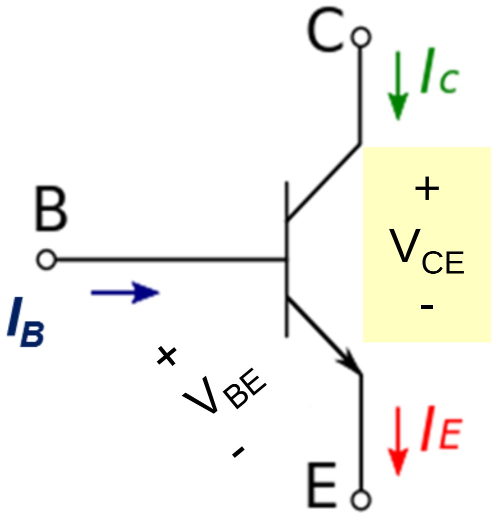
DC Analysis of BJT Circuit and Load Lines

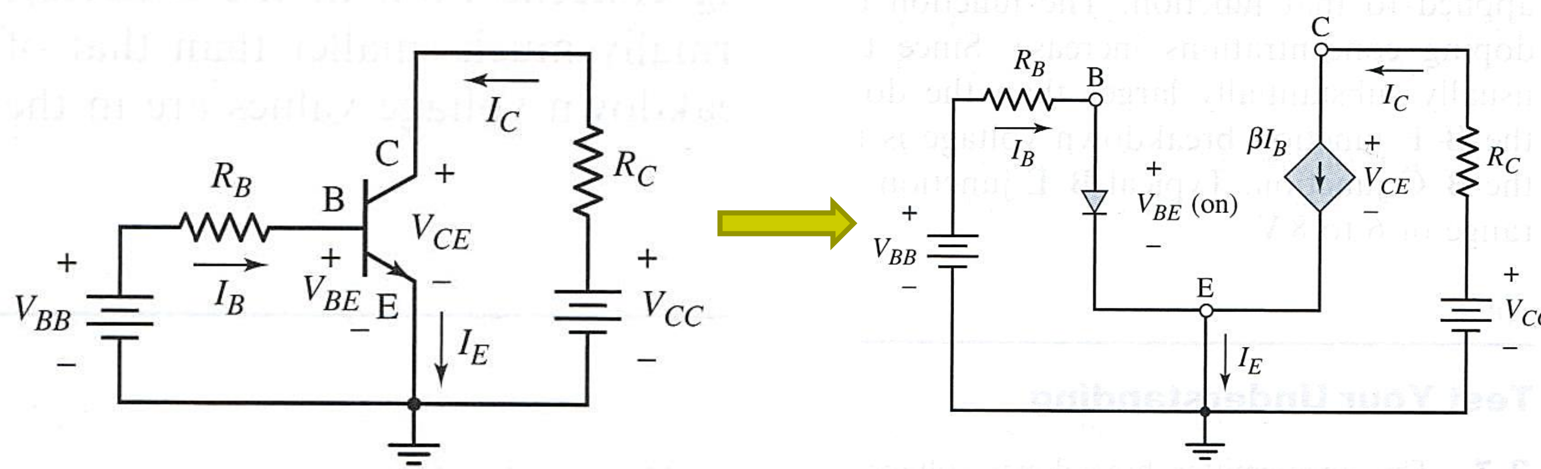
- DC analysis of BJT
  - BE Loop
  - CE Loop
  - When node voltages are known, branch current equations can be used.

