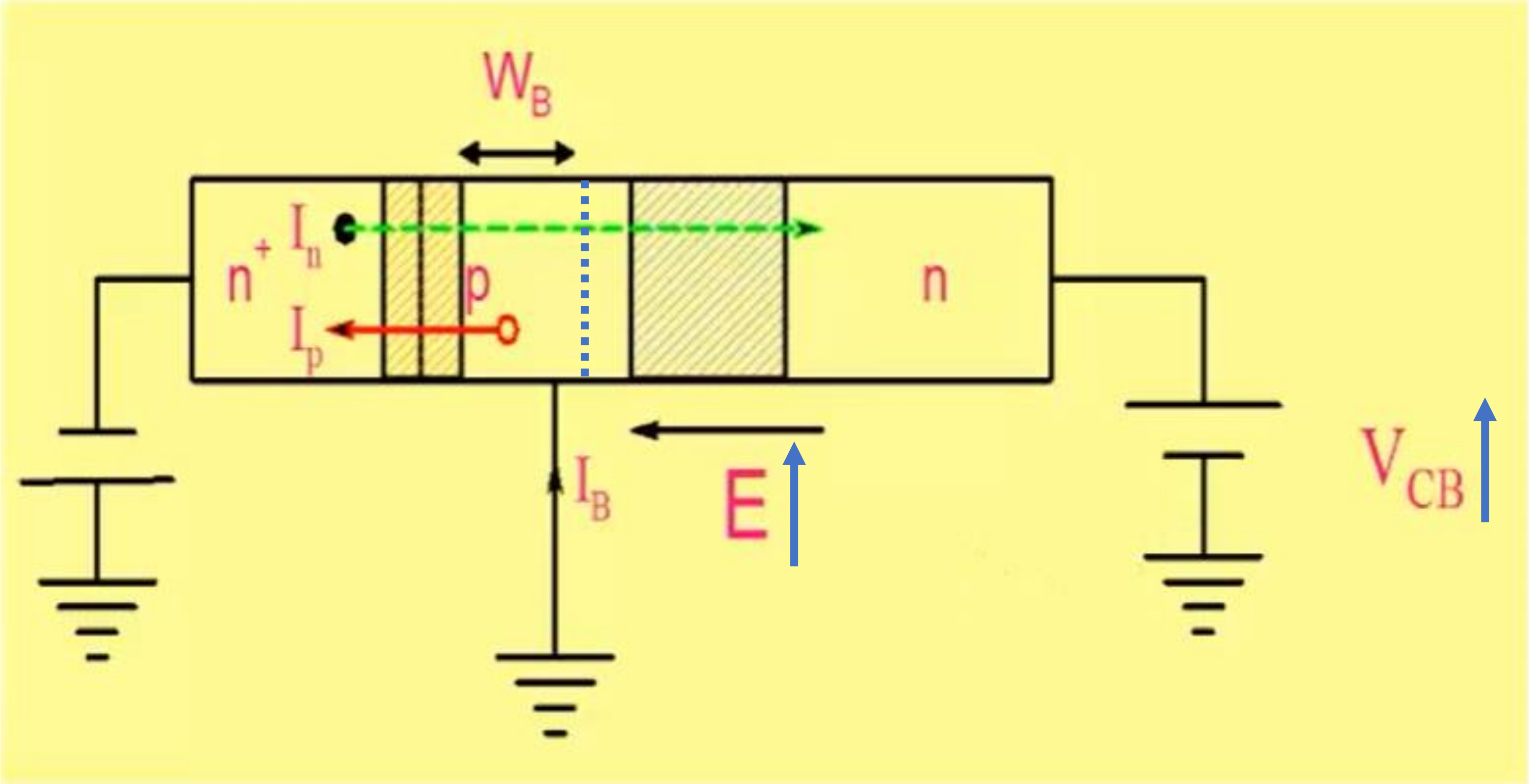
Base Width Modulation

$$I_N = qD_n \frac{dn}{dx} \cong qD_n \times \frac{n(0)}{W_B}$$



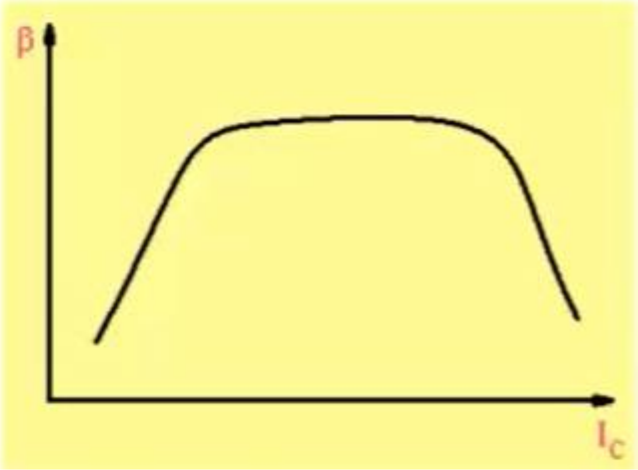
Decrease in effective base width causes an increase in collector current !

$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

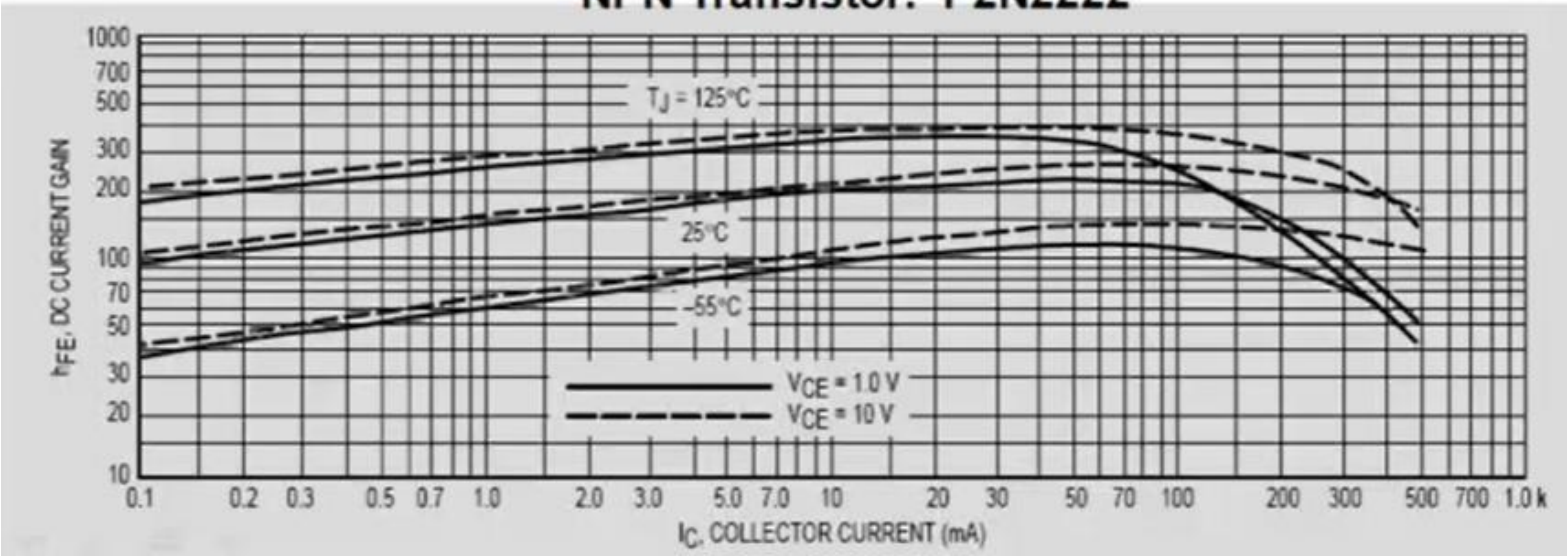
$$I_B = \frac{I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)}{\beta_F}$$

