Module – 3

Unit – 3

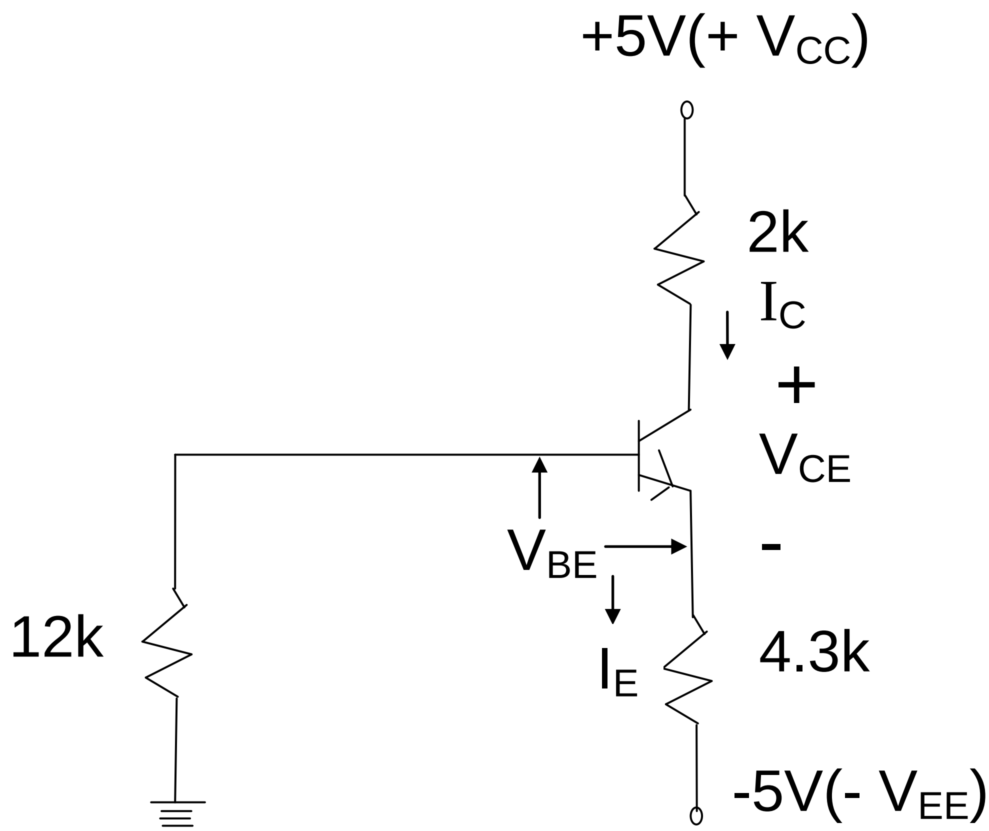
Small Signal BJT Amplifiers

Review Questions:

1. Define h – parameters for a transistor. Why are these called hybrid parameters? What are their units?
2. Out of four h – parameters, two are most important. Which are these? And why the other two have less significance?
3. h_i and Z_i both represent input impedance in h - and Z systems of parameters but they are most equal. Why?
4. What are r – parameters and how are they superior to h – parameters?
5. Common – base (CB) amplifier has limited applications. Why?
6. Among BJT amplifiers, common-emitter amplifier is most favoured. Give reasons.
7. What is an emitter follower? Discuss its main applications.
8. What are, in general, performance parameters of an amplifier?

Problems:

3.1 Calculate dynamic emitter resistance r'_e (also called ac emitter resistance) of the transistor in the circuit of fig.(V_{BE} = 0.7V)



Solution:-

The dynamic emitter resistance, $r_e^{'}$, is expressed as,

$$r'_e = \frac{25mv}{I_E}$$

Where I_E is dc emitter current.

