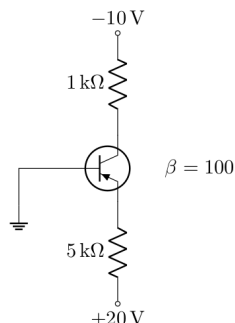


Question 1

For the transistor in the circuit below, $\beta = 100$. Find I_C , I_E , and V_{CE} .



Detailed solution

The arrow identifies a PNP transistor. Its emitter is connected to +20 V through the 5 kΩ resistor, its collector to -10 V through the 1 kΩ resistor, and its base is grounded. Use positive current magnitudes and $V_{EB} = 0.7$ V.

- Find the emitter voltage and current from the emitter branch.

$$V_E = V_B + 0.7 = 0.7 \text{ V},$$

$$I_E = \frac{20 - 0.7}{5 \text{ k}\Omega} = 3.860 \text{ mA}$$

- In forward-active operation, $I_E = I_C + I_B$ and $I_C = \beta I_B$. Retain the finite-beta correction.

$$I_B = \frac{I_E}{\beta + 1} = 38.22 \mu\text{A},$$

$$I_C = \frac{100}{101}(3.860) = 3.8218 \text{ mA}$$

- Collector current flows toward the -10 V supply. The collector is therefore above that supply by the resistor voltage drop.

$$V_C = -10 + I_C(1 \text{ k}\Omega) = -6.1782 \text{ V}$$

- By definition $V_{CE} = V_C - V_E$. For a PNP transistor this voltage is negative in normal active operation. Since $V_E > V_B > V_C$, the emitter-base junction is forward biased and the collector-base junction is reverse biased, confirming the assumption.

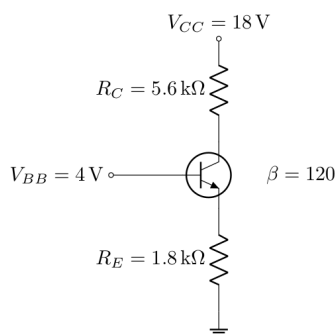
$$V_{CE} = -6.1782 - 0.7 = -6.8782 \text{ V}$$

Final answer

$$I_C \approx 3.82 \text{ mA}, \quad I_E \approx 3.86 \text{ mA}, \quad V_{CE} \approx -6.88 \text{ V}$$

Question 2

For the transistor in the circuit below, $\beta = 120$. Find the collector current I_C and the collector voltage V_C .



Detailed solution

The transistor is NPN. Assume forward-active operation with $V_{BE} = 0.7\text{ V}$; the ideal base supply fixes $V_B = 4\text{ V}$.

1. Subtract the base-emitter drop and apply Ohm's law to the emitter resistor.

$$V_E = 4 - 0.7 = 3.3\text{ V},$$

$$I_E = \frac{3.3}{1.8\text{ k}\Omega} = 1.8333\text{ mA}$$

2. Convert emitter current to collector current using the specified beta.

$$I_C = \frac{120}{121} I_E = 1.8182\text{ mA},$$

$$I_B = \frac{I_E}{121} = 15.15\text{ }\mu\text{A}$$

3. Subtract the collector resistor drop from the 18 V supply.

$$V_C = 18 - (1.8182\text{ mA})(5.6\text{ k}\Omega) = 7.8182\text{ V}$$

4. Check the region: $V_C = 7.8182\text{ V} > V_B = 4\text{ V}$, so the collector-base junction is reverse biased. Also V_{CE} is comfortably above saturation.

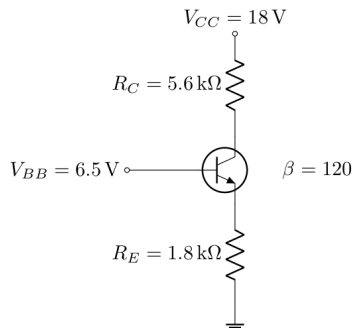
$$V_{CE} = 7.8182 - 3.3 = 4.5182\text{ V}$$

Final answer

$$I_C \approx 1.82\text{ mA}, \quad V_C \approx 7.82\text{ V}$$

Question 3

For the circuit below, $V_{BB} = 6.5 \text{ V}$. Find the collector current I_C and the collector voltage V_C .