$$I_C = \beta_F\, I_B\left(1 + \frac{V_{CE}}{V_A}\right)$$

Variation of current gain with Current

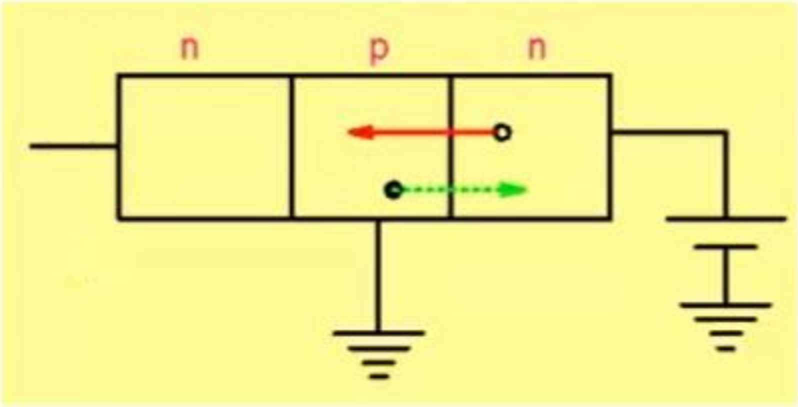


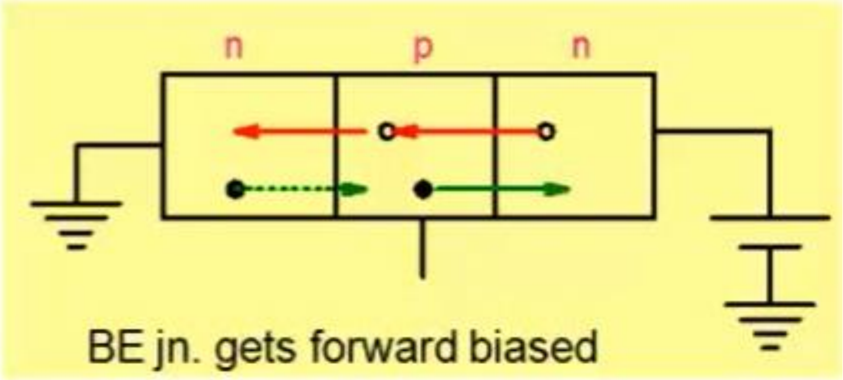
NPN Transistor: P2N2222



Breakdown

Collector-Base junction Breakdown





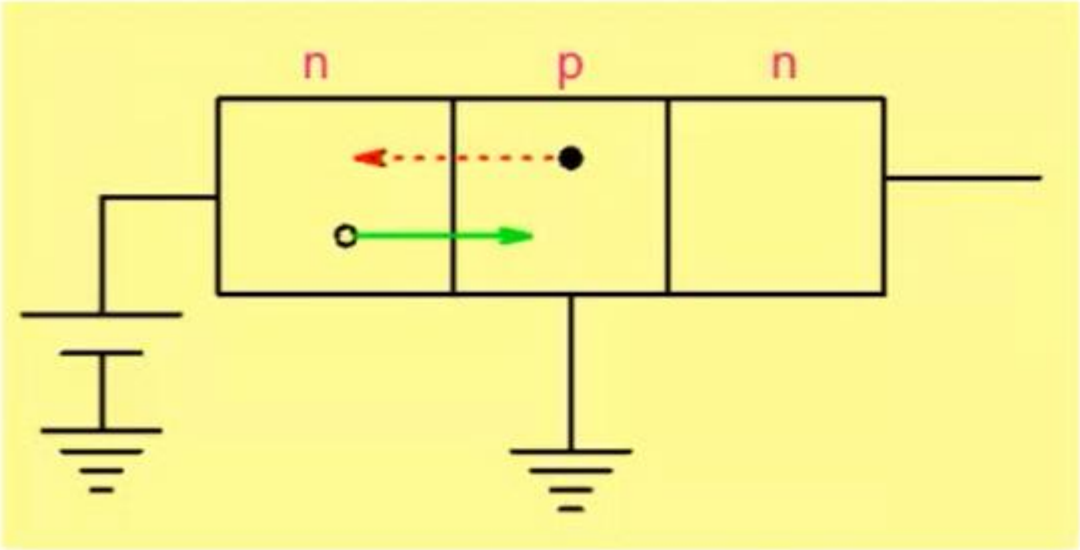
BV_{CBO}: Breakdown voltage with emitter open

BV_{CEO}: Breakdown voltage with base Open.

Example: P2N2222: BV_{CBO} ~75V while BV_{CEO} ~40V

Breakdown

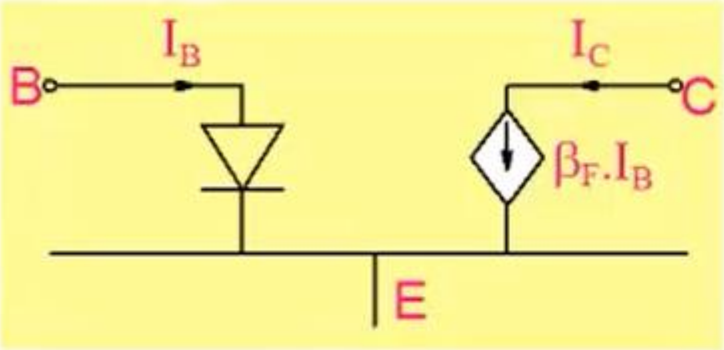
Emitter-Base junction Breakdown

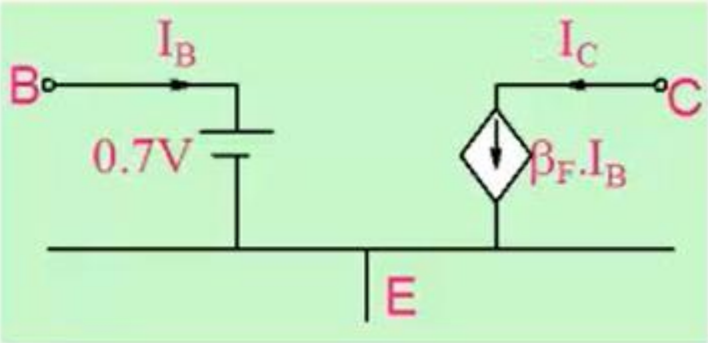


BV_{EBO}: Breakdown voltage with collector open

Example: P2N2222: BV_{EBO} ~6V (much smaller due to heavy doping)

Model of an NPN BJT



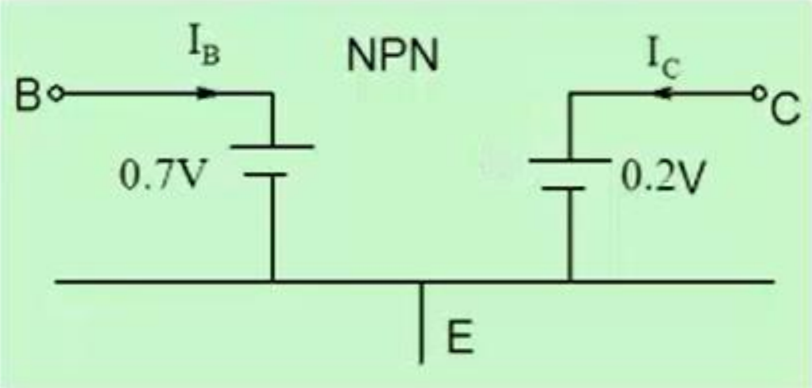


$$I_C = I_S\left(\exp(\frac{V_{BE}}{V_T}) - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$I_B = \frac{I_S\left(\exp(\frac{V_{BE}}{V_T}) - 1\right)}{\beta_F}$$

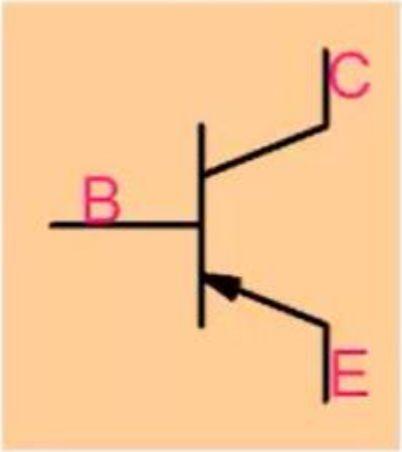
$$I_C = \beta_F\, I_B\left(1 + \frac{V_{CE}}{V_A}\right)$$

