BJT: DC Analysis

Semiconductor Devices and Circuits

(ECE 181302)

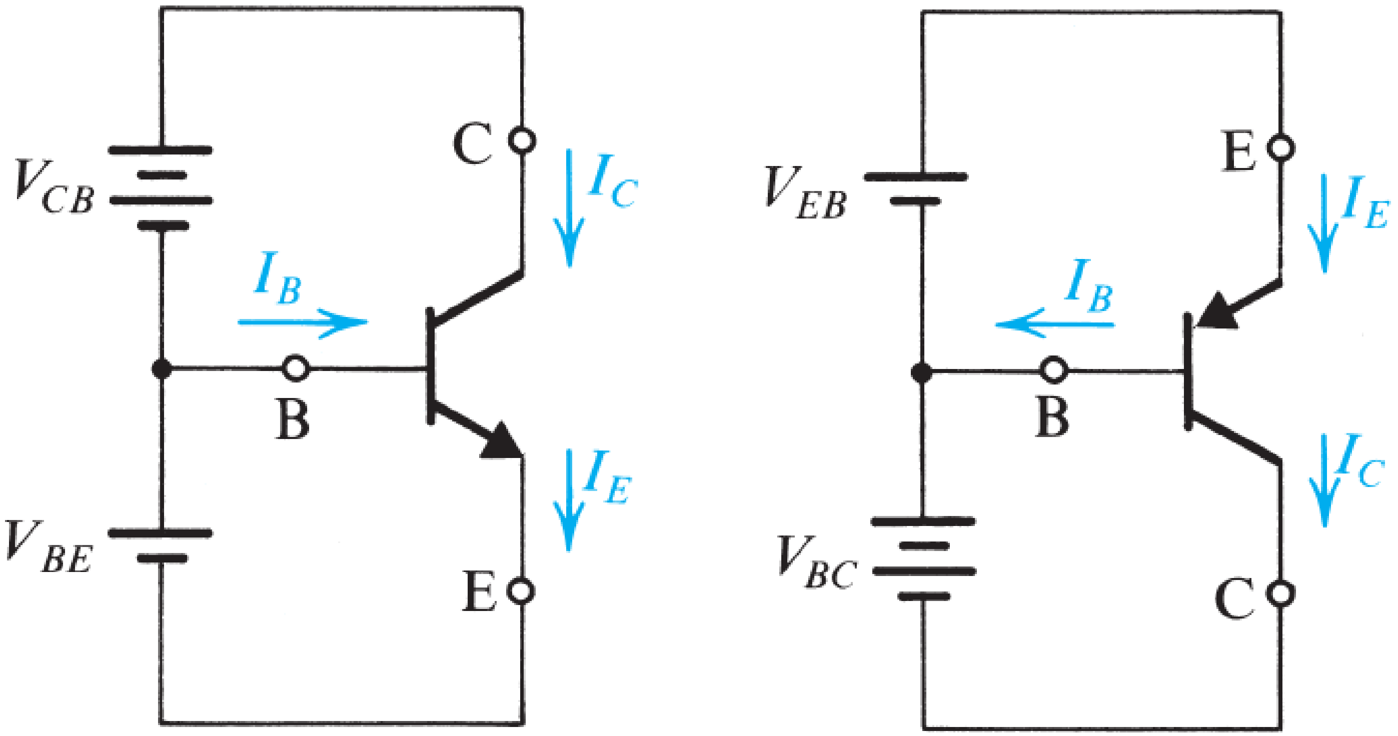
21st December 2021

Basic Transistor Relationships

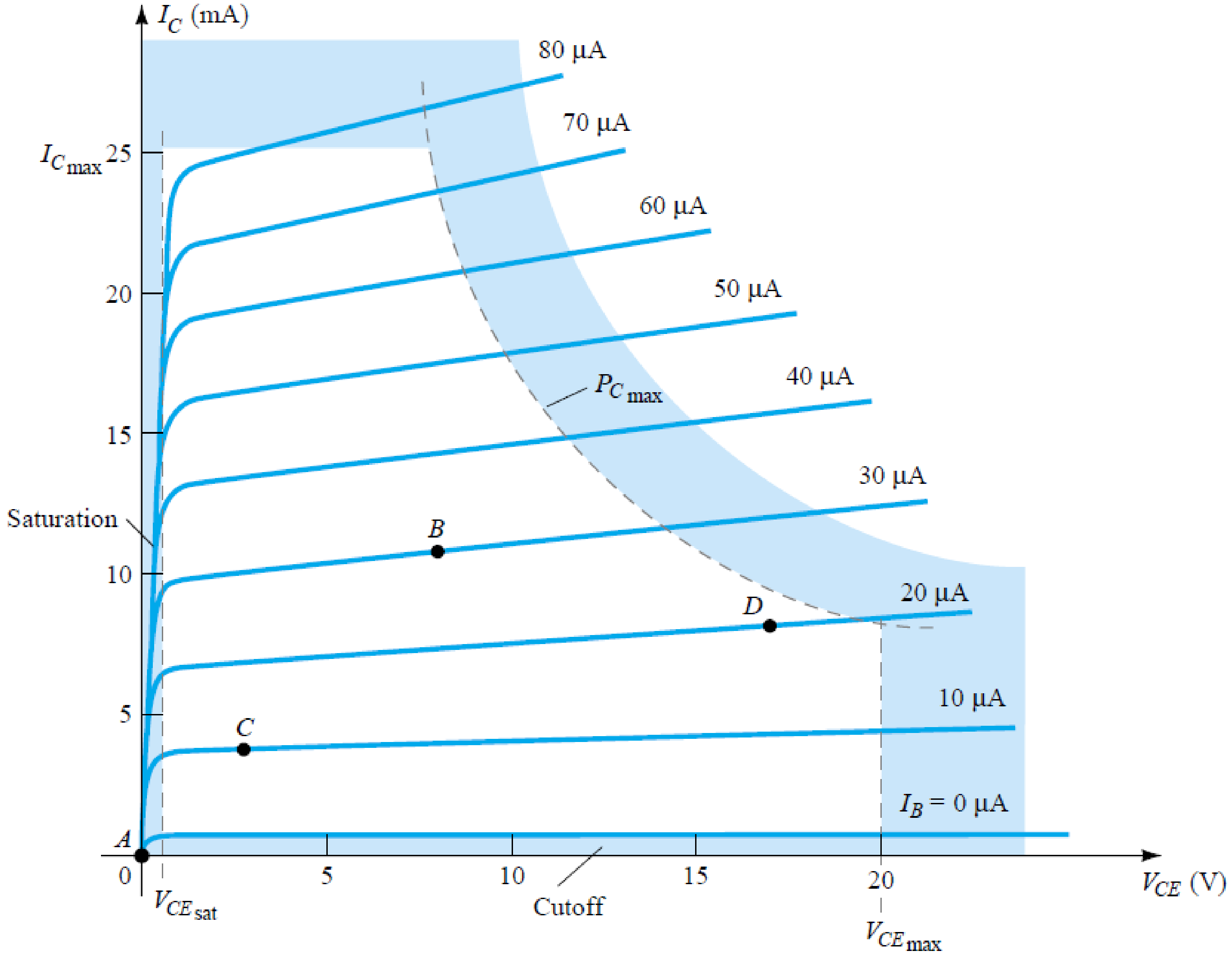
$$\boxed{V_{BE} = 0.7\text{ V}}$$