Detailed solution

Use the same NPN circuit as Question 2, now with $V_B = 6.5 \text{ V}$. Use $V_{BE} = 0.7 \text{ V}$ and the constant-voltage saturation approximation $V_{CE(\text{sat})} = 0.2 \text{ V}$.

- Find the emitter voltage and current.

$$V_E = 6.5 - 0.7 = 5.8 \text{ V},$$

$$I_E = \frac{5.8}{1.8 \text{ k}\Omega} = 3.2222 \text{ mA}$$

- Test forward-active operation before accepting the beta relation.

$$I_{C,\text{active}} = \frac{120}{121}(3.2222) = 3.1956 \text{ mA}$$

$$V_{C,\text{active}} = 18 - (3.1956)(5.6) = 0.1047 \text{ V}$$

This would give $V_{CE} = 0.1047 - 5.8 = -5.6953 \text{ V}$, and $V_C < V_B$. Forward-active operation is inconsistent; the transistor is saturated.

- In saturation, fix the collector-emitter voltage and determine collector current from the external resistor.

$$V_C = V_E + 0.2 = 6.0 \text{ V},$$

$$I_C = \frac{18 - 6.0}{5.6 \text{ k}\Omega} = 2.1429 \text{ mA}$$

- The ideal base source supplies the remaining emitter current. Do not impose $I_C = 120I_B$ in saturation; the forced beta is much smaller.

$$I_B = I_E - I_C = 1.0794 \text{ mA},$$

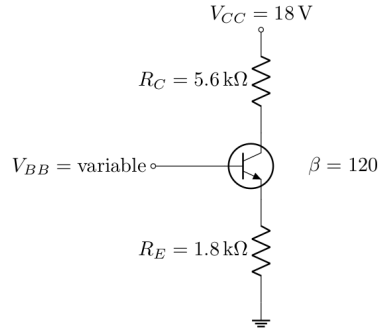
$$\beta_{\text{forced}} = \frac{I_C}{I_B} \approx 1.99$$

Final answer

Saturation: $I_C \approx 2.14 \text{ mA}$, $V_C = 6.00 \text{ V}$

Question 4

What is the maximum value of V_{BB} that keeps the transistor in the circuit below from entering saturation? Take $V_{CE(\text{sat})} = 0.2 \text{ V}$.



Detailed solution

Use $V_{BE} = 0.7 \text{ V}$ and the specified $V_{CE(\text{sat})} = 0.2 \text{ V}$. The requested limit is evaluated using this two-region, constant-voltage model.

1. Write the collector-emitter voltage in terms of emitter current, retaining the finite-beta correction.

$$\alpha = \frac{\beta}{\beta + 1} = \frac{120}{121},$$

$$V_{CE} = 18 - I_E (\alpha R_C + R_E)$$

2. Set the collector-emitter voltage to the stated saturation limit.

$$I_{E,\text{max}} = \frac{18 - 0.2}{(120/121)(5.6 \text{ k}\Omega) + 1.8 \text{ k}\Omega} = 2.4205 \text{ mA}$$

3. Recover the emitter voltage and the required base voltage.

$$V_{E,\text{max}} = I_{E,\text{max}} R_E = 4.3570 \text{ V}$$

$$V_{BB,\text{max}} = V_{E,\text{max}} + 0.7 = 5.0570 \text{ V}$$

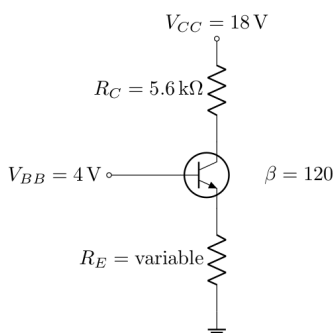
4. Increasing V_{BB} increases emitter and collector currents, lowering V_C while raising V_E . Thus V_{CE} decreases. The limiting value is about 5.06 V; choose a lower value for margin under the stated model.