KVL


C
I C
B
+
V CE
-
I B
+
V BE
-
I E
E

Common-Emitter Circuit

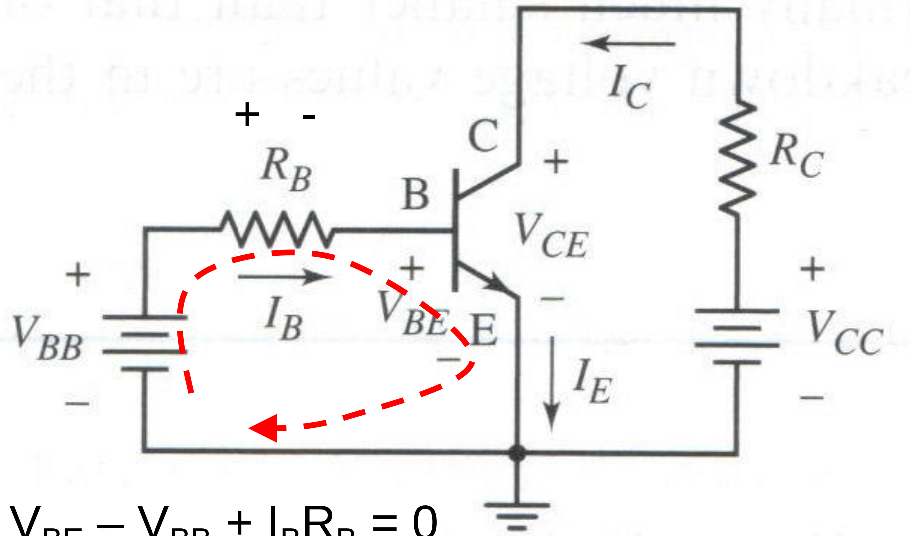
- The figures below is showing a common-emitter circuit with an npn transistor and the DC equivalent circuit.



- Assume that the B-E junction is forward biased, so the voltage drop across that junction is the cut-in or turn-on voltage V_{BE}(on).

Unless given , always assume V_{BE} = 0.7V

- KVL at B-E loop



$V_{BE} - V_{BB} + I_B R_B = 0$

$$I_B = \frac{V_{BB} - V_{BE}(on)}{R_B}$$

You can calculate I_C using $I_C = \beta I_B$

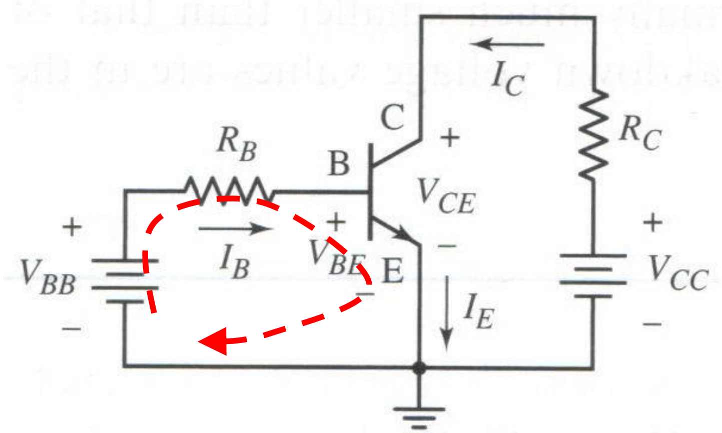
Calculate I_E using $I_E = I_B + I_C$

Input Load Line
I_B versus V_{BE}

Input Load Line – I_B versus V_{BE}

Derived using B-E loop

- The input load line is obtained from Kirchhoff's voltage law equation around the B-E loop, written as follows:



$$V_{BE} - V_{BB} + I_B R_B = 0$$

$$I_B = -\frac{V_{BE}}{R_B} + \frac{V_{BB}}{R_B}$$

$y = mx + c$

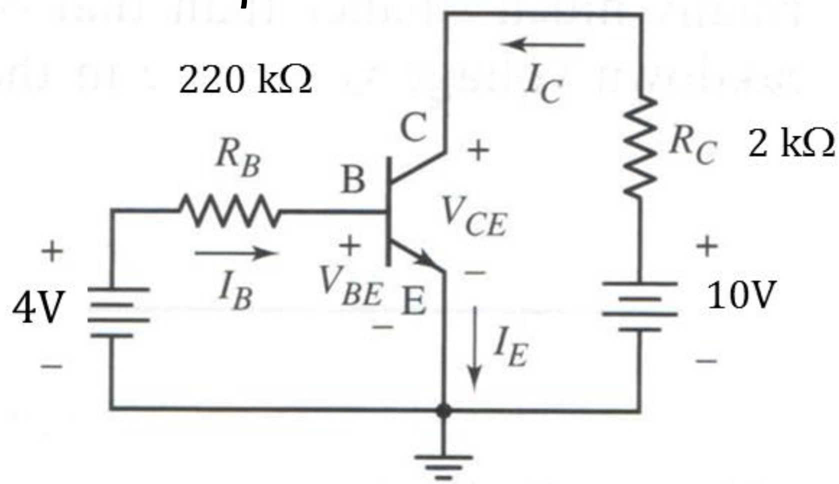
- Both the load line and the quiescent base current change as either or both V_{BB} and R_B change.