$$\boxed{I_E = (\beta + 1)I_B \cong I_C}$$

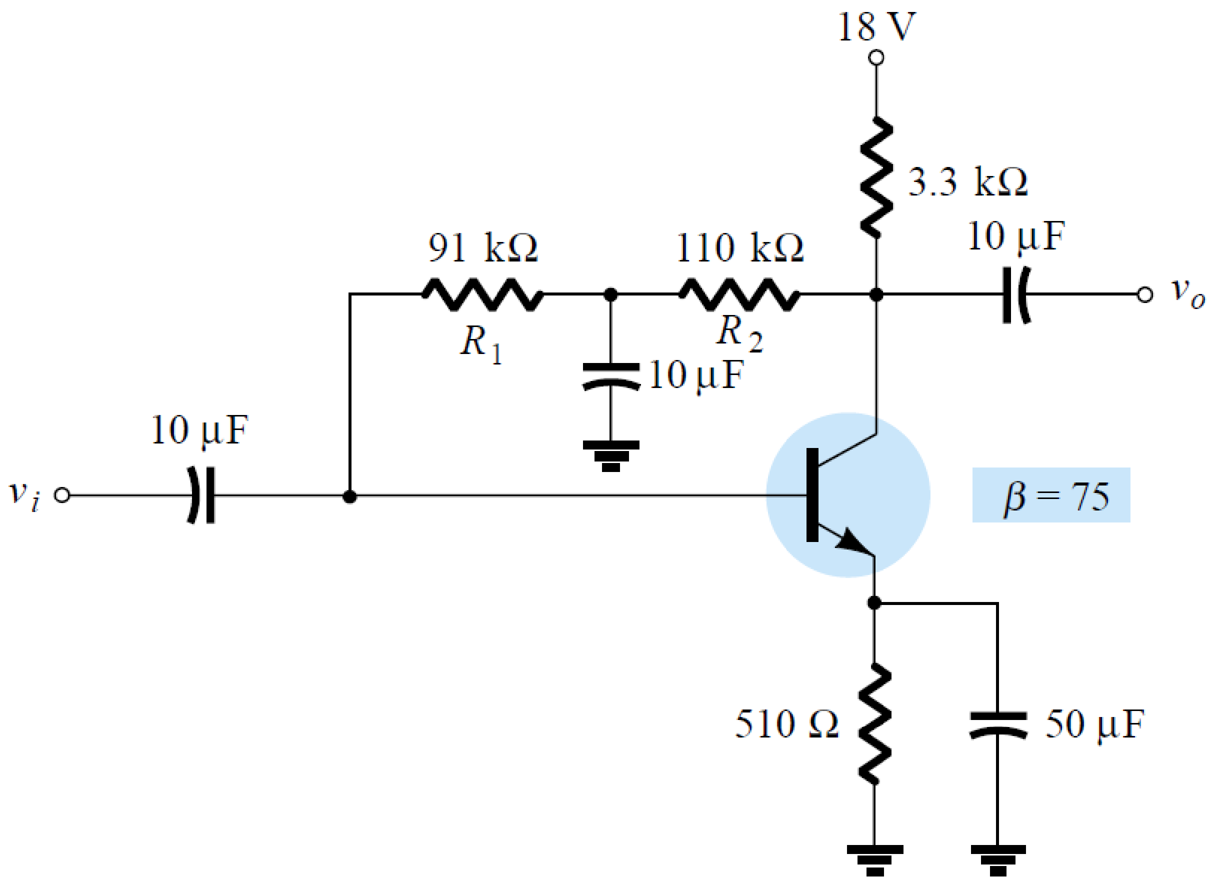
$$\boxed{I_C = \beta I_B}$$



BJT Characteristic



Example 1. Determine the dc level of I_B and V_C for the network.

