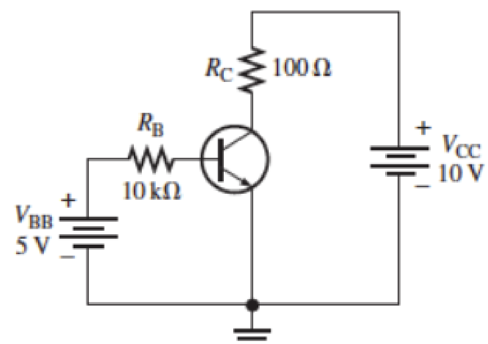
Example for Transistor's Parameters

Problem 1: Determine I_B, I_C, I_E, V_{BE}, V_{CE}, and V_{CB} in the circuit given below. The transistor has a β_{DC} = 150.

Solution 1:



The forward bias voltage drop

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

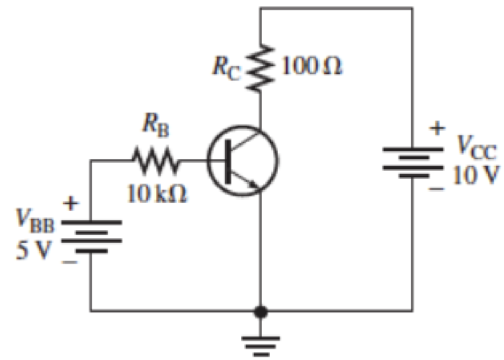
$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5\ V - 0.7\ V}{10\ k\Omega}$$

$$I_B = 0.43\ mA$$

$$I_C = \beta_{DC} I_B = 150 \times 0.43\ mA = 64.5\ mA$$

$$I_E = I_C + I_B = 64.5\ mA + 0.43\ mA = 64.93\ mA$$

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



$$V_{CE} = 10 - 64.5\, mA \times 100\ \Omega$$

$$V_{CE} = 3.55\, V$$

$$V_{CB} = V_C - V_B = V_C - V_E - (V_B - V_E)$$

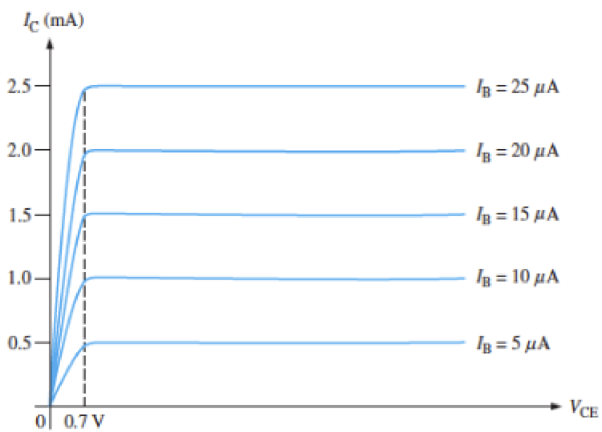
$$V_{CB} = V_{CE} - V_{BE} = 3.55\, V - 0.7\, V = 2.85\, V$$

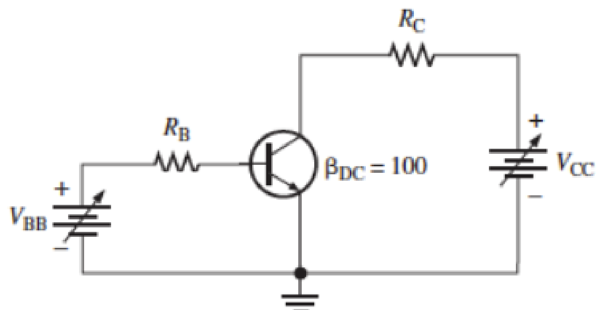
Example for Current Gain

Problem 2: Sketch an ideal family of collector curves for the shown transistor with β_{DC} = 100 for I_B varying from 5 μA to 25 μA.

