Electrical Science: 2021-22

Tutorial 11

BJT Circuits

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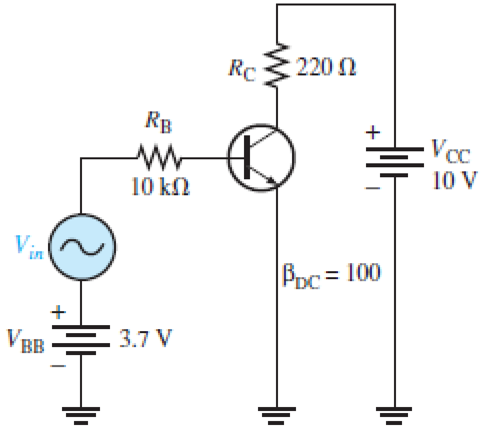
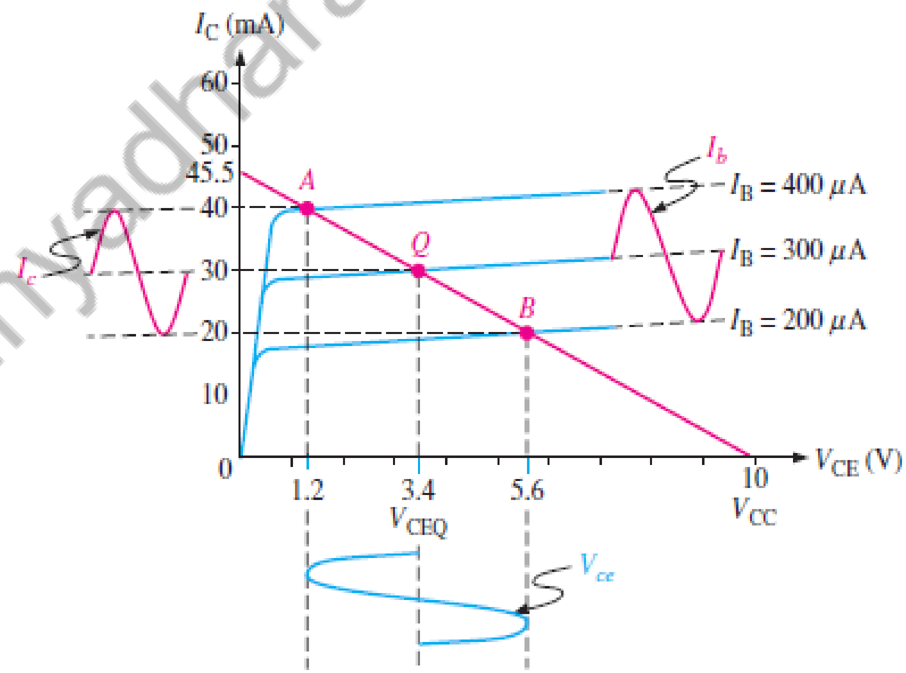
Example 1

Find the operating conditions of the circuit given below





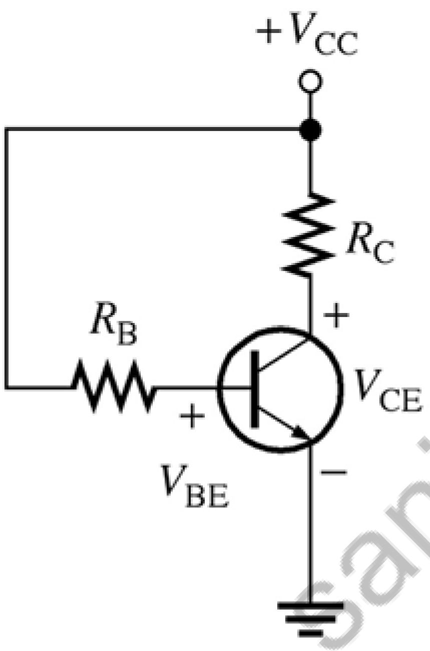
$$I_{BQ} = \frac{V_{BB} - 0.7\text{ V}}{R_B} = \frac{3.7\text{ V} - 0.7\text{ V}}{10\text{ k}\Omega} = 300\ \mu\text{A}$$

$$I_{CQ} = \beta_{DC} I_{BQ} = (100)(300\ \mu\text{A}) = 30\text{ mA}$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_C = 10\text{ V} - (30\text{ mA})(220\ \Omega) = 3.4\text{ V}$$

Example 2

Determine the Q-point values of I_C and V_{CE} for the circuit in Figure. V_{CC} = 8 V, $\boldsymbol{\beta} = 100$ R_B = 360 k$\boldsymbol{\Omega}$ and R_C = 2 k$\boldsymbol{\Omega}$.