The dc emitter current in the circuit (i.e, voltage drop across resistor R_E, divided by the resistance) is

$$I_E = \frac{V_{EE} - V_{BE}}{R_E} = \frac{5-0.7}{4.3\times10^3} = 1mA$$

Therefore,

$$r'_e = \frac{25\,mV}{1mA} = 25\Omega$$

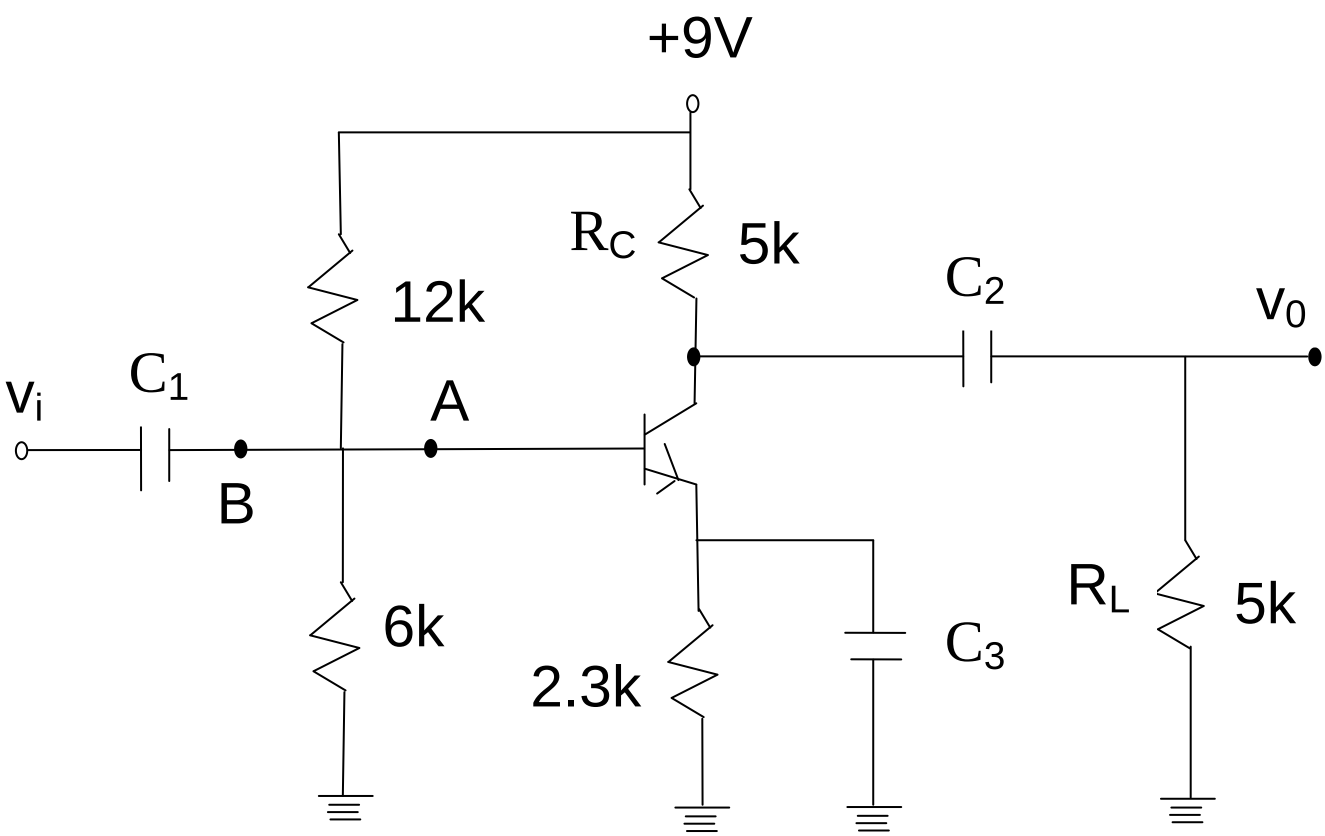
That is,

$r_e^{'}$ = 25 Ω

3.2 How much is the voltage gain of the amplifier (fig) if the dynamic emitter resistance, r'_e, is 25 Ω. The current gain of the transistor is 80.

How much is input impedance of the amplifier.