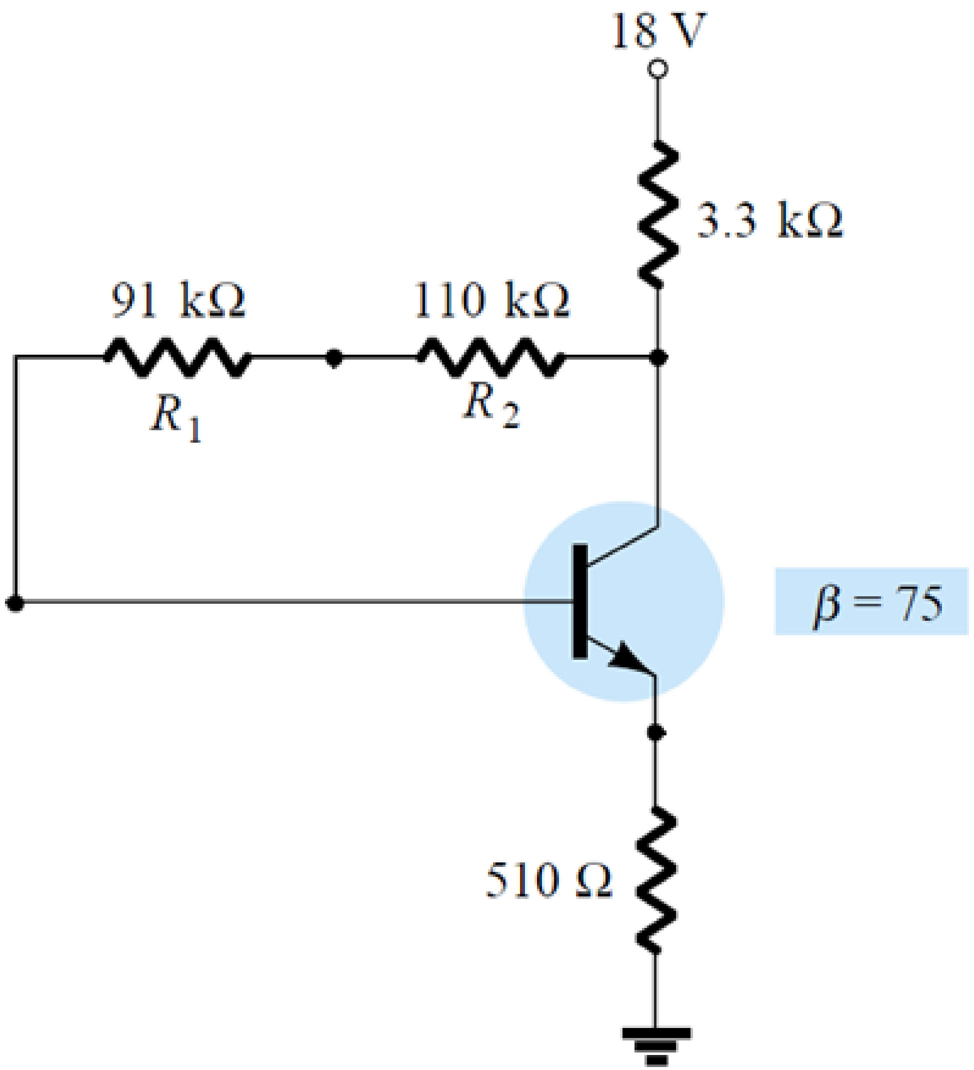


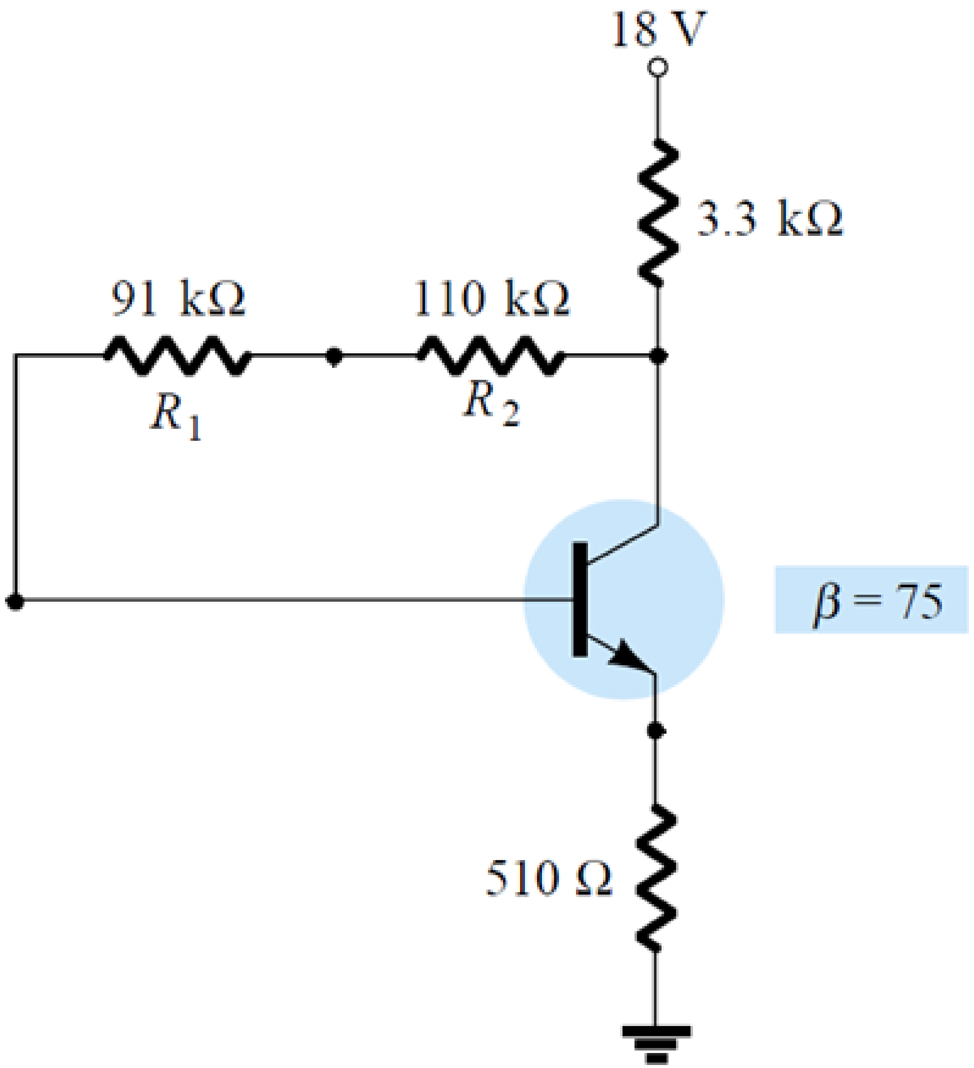
- For the BJT to be biased in its linear or active operating region the following must be true:
  1. The base–emitter junction *must* be forward-biased (*p*-region voltage more *p*ositive), with a resulting forward-bias voltage of about 0.6 to 0.7 V.
  2. The base–collector junction *must* be reverse-biased (*n*-region more *p*ositive), with the reverse-bias voltage being any value within the maximum limits of the device.
- Operation in the cutoff, saturation, and linear regions of the BJT characteristic are:

1. *Linear-region operation:*
   - Base–emitter junction forward biased
   - Base–collector junction reverse biased
2. *Cutoff-region operation:*
   - Base–emitter junction reverse biased
3. *Saturation-region operation:*
   - Base–emitter junction forward biased
   - Base–collector junction forward biased

DC Analysis: Circuit Equivalent

- Mark the actual current directions and define the voltages.
- The dc analysis can be isolated ac analysis.
- Replace the capacitors with an open circuit for the dc analysis.
- Replace the inductors with a short circuit.
- Apply Kirchhoff's voltage law.





18 V
3.3 kΩ
91 kΩ
110 kΩ
R_1
R_2
$\beta = 75$
510 Ω

- The base resistance for the dc analysis is composed of two resistors with a capacitor connected from their junction to ground.
- In the dc equivalent circuit, the capacitor is open-circuited and $R_B = R_1 + R_2$.

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

$$= \frac{18\text{ V} - 0.7\text{ V}}{(91\text{ k}\Omega + 110\text{ k}\Omega) + (75)(3.3\text{ k}\Omega + 0.51\text{ k}\Omega)}$$

$$= \frac{17.3\text{ V}}{201\text{ k}\Omega + 285.75\text{ k}\Omega} = \frac{17.3\text{ V}}{486.75\text{ k}\Omega}$$

$$= \mathbf{35.5\ \mu A}$$

$$I_C = \beta I_B$$

$$= (75)(35.5\ \mu\text{A})$$

$$= 2.66\text{ mA}$$

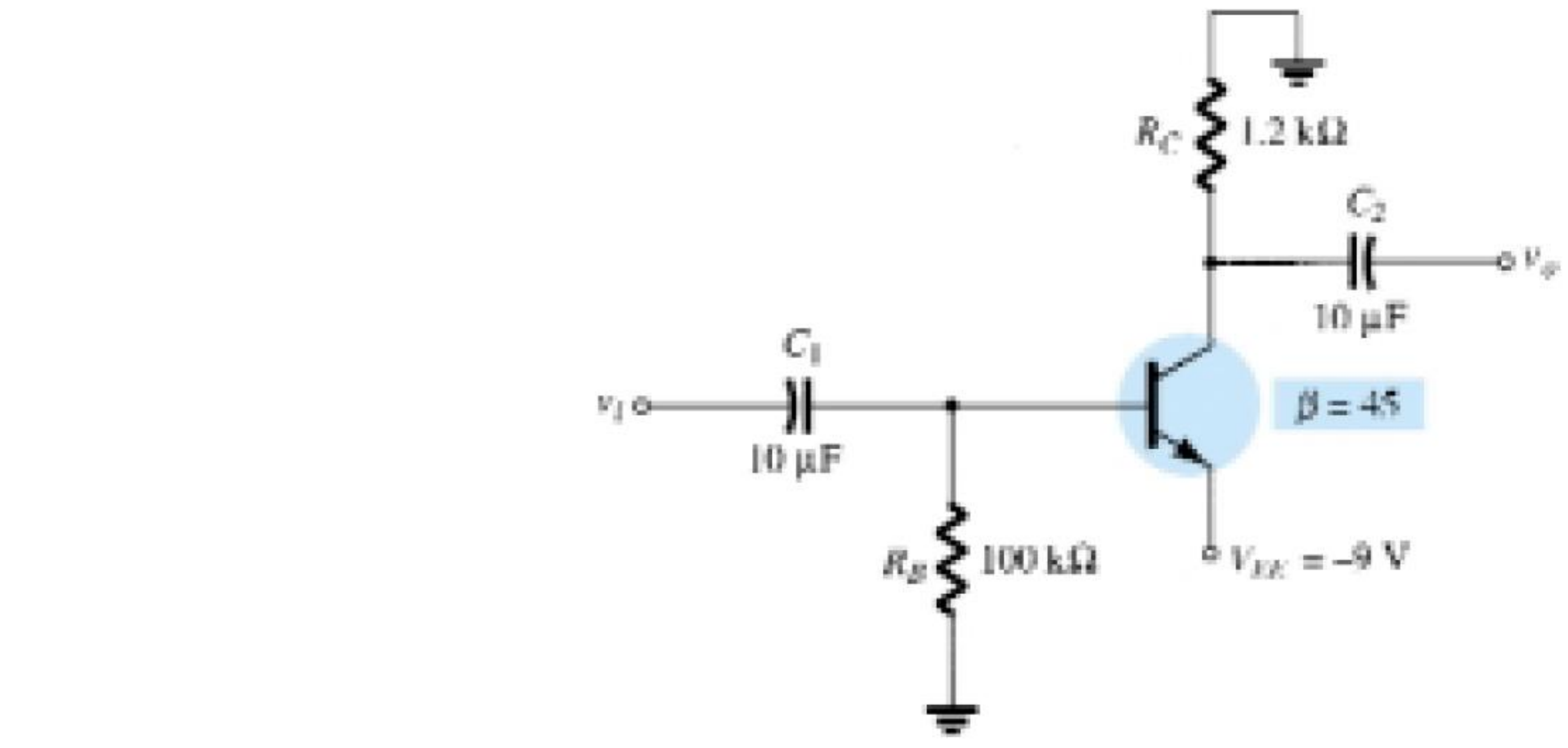
$$V_C = V_{CC} - I'_C R_C \cong V_{CC} - I_C R_C$$