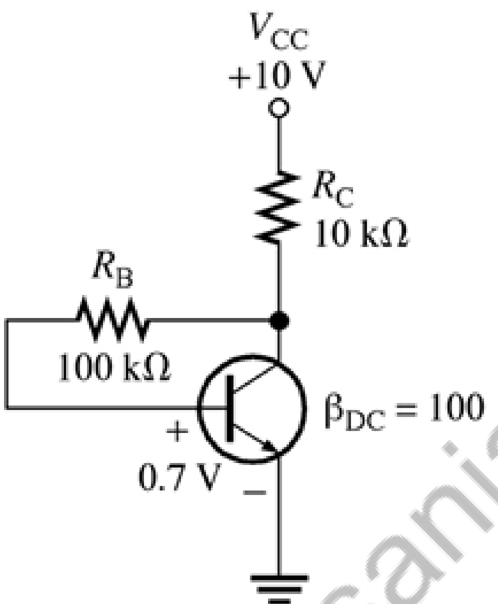
$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{8V - 0.7V}{360K\Omega} = 20.28\mu A$$

$$I_C = \beta_{DC} I_B = 100 * 20.28\mu A = 2.028mA$$

$$V_{CE} = V_{CC} - I_C R_C = 8V - (2.028mA)(2K\Omega) = 3.94V$$

Example 3

Calculate the Q-point values.



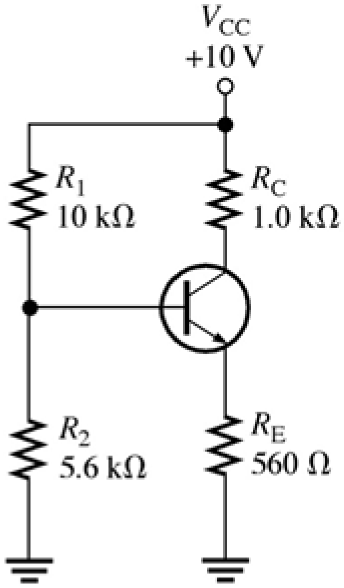
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta_{DC}+1)R_C} = \frac{10 - 0.7}{100 + (100+1)} = 8.38\ \mu A$$

$$I_C = \frac{\beta_{DC}(V_{CC} - V_{BE})}{R_B + (\beta_{DC}+1)R_C} = 100 \times 8.38\ \mu A = 0.838\ mA$$

$$V_{CE} = V_{CC} - (I_C + I_B)R_C = 10 - (0.838 + 0.00838) \times 10$$
$$= 1.536\ V$$

Example 4

Determine V_{CE} and I_C in the voltage-divider biased transistor circuit. Assume β_{DC} = 100 and $I_E \simeq I_C$



$$V_{TH} = \frac{R_2}{R_1 + R_2} V_{CC} = \frac{5.6}{10 + 5.6} \times 10 = 3.59 \text{ V}$$

$$R_{TH} = R_1 // R_2 = 5.6//10 = 3.59 \text{ k}\Omega$$

$$I_B = \frac{V_{TH} - V_{BE}}{R_{TH} + (\beta_{DC} + 1) R_E} = \frac{3.59 - 0.7}{3.59 \text{ k}\Omega + (100 + 1) 560 \, \Omega}$$

$$= 48.046 \, \mu A$$

$$I_{CQ} = \frac{\beta_{DC}(V_{TH} - V_{BE})}{R_{TH} + (\beta_{DC} + 1) R_E} = 100 \times 48.046 \, \mu A$$