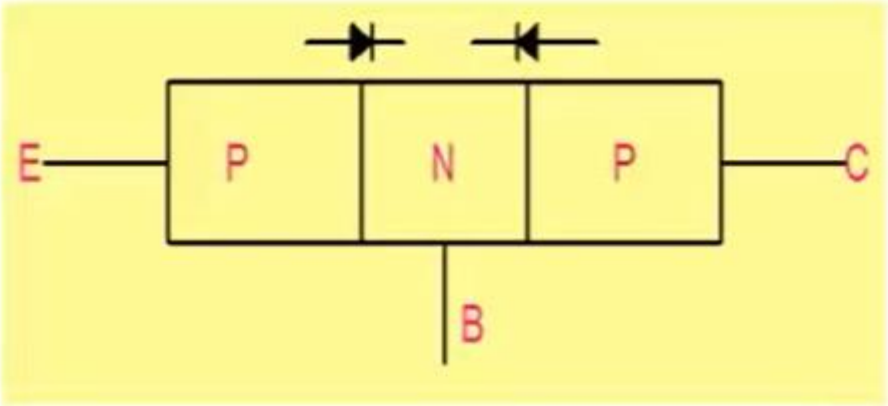
Saturation mode

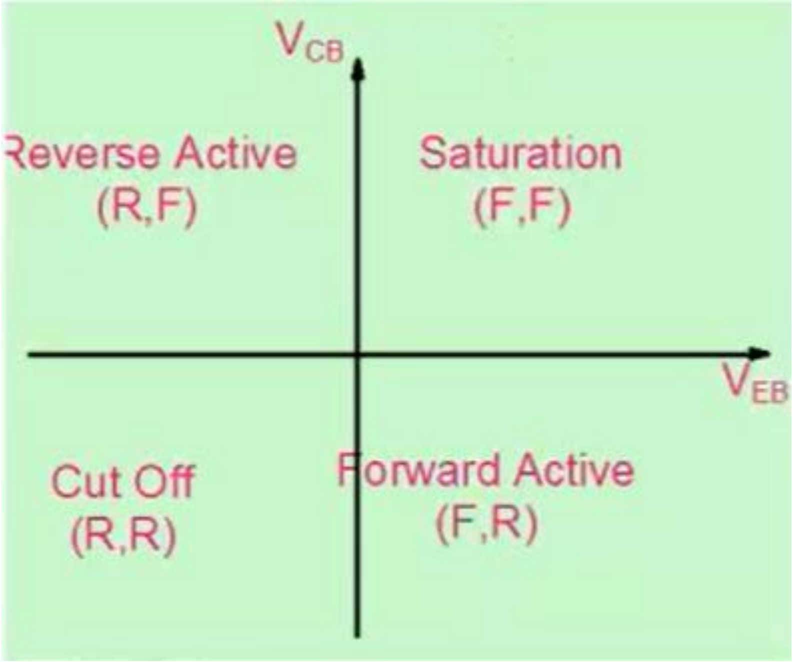


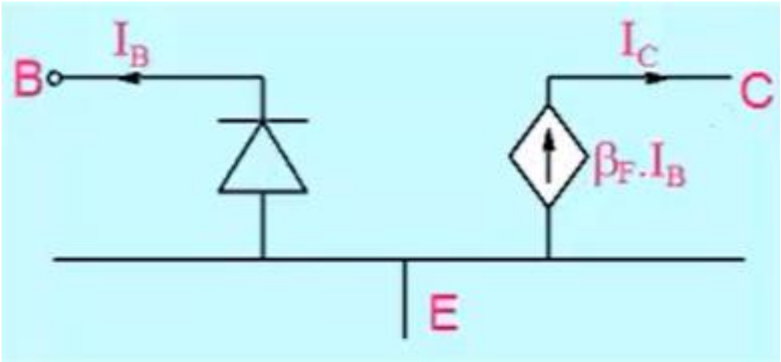
$$I_C \neq \beta_F\, I_B$$

PNP Transistor

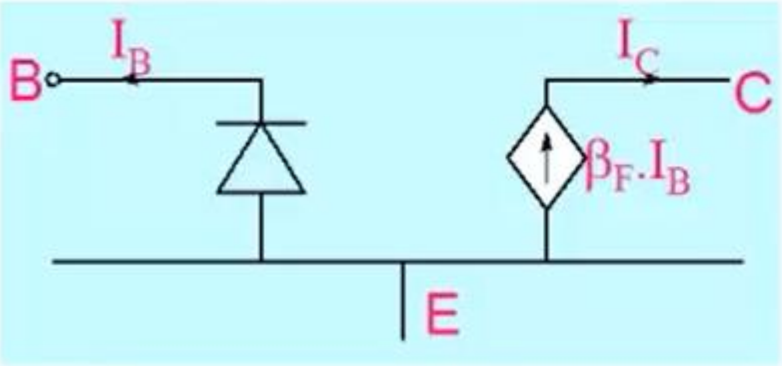


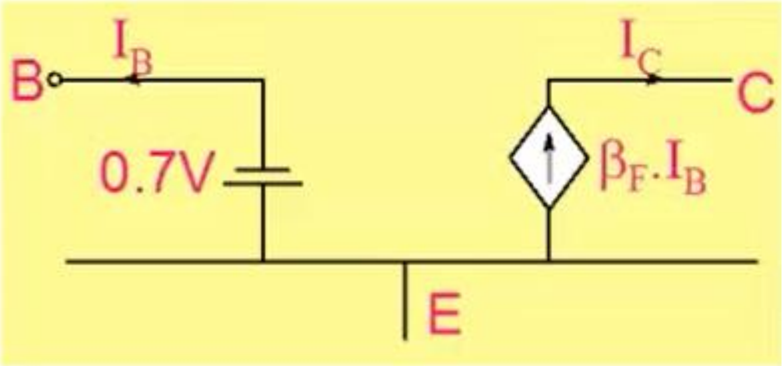






Model of an PNP BJT in forward active mode



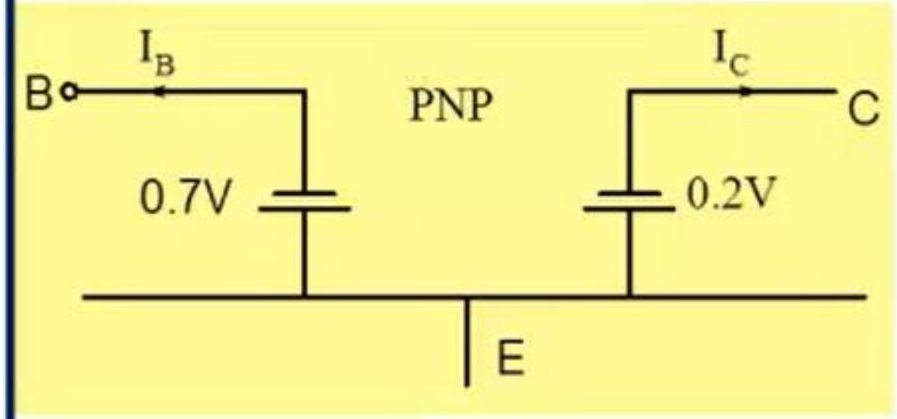


$$I_C = I_S\left(\exp(\frac{V_{EB}}{V_T}) - 1\right)\left(1 + \frac{V_{EC}}{V_A}\right)$$

$$I_B = \frac{I_S\left(\exp(\frac{V_{EB}}{V_T}) - 1\right)}{\beta_F}$$

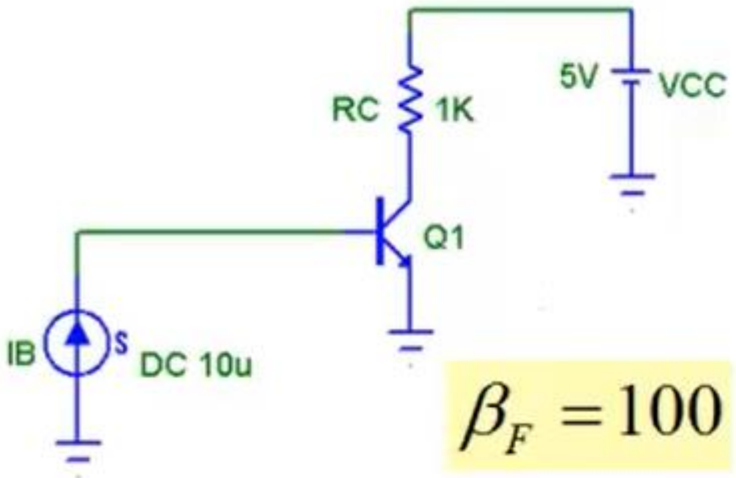
$$I_C = \beta_F\, I_B\left(1 + \frac{V_{EC}}{V_A}\right)$$

Saturation mode



DC Transistor Circuit Analysis

Example-1

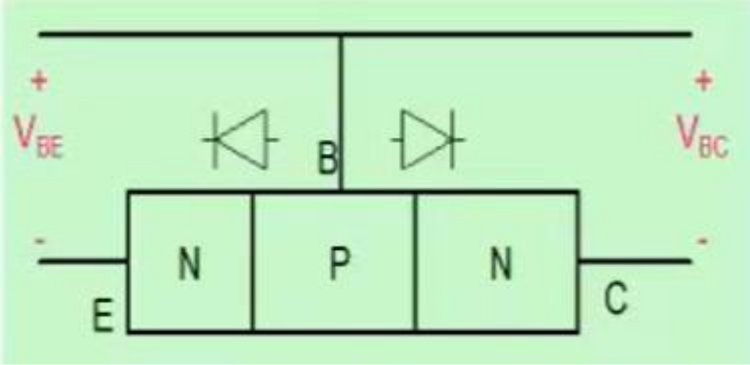


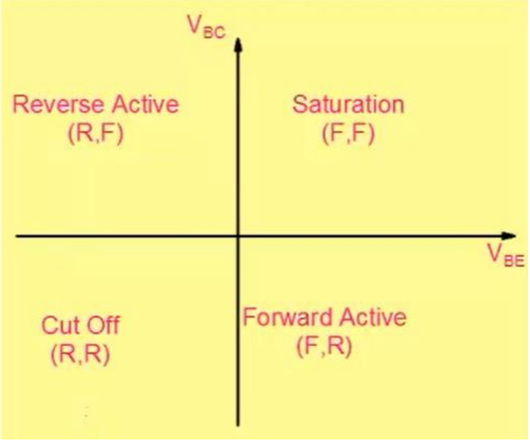
$$\beta_F = 100$$

Find I_C and V_{CE}

Base current is flowing into the transistor so base-emitter junction is forward biased.

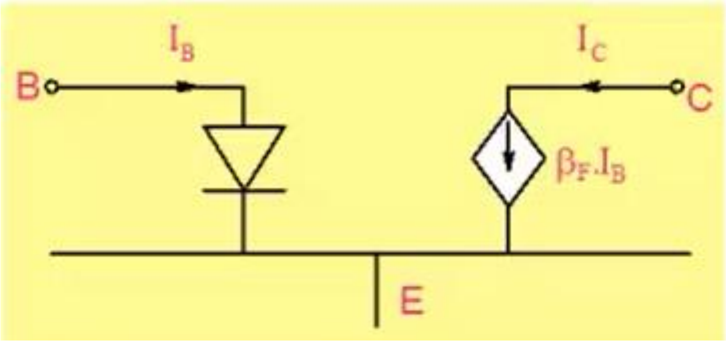
transistor can be either in forward active or saturation mode of operation.

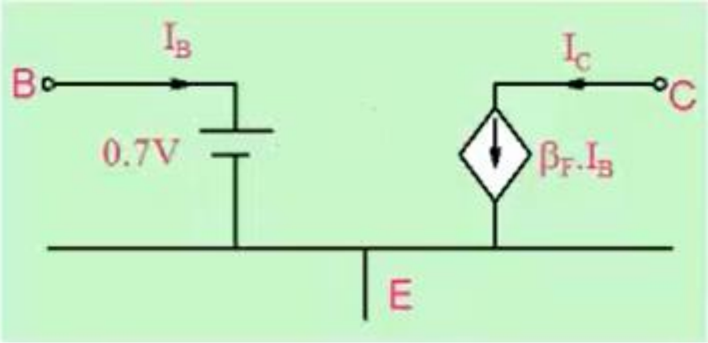


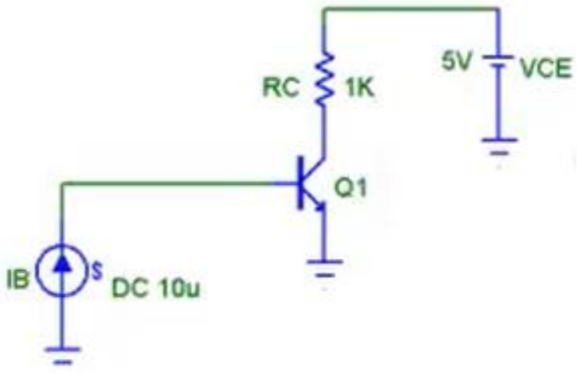


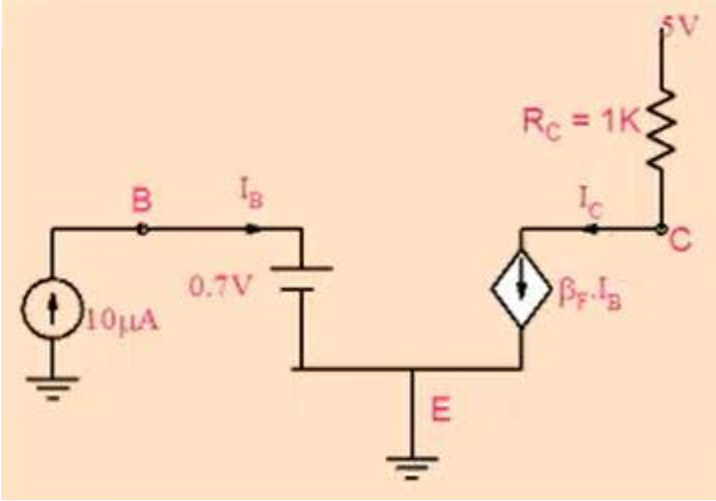
Let us assume that transistor is in forward active mode and carry out analysis but we must check later on to make sure that our assumption is correct.