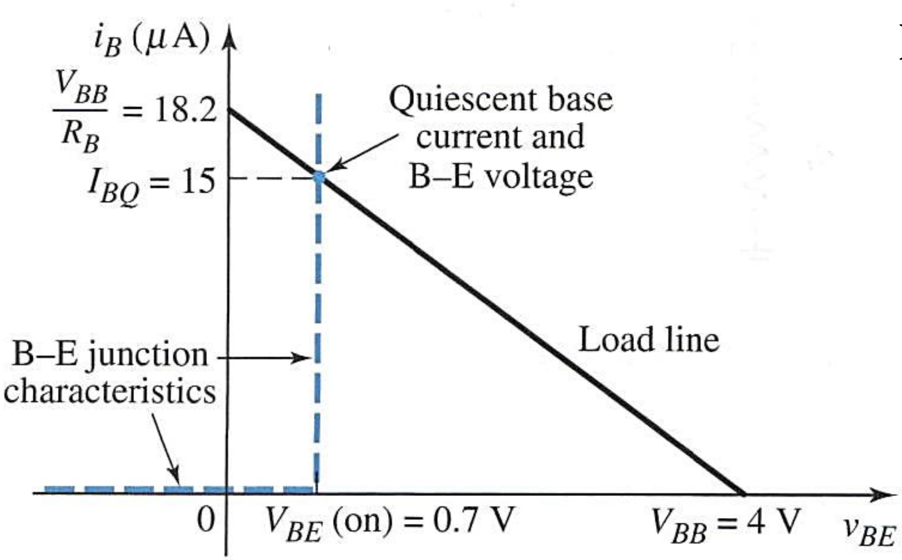
For example;

- The <u>input load line</u> is essentially the same as the load line characteristics for diode circuits.

$$V_{BE} - 4 + I_B(220k) = 0$$

β = 200



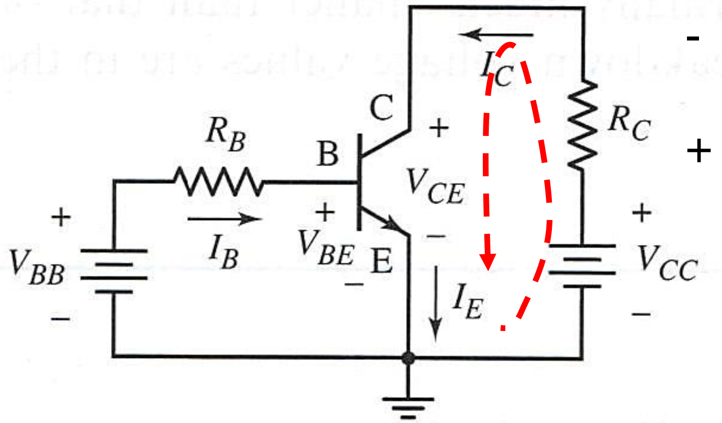


$$I_B = \frac{-V_{BE}}{220k} + \frac{4}{220k}$$

$$y = mx + c$$

- $I_{BQ} = 15\ \mu A$

- KVL at C-E loop of the circuit



You have calculated the value of I_C from the value of I_B

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

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

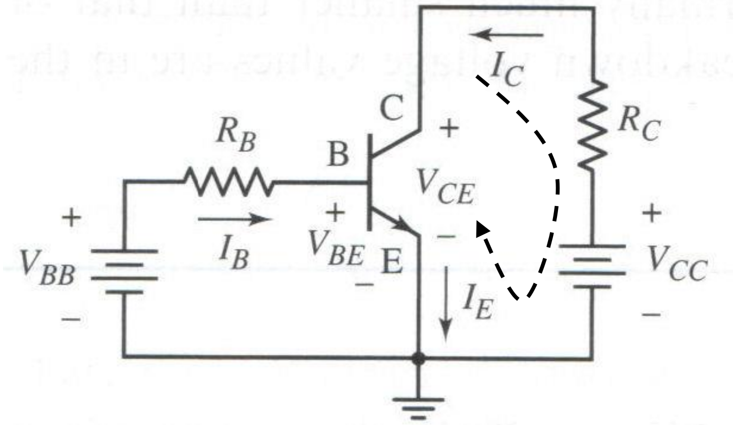
Output Load Line

I_C versus V_{CE}

Output Load Line – I_C versus V_{CE}

Derived using C-E loop

- For the C-E portion of the circuit, the load line is found by writing Kirchhoff's voltage law around the C-E loop. We obtain:



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

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

y = mx + c

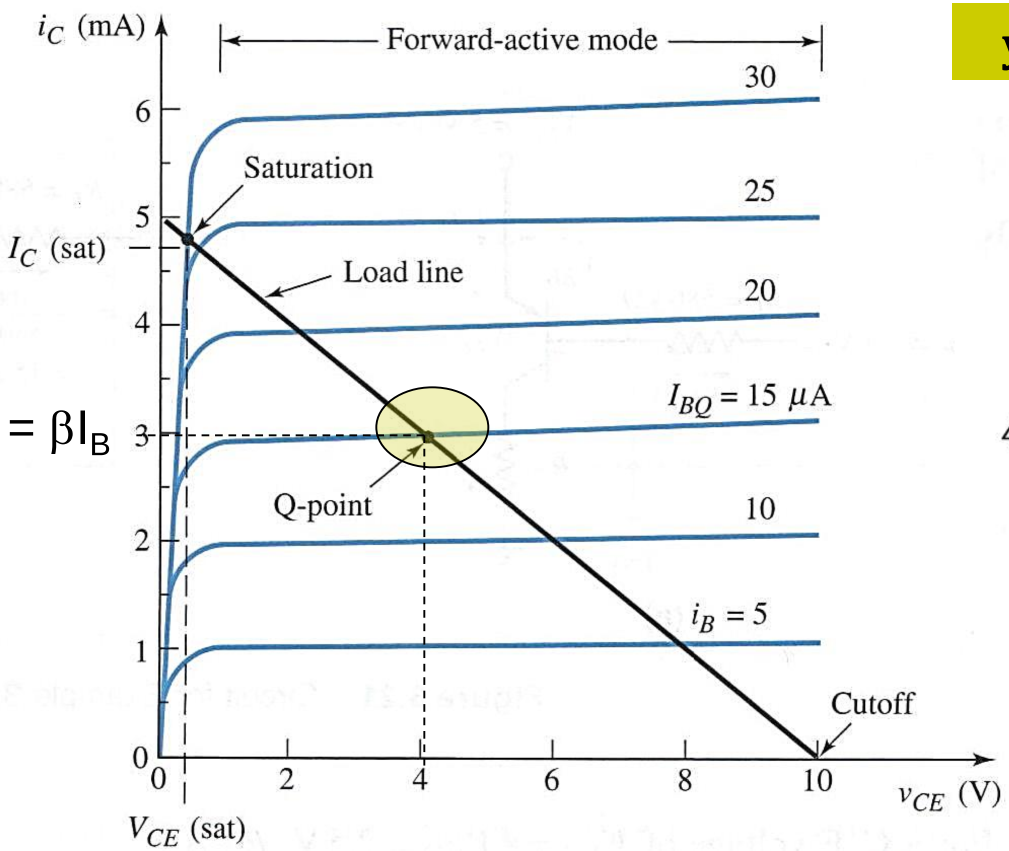
For example;

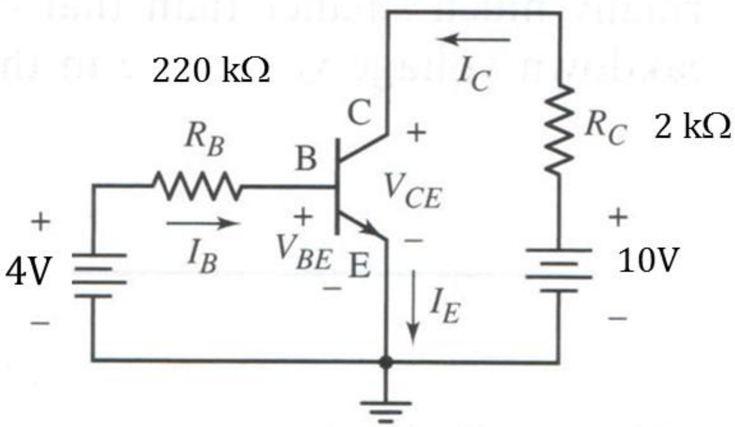
$$I_C = \frac{-V_{CE}}{2k} + \frac{10}{2k}$$