$$= 4.805 \text{ mA}$$

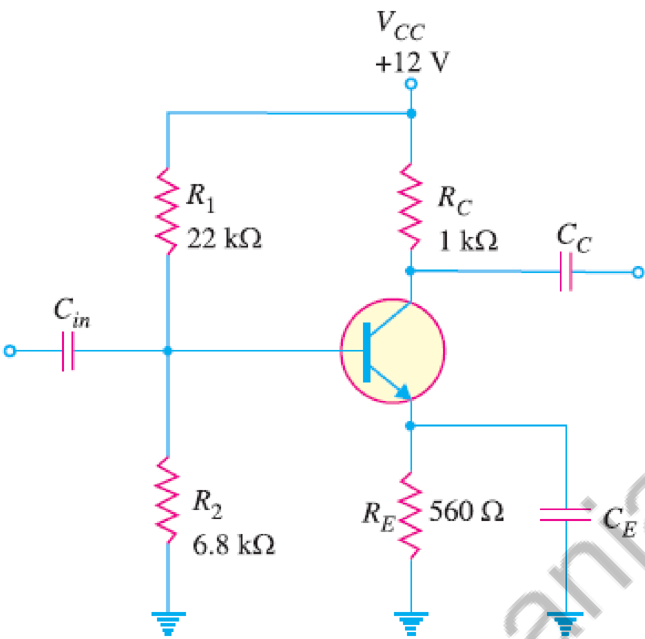
$$V_{CEQ} \approx V_{CC} - (R_C + R_E) I_{CQ}$$

$$\approx 10 - (1 \text{ k}\Omega + 560 \, \Omega) \times 4.805 \text{ mA}$$

$$= 2.504 \text{ V}$$

Example 5

Find emitter bypass capacitor in Figure if the amplifier is to operate over a frequency range from 2 kHz to 10 kHz.



$$X_{C_E} = \frac{R_E}{10}$$

In the given problem, $f_{min} = 2\text{kHz}$; $R_E = 560\Omega$.

$$\therefore \quad 10\ X_{C_E} = 560$$

or $$X_{C_E} = 560/10 = 56\Omega$$

or $$\frac{1}{2\pi\ f_{min}\ C_E} = 56$$

$$C_E = \frac{1}{2\pi\ f_{min}\ 56} = \frac{1}{2\pi \times (2 \times 10^3) \times 56} = 1.42 \times 10^{-6}\ F = \mathbf{1.42\ \mu F}$$

Example 6

In a CE amplifier, if R_C = 10 kΩ, R_L = 10 kΩ, R_{in}= 2.5 kΩ, β =100, find the output voltage for an input voltage of 1mV r.m.s

$$\text{Effective load, } R_{AC} = \frac{R_C \times R_L}{R_C + R_L} = \frac{10 \times 10}{10 + 10} = 5\text{ k}\Omega$$

$$\text{Voltage gain} = \beta \times \frac{R_{AC}}{R_{in}} = 100 \times \frac{5\text{ k}\Omega}{2.5\text{ k}\Omega} = 200$$

$$\frac{V_{out}}{V_{in}} = 200$$

$$V_{out} = 200 \times V_{in} = 200 \times 1\text{ mV} = \mathbf{200\text{ mV}}$$

Example 7

In a transistor amplifier, when the signal changes by 0.02V, the base current changes by 10 μA and collector current by 1mA. If collector load R_C = 5 kΩ and R_L= 10 kΩ, find: (i) current gain (ii) input impedance (iii) a.c. load (iv) voltage gain (v) power gain

$$\Delta I_B = 10\ \mu A,\ \Delta I_C = 1 mA,\ \Delta V_{BE} = 0.02\ V,\ R_C = 5\ k\Omega,\ R_L = 10\ k\Omega$$

$$\text{Input impedance, } R_{in} = \frac{\Delta V_{BE}}{\Delta I_B} = \frac{0.02\ V}{10\ \mu A} = 2\ k\Omega$$

$$\text{Current gain, } \beta = \frac{\Delta I_C}{\Delta I_B} = \frac{1\ mA}{10\ \mu A} = 100$$

