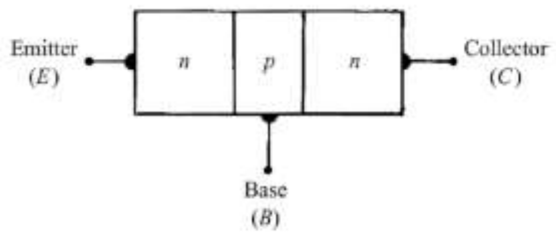
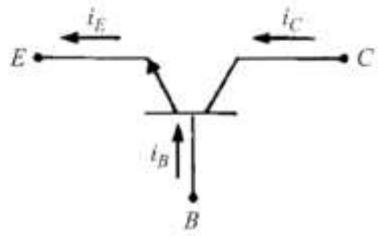
Tutorial Sheet - Solutions

Bipolar Junction Transistor

1. In a npn transistor, 10^8 holes/μs move from the base to the emitter region while 10^{10} electrons/μs move from the emitter to the base region. An ammeter reads the base current as I_B = 16μA.

   a) Determine the emitter current I_E and the collector current I_C.





The emitter current is found out as the net rate of flow of positive charge into the emitter region:

$$I_E = (1.602\times10^{-19}\,C/\text{hole})(10^8\,holes/\mu s) - (-1.602\times10^{-19}\,C/electron)(10^{10}\,holes/\mu s)$$
$$= (1.602\times10^{-19}\,C/\text{hole})(10^{14}\,holes/s) - (-1.602\times10^{-19}\,C/electron)(10^{16}\,holes/s)$$
$$= 1.602\times10^{-5} + 1.602\times10^{-3}$$
$$I_E = 1.61802\,mA$$

Further, by KCL,

$$I_C = I_E - I_B = 1.618\times10^{-3} - 16\times10^{-6} = 1.602\,mA$$

Therefore, emitter current, I_E = 1.618 mA and collector current, I_C = 1.602 mA

   b) For the previous example, find the α and β, if the leakage currents are considered negligible, and the described charge flow is constant.
   Given data: npn transistor, I_B = 16µA, I_E = 1.618mA, I_C=1.602m

If we assume $I_{CBO} = I_{CEO} = 0$, then

$$\alpha = \frac{I_C}{I_E} = \frac{I_E - I_B}{I_E} = \frac{1.618 - 0.016}{1.618} = 0.9901$$
$$\beta = \frac{I_C}{I_B} = \frac{I_E - I_B}{I_B} = \frac{1.618 - 0.016}{0.016} = 100.125$$
$$\beta = \frac{\alpha}{1-\alpha} \text{ gives the same result.}$$

Therefore, gains, α = 0.9901 and β = 100.125

2. A BJT has α=0.99, Base current, I_B=25µA, Leakage current, I_{CBO} = 200nA
   Find the following parameters:
   i. DC collector Current
   ii. DC emitter Current
   iii. % Error in the emitter current when the leakage current is neglected.

a) With $\alpha = 0.99$,

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = 99$$

$$I_C = \beta I_B + (\beta+1) I_{CBO} = 99(25\times10^{-6}) + (99+1)(200\times10^{-9}) = 2.495mA$$

b) The dc emitter current (I_E) is

$$I_E = \frac{I_C - I_{CBO}}{\alpha} = \frac{2.495\times10^{-3} - 200\times10^{-9}}{0.99} = 2.52mA$$

c) Neglecting the leakage current, we have

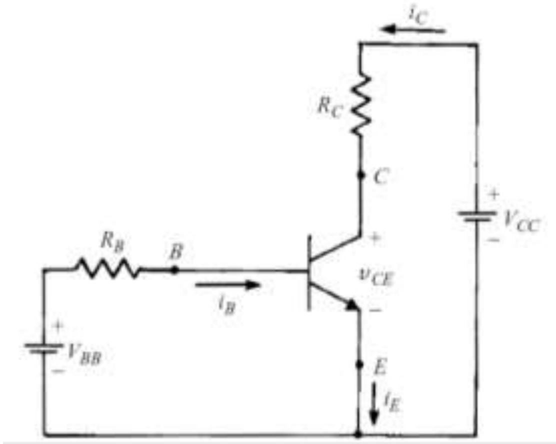
$$I_C = \beta I_B = 99(25\times10^{-6}) = 2.475mA$$

$$I_E = \frac{I_C}{\alpha} = \frac{2.475}{0.99} = 2.5mA$$

giving an emitter current error of

$$\frac{2.52-2.5}{2.52} \times 100\% = 0.793\%$$

3. In the circuit of Figure, β = 100; I_{BQ} = 20µA, V_{CC}=15 V and R_C= 3k. If I_{CBO}= 0, find (a) I_{EQ} b) V_{CEQ}. (c) Find V_{CEQ} if R_C is changed to 6 KΩ and all else remains the same.