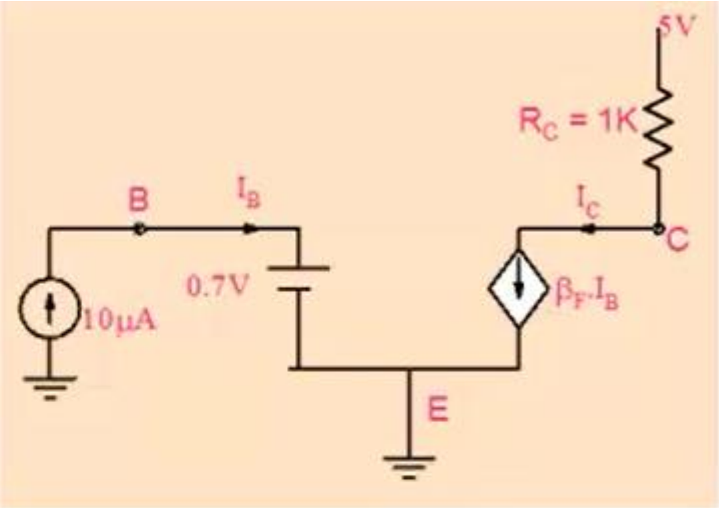
For the active mode, the transistor can be represented as











$$I_B = 10\mu A$$

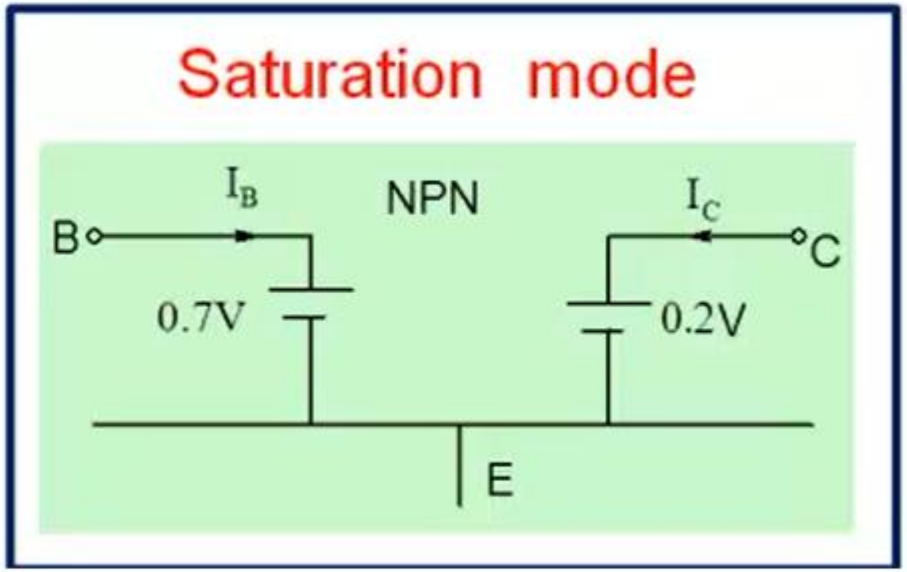
$$I_C = \beta_F I_B = 1mA$$

$$V_{CE} = 5 - I_C \times R_C = 4V$$

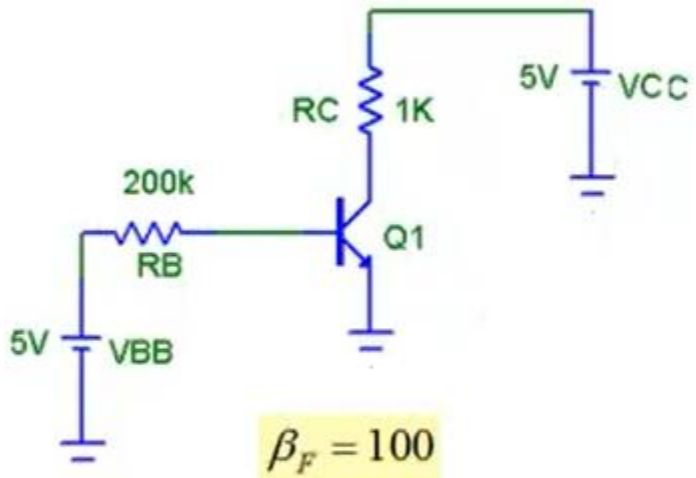
How do we check if transistor is indeed in forward active mode?

We check if $V_{CE} > 0.2V$

Since this is true for our circuit, the analysis is correct and our answers are right



Example-2

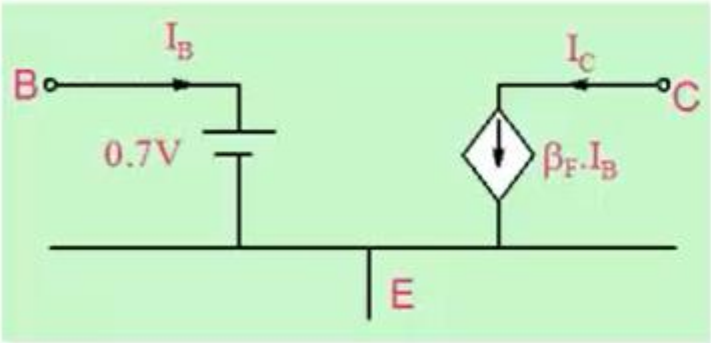


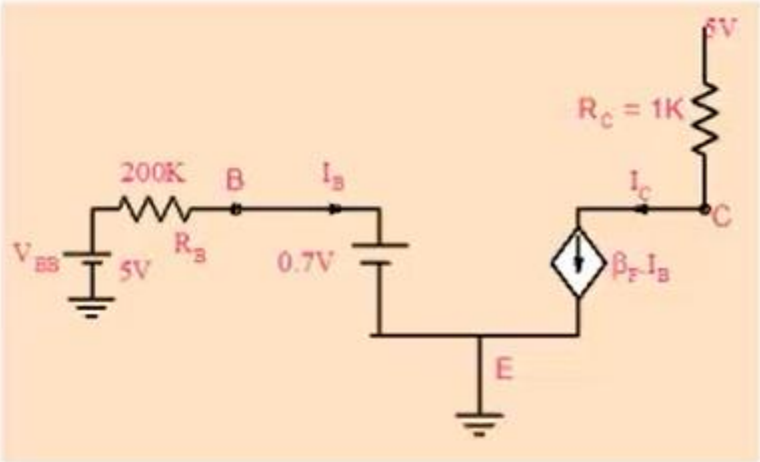
$\beta_F = 100$

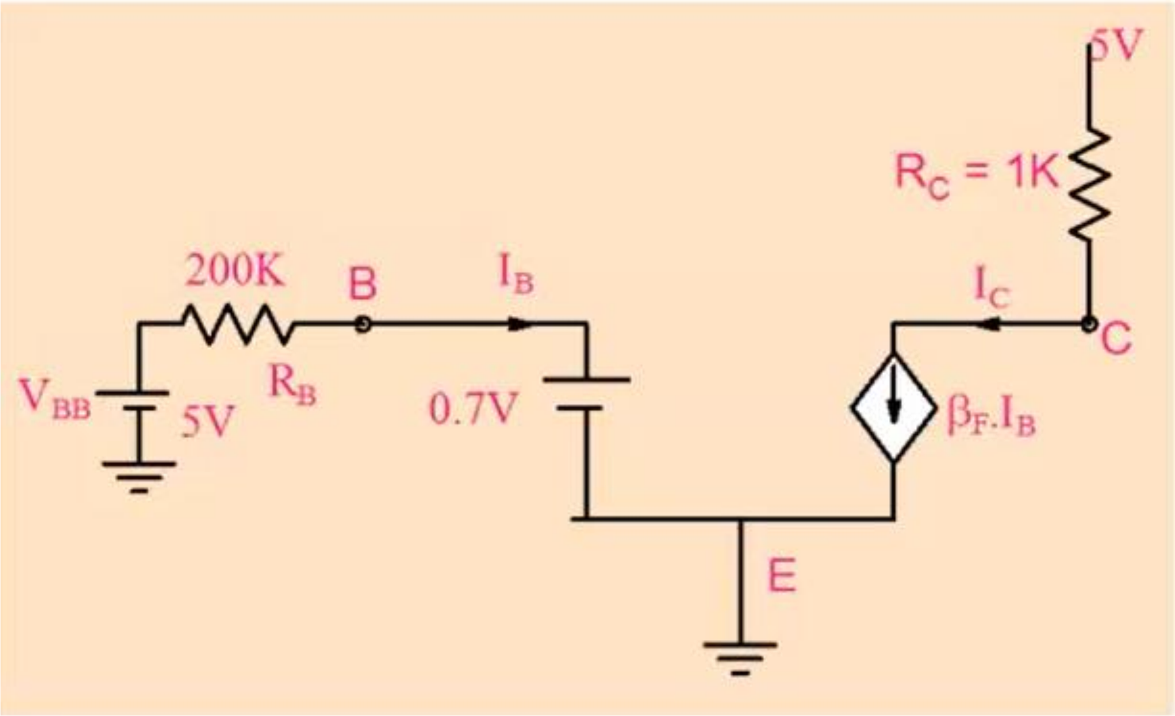
Find I_C and V_{CE}

Let us assume that transistor is in forward active mode and carry out analysis but we must check later on to make sure that our assumption is correct.

