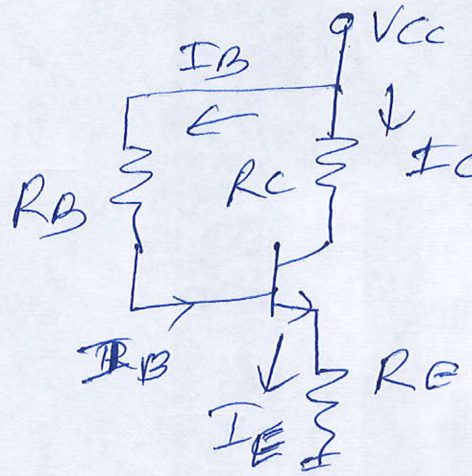
LECTURE 9/11/2020

(1)

(3) EMITTER FEEDBACK BIAS / BASE BIAS WITH EMITTER FEEDBACK / EMITTER RESISTOR BIASING

It is a modification of fixed bias circuit (method no. 1). It uses an additional resistor R_E which is connected in the emitter. It has 3 resistor R_B, R_C & R_E



Analysis:

Determination of Q point.

(i) Input section:

$$V_{CC} = I_B R_B + V_{BE} + I_E R_E$$

$$\left[\begin{aligned} &\text{put } I_E R_E = (\beta+1) I_B R_E \\ &I_E = I_C + I_B \\ &\quad = \beta I_B + I_B = (\beta+1) I_B \end{aligned}\right]$$

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

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

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

$$\simeq \frac{V_{CC}}{R_B + \beta R_E}$$

Assuming $\beta \gg 1$ & $V_{BE} \ll V_{CC}$.

$$I_C = \beta I_B = \frac{\beta V_{CC}}{R_B + \beta R_E} = \frac{V_{CC}}{\frac{R_B}{\beta} + R_E} \quad \text{.. (1)}$$

(ii) Output section.

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

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

as $I_C \simeq I_E$ .. (2)

Deriva^n^ of Equation showing the effect of feedback.

$$V_{CC} = R_B I_B + V_{BE} + I_E R_E$$

$$\therefore I_B = \frac{V_{CC} - I_E R_E - V_{BE}}{R_B}$$

If V_{BE} is neglected then

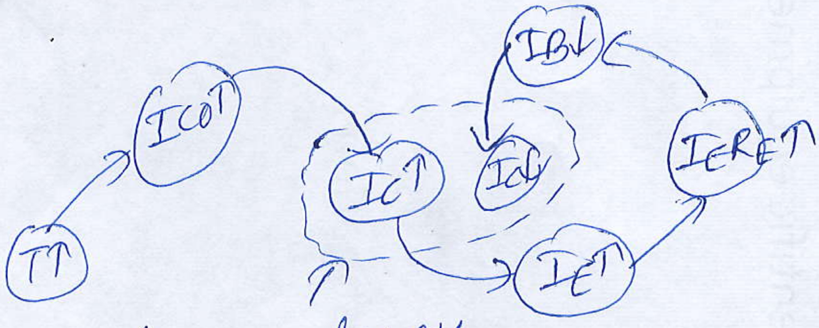
$$I_B = \frac{V_{CC} - I_E R_E}{R_B} \quad \text{.. (3)}$$

Suitability as biasing circuit

(1) Effect of temperature.

As the temperature increases I_{CO} increases $\therefore I_C$ increases and I_E increase $\therefore I_E R_E$ increases. This reduces $V_{CC} - I_E R_E$ $\therefore I_B$ reduces which results in reduction of I_C. I_C is not allowed to increase to the extent it would have been in absence of R_E.

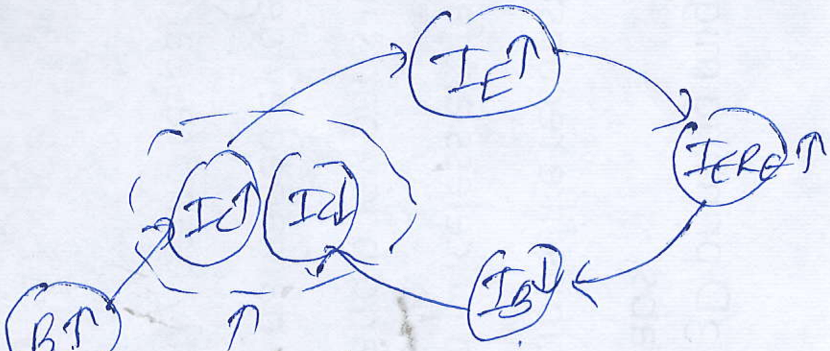
(Refer equation (3))



Rizing tendency is checked.