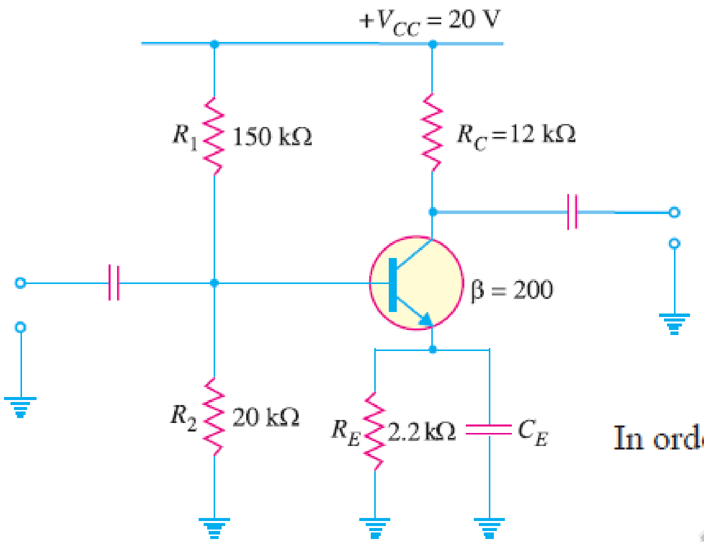
$$\text{a.c. load, } R_{AC} = \frac{R_C \times R_L}{R_C + R_L} = \frac{5 \times 10}{5 + 10} = 3.3\ k\Omega$$

$$\text{Voltage gain, } A_v = \beta \times \frac{R_{AC}}{R_{in}} = 100 \times \frac{3.3}{2} = 165$$

$$\text{Power gain, } A_p = \text{current gain} \times \text{voltage gain} = 100 \times 165 = 16500$$

Example 8

Determine the ac emitter resistance for the transistor circuit shown in Figure



In order to find D.C. I_E, we shall proceed as under :

$$\text{D.C. voltage across } R_2,\ V_2 = \frac{V_{CC}}{R_1 + R_2} \times R_2 = \frac{20}{150 + 20} \times 20 = 2.35 \text{ V}$$

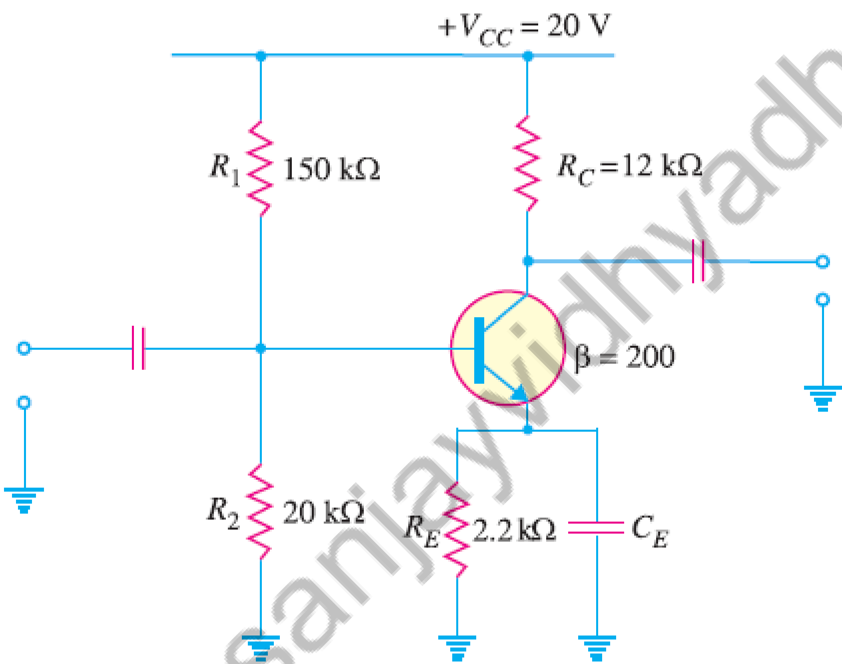
$$\text{D.C. voltage across } R_E,\ V_E = V_2 - V_{BE} = 2.35 - 0.7 = 1.65 \text{ V}$$

$$\therefore \quad \text{D.C. emitter current, } I_E = \frac{V_E}{R_E} = \frac{1.65\ V}{2.2\ \text{k}\Omega} = 0.75 \text{ mA}$$