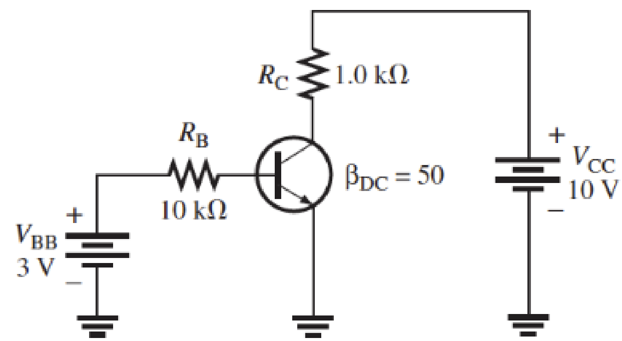
Solution 2:

For active region $I_C = \beta_{DC} I_B$





Problem 1: Determine whether or not the following BJT transistor is in saturation. Assume $V_{CE(sat)}$=0.2 V.



Solution 1:

The collector saturation current, $I_{C(sat)}$ is given by

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$$

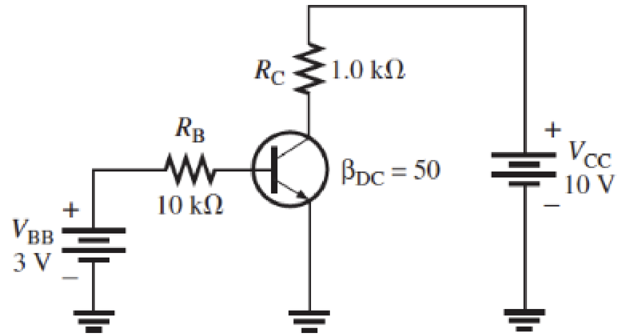
$$I_{C(sat)} = \frac{10\ V - 0.2\ V}{1\ k\Omega} = 9.8\ mA$$

$$I_{B(sat)} = \frac{I_{C(sat)}}{\beta_{DC}}$$

$$I_{B(sat)} = \frac{9.8\ mA}{50} = 0.196\ mA$$

Solution 1:

Now we we will see I_B is sufficient to produce $I_{C(sat)}$.



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

$$I_B = \frac{3\,V - 0.7\,V}{10\,k\Omega} = 0.23\,mA$$

Since $I_B > I_{B(sat)}$, BJT is saturated.

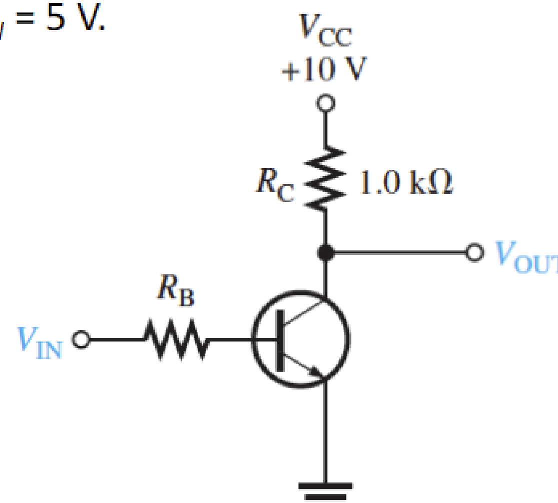
$$I_C = I_{C(sat)} = 9.8\,mA$$

$$V_{CE} = V_{CE(sat)} = 0.2\,V$$

Problem 2: (a) For the transistor circuit given below, what is V_{CE} when V_{IN} =0 V?

(b) What minimum value of I_B is required to saturate this transistor if β_{DC} is 200? Neglect $V_{CE(sat)}$.

(c) Calculate the maximum value of R_B that will put the transistor in saturation assuming β_{DC}=200 when V_{IN} = 5 V.



Solution 2:

(a) When V_{IN} =0 V, $V_{BE} = 0\ V$

The transistor is in cut-off.

BJT is in cut-off, I_C=0 A

$V_{CE} = V_{CC} = 10\ V$

saturation assuming β_{DC} = 200 when V_{IN} = 5 V.