(2) Transistor replaced by another transistor of same type having different value of β:

This circuit provides stabilization of Q point. If β increases then I_C increases ∴ I_E also increases ∴ $I_E R_E$ increases ∴ I_B decreases and hence I_C decreases.



Rising tendency is checked.

Drawback of Emitter feedback bias circuit

The resistor R_E is present at the output side as well as the input side of the circuit. A feedback occurs through this resistor. The feedback voltage is proportional to I_E. Hence this circuit is also called current feedback biasing circuit.

While d.c. feedback helps in the stabilization of Q point, the a.c. feedback reduces the voltage gain of the amplifier. (4)

This drawback can be remedied by putting a capacitor C_E across the resistor R_E. The capacitor C_E offers very low impedance to the a.c. current. The E is effectively placed at ground potential for the a.c. signal. The circuit now provides d.c. feedback for stabilization of Q point but does not give any a.c. feedback. The amplification of ac signal remains unaffected

<u>stability factor</u>.

$$V_{CC} = I_B R_B + V_{BE} + I_E R_E.$$

putting $I_E = I_C + I_B$.

$$V_{CC} = I_B R_B + V_{BE} + (I_C + I_B) R_E$$

$$V_{CC} = I_B (R_B + R_E) + V_{BE} + I_C R_E$$

$$\therefore I_B (R_B + R_E) = V_{CC} - V_{BE} - I_C R_E$$

$$\therefore I_B = \frac{V_{CC} - V_{BE}}{R_B + R_E} - I_C \frac{R_E}{R_E + R_B}$$

Differentiating w.r.t. I_C.

$$\frac{dI_B}{dI_C} = \frac{-R_E}{R_E + R_B}.$$

$$\therefore S = \frac{1+\beta}{1 - \beta \frac{dI_B}{dI_C}} = \frac{1+\beta}{1 - \beta \times \frac{-R_E}{R_E + R_B}} = \frac{1+\beta}{1 + \frac{\beta R_E}{R_E + R_B}}$$

Why this circuit is not used.

The denominator in the equation

$$I_C = \frac{V_{CC}}{\frac{R_B}{\beta} + R_E}$$

can be independent of β only if $R_E \geq \frac{R_B}{\beta}$.

This means that either R_E should be very high or R_B be very low.

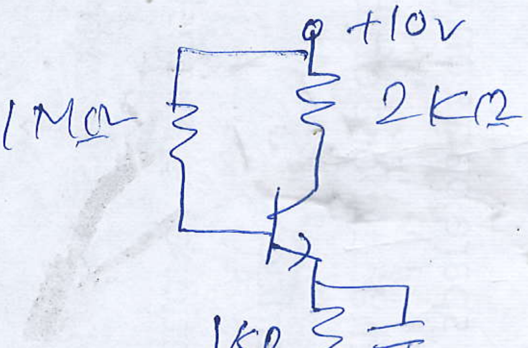
(i) <u>High value of R_E</u>

It will cause a large voltage drop across it. To obtain a particular operating point under this condition it will require a high d.c. source V_{CC}.

(ii) Low value of R_B - requires a separate low voltage supply in the circuit. Both the alternatives are impractical.

Solved problems.

(1) Calculate the values of I_B, I_C & I_E



$$I_B = \frac{V_{CC}}{R_B + \beta R_E} = \frac{10}{1\times10^6 + 100\times1\times10^3}$$

$= 9.09\ \mu A$.