For the active mode, the transistor can be represented as







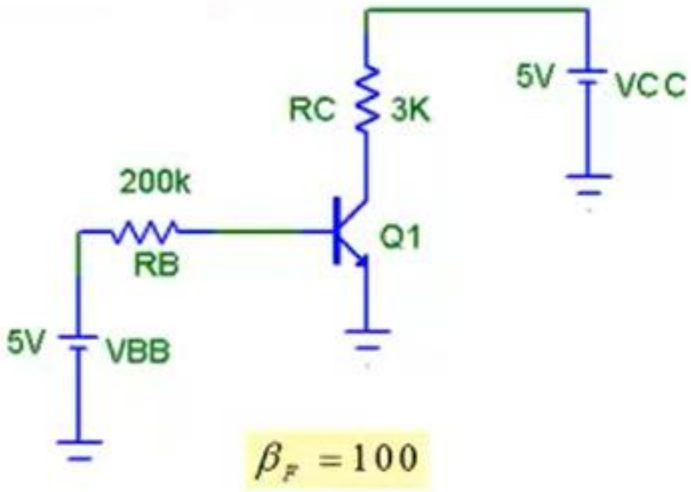
$$I_B = \frac{V_{BB} - 0.7}{R_B} = 21.5\mu A$$

$$I_C = \beta_F I_B = 2.15mA$$

$$V_{CE} = 5 - I_C \times R_C = 2.85V$$

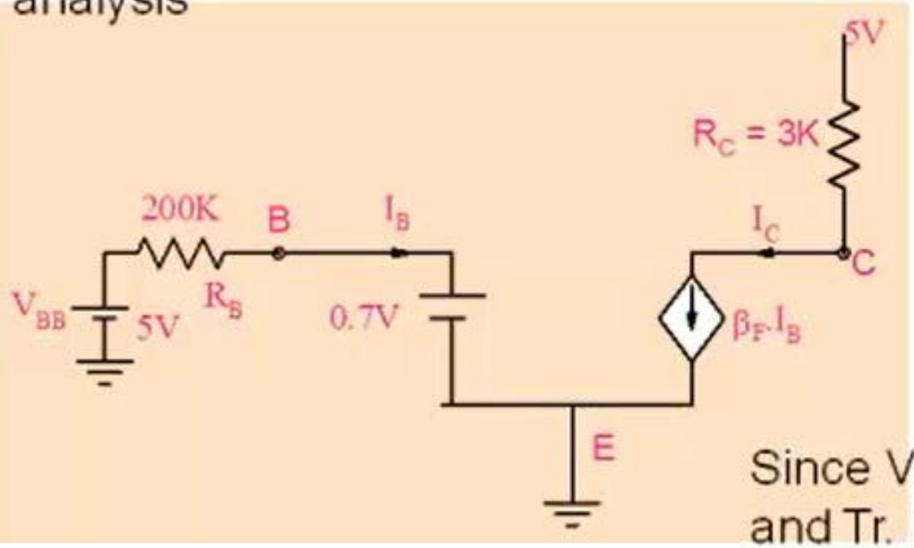
Since $V_{CE} > 0.2V$, our analysis is correct and Tr. Is in active mode.

Example-3



It is same as example-2 except that RC has been increased to 3K.

As before we assume that transistor is in forward active mode and carry out analysis



$$I_B = \frac{V_{BB} - 0.7}{R_B} = 21.5\mu A$$

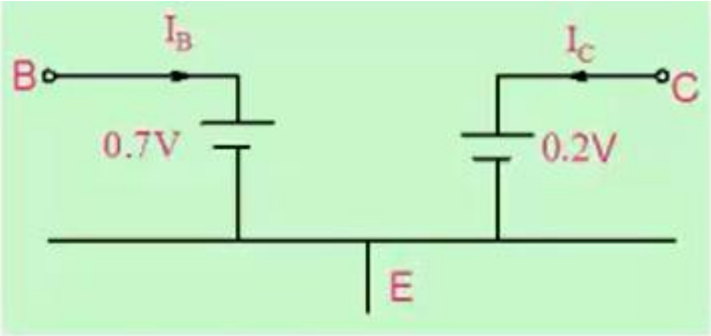
$$I_C = \beta_F I_B = 2.15mA$$

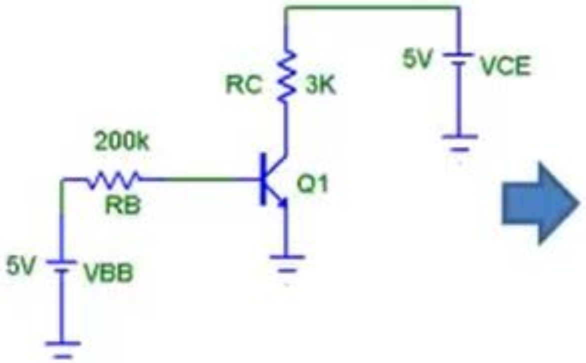
$$V_{CE} = 5 - I_C \times R_C = -1.45V$$

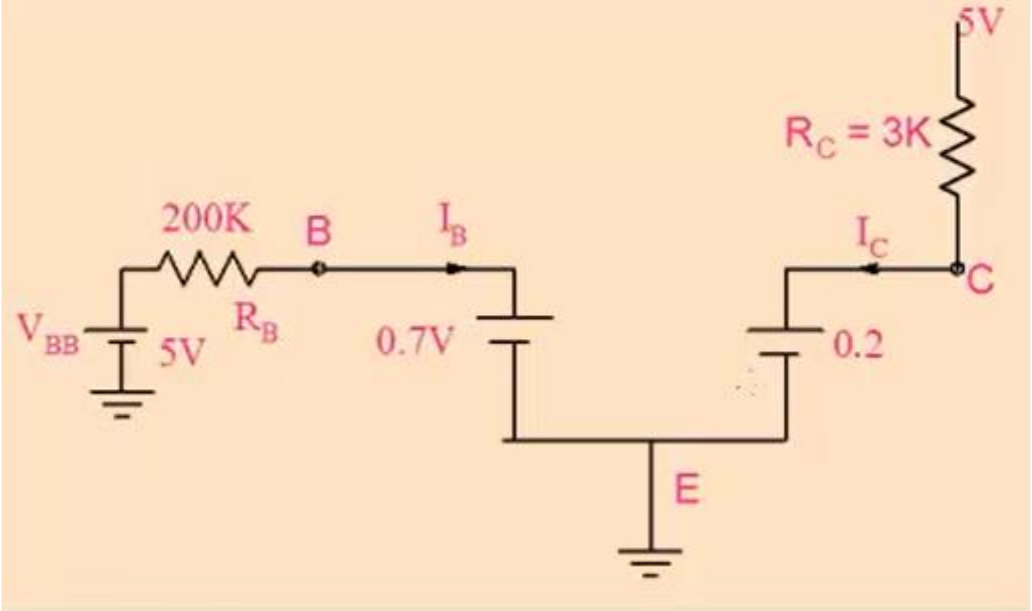
Since $V_{CE} < 0.2V$, our assumption is incorrect and Tr. Is actually in saturation mode.

In saturation mode: $I_C \neq \beta_F I_B$

The transistor model in saturation is







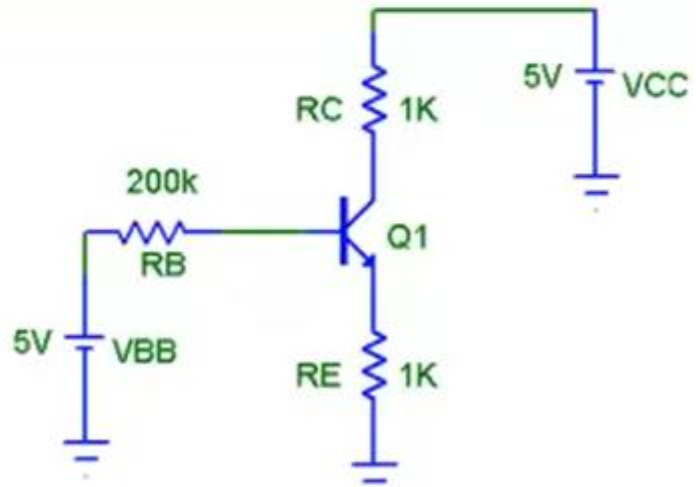
$$I_C = \frac{5-0.2}{3K} = 1.6mA$$

Base current is same as before at 21.5uA.