Final answer

$$V_{BB,\text{max}} \approx 5.06 \text{ V} \quad (\text{using the stated saturation criterion})$$

Question 5

What is the minimum value of R_E that keeps the transistor in the circuit below from entering saturation? Take $V_{CE(\text{sat})} = 0.2 \text{ V}$.



Detailed solution

The base supply fixes $V_B = 4 \text{ V}$. Use $V_{BE} = 0.7 \text{ V}$ and the specified $V_{CE(\text{sat})} = 0.2 \text{ V}$.

1. Determine the emitter voltage; it does not depend on the emitter resistor in this ideal-base-source model.

$$V_E = 4 - 0.7 = 3.3 \text{ V}$$

2. At the specified saturation limit, find the lowest allowed collector voltage and the corresponding maximum collector current.

$$V_{C,\text{min}} = 3.3 + 0.2 = 3.5 \text{ V},$$

$$I_{C,\text{max}} = \frac{18 - 3.5}{5.6 \text{ k}\Omega} = 2.5893 \text{ mA}$$

3. Convert this to emitter current and apply Ohm's law.

$$I_{E,\text{max}} = \frac{121}{120} I_{C,\text{max}} = 2.6109 \text{ mA}$$

$$R_{E,\text{min}} = \frac{3.3 \text{ V}}{2.6109 \text{ mA}} = 1.26395 \text{ k}\Omega$$

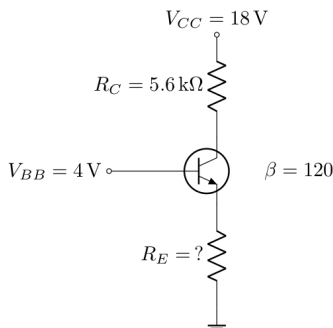
4. A smaller R_E raises the currents and lowers V_{CE} beyond the stated limit. Equality is the limiting design value; select a larger resistor for margin.

Final answer

$$R_{E,\text{min}} \approx 1.264 \text{ k}\Omega$$

Question 6

What value of R_E is required in the circuit below to obtain $I_C = 1 \text{ mA}$?



Detailed solution

Use $V_{BE} = 0.7 \text{ V}$, $V_B = 4 \text{ V}$, and $\beta = 120$. The target is the collector current, not the emitter current.

- Find the emitter voltage and the base current required for the target collector current.

$$V_E = 4 - 0.7 = 3.3 \text{ V},$$

$$I_B = \frac{1 \text{ mA}}{120} = 8.333 \mu\text{A}$$

- Add base current to collector current before sizing the emitter resistor.

$$I_E = I_C + I_B = 1.00833 \text{ mA}$$

$$R_E = \frac{3.3 \text{ V}}{1.00833 \text{ mA}} = 3.2727 \text{ k}\Omega$$

- Verify that the resulting operating point is forward active.

$$V_C = 18 - (1 \text{ mA})(5.6 \text{ k}\Omega) = 12.4 \text{ V},$$

$$V_{CE} = 12.4 - 3.3 = 9.1 \text{ V}$$

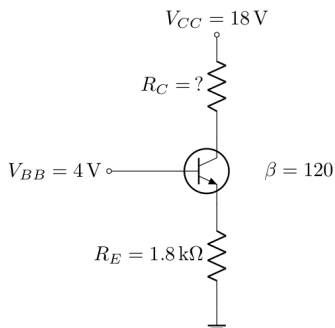
Since $V_C = 12.4 \text{ V} > V_B = 4 \text{ V}$, the collector-base junction is reverse biased. The finite-beta result is $3.27 \text{ k}\Omega$; using $I_E \approx I_C$ would give the slightly less accurate value $3.30 \text{ k}\Omega$.

Final answer

$$R_E \approx 3.27 \text{ k}\Omega$$

Question 7

What value of R_C is required in the circuit below to obtain $V_{CE} = 1\text{ V}$?