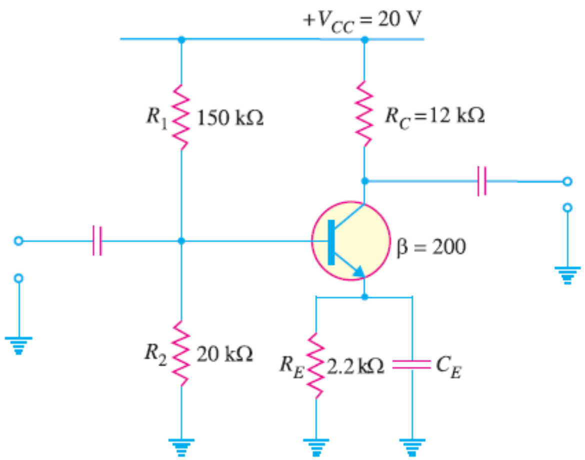
$$\therefore \quad \text{AC emitter resistance, } r_e' = \frac{25 \text{ mV}}{I_E} = \frac{25 \text{ mV}}{0.75 \text{ mA}} = 33.3\ \Omega$$

Example 9

For the amplifier circuit shown in Figure, find the voltage gain of the amplifier with (i) C_E connected in the circuit (ii) C_E removed from the circuit.



Example 9



In order to find D.C. I_E, we shall proceed as under :

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$$\therefore \quad \text{D.C. emitter current, } I_E = \frac{V_E}{R_E} = \frac{1.65\ V}{2.2 \text{ k}\Omega} = 0.75 \text{ mA}$$

$$\therefore \quad \text{AC emitter resistance, } r_e' = \frac{25 \text{ mV}}{I_E} = \frac{25 \text{ mV}}{0.75 \text{ mA}} = 33.3\ \Omega$$

With C_E connected :

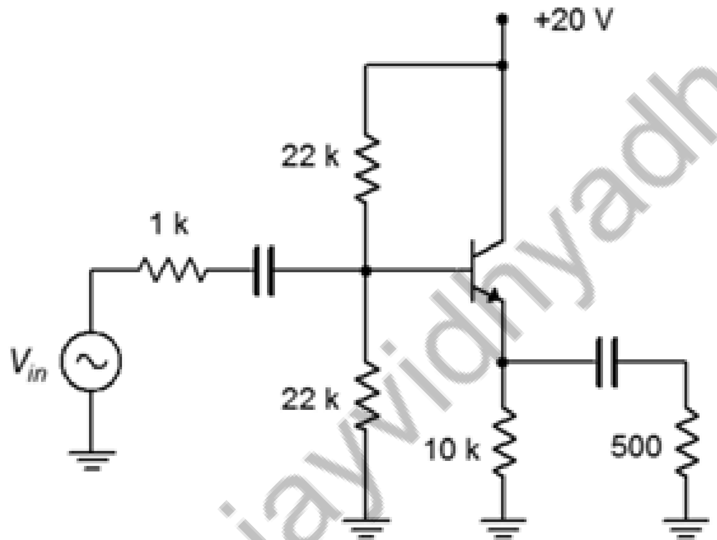
$$\text{Voltage gain, } A_v = \frac{R_C}{r_e'} = \frac{12 \text{ k}\Omega}{33.3\ \Omega} = \mathbf{360}$$

Without C_E :

$$\text{Voltage gain, } A_v = \frac{R_C}{r_e' + R_E} = \frac{12 \text{ k}\Omega}{33.3\ \Omega + 2.2 \text{ k}\Omega} = \mathbf{5.38}$$