$I_C = \beta I_B = 100 \times 9.09 \times 10^{-6} = 0.909\,mA$ 6

$I_E = I_C + I_B = 9.09\,\mu A + 0.909\,mA$

$\simeq 0.909\,mA$

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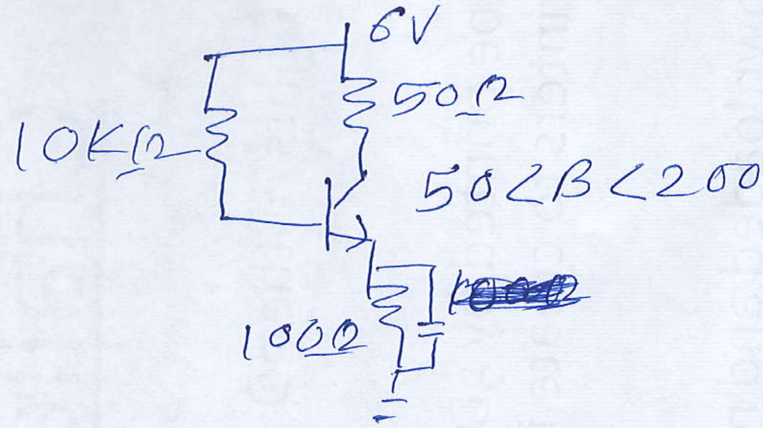
(2) Calculate the minimum and maximum value of I_E for the biasing circuit. Also calculate the corresponding value of V_{CE}. Germanium transistor is used (means $V_{BE} = 0.3V$)



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

Multiply both sides by $\beta+1$

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

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

(a) $\beta = 50$

$$I_E = \frac{(6 - 0.3)(50+1)}{10 \times 10^3 + 50 \times 100}$$

$= 19.38\,mA$.

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

$= 6 - (100 + 50) \times 19.38 \times 10^{-3}$

$= 3.09\ V.$

(b) $\beta = 200$

$$I_E = \frac{(6 - 0.3)(200+1)}{10 \times 10^3 + 200 \times 100}$$

$= 38.19\ mA.$

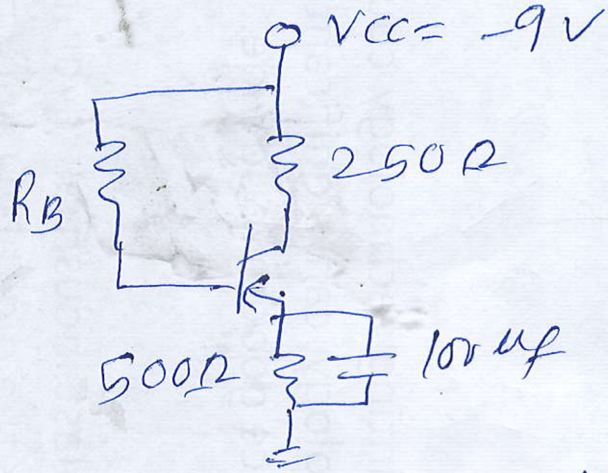
$V_{CE} = 6 - (50 + 100) \times 38.19 \times 10^{-3}$

$= 0.27\ V.$

(Conclusion (i) When β becomes 4 times I_E becomes almost double.

(ii) When β changes from 50 to 200, operating point shifts very near saturation point.

(3) Calculate the value of R_B in the biasing circuit so that the Q point is fixed at $I_C = 8\ mA$, $V_{CE} = 3\ V$.



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

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

V_{BE} is neglected

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

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

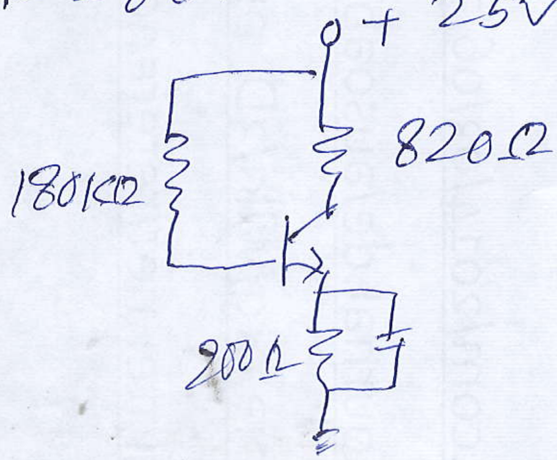
Now $I_B = \frac{I_C}{\beta} = \frac{8\times10^{-3}}{80} = 100\mu A$.

$$\therefore R_B = \frac{9 - (80+1)\times100\times10^{-6}\times500}{100\times10^{-6}}$$

$$= 49.5 K\Omega.$$

Assignment Problems.