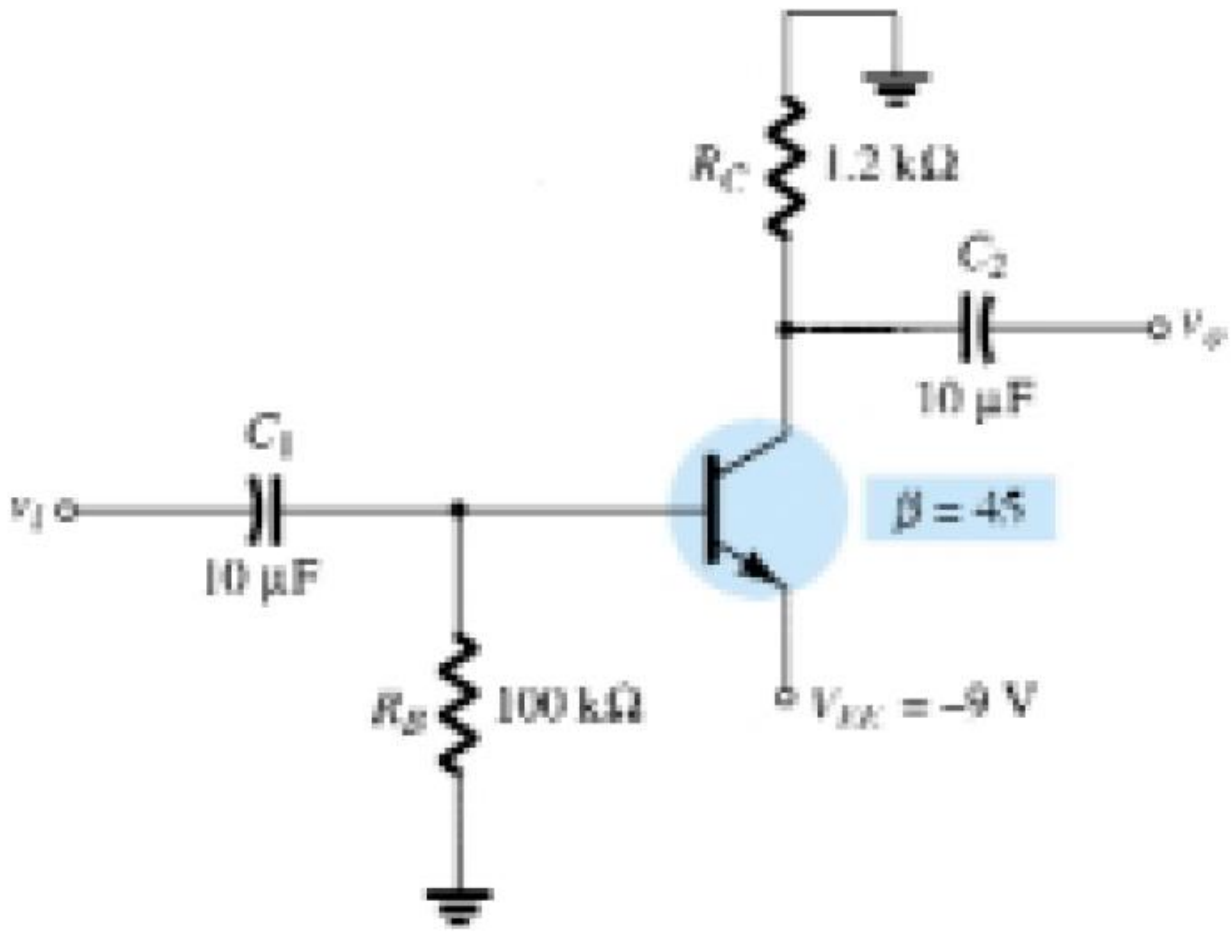
$$= 18\text{ V} - (2.66\text{ mA})(3.3\text{ k}\Omega)$$

