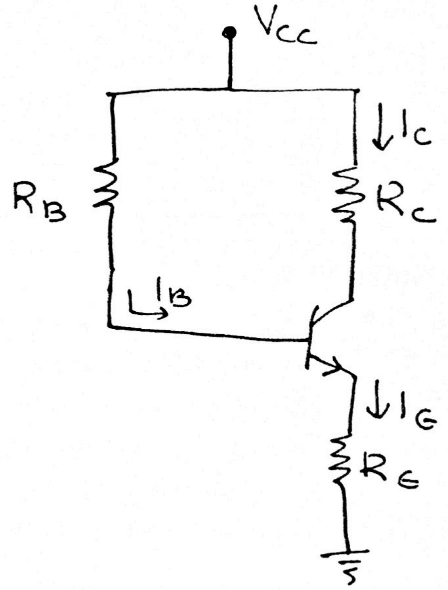
Question # 1 (Points: 20, 5 + 5 + 10, CLO – 2)
Calculate Q-point parameters i.e., I_C, and V_{CE}, and V_{CB} for the following cases. Assume V_{BE} = 0.7V for the analysis purposes. Also, identify whether the transistor is working in forward active region i.e., as an amplifier or not? Assume common-emitter topology for the analysis. Draw the circuits as well.

a) An emitter degeneration-based biasing scheme having V_{CC} = 20V, R_B = 430kΩ, R_C = 2kΩ, R_E = 1kΩ, β = 50.



Applying KVL on the base emitter loop gives,

$$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0 \quad — \text{(A)}$$

we know that,

$$I_C = \alpha I_E$$

$$\beta I_B = \left(\frac{\beta}{\beta+1}\right) I_E$$

$$I_E = (1+\beta) I_B$$

putting value of I_E in eq (A)

$$V_{CC} - I_B R_B - V_{BE} - (1+\beta) R_E = 0$$

$$V_{CC} - V_{BE} = I_B \left((1+\beta) R_E + R_B\right)$$

$$I_B = \frac{V_{CC} - V_{BE}}{(1+\beta) R_E + R_B}$$

$$I_B = \frac{20 - 0.7}{(1+50)(1000) + 430 \times 10^3}$$

$$\boxed{I_B = 40.12\mu A}$$

Now we know,

$$I_C = \beta I_B$$

$$I_C = 50 \times (40.12\mu)$$

$$\boxed{I_C = 2.006mA}$$

Applying KVL on collector-emitter loop,

$$V_{CE} = V_{CC} - I_C R_C + I_E R_E$$

As $I_C \approx I_E$

$$V_{CE} = V_{CC} - I_C R_C - I_C R_E$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

$$\boxed{V_{CE} = 13.982V}$$

Now, $V_{CB} = V_{CE} - V_{BE}$

$$V_{CB} = 13.982 - 0.7$$

$$\boxed{V_{CB} = 13.282V}$$

for active region $V_{BE} > 0$ and $V_{BC} \ngtr < 0$

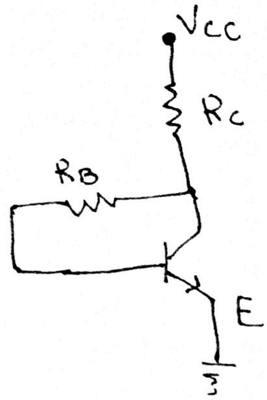
$$V_{BC} = V_{BE} - V_{CE}$$

$$= 0.7 - 13.982 = -13.282$$

which is proved hence in forward active region

) A self-bias (feedback bias) scheme having $V_{CC} = 10V$, $R_B = 180k\Omega$, $R_C = 1.5k\Omega$, $\beta = 100$.

Applying KVL to the base-emitter loop gives,



$$V_{CC} - I_C R_C - I_B R_B - V_{BE} = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta R_C}$$