(1) Determine the values of I_C, V_{CE} and stability factor. Given $V_{BE} = 0.7v$ and $\beta = 80$.



~~$I_C = V_{CC} - V_{BE}$~~ Draw circuits for (2) & (3).

(2) Calculate Q point. Neglect V_{BE}. Given $V_{CC} = 20v$, $R_B = 400 K\Omega$, $R_C = 2K\Omega$, $R_E = 1K\Omega$ & $\beta = 100$

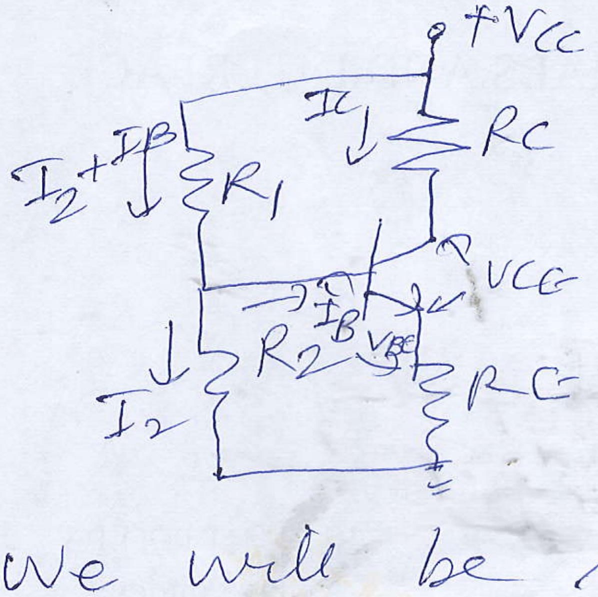
(3) Calculate Q point; Given $V_{BE} = 0.25v$. Given $V_{CC} = 10v$, $R_B = 75K\Omega$, $\beta = 80$, $R_C = 0.5K\Omega$, $R_E = 470\Omega$

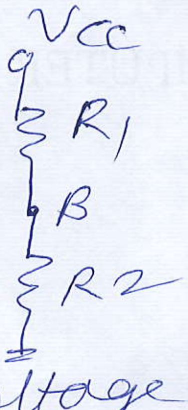
(4). VOLTAGE DIVIDER BIAS/SELF BIAS (9)

In all previous circuits I_C & V_{CE} depend upon β of the transistor. β is temperature sensitive especially for Si transistors therefore this circuit is designed which is independent of β. It is most widely used method.

Here R_1 & R_2 are connected across the supply voltage Vcc to provide biasing. R_E provides stabilisation. The name 'voltage divider' comes from the voltage divider formed by R_1 & R_2.

The voltage drop across R_2 forward biases the B–E junction.



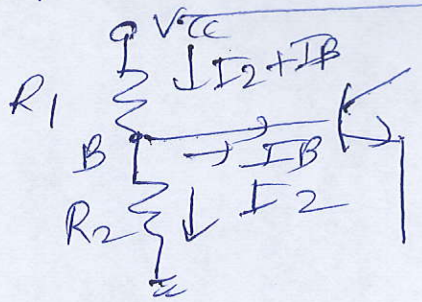


voltage divider.

We will be studying 2 analysis for the voltage-divider bias circuit

(i) APPROXIMATE ANALYSIS

(a) Base circuit



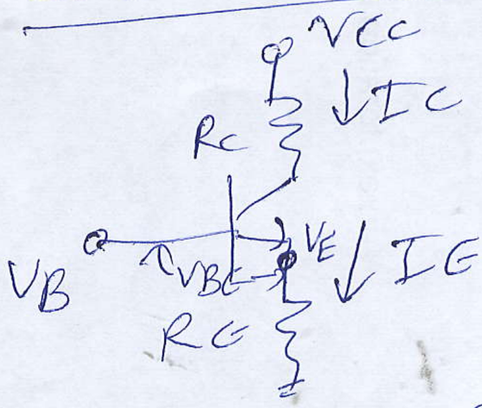
voltage across R_2 is the B voltage V_B

$$\therefore V_B = \frac{R_2 \quad I_2}{R_1(I_2+I_B)+R_2 I_2} \times V_{CC}$$

as $I_2 >> I_B$

$$\therefore V_B = \frac{R_2}{R_1+R_2} \times V_{CC}$$

(b) Collector circuit



$$V_E = I_E R_E = V_B - V_{BE}.$$

$$\therefore I_E = \frac{V_B - V_{BE}}{R_E}$$

$V_{BE} << V_B$

$$\therefore I_E = \frac{V_B}{R_E}$$

Applying KVL to the C circuit

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

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

As $I_C \simeq I_E$.