y = mx + c

$\beta = 200$

$I_C = \beta I_B$





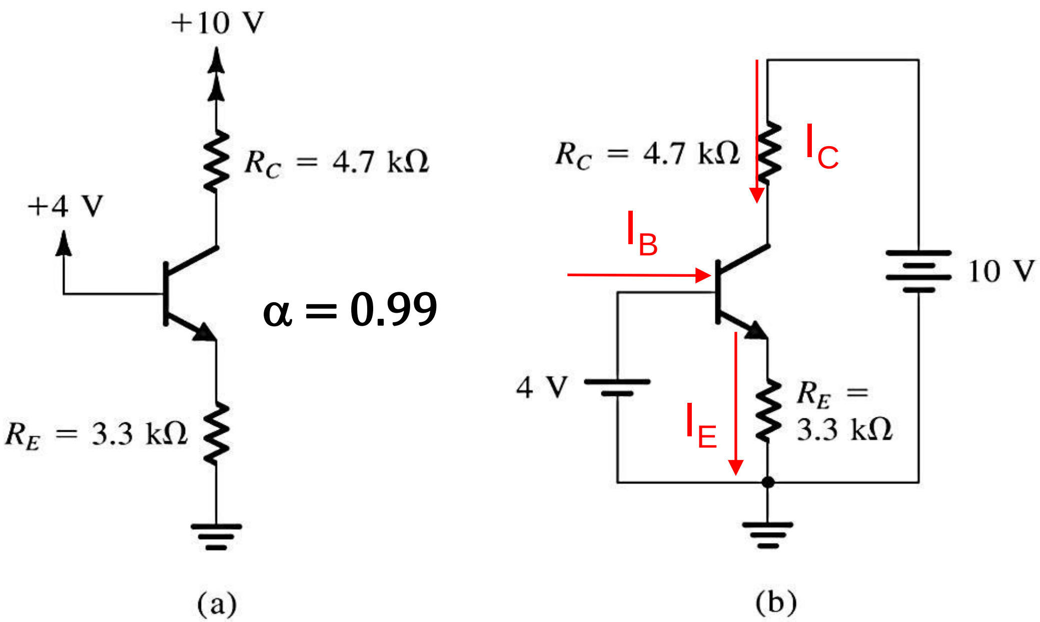
- To find the intersection points setting $I_C = 0$, $V_{CE} = V_{CC} = 10$ V
- setting $V_{CE} = 0$ $I_C = V_{CC}/R_C = 5$ mA

Q-point is the intersection of the load line with the i_C *vs* v_{CE} curve, corresponding to the appropriate base current