Solution 2:

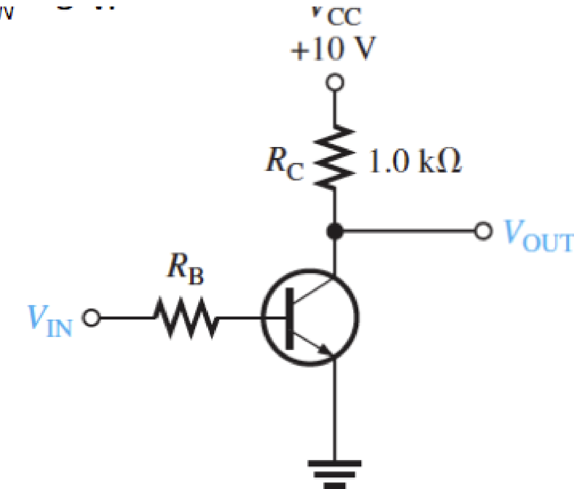
(b)

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$$

$$I_{C(sat)} = \frac{10 - 0}{1\ k\Omega} = 10\ mA$$

$$I_{B(min)} = I_{B(sat)} = \frac{I_{C(sat)}}{\beta_{DC}}$$

$$I_{B(min)} = \frac{10\ mA}{200} = 50\ \mu A$$



Solution 2:

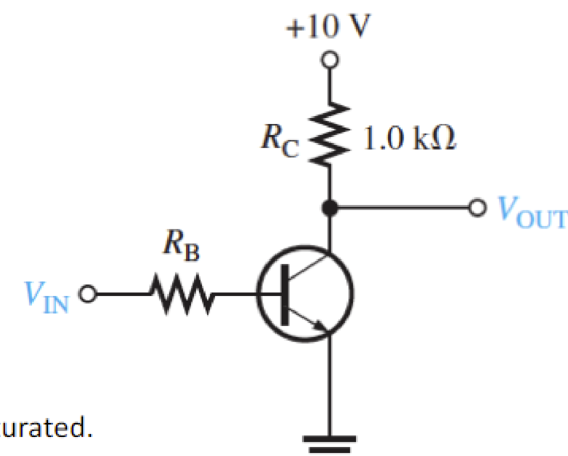
(c)

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

$$R_{B(max)} = \frac{V_{IN} - V_{BE}}{I_{B(min)}}$$

$$= \frac{5 - 0.7}{50\ \mu A} = 86\ k\Omega$$

If R_B>86 kΩ, the transistor will not be saturated.



Problem 1: Determine V_{CE} and I_C in the shown voltage-divider biased transistor circuit if β_{DC} = 100, and $V_{CE(sat)}$=0.2 V. Is this transistor in saturation?

Solution 1:

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

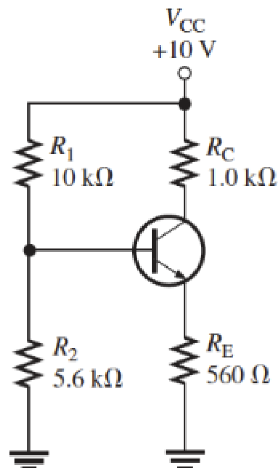
$$V_{TH} = \frac{5.6\ k\Omega}{10\ k\Omega + 5.6\ k\Omega} \times 10\ V$$

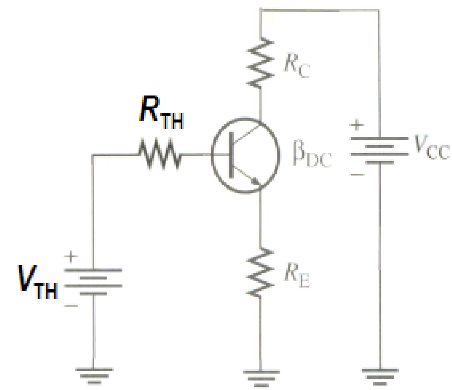
$$V_{TH} = 3.59\ V$$

$$R_{TH} = R_1 || R_2$$

$$R_{TH} = \frac{10\ k\Omega \times 5.6\ k\Omega}{10 k\Omega + 5.6\ k\Omega}$$

$$R_{TH} = 3.59\ k\Omega$$





Solution 1:

$$V_{TH} = R_{TH}I_B + V_{BE} + I_ER_E$$

$$V_{TH} = R_{TH}I_B + 0.7 + (\beta_{DC} + 1)I_B \times 560\ \Omega$$

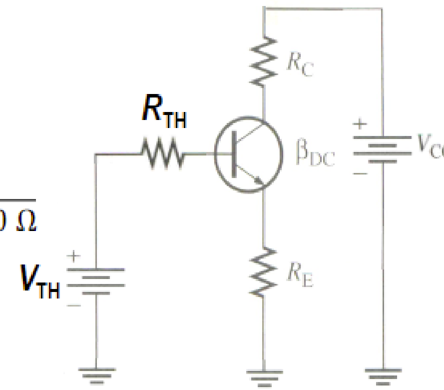
$$I_B = \frac{V_{TH} - 0.7}{R_{TH} + (\beta_{DC} + 1)I_B \times 560\ \Omega} = \frac{3.59\ V - 0.7\ V}{3.59\ k\Omega + (101) \times 560\ \Omega}$$

$$I_B = 51.1\ \mu A$$

$$I_C = \beta_{DC} \times I_B = 100 \times 51.1\ \mu A = 5.1\ mA$$

$$V_{CE} = V_{CC} - I_CR_C - I_ER_E$$

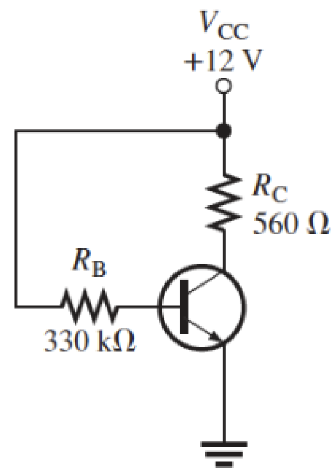
$$V_{CE} = 10\ V - 5.1\ mA \times 1\ k\Omega - (\beta_{DC} + 1)I_B \times 560\ \Omega = 2.01\ \text{V}$$



$$\boldsymbol{V_{CE} = 2.01\ \text{V} >> V_{CE(sat)}}$$

Problem 2: Determine the Q-point (I_C, V_{CE}) for the shown circuit if β_{DC}=200 and $V_{CE(sat)}$=0.2 V.

Solution 2:



$$I_B = \frac{12\ V - 0.7\ V}{330\ k\Omega} = 34.2\ \mu A$$

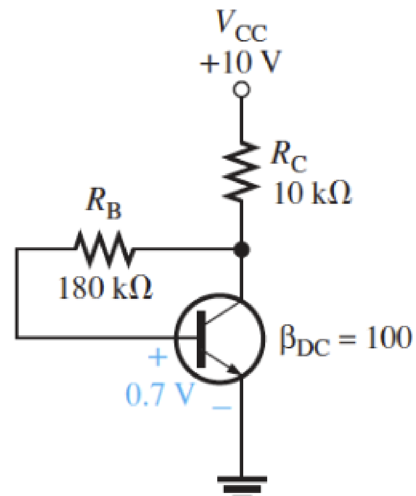
$$I_C = \beta_{DC} \times I_B = 200 \times 34.2\ \mu A = 6.8\ mA$$

$$V_{CE} = 12 - 6.8\ mA \times 560\Omega = 8.2\ V$$

$$\mathbf{V_{CE} = 8.2\ V >> V_{CE(sat)}}$$

Problem 3: Find the Q-point values (I_C and V_{CE}) for the given circuit if β_{DC}=100 and $V_{CE(sat)}$=0.2 V.

Solution 3:



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

$$I_E = (\beta_{DC} + 1) I_B$$

$$I_B = \frac{V_{CC} - V_{CE}}{(\beta_{DC} + 1) R_C + R_B}$$

$$I_B = \frac{10\ V - 0.7\ V}{101 \times 10\ k\Omega + 180\ k\Omega} = 7.82\ \mu A$$