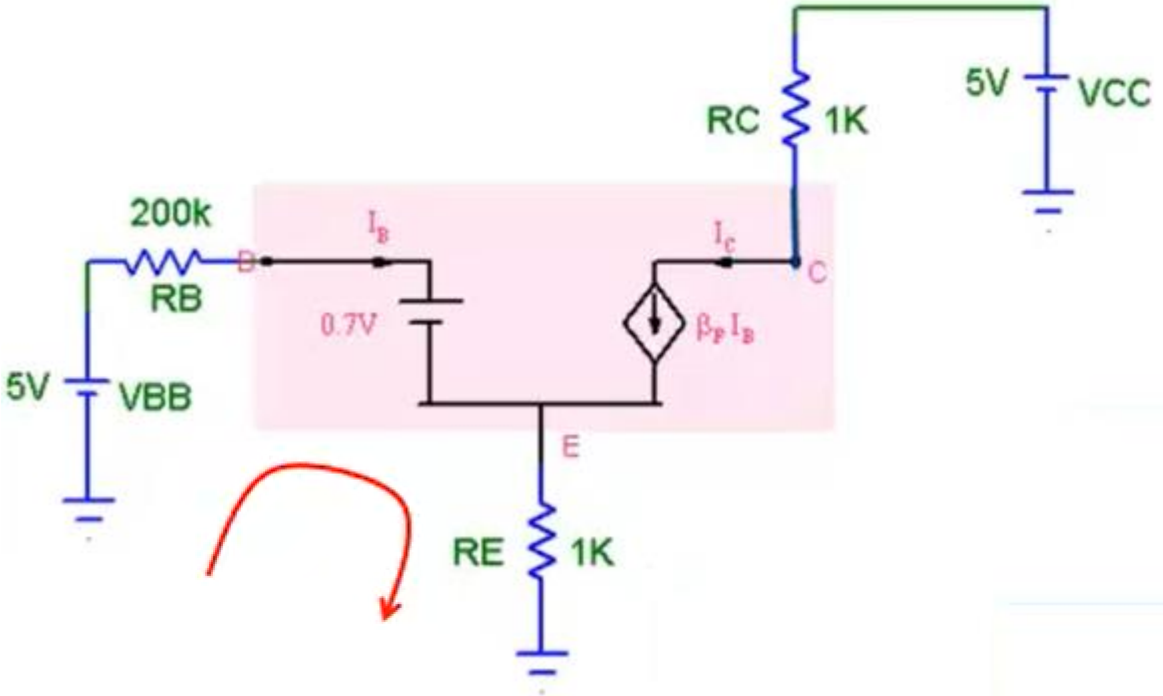
$$\frac{I_C}{\beta_F I_B} = 0.744$$

Example-4

$$\beta_F = 100$$



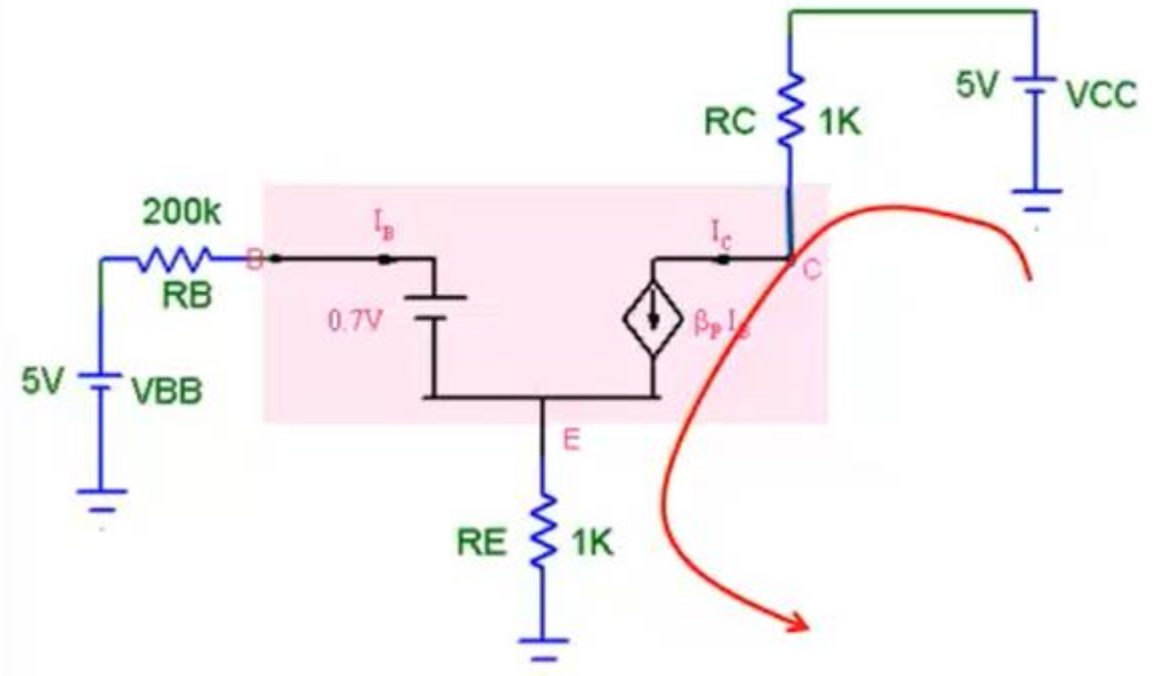
Find I_C and V_{CE}



$$-V_{BB} + I_B R_B + 0.7 + I_E R_E = 0$$

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

$$I_B = \frac{V_{BB} - 0.7}{R_B + (1+\beta) R_E} = 14.29\mu A$$



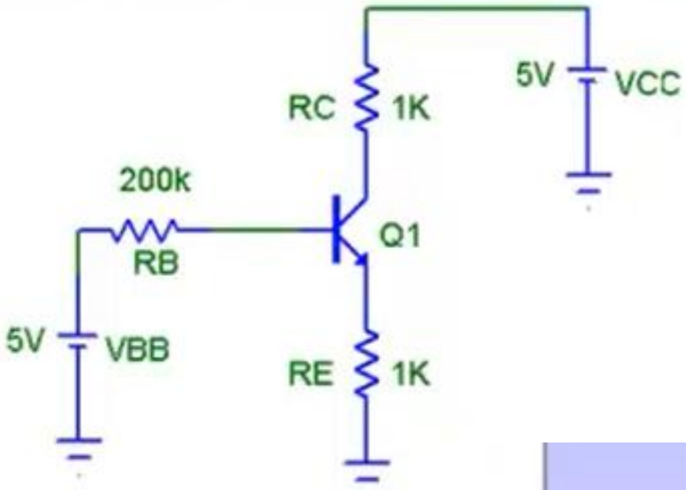
$$I_C = \beta_F I_B = 1.429mA$$

$$I_E = (\beta_F + 1)I_B = 1.443mA$$

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

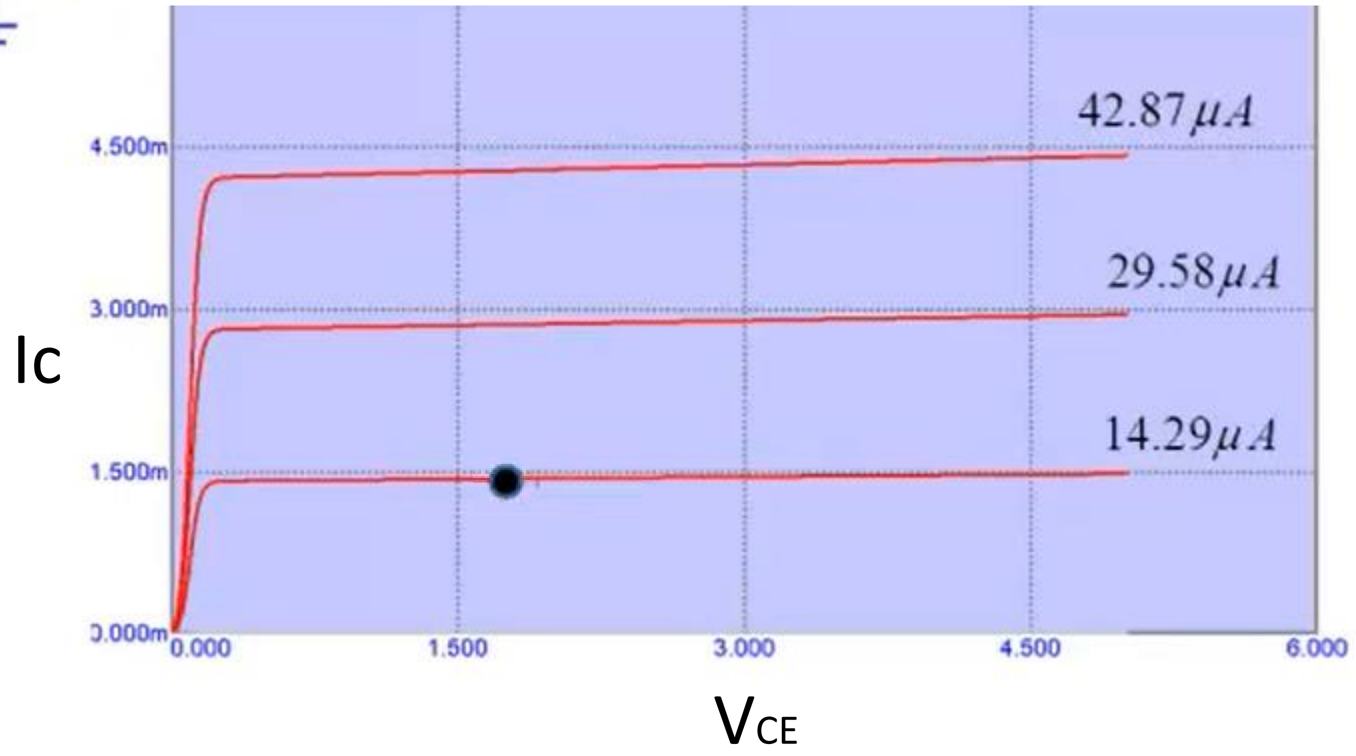
$$V_{CE} = 2.129V$$

Bias Point (Quiescent Point)

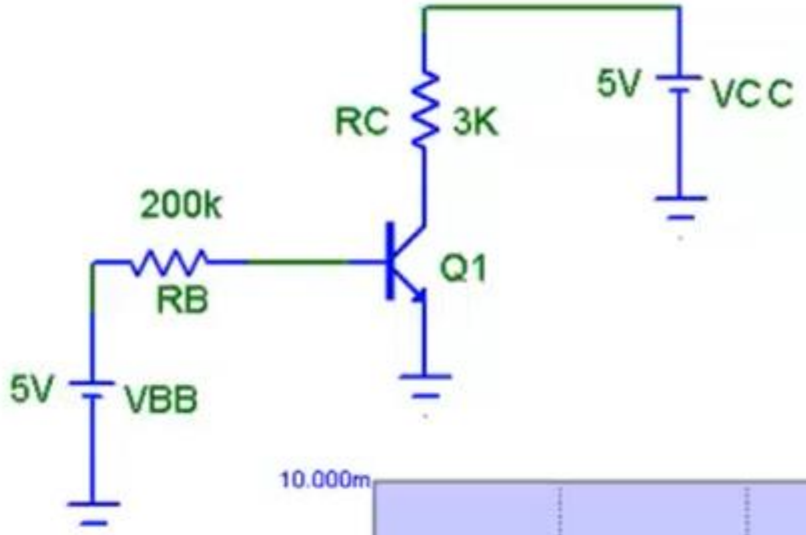


$I_B = 14.29\mu A$ $I_C = 1.429mA$

$V_{CE} = 2.129V$

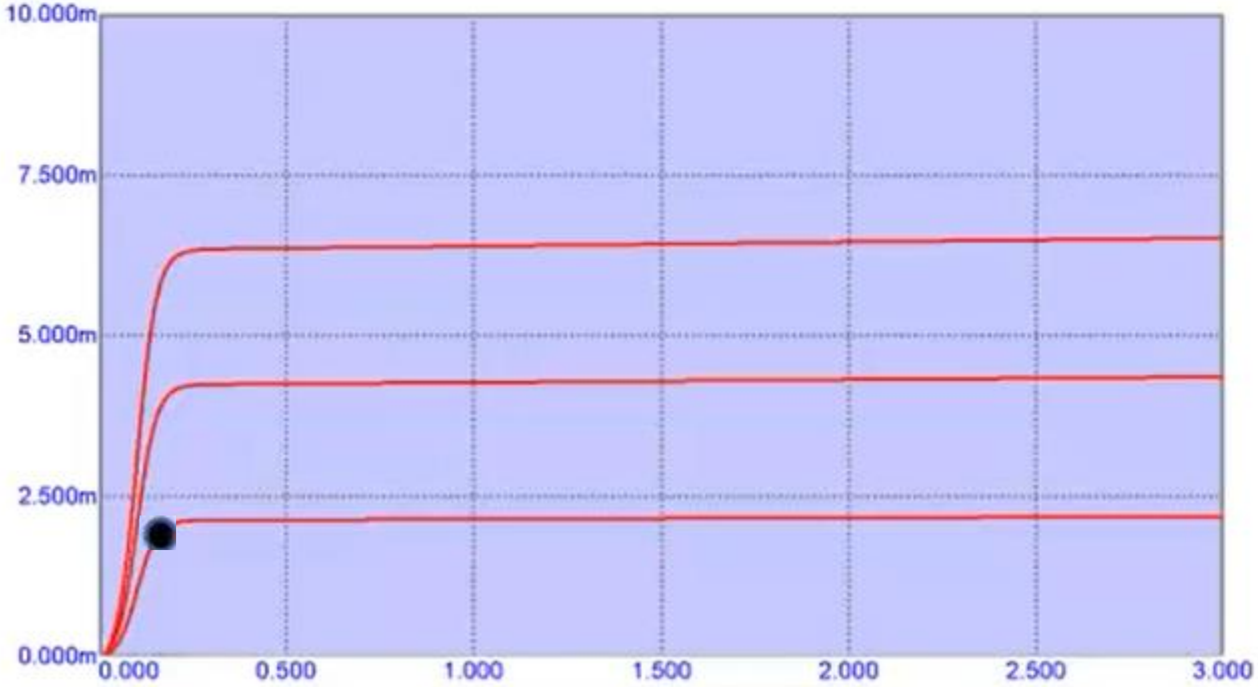


Bias Point (Quiescent Point)