$$= 18\text{ V} - 8.78\text{ V}$$

$$= \mathbf{9.22\ V}$$

Example 2. Determine V_C and V_B for the network.





R_C
1.2 kΩ
C_2
v_o
10 μF
C_1
v_i
$\beta = 45$
10 μF
R_B
100 kΩ
$V_{EE} = -9$ V

- Applying Kirchhoff's voltage law in the clockwise direction for the base–emitter loop

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

$$I_B = \frac{V_{EE} - V_{BE}}{R_B}$$

- Through substitutions:

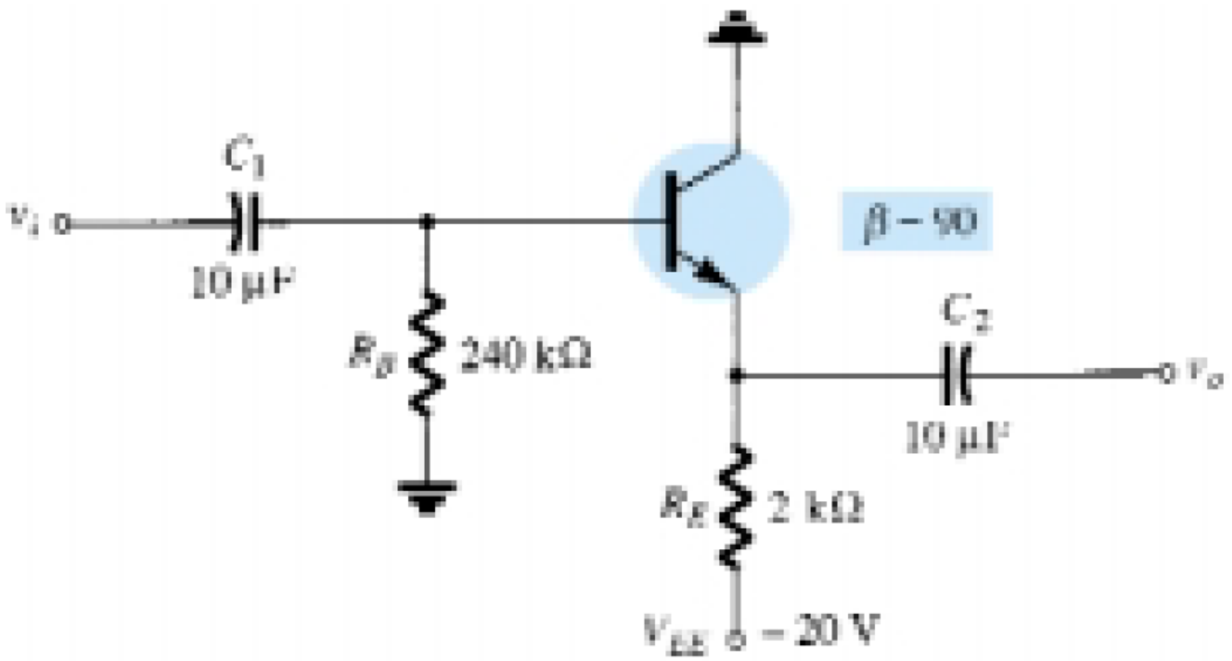
$$I_B = \frac{9\text{ V} - 0.7\text{ V}}{100\text{ k}\Omega} = \frac{8.3\text{ V}}{100\text{ k}\Omega} = 83\ \mu\text{A}$$

