

SOLVED PROBLEMS

Problem 1. A transistor has $\alpha = 0.99$. If it is connected in CE mode what would be the change in collector current for a change of $10 \mu\text{A}$ in base current?

Solution:

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

$$\text{Now } \beta = \frac{\Delta I_C}{\Delta I_B}$$

$$\therefore \Delta I_C = \beta \Delta I_B = 99 \times 10 \mu\text{A} = 0.99 \text{ mA.}$$

Problem 2. In a transistor connected in CE mode if the base current is changed from $20 \mu\text{A}$ to $30 \mu\text{A}$ at a fixed $V_{CE} = 7.5 \text{ V}$, the collector current changes from 2.2 mA to 3.2 mA . Find $\beta_{a.c.}$ and also $\beta_{d.c.}$ at the mean operating point.

Solution:

$$\beta_{a.c.} = \left. \frac{\Delta I_C}{\Delta I_B} \right|_{V_{CE}=\text{constant}}$$

$$= \frac{3.2 \text{ mA} - 2.2 \text{ mA}}{30 \mu\text{A} - 20 \mu\text{A}} = \frac{1 \text{ mA}}{10 \mu\text{A}} = 100$$

$$\beta_{d.c.} = \frac{I_C}{I_B} = \frac{(3.2 + 2.2) \text{ mA} \div 2}{(30 + 20) \mu\text{A} \div 2} = \frac{2.7 \text{ mA}}{25 \mu\text{A}} = 108.$$

Problem 3. The transistor of Fig. 5.P-3 has $\beta = 100$. Determine the region of operation and the values of I_B , I_C and V_{CE} for R_B equal to (i) $500 \text{ k}\Omega$ and (ii) $120 \text{ k}\Omega$. Neglect reverse saturation current.

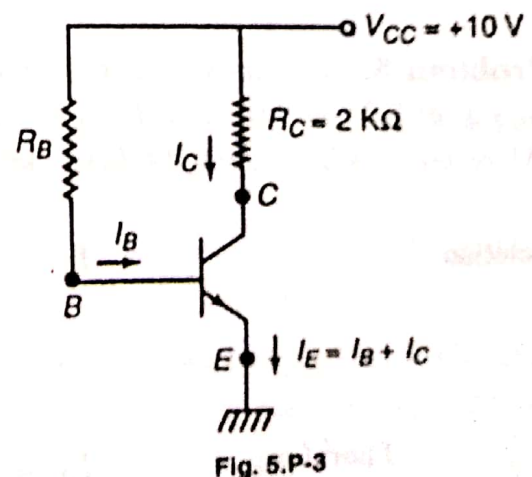
Solution: Since the emitter is grounded and the base is at some +ve potential, $V_{BE} > 0$. Thus the emitter-base junction is forward-biased. To determine the biasing of collector junction we are to calculate V_{CB} . To begin with we assume that the transistor is in the active region.

$$\begin{aligned} \text{(i) Now } I_B &= \frac{V_{CC} - V_{BE}}{R_B} \\ &= \frac{10 \text{ V} - 0.7 \text{ V}}{500 \text{ k}\Omega} = 18.6 \mu\text{A} \end{aligned}$$

$$I_C \approx \beta I_B = 100 \times 18.6 \mu\text{A} = 1.86 \text{ mA}$$

$$\begin{aligned} V_{CE} &= V_{CC} - I_C R_C \\ &= 10 \text{ V} - 1.86 \text{ mA} \times 2 \text{ k}\Omega \\ &= 6.28 \text{ V} \end{aligned}$$

$$\begin{aligned} V_{CB} &= V_{CE} - V_{BE} = 6.28 \text{ V} - 0.7 \text{ V} \\ &= 5.58 \text{ V} \end{aligned}$$



It indicates that the collector junction of the $n-p-n$ transistor is reverse-biased. Thus the transistor is really in the active region.