The coupling and bypass capacitors may be assumed of negligible impedance at the signal frequency. Take V_{BE} = 0.7V



Solution:-

The voltage gain A_V, for a common emitter amplifier with resistor R_E by- passed is

$$A_V = \frac{r_c}{r'_e}$$

Where r_c is effective (ac) impedance seen by the collector and it is

$r_c = R_c || R_L = 5k || 5k = 2.5\ k\Omega$

And $r_e' = 25\Omega$ (given)

Therefore,

$$A_V = \frac{2.5 \times 10^3 \Omega}{25\Omega} = 100$$

First we find out impedance between base (point A in Fig 3.2) and ground, $Z_{i(base)}$ and we know, it is given by

$Z_{i(base)} = \beta\ r_e'$

$= 80 \times 25$

or $Z_{i(base)} = 2\ k\Omega$

And, input impedance of the amplifier $Z_{i(amp)}$ is,

$Z_{i(amp)} = R_B || Z_{i(base)}$

Where R_B is effective biasing resistance, and

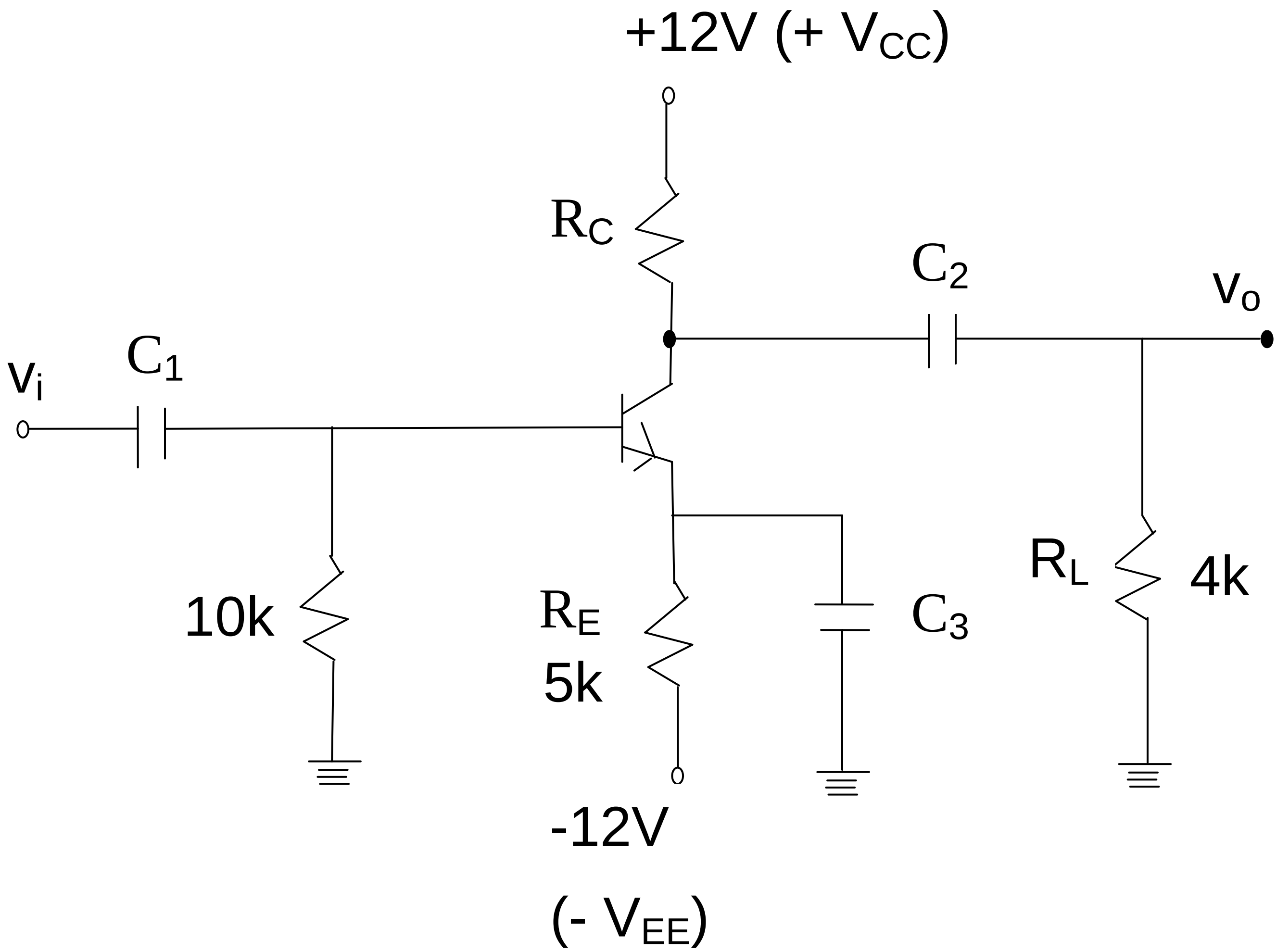
$R_B = R_1 || R_2 = 12k || 6k = 4\ k\Omega$