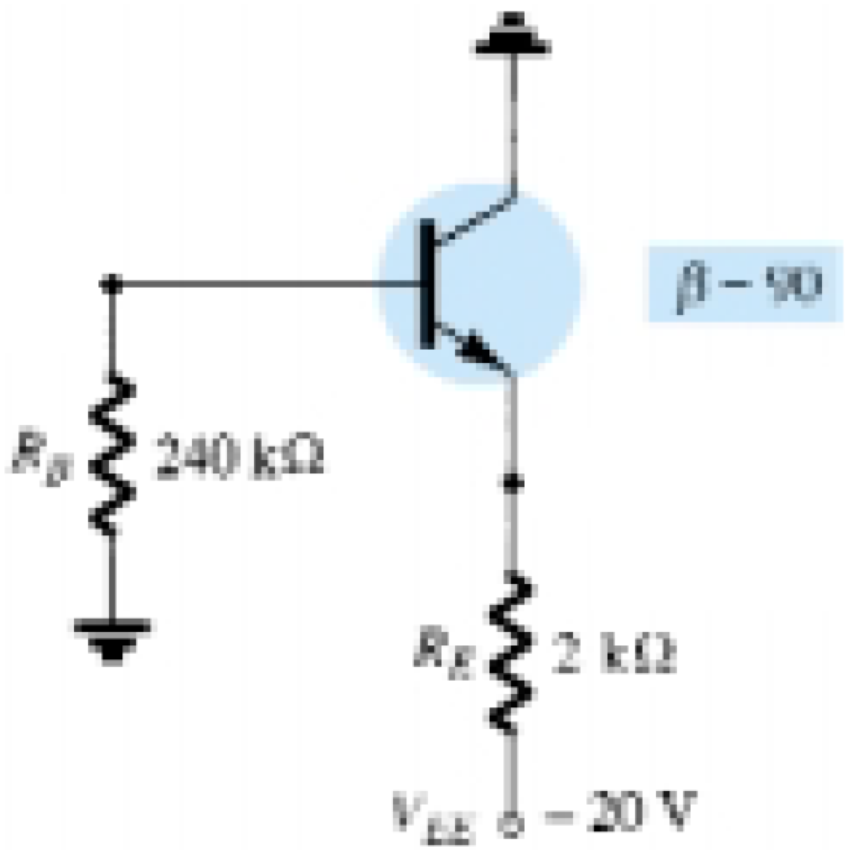
$$I_C = \beta I_B = (45)(83\ \mu\text{A}) = 3.735\text{ mA}$$

$$V_C = -I_C R_C = -(3.735\text{ mA})(1.2\text{ k}\Omega) = \mathbf{-4.48\ V}$$

$$V_B = -I_B R_B = -(83\ \mu\text{A})(100\text{ k}\Omega) = \mathbf{-8.3\ V}$$

Example 3. Determine V_{CEQ} and I_E for the network





β = 90
R_B 240 kΩ
R_E 2 kΩ
V_{EE} − 20 V

- Applying Kirchhoff's voltage law to the input circuit

$$-I_BR_B - V_{BE} - I_ER_E + V_{EE} = 0$$
$$I_E = (\beta + 1)I_B$$
$$V_{EE} - V_{BE} - (\beta + 1)I_BR_E - I_BR_B = 0$$
$$I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1)R_E}$$

- Through substitutions:

$$I_B = \frac{20\text{ V} - 0.7\text{ V}}{240\text{ k}\Omega + (91)(2\text{ k}\Omega)}$$
$$= \frac{19.3\text{ V}}{240\text{ k}\Omega + 182\text{ k}\Omega} = \frac{19.3\text{ V}}{422\text{ k}\Omega}$$
$$= 45.73\ \mu\text{A}$$
$$I_C = \beta I_B$$
$$= (90)(45.73\ \mu\text{A})$$
$$= 4.12\text{ mA}$$

- Applying Kirchhoff's voltage law to the output circuit

$$-V_{EE} + I_ER_E + V_{CE} = 0$$
$$I_E = (\beta + 1)I_B$$
$$V_{CE_Q} = V_{EE} - (\beta + 1)I_BR_E$$
$$= 20\text{ V} - (91)(45.73\ \mu\text{A})(2\text{ k}\Omega)$$
$$= \mathbf{11.68\ V}$$
$$I_E = \mathbf{4.16\ mA}$$

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