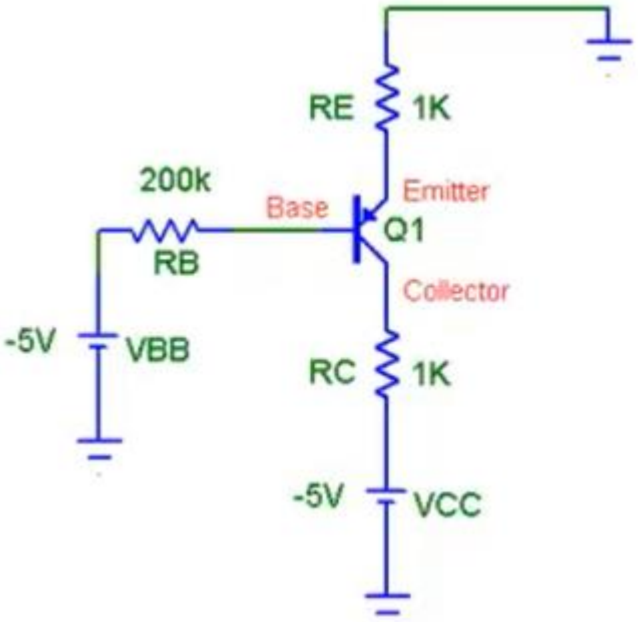


$I_B = 21.5\mu A$ $\quad$ $I_C = 1.6mA$

$V_{CE} \sim 0.2V$



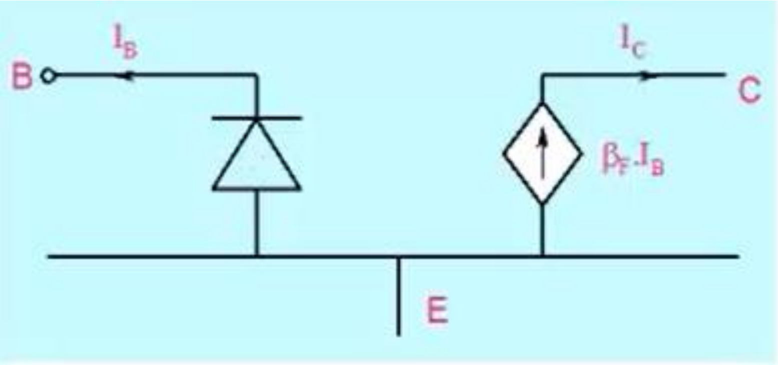
PNP dc Circuits

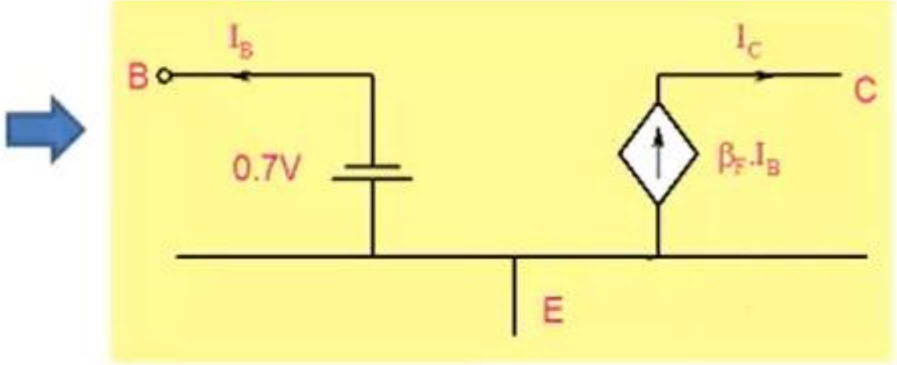


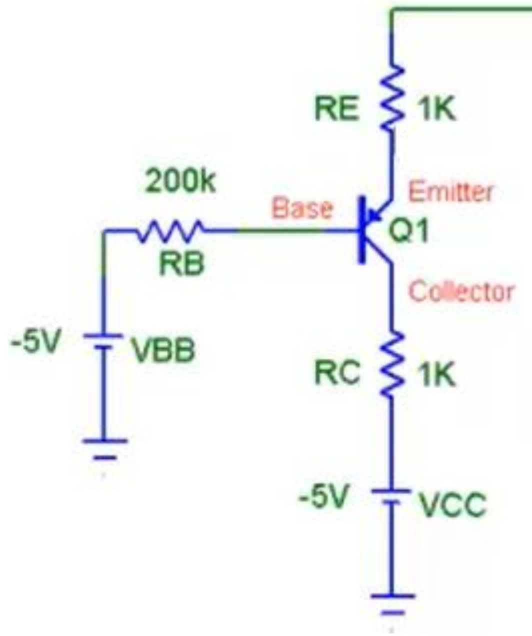
Find I_C and V_{EC}

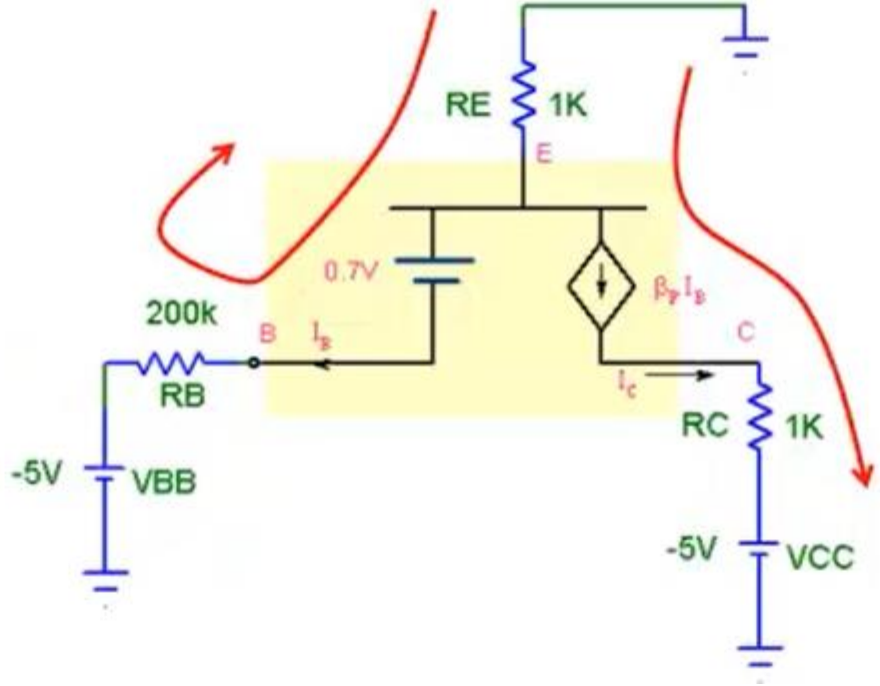
As before we assume that transistor is in forward active mode and carry out analysis