Therefore,

$Z_{i(amp)} = 4k || 2k$

or $Z_{i(amp)} = 1.33\ k\Omega$

3.3 Calculate the value of resistor R_C so that the voltage gain of the amplifier in fig is 100. Capacitors C_1, C_2, and C_3 may be assumed short at signal frequency.



Solution:-

In case, R_E is by-passed, the voltage gain A_v of the amplifier is,

$$A_V = \frac{r_c}{r'_e}$$

Where r_c is the effective (ac) resistance seen by the collector of the transistor, and $r_e^{'}$ is the dynamic resistance of the emitter.

We know,

$$r'_e = \frac{25mv}{I_E}$$

Now,

$$I_E = \frac{V_{EE} - V_{BE}}{R_E} = \frac{12.0 - 0.7}{5 \times 10^3} = 2.26\,mA$$

Therefore,

$$r'_e = \frac{25\,mV}{2.26\,mA} \approx 11\,\Omega = 0.011k\Omega$$

And,

$$R_c = R_C \| R_L = \frac{4R_C}{R_C + 4}$$

Where resistances have been taken in kΩ

Therefore,

$$A_V = \frac{r_c}{r'_e}$$

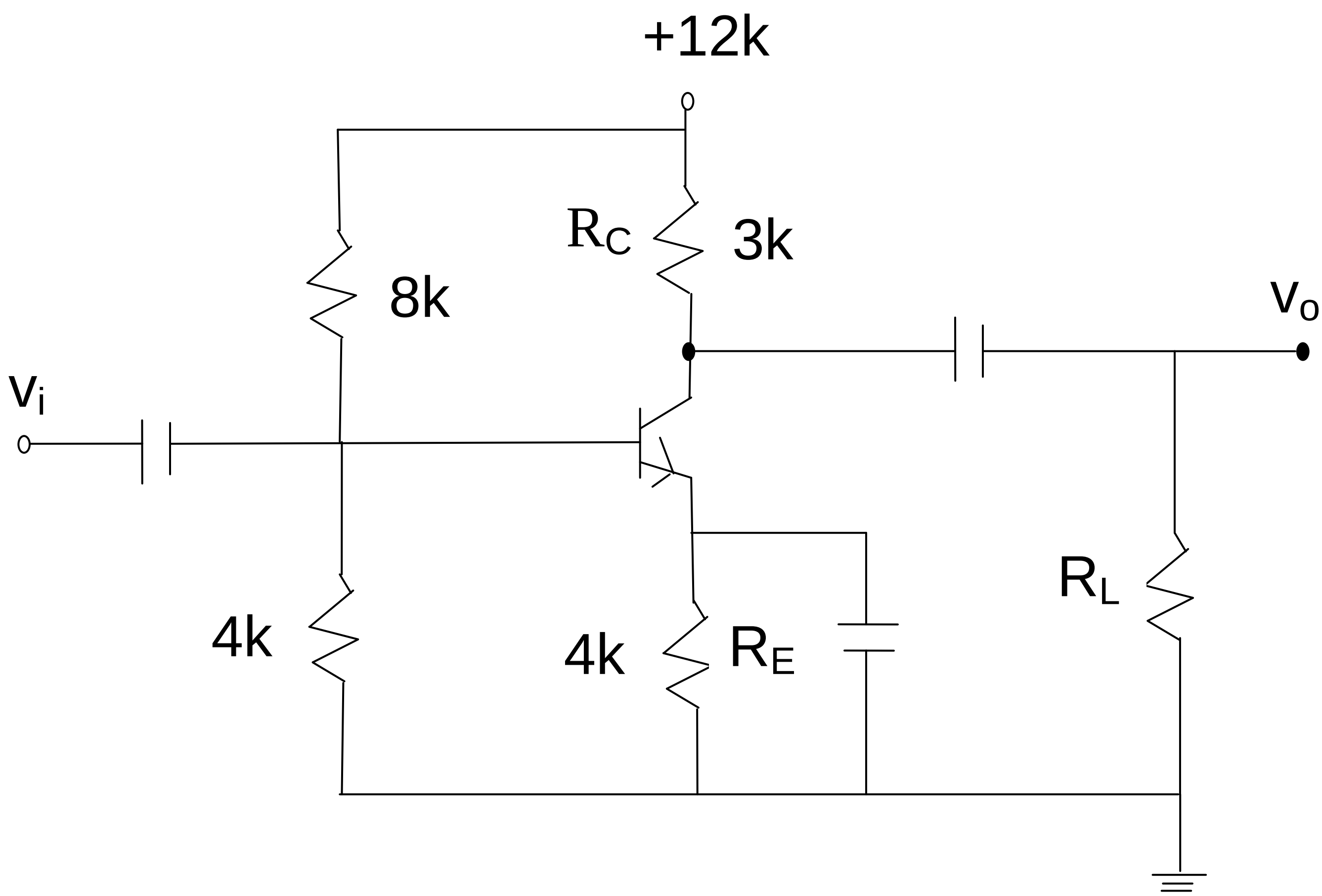
$$= \left(\frac{4R_c}{R_c + 4}\right)\frac{1}{0.011}$$