Detailed solution

The base voltage and emitter resistor fix the current. Use $V_{BE} = 0.7\text{ V}$ and $\beta = 120$, then choose the collector resistor for the required V_{CE} .

1. Calculate emitter voltage, emitter current, and collector current.

$$V_E = 4 - 0.7 = 3.3\text{ V},$$

$$I_E = \frac{3.3}{1.8\text{ k}\Omega} = 1.8333\text{ mA}$$

$$I_C = \frac{120}{121} I_E = 1.8182\text{ mA}$$

2. Add the required collector-emitter voltage to the emitter voltage to find the desired collector voltage.

$$V_C = V_E + V_{CE} = 3.3 + 1.0 = 4.3\text{ V}$$

3. Divide the required collector resistor drop by collector current.

$$R_C = \frac{18 - 4.3}{1.8182\text{ mA}} = 7.535\text{ k}\Omega$$

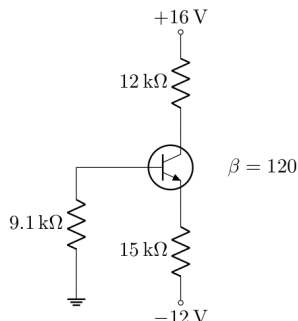
4. The check $V_C = 4.3\text{ V} > V_B = 4\text{ V}$ confirms reverse bias of the collector-base junction. Also $V_{CE} = 1\text{ V} > 0.2\text{ V}$, so the active-current calculation is consistent.

Final answer

$$R_C \approx 7.54\text{ k}\Omega$$

Question 8

For the circuit below, find I_C and V_{CE} .



Detailed solution

This is an NPN transistor with +16 V at the collector supply and -12 V at the emitter supply. The base is connected to ground through 9.1 kΩ, so base current makes V_B slightly negative. Use $V_{BE} = 0.7$ V and $\beta = 120$.

1. Write base voltage, emitter voltage, and emitter current in terms of base current.

$$\begin{aligned} V_B &= -I_B(9.1 \text{ k}\Omega), \\ V_E &= V_B - 0.7, \\ I_E &= 121I_B \end{aligned}$$

2. Apply KVL from ground, through the base-emitter junction and emitter resistor, to the -12 V supply.

$$\begin{aligned} 12 &= I_B(9.1 \text{ k}\Omega) + 0.7 + 121I_B(15 \text{ k}\Omega) \\ I_B &= \frac{11.3}{9.1 \text{ k}\Omega + 121(15 \text{ k}\Omega)} = 6.1948 \mu\text{A} \end{aligned}$$

3. Calculate the currents and node voltages.

$$\begin{aligned} I_C &= 120I_B = 0.74338 \text{ mA}, \\ I_E &= 121I_B = 0.74958 \text{ mA} \\ V_B &= -0.05637 \text{ V}, \quad V_E = -0.75637 \text{ V} \\ V_C &= 16 - I_C(12 \text{ k}\Omega) = 7.07944 \text{ V} \end{aligned}$$

4. Subtract emitter voltage, including its negative sign. Since $V_C > V_B > V_E$, the NPN transistor is forward active.

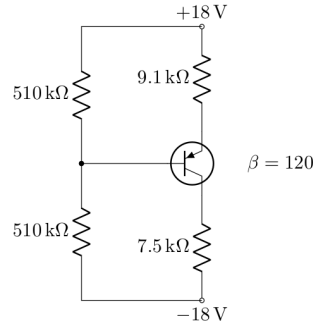
$$V_{CE} = 7.07944 - (-0.75637) = 7.83581 \text{ V}$$

Final answer

$$I_C \approx 0.743 \text{ mA}, \quad V_{CE} \approx 7.84 \text{ V}$$

Question 9

For the circuit below, find the collector voltage V_C .