Example 10

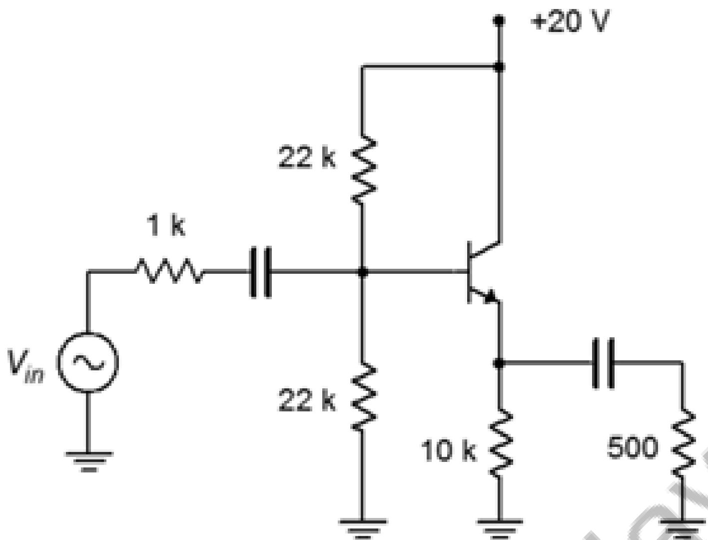
For the follower shown in Figure, determine the input impedance, output impedance and load voltage. Assume β=100 and *Vin*=100 mV.



Assuming an unloaded divider, *VB* will equal half of the DC supply, or 10 volts. We lose 0.7 volts across the base-emitter junction leaving 9.3 volts across the 10 kΩ. This results in a collector current of 930 μA and an $r'e$ of 28 Ω.

Example 10

For the follower shown in Figure, determine the input impedance, output impedance and load voltage. Assume β=100 and *Vin*=100 mV.



$r'e$ = 28 Ω.

$$Z_{in(base)} = \beta(r'_e + r_E)$$

$$Z_{in(base)} = 100(28\Omega + 10k\Omega||500\Omega)$$

$$Z_{in(base)} = 50.4k\Omega$$

$$Z_{in} = R_1||R_2||Z_{in(base)}$$

$$Z_{in} = 22k\Omega||22k\Omega||50.4k\Omega$$

$$Z_{in} = 9.03k\Omega$$

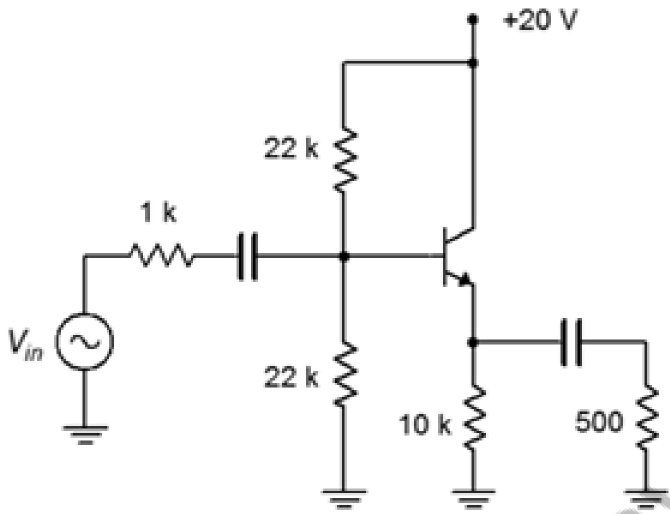
$$Z_{out} = R_E||\left(r'_e + \frac{r_B||r_{gen}}{\beta}\right)$$

$$Z_{out} = 10k\Omega||\left(28\Omega + \frac{22k\Omega||22k\Omega||1k\Omega}{100}\right)$$

$$Z_{out} = 37\Omega$$

Example 10

For the follower shown in Figure, determine the input impedance, output impedance and load voltage. Assume β=100 and Vin=100 mV.



$r'e = 28\ \Omega$.

$$A_v = \frac{r_E}{r'_e + r_E}$$

$$A_v = \frac{500\Omega||10k\Omega}{28\Omega + 500\Omega||10k\Omega}$$

$$A_v = 0.9444$$

$$A_{divider} = \frac{Z_{in}}{Z_{in} + Z_{source}}$$

$$A_{divider} = \frac{9.03k\Omega}{9.03k\Omega + 1k\Omega}$$

$$A_{divider} = 0.9$$

$$A_{v(system)} = A_v \times A_{divider}$$

$$A_{v(system)} = 0.9444 \times 0.9$$

$$A_{v(system)} = 0.85$$

$$V_{load} = A_{v(system)} \times V_{in}$$

$$V_{load} = 0.85 \times 100mV$$

$$V_{load} = 85mV$$

Thank you