$V_{CE} = V_{CC} - (R_C + R_E) I_C$ (19)

In the above analysis β does not appear which means that Q point does not depend upon the β.

Stabilization:

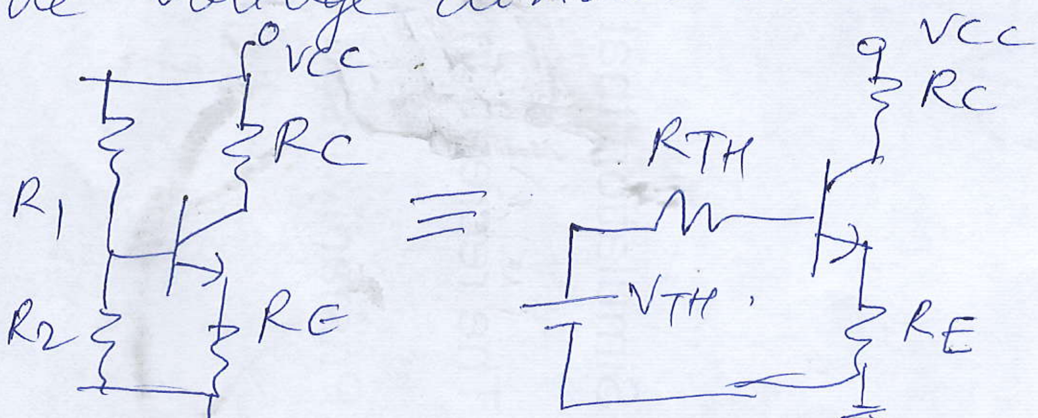
In this circuit excellent stabilisation is provided by R_E.

$$V_B = V_{BE} + I_E R_E$$

Suppose I_C increases due to rise in temperature. This will cause the voltage drop across ~~R_E~~ ~~i.e.~~ ~~V_B~~ R_E to increase. As V_B is independent of ~~β~~ I_C therefore V_{BE} decreases. This in turn causes I_B to decrease. $\therefore$ I_C will decrease.

(II) ACCURATE ANALYSIS / EXACT ANALYSIS

Let us apply Thevenin's theorem to the voltage divider circuit



(12)

(a) ~~Input section~~.

$$VTH = \frac{R2}{R1+R2} \times VCC$$

$$RTH = \frac{R_1 R2}{R_1+R2}$$

(a) Input section:

$$VTH = IB\, RTH + VBE + IE\, RE$$

putting $IE = (\beta+1) IB$

$$\therefore VTH = IB\, RTH + VBE + (\beta+1) IB\, RE$$

$$IB\, RTH + (\beta+1) IB\, RE = VTH - VBE$$

$$IB\left(RTH + (\beta+1) RE\right) = VTH - VBE$$

$$\therefore IB = \frac{VTH - VBE}{RTH + (\beta+1) RE}$$

Assuming $\beta \gg 1$

$$\therefore IB = \frac{VTH - VBE}{RTH + \beta RE}$$

$$IC = \beta IB$$

$$\therefore IC = \frac{VTH - VBE}{\frac{RTH}{\beta} + RE} \simeq IE \quad \dots (1)$$

(b) Output section

$$VCC = VCE + (RC + RE) IC$$

$$\therefore VCE = VCC - (RC + RE) IC \quad \dots (2)$$

$$I_C \simeq I_E = \frac{V_{TH} - V_{BE}}{\frac{R_{TH}}{\beta} + R_E}$$

To make I_E independent of β

$$R_E >> \frac{R_{TH}}{\beta}$$

In actual practice it is achieved by making R_E 10 times greater than $\frac{R_{TH}}{\beta}$

$$\therefore R_E \geq 10 \frac{R_{TH}}{\beta}.$$

or $R_{TH} \leq 0.1 \beta R_E$

Usually $R_2 < R_1$

$$\therefore R_{TH} = R_1 // R_2 \simeq R_2$$

$$\therefore \boxed{R_2 \leq 0.1 \beta R_E}$$

STABILITY FACTOR OF VOLTAGE DIVIDER BIAS.