(ii) For the second case

$$I_B = \frac{10\text{ V} - 0.7\text{ V}}{120\text{ k}\Omega} = 77.5\text{ }\mu\text{A}$$

$$I_C \approx 100 \times 77.5\text{ }\mu\text{A} = 7.75\text{ mA}$$

$$\begin{aligned} V_{CE} &= 10\text{ V} - 7.75\text{ }\mu\text{A} \times 2\text{ k}\Omega \\ &= -5.5\text{ V} \end{aligned}$$

$$\begin{aligned} V_{CB} &= V_{CE} - V_{BE} = -5.5\text{ V} - 0.7\text{ V} \\ &= -6.2\text{ V} \end{aligned}$$

Since for an $n-p-n$ transistor collector is $-ve$ with respect to the base, the collector junction is forward biased and the transistor is in the saturation region. So our initial assumption is not true. In the saturation region $V_{BE,\text{sat}} = 0.8\text{ V}$ and $V_{CE,\text{sat}} = 0.2\text{ V}$. Therefore,

$$I_B = \frac{10\text{ V} - 0.8\text{ V}}{120\text{ k}\Omega} = 0.076\text{ mA}$$

$$\text{and } I_C = \frac{V_{CC} - V_{CE,\text{sat}}}{R_C} = \frac{10\text{ V} - 0.2\text{ V}}{2\text{ k}\Omega} = 4.9\text{ mA}.$$

Problem 4. Consider the problem 3. with $R_B = 500\text{ k}\Omega$ and calculate the collector power dissipation.

Solution: As shown in Problem 3

$$I_C = 1.86\text{ mA}, \quad V_{CE} = 6.28\text{ V}$$

Therefore, the collector power dissipation is

$$P_C = V_{CE} \cdot I_C = (6.28\text{ V})(1.86\text{ mA}) = 11.68\text{ mW}$$

Problem 5. A transistor in CE mode is connected with a resistance $5\text{ k}\Omega$ and a power supply of 5 V in the collector circuit. If $\alpha = 0.998$ and the voltage drop across the $5\text{ k}\Omega$ resistor is 5 V , find the base current. (C.U. 2000)

Solution:

$$I_C = \frac{5\text{ V}}{5\text{ k}\Omega} = 1\text{ mA}$$

$$\beta = \frac{\alpha}{1 - \alpha} = \frac{0.998}{1 - 0.998} = 499$$

$$\text{Therefore, } I_B = \frac{I_C}{\beta} = \frac{1\text{ mA}}{499} \approx 2\text{ }\mu\text{A}.$$

Problem 6. Suppose the transistor of Fig. 5.P-6 has $\beta = h_{FE} = 100$. Find (i) whether the transistor is operating in the active, saturation or cut-off region (ii) the value of output voltage V_0 . Assume $|V_{BE}| = 0.7 \text{ V}$ and $|V_{CE,\text{sat}}| = 0.2 \text{ V}$. (C.U. 1998)

Solution: At first we assume that the transistor is operating in the active region. Now

$$I_C = \beta I_B$$

$$I_E = I_B + I_C = (1 + \beta)I_B$$

Therefore, using KVL to the circuit

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

$$\begin{aligned} \text{or, } I_B &= \frac{V_{BB} + V_{BE}}{R_B + (1 + \beta)R_E} \\ &= \frac{3 \text{ V} - 0.7 \text{ V}}{100 \text{ k}\Omega + (1 + 100)0.5 \text{ k}\Omega} \\ &= 0.0153 \text{ mA} \end{aligned}$$

$$I_C = \beta I_B = 1.53 \text{ mA}$$

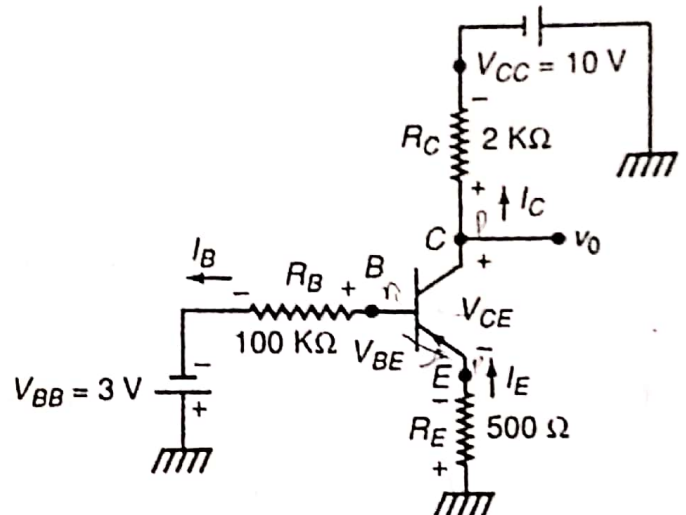


Fig. 5.P-6

Using KVL to the collector circuit,

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

$$\begin{aligned} V_{CE} &= -V_{CC} + I_C(R_C + R_E) \quad [\because I_E \approx I_C] \\ &= -10 \text{ V} + 1.53 \text{ mA}(2 \text{ k}\Omega + 0.5 \text{ k}\Omega) = -6.175 \text{ V} \end{aligned}$$