As $A_v = 100$ (given), R_c (in kΩ) is,

$$100 = \frac{4R_c}{(R_c + 4)(0.011)}$$

$$or\ R_c = 1.51 k\Omega$$

3.4 Find out the smallest value of load R_L in the amplifier circuit shown in fig so that the voltage gain is at least 40. The dynamic emitter resistance of the transistor is 25 Ω. The coupling and by-pass capacitors may be assumed short at signal frequency.



Solution:-

The voltage gain of the common emitter amplifier with resistor R_E by-passed (see fig.) is expressed as

$$A_V = \frac{r_c}{r'_e} = 40 \quad (required \;\; gain)$$

Where r_c is effective ac impedance seen by the collector, Which is

$$r_c = R_C \,||\, R_L = \frac{R_C R_L}{R_C + R_L}$$

Taking resistances in kΩ

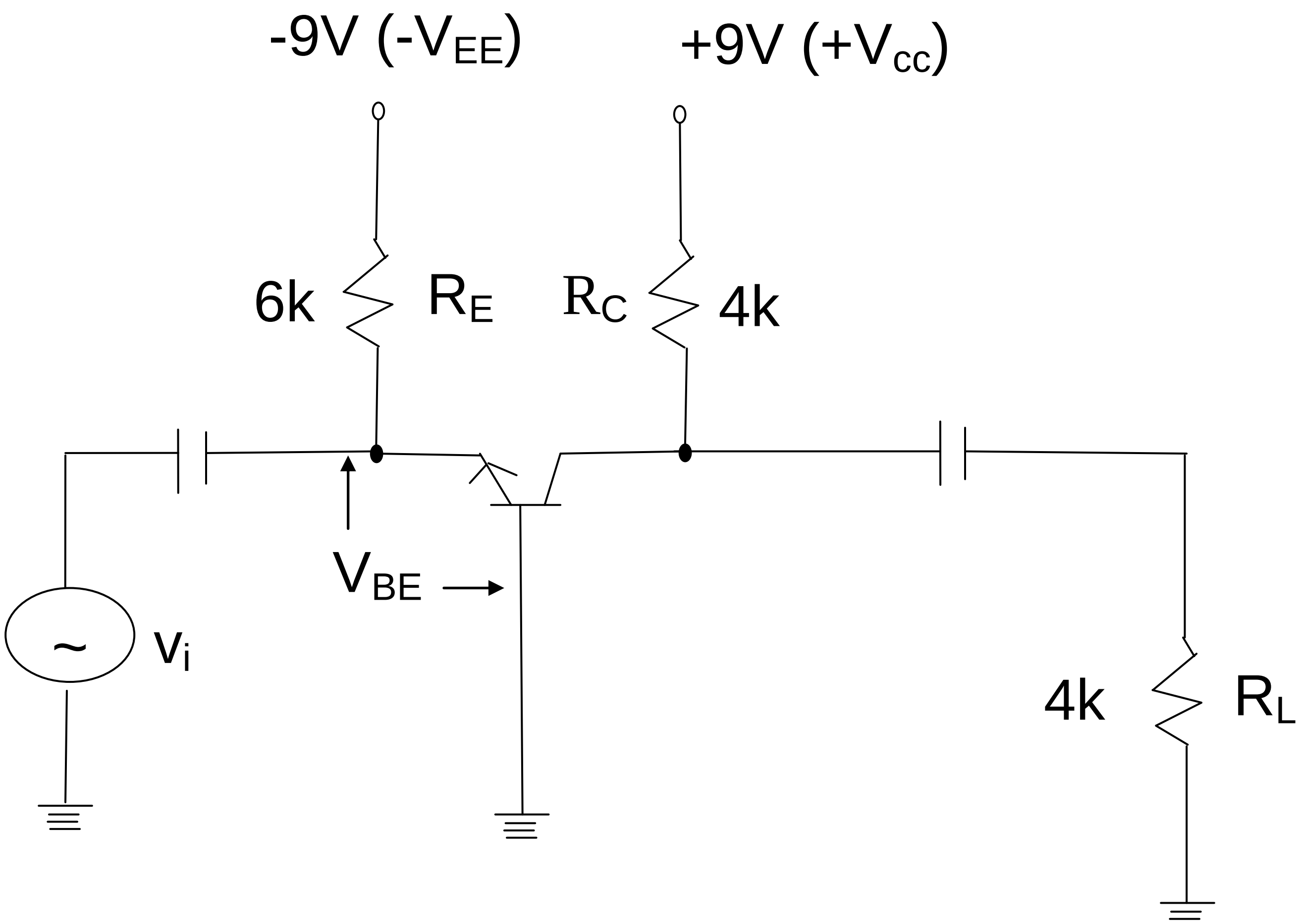
$$r_c = \frac{3R_L}{3 + R_L}$$

And,

$$A_V = \left(\frac{3R_L}{3 + R_L}\right)\frac{1}{25\times 10^{-3}} = 40$$

$$or \;\; R_L = 1.5 k\Omega$$

3.5 The silicon transistor in the common- base amplifier has the current gain α of 0.98. Find the input impedance and voltage gain of the amplifier in fig. (V_{BE} = 0.7V)



Solution:-

The dc voltage sources have to be grounded for ac analysis of the amplifier. Then the input impedance of the CB amplifier (in fig.) is

$Z_{i(amp)} = R_E || r'_e \approx r'_e$

Where r'_e is dynamic emitter resiatance and $r'_e << R_E$

Also,

$$r'_e = \frac{25mV}{I_E}$$

Where I_E is dc emitter current in the circuit

$$I_E = \frac{|V_{EE} - V_{BE}|}{R_E}$$

$$or,\ I_E = \frac{9 - 0.7}{6 \times 10^3} = 1.38\ mA$$

Therefore,

$$r'_e = \frac{25mV}{1.38mA} \approx 18\Omega$$

Thus, the input impedance $Z_{i(amp)}$ is,

$Z_{i(amp)} \approx r'_e = 18\Omega$

The low value of input impedance is the main reason for limited applications of CB amplifier.