$$V_{TH} = I_B R_{TH} + V_{BE} + I_E R_E.$$

putting $I_E = I_C + I_B$.

$$\therefore V_{TH} = I_B R_{TH} + V_{BE} + (I_C + I_B) R_E$$

$$V_{TH} = I_B R_{TH} + I_B R_E + V_{BE} + I_C R_E$$

$$\therefore I_B (R_{TH} + R_E) = V_{TH} - V_{BE} - I_C R_E$$

$$\therefore I_B = \frac{V_{TH} - V_{BE}}{R_E + R_{TH}} - \frac{I_C R_E}{R_E + R_{TH}}$$

differentiating w.r.t. I_C.

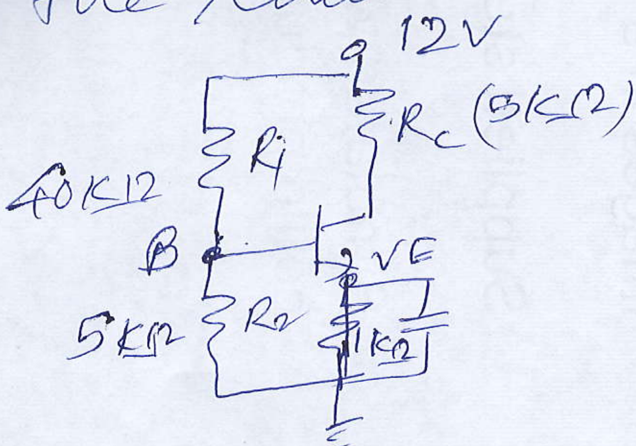
$$\therefore \frac{dI_B}{dI_C} = - \frac{R_E}{R_E + R_{TH}}.$$

$$\therefore S = \frac{1+\beta}{1-\beta \frac{dI}{dR}} = \frac{1+\beta}{1-\beta \times \frac{-R_E}{R_E+R_{TH}}}$$

$$= \frac{1+\beta}{1+\beta \frac{R_E}{R_E+R_{TH}}}.$$

Problems on voltage divider bias

(1) Using approximate analysis, calculate the d.c. bias voltages & currents for the circuit. Assume $V_{BE} = 0.3V$ & $\beta = 60$



$$V_B = \frac{R_2}{R_1+R_2} V_{CC} = \frac{5\times10^3}{(40+5)\times10^3} \times 12$$

$$= 1.3V.$$

$$I_E = \frac{V_B - V_{BE}}{R_E} = \frac{1.3-0.3}{1\times10^3} = 1mA$$

$$I_C \simeq I_E = 1mA \quad \cdots (1)$$

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

$$= 12 - (5+1)\times10^3\times10^{-3}$$

$$= 12 - 6 = 6V \cdot (2)$$

(8) Solve problem ① using exact analysis / Thevenin's theorem.

$$V_{TH} = \frac{R_2}{R_1+R_2} \times V_{CC} = \frac{5\times10^3}{(40+5)\times10^3} \times 12$$

$$= 1.3\,V.$$

$$R_{TH} = \frac{R_1 R_2}{R_1+R_2} = \frac{40\times10^3 \times 5\times10^3}{(40+5)\times10^3}$$

$$= 4.44\,K\Omega$$

$$I_B = \frac{V_{TH}-V_{BE}}{R_{TH}+\beta R_E} = \frac{1.3-0.3}{4.44\times10^3+60\times1\times10^3}$$

$$= 15.52\,\mu A.$$

$$I_C = \beta I_B = 60\times15.52\times10^{-6} = 0.93\,mA$$

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

$$= 6.42\,V.$$

Assignment problems.

Calculate V_{CE} & I_C for the circuit

Given $R_1 = 40\,K\Omega$, $R_2 = 4\,K\Omega$, $R_C = 10\,K\Omega$

$R_E = 1.5\,K\Omega$, $V_{BE} = 0.5\,V$, $\beta = 40$ & $V_{CC} = 22\,V$

(1) Using approximate analysis

(2) Using exact analysis