Examples

BJT DC Analysis

Example 2



KVL at BE loop: $0.7 + I_E R_E - 4 = 0$

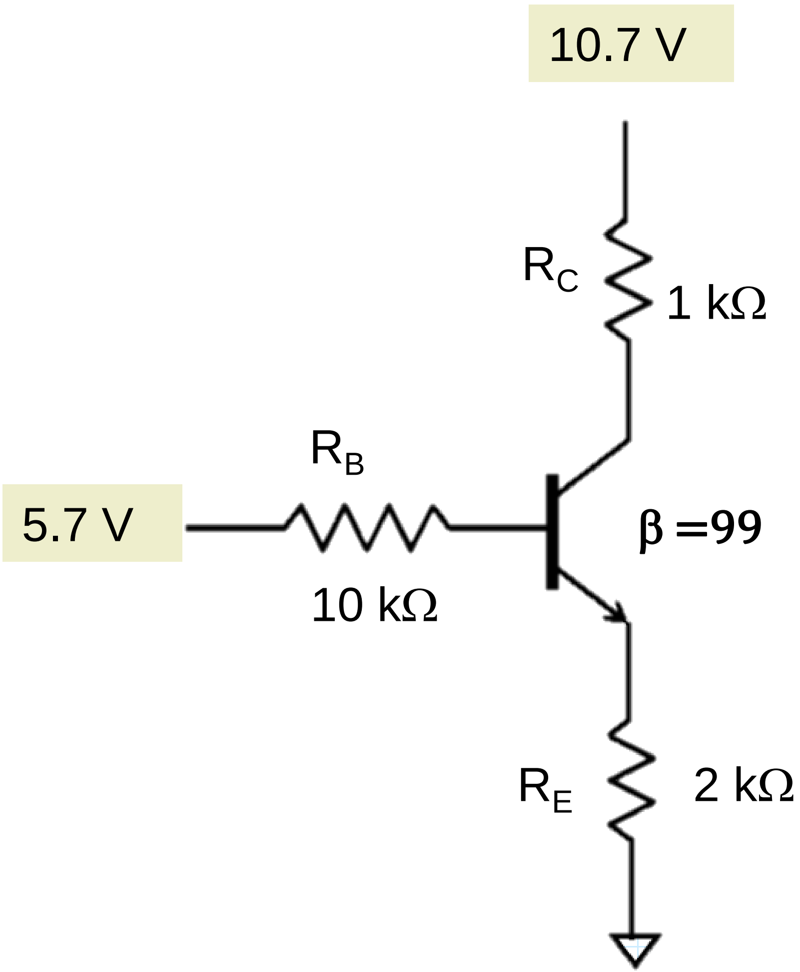
$I_E = 3.3 / 3.3 =$ **1 mA**

Hence, $I_C = \alpha I_E =$ **0.99 mA**

$I_B = I_E - I_C =$ **0.01 mA**

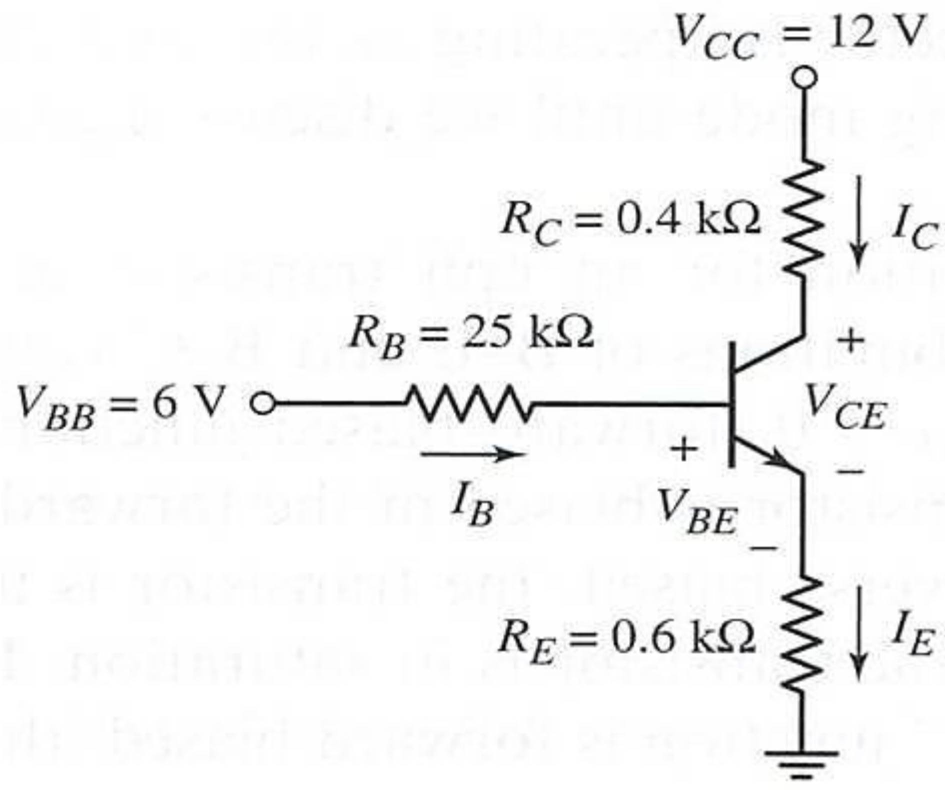
KVL at CE loop: $I_C R_C + V_{CE} + I_E R_E - 10 = 0$

$V_{CE} = 10 - 3.3 - 4.653 =$ **2.047 V**


10.7 V
RC
1 kΩ
RB
5.7 V
β =99
10 kΩ
RE
2 kΩ

Example 3: DC Analysis and Load Line

Calculate the characteristics of a circuit containing an emitter resistor and plot the output load line.
For the circuit, let $V_{BE}(\text{on}) = 0.7$ V and $\beta = 75$.