$$I_B = \frac{10 - 0.7}{180k + (100)(1.5k)}$$

$$\boxed{I_B = 28.18\,\mu A}$$

$$I_C = \beta I_B$$

$$\boxed{I_C = 2.818\,mA}$$

Applying KVL on collector-emitter loop,

$$V_{CE} = V_{CC} - I_C R_C$$

$$V_{CE} = 10 - (2.818m)(1.5k)$$

$$\boxed{V_{CE} = 5.773}$$

we know,

$$V_{CB} = V_{CE} - V_{BE}$$

$$V_{CB} = 5.773 - 0.7$$

$$\boxed{V_{CB} = 5.073V}$$

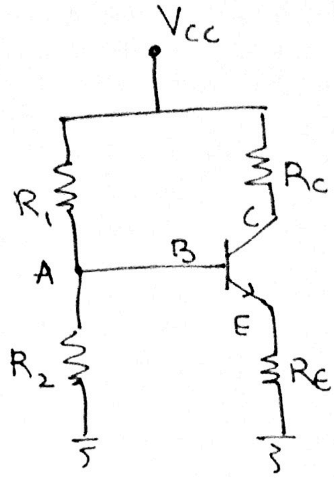
for forward region,

$V_{BC} = -5.073$ $\quad V_{BE} = 0.7$

$V_{BC} < 0$ and $V_{BE} > 0$ $\quad \Big\}$ forward region

c) A voltage divider network-based biasing scheme having $V_{CC} = 10V$, $R_1 = 18k\Omega$, $R_2 = 4.7k\Omega$, $R_E = 1.1k\Omega$, $R_C = 3k\Omega$, $\beta = 50$.