Detailed solution

The arrow is on the upper branch and points into the base: this is a PNP transistor. The upper 9.1 kΩ resistor is in the emitter branch; the lower 7.5 kΩ resistor is in the collector branch. Use $V_{EB} = 0.7$ V, $\beta = 120$, and positive current magnitudes.

1. Replace the two 510 kΩ divider resistors by their Thevenin equivalent, including both +18 V and -18 V supplies.

$$V_{TH} = \frac{18 + (-18)}{2} = 0 \text{ V},$$

$$R_{TH} = (510 \text{ k}\Omega) \parallel (510 \text{ k}\Omega) = 255 \text{ k}\Omega$$

2. PNP base current flows out of the transistor into the divider. Consequently $V_B = V_{TH} + I_B R_{TH}$, not the NPN minus-sign expression.

$$V_B = 255 \text{ k}\Omega I_B,$$

$$V_E = V_B + 0.7,$$

$$I_E = 121 I_B$$

3. Apply Ohm's law in the emitter branch to solve for base current.

$$18 - V_E = I_E(9.1 \text{ k}\Omega)$$

$$I_B = \frac{18 - 0.7}{255 \text{ k}\Omega + 121(9.1 \text{ k}\Omega)} = 12.7572 \mu\text{A}$$

4. Find collector current and the voltage above the -18 V collector supply.

$$I_C = 120 I_B = 1.53086 \text{ mA}$$

$$V_C = -18 + I_C(7.5 \text{ k}\Omega) = -6.51855 \text{ V}$$

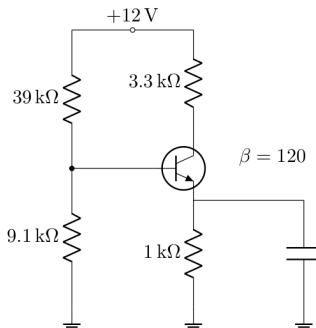
5. Check the region: $V_B = 3.25308$ V and $V_E = 3.95308$ V, so $V_E > V_B > V_C$. The PNP transistor is forward active. The negative collector voltage is expected from the negative supply and does not indicate an error.

Final answer

$$V_C \approx -6.52 \text{ V}$$

Question 10

For the circuit below, find I_C and V_{CE} .



Detailed solution

This is a DC bias calculation. At steady state the emitter bypass capacitor is an open circuit, so the 1 kΩ emitter resistor remains in the DC path. Use $V_{BE} = 0.7$ V and $\beta = 120$.

1. Replace the loaded base divider by its Thevenin equivalent.

$$V_{TH} = 12 \frac{9.1}{39 + 9.1} = 2.27027 \text{ V},$$

$$R_{TH} = 39 \parallel 9.1 = 7.37838 \text{ k}\Omega$$

2. Write KVL around the Thevenin source, base resistor, base-emitter junction, and emitter resistor.

$$V_{TH} = I_B R_{TH} + 0.7 + (\beta + 1) I_B R_E$$

$$I_B = \frac{2.27027 - 0.7}{7.37838 \text{ k}\Omega + 121(1 \text{ k}\Omega)} = 12.2316 \mu\text{A}$$

3. Calculate the collector and emitter currents and the emitter voltage.

$$I_C = 120 I_B = 1.46779 \text{ mA},$$

$$I_E = 121 I_B = 1.48002 \text{ mA}$$

$$V_E = I_E (1 \text{ k}\Omega) = 1.48002 \text{ V}$$

4. Find collector voltage and then the collector-emitter voltage.

$$V_C = 12 - (1.46779 \text{ mA})(3.3 \text{ k}\Omega) = 7.15629 \text{ V}$$

$$V_{CE} = 7.15629 - 1.48002 = 5.67627 \text{ V}$$

5. The loaded base voltage is $V_B = V_E + 0.7 = 2.18002$ V, slightly below the unloaded divider voltage. Since $V_C > V_B > V_E$, forward-active operation is consistent. The capacitor changes AC behavior, but not this steady-state DC operating point.

Final answer

$$I_C \approx 1.47 \text{ mA}, \quad V_{CE} \approx 5.68 \text{ V}$$