The voltage gain of CB amplifier is expressed as,

$$A_V = \frac{\alpha\ r_c}{r'_e}$$

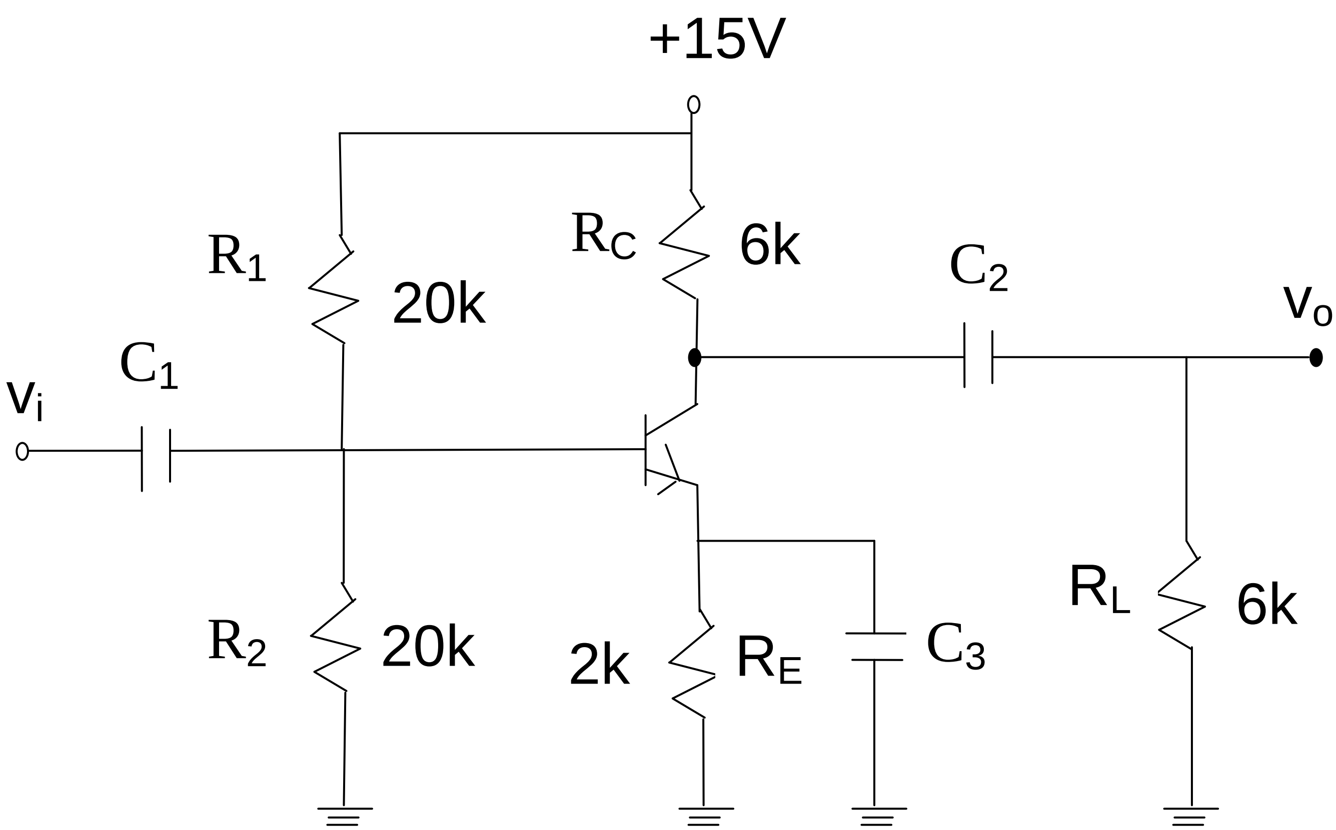
Since, $r_c = R_C || R_L = 4k || 4k = 2k\Omega = 2000\ \Omega$

Then ,

$$A_V = \frac{0.98 \times 2000}{18} = 108.8$$

$$A_V = 108.8$$

3.6 The transistor in the amplifier circuit shown in fig, has h – parameters, h_{ie} = 2kΩ and h_{fl} = 80. The values of h_{oe} and h_{re} are negligible. Calculate the voltage gain and input impedance $Z_{i(amp)}$ of the amplifier. Capacitors C_1, C_2, and C_3 may be assumed short at signal frequency due to small impedances.