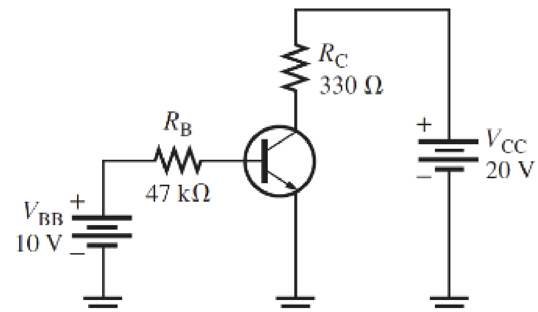
$$I_C = \beta_{DC} \times I_B = 100 \times 7.82\ \mu A = 0.782\ mA$$

$$V_{CE} = V_{CC} - I_E R_C = 10 - 0.782\ mA \times 10\ k\Omega = 2.18\ V$$

$$\boldsymbol{V_{CE} = 2.18\ V >> V_{CE(sat)}}$$

Problem 1: Determine the Q-point for the circuit given below and draw the dc load line. Find the maximum peak value of base current and collector current to avoid distortion. Assume $V_{CE(sat)}=0$, and $\beta_{DC} = 200$

Solution 1:



$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$$

$$I_{C(sat)} = \frac{20\,V - 0}{330\,\Omega} = 60.6\,mA$$

$$I_{B(sat)} = \frac{I_{C(sat)}}{\beta_{DC}} = 303\,\mu A$$

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

$$I_B = \frac{10\,V - 0.7\,V}{47\,k\Omega}$$

$$I_B = 198\,\mu A < I_{B(sat)}$$

Solution 1:

$$I_C = \beta_{DC} I_B = 200 \times 198\ \mu A$$

$$I_C = \beta_{DC} I_B = 39.6\ mA$$

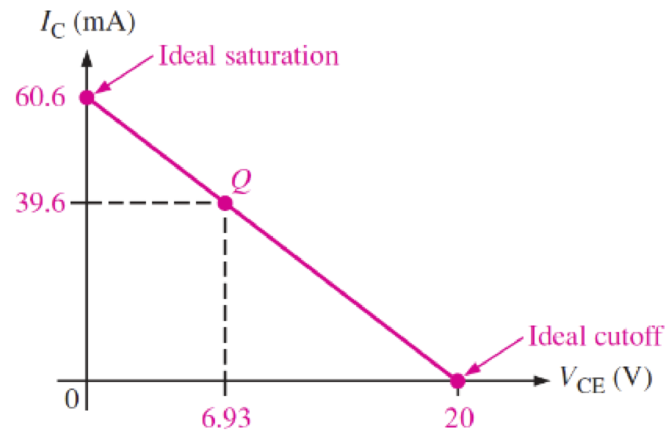
$$V_{CE} = V_{CC} - I_C R_C$$

$$V_{CE} = 20\ V - 39.6\ mA \times 330\ \Omega$$

$$V_{CE} = 6.93\ V$$

$$Q\ point\ V_{CE} = 6.93\ V, I_C = 39.6\ mA$$

$$I_B = 198\ \mu A$$



Solution 1:

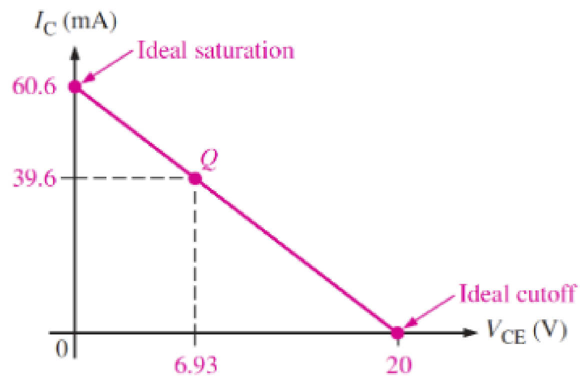
$$I_{c(peak)} = min\{(I_{C(sat)} - I_{CQ}), (I_{CQ} - I_{C(off)})\}$$

$$I_{c(peak)} = min\{(60.6\ mA - 39.6\ mA), (39.6\ mA - 0)\}$$

$$I_{c(peak)} = min\{(21mA), (39.6\ mA)\}$$

$$I_{c(peak)} = 21\ mA$$

$$I_{b(peak)} = \frac{I_{c(peak)}}{\beta_{DC}} = \frac{21\ mA}{200} = 0.105\ mA$$



Problem 2: Determine the r_e' of a transistor that is operating with a dc emitter current of 1.62 mA.

Solution 2:

$$r_e' = \frac{25\text{ mV}}{I_E} = \frac{25\text{ mV}}{1.62\text{ mA}} = 15.4\ \Omega$$