1. Use approximate approach for analysis



Voltage divider at node A,

$$V_A = \frac{R_2 V_{CC}}{R_1 + R_2}$$

$$= \frac{(4.7k)(10)}{18k + 4.7k}$$

$$\boxed{V_A = 2.07V}$$

Now as we can see $V_B = V_A$,

$$\boxed{V_B = 2.07V}$$

$$V_B = V_{BE} + V_{RE}$$

$$V_{RE} = V_B - V_{BE}$$

$$\boxed{V_{RE} = 1.37V}$$

$$V_{RE} = I_{RE} R_E$$

$$I_{RE} = \frac{1.37}{1.1k}$$

$$\boxed{I_{RE} = 1.245mA}$$

As $I_{RE} = I_E \approx I_C$

$$\boxed{I_C = 1.245mA}$$

Applying KVL on collector-emitter loop,

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

$$V_{CE} = V_{CC} - I_C(R_C + R_E) \quad \because I_C \approx I_E$$

$$V_{CE} = 10 - (1.245m)(3k + 1.1k)$$

$$\boxed{V_{CE} = 4.896V}$$

Now, $V_{CB} = V_{CE} - V_{BC}$

$$V_{CB} = 4.896 - 0.7$$

$$\boxed{V_{CB} = 4.196V}$$

As $V_{BC} < 0$

$$V_{BC} = -V_{CB}$$

$$= -4.196V$$

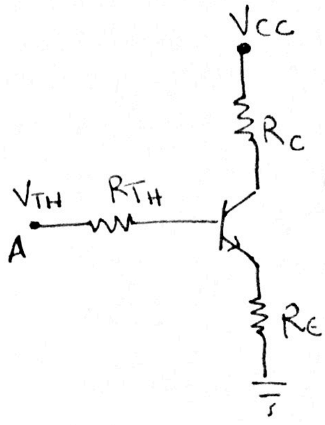
and $V_{BE} > 0$

$$V_{BE} = 0.7$$

so in forward active region

2. Use accurate approach for analysis

Thevenin equivalent circuit,



$V_{TH} = V_A$

from previous part,

$\boxed{V_{TH} = 2.07V}$

for R_{TH} removing the sources R_1 and R_2 in parallel

$R_{TH} = R_1 \parallel R_2$

$\boxed{R_{TH} = 3.73K\Omega}$

Now using KVL,

$V_{TH} - I_B R_{TH} - V_{BE} - I_E R_E = 0$

$\Rightarrow V_{TH} - I_B R_{TH} - V_{BE} - (1+\beta) I_B R_E = 0$

$$I_B = \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta) R_E}$$

$$I_B = \frac{2.07 - 0.7}{3.73K + (1+50)(1.1K)}$$

$\boxed{I_B = 22.9 \mu A}$

Now, $I_C = \beta I_B$

$\boxed{I_C = 1.145 mA}$

So, $I_E = (1+\beta) I_B$

$\boxed{I_E = 1.168 mA}$

Now,

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

$V_{CE} = 10 - (1.145m)(3000) - (1.168m)(1100)$

$\boxed{V_{CE} = 5.28 V}$

$V_{CB} = V_{CE} - V_{BE}$

$= 5.28 - 0.7$

$\boxed{V_{CB} = 4.58V}$

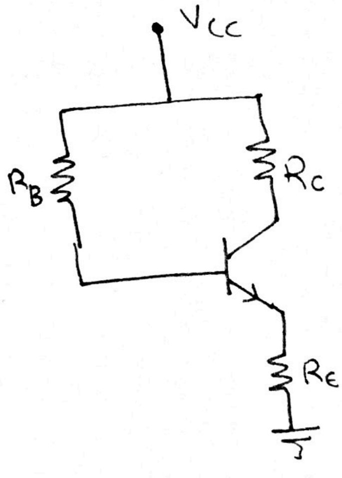
Now $V_{BC} < 0$ and $V_{BE} > 0$

$V_{BC} = -4.58V$ $\quad$ $V_{BE} = 0.7$

So in <u>forward active region</u>

Question # 2: (Points: 40, 10 + 20 + 10, CLO - 3)

a) Design an emitter-bias BJT configuration with the following specifications: $I_{C,Q} = (½)\ I_{sat}$, $I_{Csat} = 8$ mA, $V_{CC} = 28V$, $V_C = 18V$, $V_{BE} = 0.7V$ and $\beta=110$. Determine R_C, R_E, and R_B. Assume V_E as 10% of V_{CC}.



$I_{CQ} = \frac{1}{2} I_{sat_C} = \frac{1}{2} \times 8mA$

$\boxed{I_{C,Q} = 4mA}$

$V_E = 10\%$ of V_{CC}

$V_E = 2.8V$

$I_E = \frac{I_C}{\alpha} = \frac{4m}{(110/111)}$

$\boxed{I_E = 4.036mA}$

Now as,

$V_E = R_E I_E$

$R_E = \frac{2.8}{4.036m}$

$\boxed{R_E = 693.756\ \Omega}$

Applying KVL at base-emitter,

$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$

$R_B = \frac{V_{CC} - V_{BE} - V_E}{(I_C/\beta)}$

$\boxed{R_B = 673.75k\Omega}$

Applying KVL at the collector - emitter,

$V_{CE} = V_{CC} - I_C R_C - I_E R_E$

$V_{CE} = V_C - V_E$

$= 18 - 2.8$

$V_{CE} = 15.2V$

So, $R_C = \frac{V_{CC} - V_{CE} - I_E R_E}{I_C}$

$= \frac{28 - 15.2 - 2.8}{4m}$

$\boxed{R_C = 2500\ \Omega}$

) Design an voltage divider-bias BJT configuration with the following specifications: $I_{C,Q} = 10mA$, $V_{CC} = 20V$, $V_{CE,Q} = 8V$, $V_{BE} = 0.7V$, and $\beta = 80$. Determine R_C, R_E, and R_B. Use both approaches (use notes uploaded on LMS) to design the biasing stage. Assume V_E as 10% of V_{CC}.