Therefore, the collector of the given $p-n-p$ transistor is forward biased. Since $|V_{CE}| > V_{CE,\text{sat}}$, our assumption is correct, i.e., the transistor is operating in the active region. Now output V_0 is given by

$$V_{CC} - I_C R_C + V_0 = 0$$

$$\begin{aligned} \therefore V_0 &= -V_{CC} + I_C R_C \\ &= -10 \text{ V} + 1.53 \text{ mA} \times 2 \text{ k}\Omega \\ &= -6.94 \text{ V} \end{aligned}$$

Problem 7. For the transistor in Fig. 5.P-7 $\beta = h_{FE} = 50$, $V_{BE,\text{sat}} = 0.8 \text{ V}$ and $V_{CE,\text{sat}} = 0.2 \text{ V}$. Find the limiting value of R_B for which the transistor will be driven into saturation.

Solution: Assuming that the transistor is operating in the saturation region we can write

$$\begin{aligned} I_{C,\text{sat}} &= \frac{V_{CC} - V_{CE,\text{sat}}}{R_C} \\ &= \frac{5\text{ V} - 0.2\text{ V}}{1\text{ k}\Omega} = 4.8\text{ mA}. \end{aligned}$$

Now the minimum base current for saturation is

$$\begin{aligned} I_{B,\text{min}} &= \frac{I_{C,\text{sat}}}{h_{FE}} = \frac{4.8\text{ mA}}{50} = 0.096\text{ mA} \\ \therefore R_{B,\text{max}} &= \frac{V_{BB} - V_{BE}}{I_{B,\text{min}}} = \frac{5\text{ V} - 0.8\text{ V}}{0.096\text{ mA}} \\ &= 43.75\text{ k}\Omega. \end{aligned}$$

This is the value of R_B at the edge of saturation. Any value of R_B smaller than $43.75\text{ k}\Omega$ will increase I_B and hence the transistor will be driven into saturation.

Problem 8. The dynamic emitter resistance of a transistor operating in CB mode is $40\ \Omega$. The load resistance in collector circuit is $3\text{ k}\Omega$ and current gain of the amplifier is 0.985 . Calculate the voltage and the power gain.

Solution:

$$\begin{aligned} A_V &= \alpha_{a.c.} \cdot \frac{R_L}{r_e} = 0.985 \times \frac{3000\ \Omega}{40\ \Omega} = 73.87 \\ A_P &= \alpha_{a.c.}^2 \cdot \frac{R_L}{r_e} \\ &= \alpha_{a.c.} \times A_V = 0.985 \times 73.87 = 72.76. \end{aligned}$$

Problem 9. In a transistor operating in CE mode a constant base current of $20\ \mu\text{A}$ flows. The collector current changes from 3.0 mA to 3.5 mA when the collector-emitter voltage changes from 6 V to 12 V . Find the value of output resistance and β at 12 V .

Solution:

$$\begin{aligned} \text{Output resistance } r_o &= \frac{\Delta V_{CE}}{\Delta I_C} = \frac{12\text{ V} - 6\text{ V}}{3.5\text{ mA} - 3.0\text{ mA}} \\ &= 12\text{ k}\Omega \\ \beta &= \frac{I_C}{I_B} = \frac{3.5\text{ mA}}{20\ \mu\text{A}} \\ &= 175. \end{aligned}$$

Problem 10. Consider the circuit of Fig. 5.P-10. Find the value of R_B and R_C required to operate the transistor at $I_C = 1\text{ mA}$ and $V_{CE} = 5\text{ V}$. Assume $\beta_{d.c.} = 100$ and $V_{BE} = 0.7\text{ V}$.