Output Load Line

Use KVL at B-E loop to find the value of I_B

Solution:

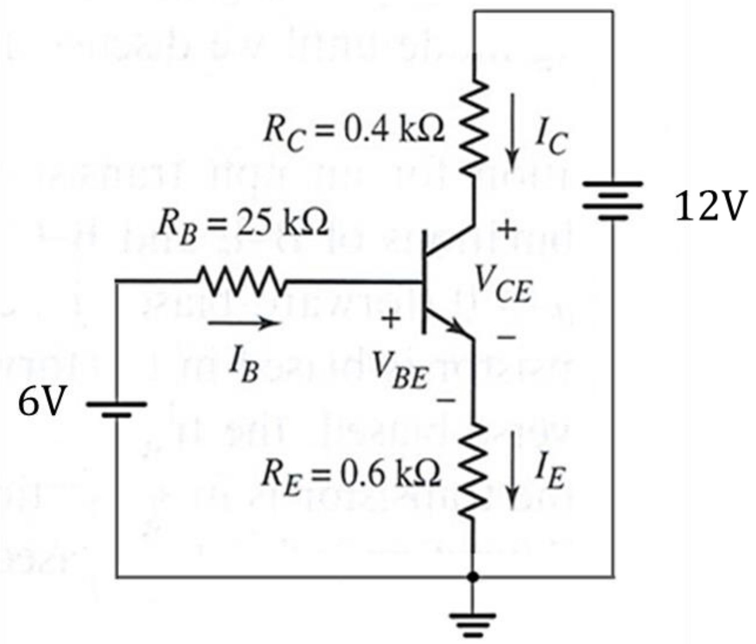
***Q*-Point Values:**

Writing the Kirchhoff's voltage law equation around the B–E loop, we have

$$V_{BB} = I_B R_B + V_{BE}(\text{on}) + I_E R_E$$

Assuming the transistor is biased in the forward-active mode, we can write $I_E = (1+\beta)I_B$. We can then solve for the base current:

$$I_B = \frac{V_{BB} - V_{BE}(\text{on})}{R_B + (1+\beta)R_E} = \frac{6-0.7}{25+(76)(0.6)} \Rightarrow 75.1\ \mu\text{A}$$



Use KVL at C-E loop – to obtain the linear equation

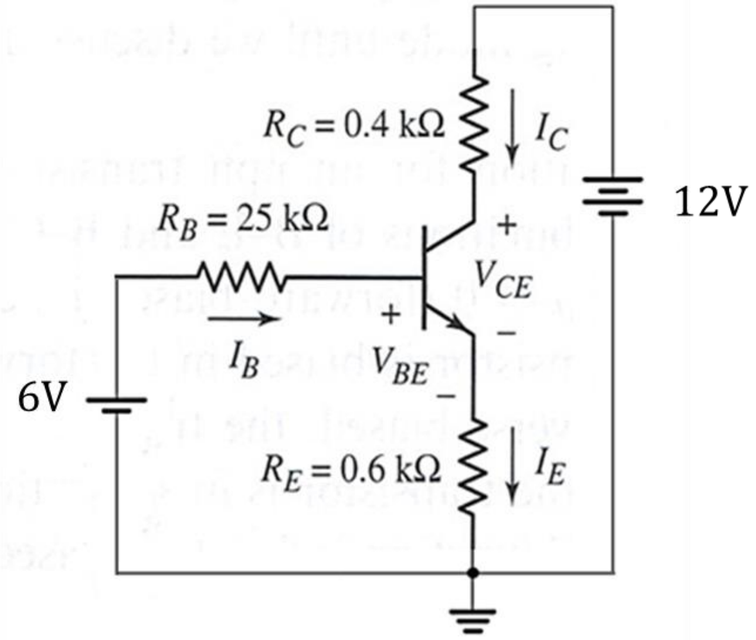
$$I_C R_C + V_{CE} + I_E R_E - 12 = 0$$

$$I_C R_C + V_{CE} + (I_C/\alpha) R_E - 12 = 0$$

$$V_{CE} = V_{CC} - I_C\left[R_C + \left(\frac{1+\beta}{\beta}\right)R_E\right] = 12 - I_C\left[0.4 + \left(\frac{76}{75}\right)(0.6)\right]$$