a) From $\alpha = \frac{\beta}{1+\beta} = 0.9901$

Now, with I_{CBO}=I_{CEO}=0, we get

$$I_{CQ} = \beta I_{BQ} = 2mA$$

$$I_{EQ} = \frac{I_{CQ}}{\alpha} = \frac{2mA}{0.9901} = 2.02mA$$

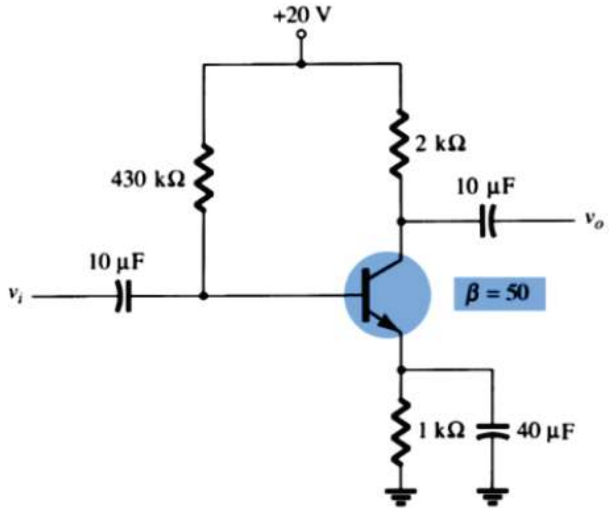
b) From an application of KVL around the collector circuit,

$$V_{CBQ} = V_{CC} - I_{CQ} R_C = 15 - (2mA \times 3k) = 9V$$

c) If I_{BQ} is unchanged, then I_{CQ} is unchanged.

$$V_{CBQ} = V_{CC} - I_{CQ} R_C = 15 - (2mA \times 6k) = 3V$$

4. For the emitter bias circuit shown below, determine collector current *Ic (in mA)*. Assume V_{BE} = 0.7 V



Consider the unit of I_C, I_B in mA

$V_E = I_E \times (1\ k\Omega) = (I_c + I_B) \times 1\ k\Omega = I_C + I_B = (1 + \beta)\ I_B = 51 I_B$

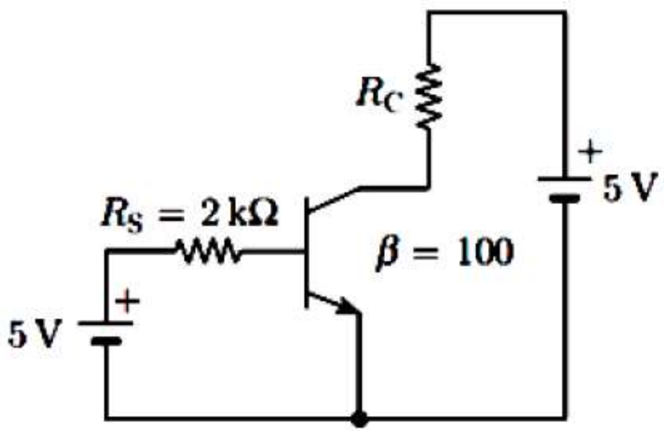
$V_B = 20 - 430\ I_B$

$V_B - V_E = 0.7$ V

⇨ $20 - 430\ I_B - 51\ I_B = 0.7$

⇨ $I_c = 50\ I_B = 2.006$

5. The transistor in the given circuit should always be in the active region. Take $V_{CE(Sat)}$ = 0.2 V, V_{BE} = 0.7 V. What is the maximum value of R_c in Ω which can be used?



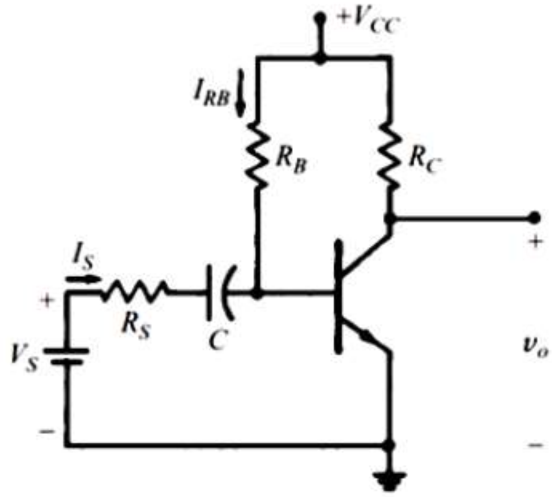
$5 - R_S I_B = V_{BE} = 0.7$

⇨ $I_C = 100 I_B = (100*4.3/2)$ mA = 0.215 A

$5 - R_C I_C = V_{CE} > 0.2$

⇨ $R_C < 4.8/I_C = 22.32\ \Omega$

6. In the circuit of given figure Vcc = 12 V, Vs = 2V, Rc = 4 kΩ, and R = 100 kΩ. The Ge transistor is characterized by β= 50; I_{CEO} = 0, and V = 0.2V. Find the value of R (in kΩ) that just results in saturation if the capacitor is replaced with a short circuit. V_{BE} for germanium transistor = 0.3 V



$V_B = 2 - 100\ I_S$

⇨ $I_S = 0.017$ mA

$I_C = \beta\ (I_S + (12 - 0.3)/R_B) = 12 - V_{CE} / 4$

⇨ $R_B = 278.57$ kΩ