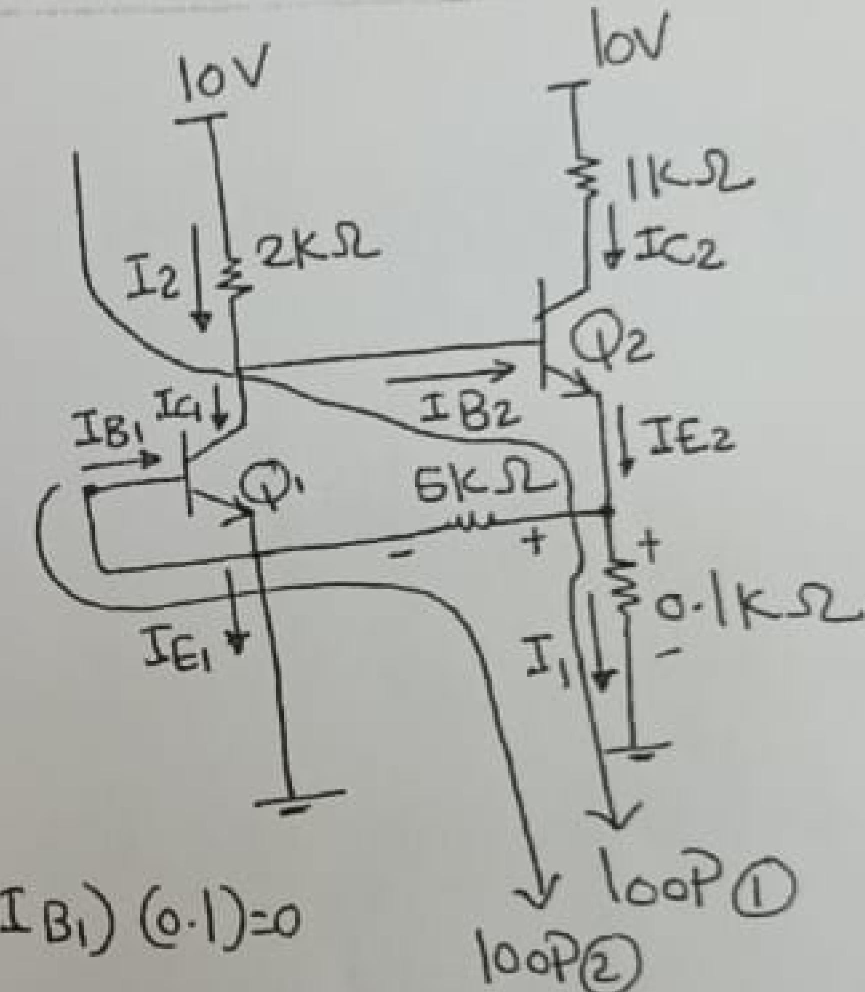
Sol:-

$\rightarrow I_2 = I_{C1} + I_{B2}$

$= \beta I_{B1} + I_{B2}$

$\rightarrow I_{E2} = I_1 + I_{B1}$

$= (1+\beta) I_{B2}$



loop 1

$10 - (\beta I_{B1} + I_{B2})(2) - 0.7 - (I_{E2} - I_{B1})(0.1) = 0$

$10 - (\beta I_{B1} + I_{B2})(2) - 0.7 - ((\beta+1) I_{B2} - I_{B1})(0.1) = 0$

$10 - 2\beta I_{B1} - 2 I_{B2} - 0.7 - (0.1)\beta I_{B2} - (0.1) I_{B2} + (0.1) I_{B1} = 0$

$9.3 + (-2\beta + (0.1)) I_{B1} + (-2 - 0.1\beta - 0.1) I_{B2} = 0$

$99.9 I_{B1} -- 7.1 I_{B2} = -9.3 \longrightarrow$ (1)

loop 2

$0.7 + 5 I_{B1} - 0.1 I_1 = 0$

$0.7 + 5 I_{B1} - 0.1((\beta + 1) I_{B2} - I_{B1}) = 0$

Eman

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$0.7 + 5I_{B_1} - 0.1\beta I_{B_2} - 0.1 I_{B_2} + 0.1 I_{B_1} = 0$

$0.7 + (5 + 0.1) I_{B_1} + (-0.1\beta - 0.1) I_{B_2} = 0$

$5.1 I_{B_1} - 5.1 I_{B_2} = -0.7 \longrightarrow (2)$

Solving (1) and (2) we can get

I_{B_1}, I_{B_2}

$I_{E_1} = (\beta + 1) I_{B_1}$

$I_{C_1} = (\beta) I_{B_1}$

$I_{E_2} = (\beta + 1) I_{B_2}$

$I_{C} = (\beta) I_{B_2}$

$I_1 = I_{E_2} - I_{B_1}$

$I_2 = I_{C_1} + I_{B_1}$

$V_{C_1} = 10 - 2 I_2$

$V_{B_1} = V_{BE}$

$V_{E_1} = \text{zero}$

$V_{C_2} = 10 - 2I_{C_2}$

$V_{B_2} = V_{BE} + 0.1 I_1$

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