1. Accurate Approach

$V_E = 10\%$ of $V_{CC} = 2V$

$I_E = I_C / \alpha = 10m / \left(\frac{80}{81}\right)$

$\boxed{I_E = 10.125 mA}$

$R_E = \frac{V_E}{I_E} = \frac{2}{10.125m}$

$\boxed{R_E = 197.53\,\Omega}$

$V_B = V_{BE} + V_E$

$= 0.7 + 2$

$\boxed{V_B = 2.7V}$

$R_B = \frac{(1+\beta)R_E}{10} = \frac{(1+80)(197.53)}{10}$

$R_B = 1600\,\Omega$

as $R_B = R_{TH}$,

$V_{CC} \times \frac{R_B}{V_B} = R_1$

$R_1 = \frac{20 \times 1600}{2.7}$

$\boxed{R_1 = 11.852 k\Omega}$

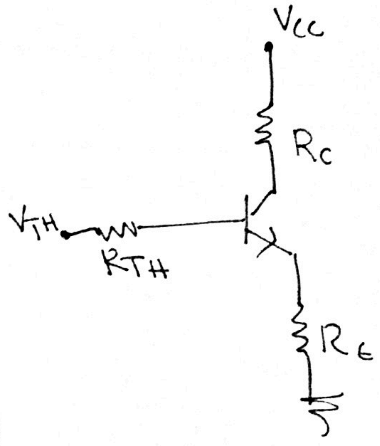
As $R_{TH} = \frac{R_1 R_2}{R_1 + R_2}$

$R_{TH}R_1 + R_{TH}R_2 = R_1 R_2$

$R_2 = \left[\frac{-R_{TH}R_1}{(R_{TH} - R_1)}\right]$

$R_2 = \left[\frac{-(1600)(11.852k)}{1600 - 11.852k}\right]$

$\boxed{R_2 = 1.85 k\Omega}$



$V_{TH} = \frac{R_2 V_{CC}}{R_1 + R_2}$

$R_{TH} = R_1 \| R_2$

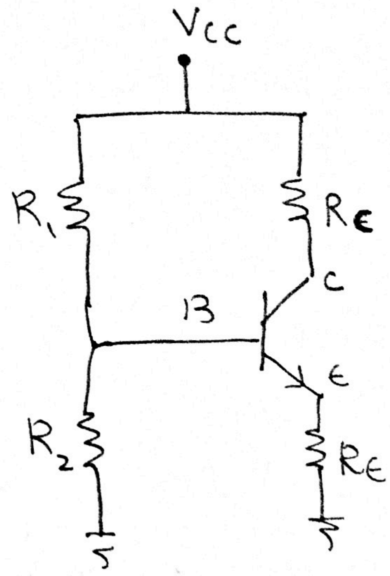
$V_{CC} - I_C R_C - V_{CE} - V_E = 0$

$R_C = \frac{V_{CC} - V_{CE} - V_E}{I_C}$

$R_C = \frac{20 - 8 - 2}{10m}$

$\boxed{R_C = 1000\,\Omega}$

2. Approximate Approach



from previous part,

$V_E = 2V$

$I_E = 10.125\,mA$

and

$\boxed{R_E = 197.53\,\Omega}$

let, $I_1 = 10 I_B$

$I_B = I_C/\beta$

$\boxed{I_B = 125\,\mu A}$

$I_1 = \dfrac{V_{CC}}{R_1 + R_2}$

$\boxed{R_1 + R_2 = 16k\,\Omega}$

Now,

$V_B = V_{BE} + V_E$

$\dfrac{V_{CC} R_2}{R_1 + R_2} = 0.7 + 2$

$(2.7)(16K) = 20 R_2$

$\boxed{R_2 = 2160\,\Omega}$

$R_1 = 16000 - 2160$

$\boxed{R_1 = 13840\,\Omega}$

Now,

$V_{CC} - I_C R_C - V_{CE} - V_E = 0$

$R_C = \dfrac{V_{CC} - V_{CE} - V_E}{I_C}$

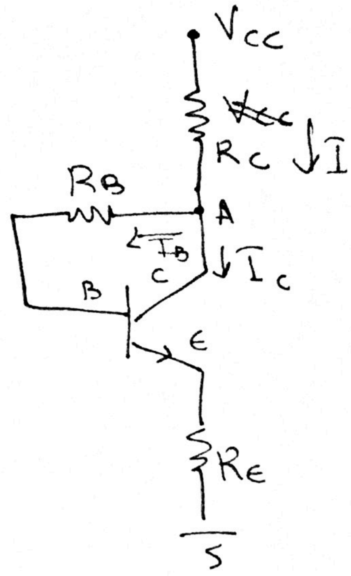
$\boxed{R_C = 1K}$

$R_B = R_1 \| R_2$

$\boxed{R_B = 1.87k\,\Omega}$

c) Design a self-bias (collector feedback bias) BJT configuration with the following specifications:
$I_{C,Q} = 10mA$, $V_{CC} = 20V$, $V_{CE,Q} = 8V$, $V_{BE} = 0.7V$, and $\beta = 80$. Determine R_C, R_E, and R_B. Assume V_E as 10% of V_{CC}

$\boxed{V_E = 2V}$



$I_E = I_C/\alpha = 10.125\,mA$

$\boxed{R_E = 197.53\,\Omega}$

Applying KCL at node A,

$I = I_C + I_B$

$I_B = I_C/\beta$

$\boxed{I_B = 0.125\,mA}$

Now,

$V_{CC} - IR_C - V_{CE} - I_E R_E = 0$

$R_C = \dfrac{V_{CC} - V_{CE} - V_E}{I_C + I_B}$

$\boxed{R_C = 987.654\,\Omega}$

$V_A = V_{CC} - R_C I$

$V_A = I_B R_B + V_{BE} + V_E$

So,

$V_{CC} - R_C I = I_B R_B + V_{BE} + V_E$

$R_B = \dfrac{V_{CC} - R_C(I_C + I_B) - V_{BE} - V_E}{I_B}$

$\boxed{R_B = 58.4\,k\Omega}$