Replace pnp transistor by its model given below









$$I_E R_E + 0.7 + I_B R_B + V_{BB} = 0$$

$$I_B = \frac{-V_{BB} - 0.7}{R_B + (1+\beta)R_E} = 14.29\mu A$$

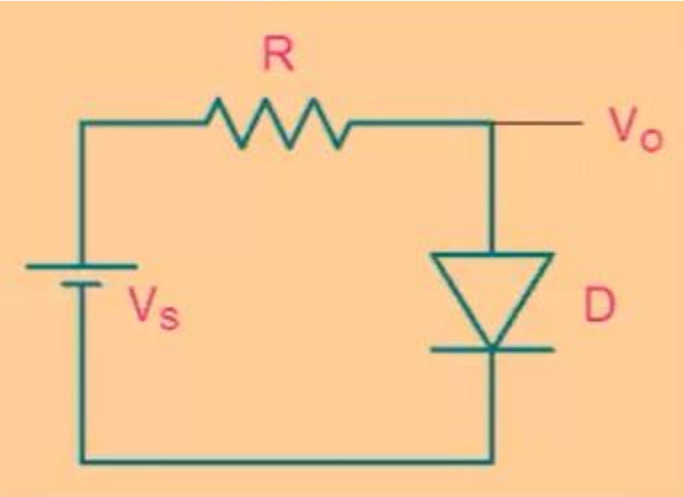
$$I_C = \beta_F I_B = 1.429mA$$

$$I_E = (\beta_F + 1) I_B = 1.443mA$$

$$I_E R_E + V_{EC} + I_C R_C + V_{CC} = 0$$

$$V_{EC} = 2.129V$$

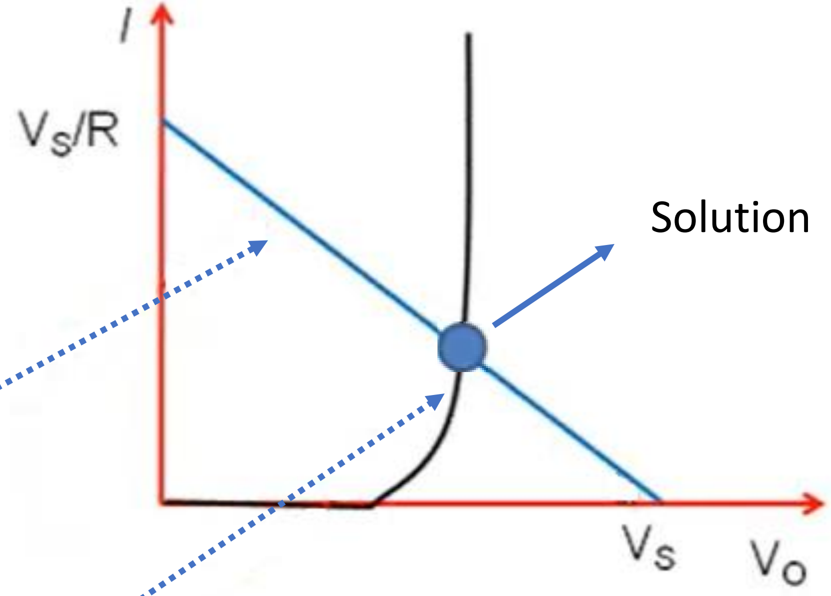
Concept of Load Line

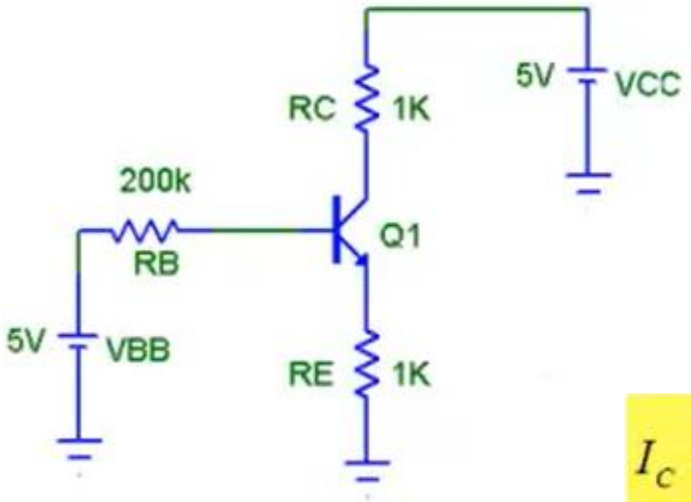


$$V_s = I \times R + V_o$$

$$I = \frac{V_s - V_o}{R}$$

$$I = I_s \times \{\exp(\frac{V_o}{nV_T}) - 1\}$$



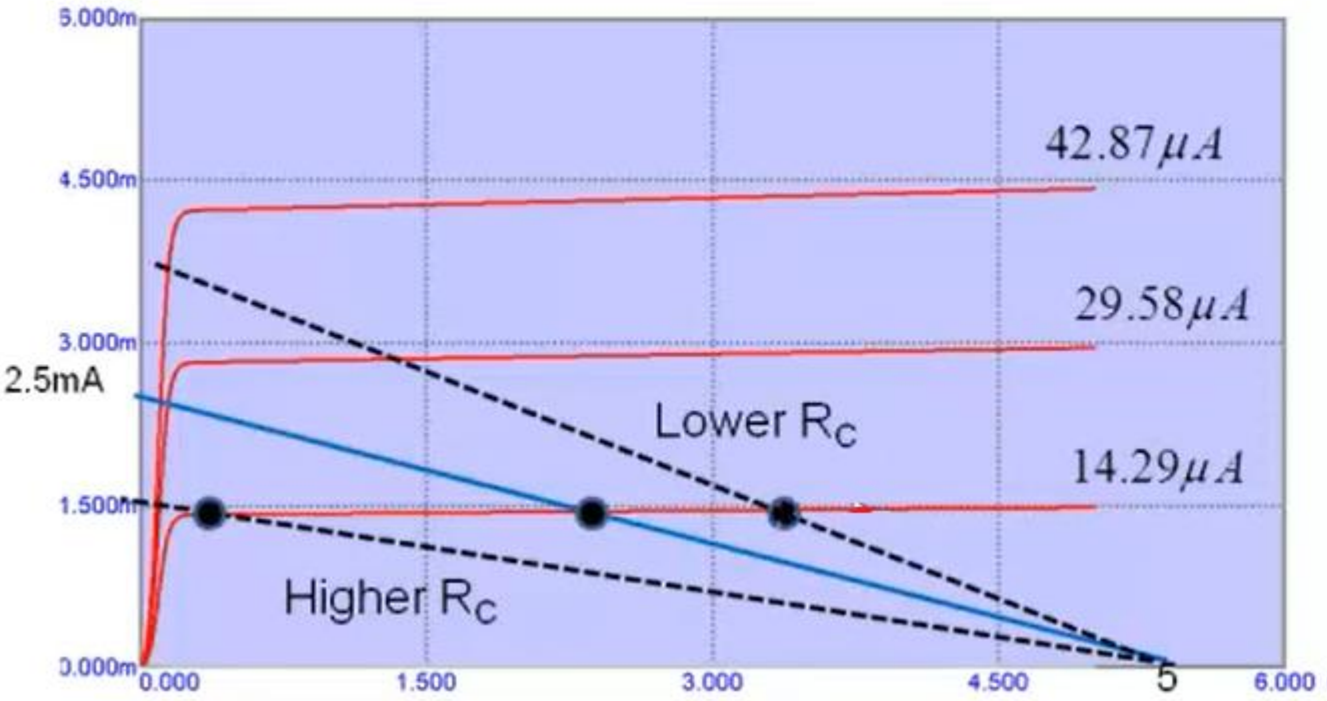


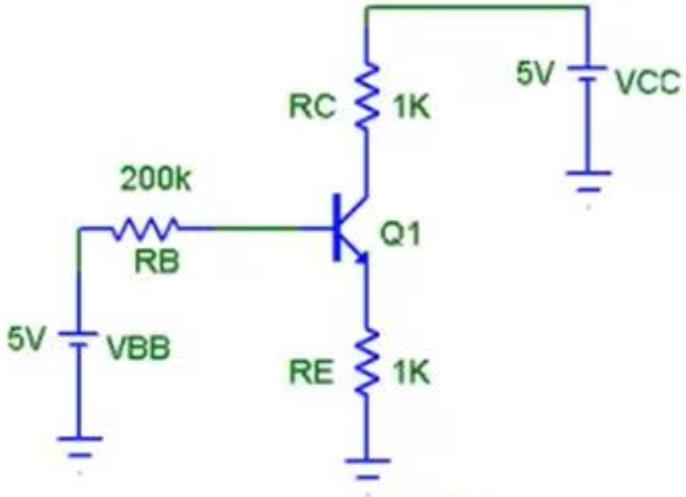
$$I_B = 14.29\mu A$$

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

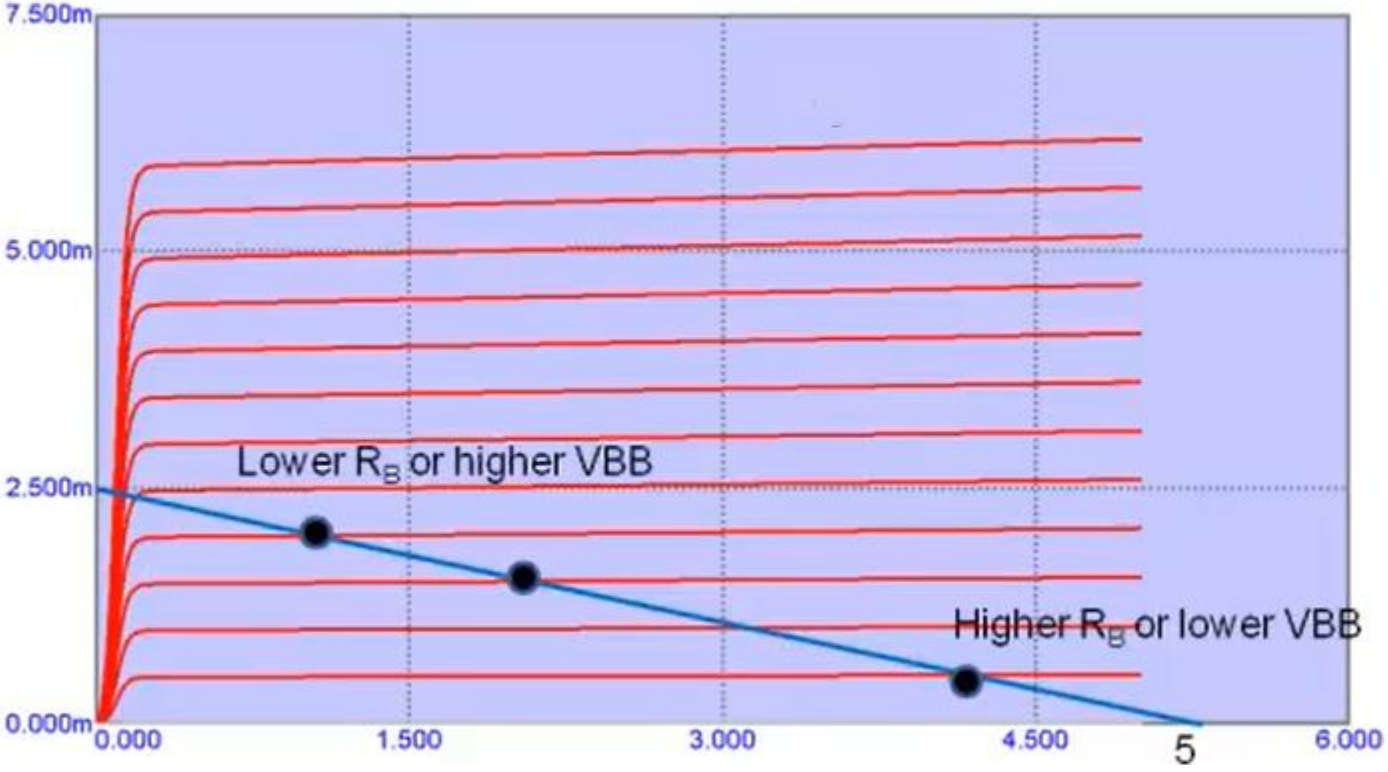
$$I_C = \frac{\beta}{\beta + 1} I_E = \alpha I_E \cong I_E$$

$$I_C = \frac{V_{CC}}{R_C + R_E} - \frac{V_{CE}}{R_C + R_E} = 2.5mA - \frac{V_{CE}}{2K}$$





$$I_C = \frac{V_{CC}}{R_C + R_E} - \frac{V_{CE}}{R_C + R_E} = 2.5mA - \frac{V_{CE}}{2K}$$



AMPLIFICATION