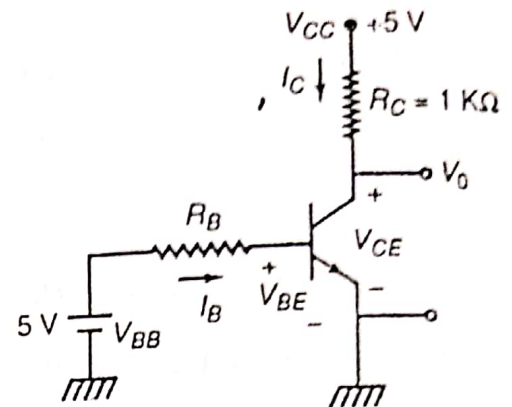


Fig. 5.P-7

Solution:

$$R_C = \frac{V_{CC} - V_{CE}}{I_C} = \frac{10 \text{ V} - 5 \text{ V}}{1 \text{ mA}} = 5 \text{ k}\Omega$$

$$I_B \approx \frac{I_C}{\beta_{d.c.}} = \frac{1 \text{ mA}}{100} = 0.01 \text{ mA}$$

$$R_B = \frac{V_{BB} - V_{BE}}{I_B} = \frac{5 \text{ V} - 0.7 \text{ V}}{0.01 \text{ mA}} = 430 \text{ k}\Omega$$

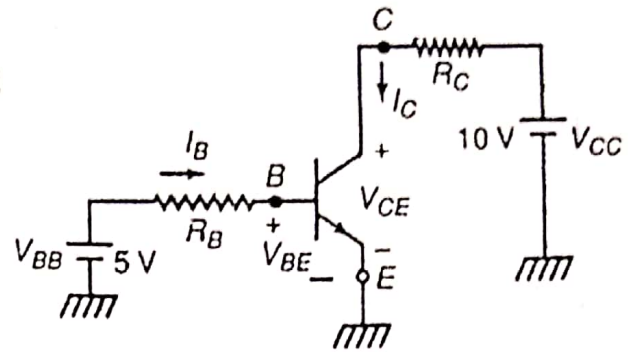


Fig. 5.P-10

Problem 11. The transistor in Fig. 5.P-11 has $\beta = 100$ and $I_{CBO} = 20 \text{ nA}$. Calculate I_B , I_C , V_{CE} and hence decide in which region the transistor operates. Given $V_{BE, \text{active}} = 0.7 \text{ V}$; $V_{BE, \text{sat}} = 0.8 \text{ V}$; $V_{CE, \text{sat}} = 0.2 \text{ V}$. (C.U. 1997; cf. C.U. 2010)

Solution: At first we assume that the transistor is operating in active region. Now

$$I_E = I_B + I_C \approx I_B + \beta I_B = (1 + \beta) I_B$$

$\therefore$ Applying KVL to the base circuit we get

$$V_{BB} = I_B R_B + V_{BE} + I_E R_E$$

$$\begin{aligned} \therefore I_B &= \frac{V_{BB} - V_{BE}}{R_B + (1 + \beta) R_E} \\ &= \frac{5 \text{ V} - 0.7 \text{ V}}{50 \text{ k}\Omega + 101 \times 2 \text{ k}\Omega} \\ &= 17.06 \mu\text{A} \end{aligned}$$

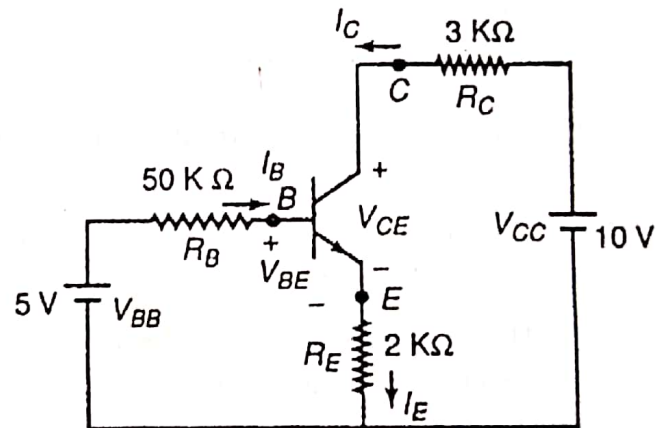


Fig. 5.P-11

$$\begin{aligned} I_C &= \beta I_B + (1 + \beta) I_{CBO} \\ &= 100 \times 17.06 \mu\text{A} + 101 \times 20 \text{ nA} \\ &= 1.708 \text{ mA} \end{aligned}$$

Application of KVL to collector circuit yields

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

$$\begin{aligned} \therefore V_{CE} &= V_{CC} - I_C (R_C + R_E) \quad [\because I_E \approx I_C] \\ &= 10 - 1.708 \text{ mA} \times 5 \text{ k}\Omega \\ &= 1.46 \text{ V} \end{aligned}$$

Since $V_{CE} > V_{CE, \text{sat}}$ our assumption is correct i.e., the transistor is operating in the active region.