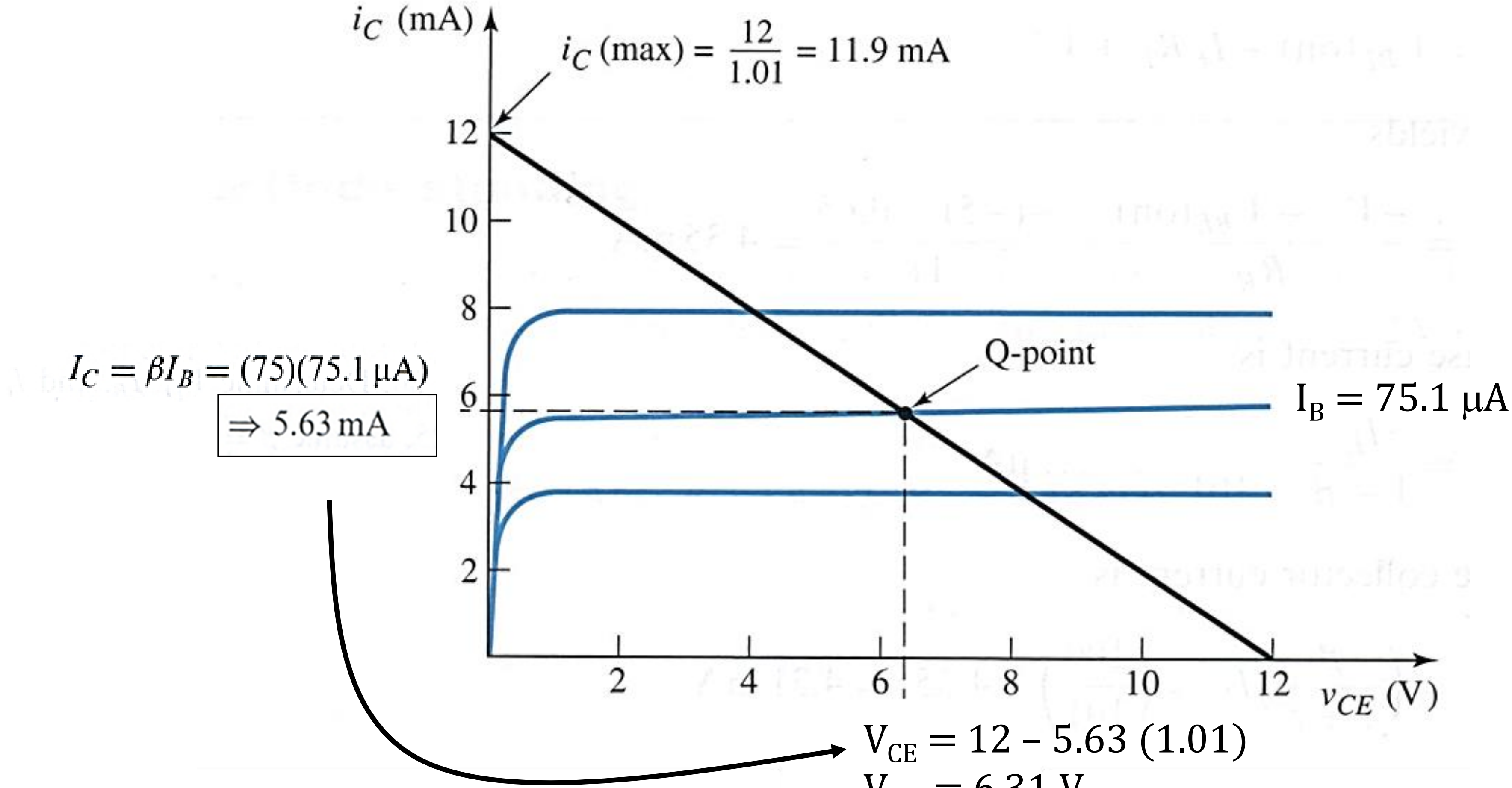
or

$$V_{CE} = 12 - I_C(1.01)$$



$$V_{CE} = 12 - I_C\,(1.01)$$

$$I_C = \frac{-V_{CE} + 12}{1.01}$$



$$V_{CE} = 12 - 5.63\,(1.01)$$

$$V_{CE} = 6.31\ V$$