Solution:-

The magnitude of voltage gain with h-parameters h_{oe} and h_{re} dropped, and emitter resistance R_E by-passed by capacitor C_3 is

$$A_V = \frac{h_{fe} . Z_l}{h_{ie}}$$

$$= \frac{80 \times 3k\Omega}{2k\Omega} = 120$$

Because the ac load at collector, Z_l, is

$Z_l = R_C || R_L = 6k || 6k = 3k\Omega$

Further, the impedance between base and ground , $Z_{i(base)}$ is,

$Z_{i(base)} = h_{ie} = 2k\Omega$

And, input impedance of amplifier, $Z_{i(amp)}$ is,

$Z_{i(amp)} = R_1 || R_2 || Z_{i(base)}$

$= 20k || 20k || Z_{i(base)}$

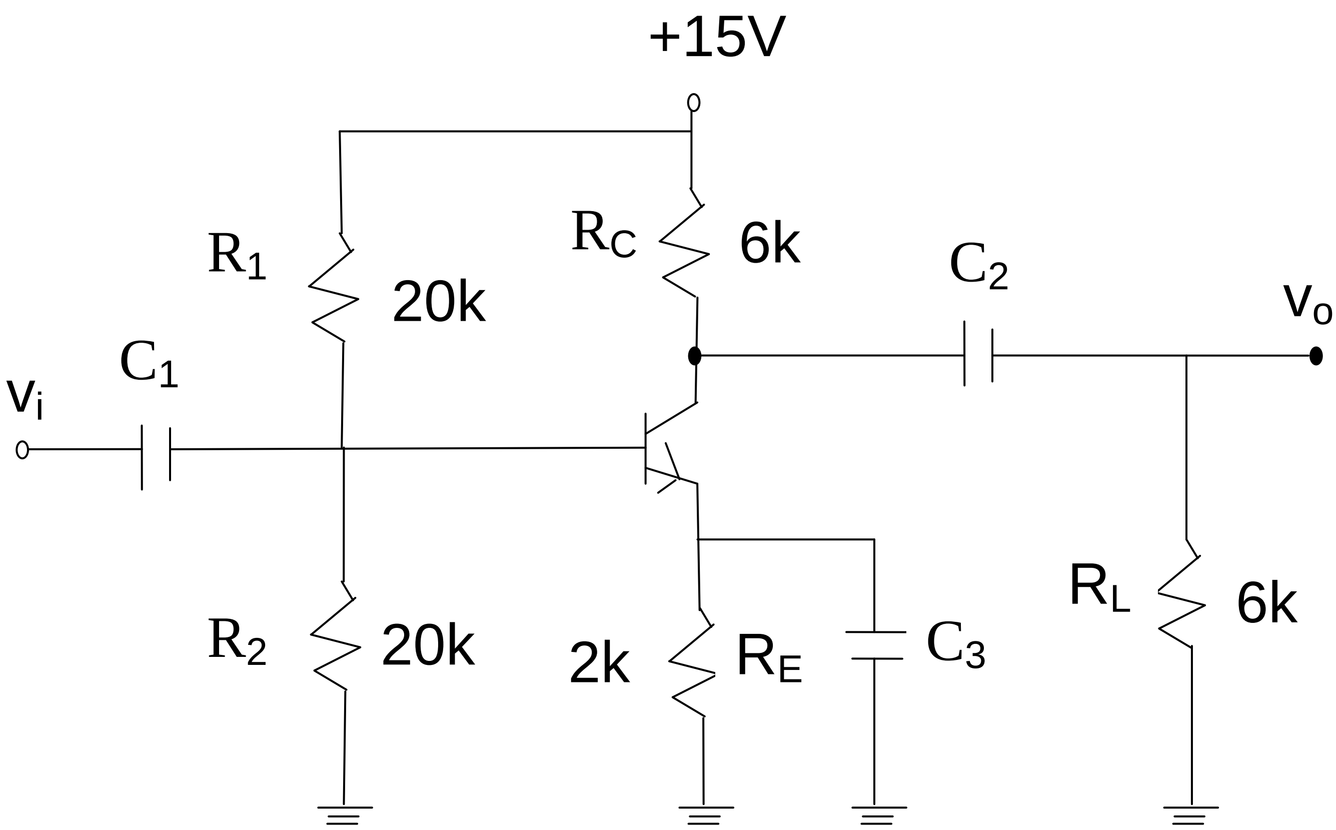
$= 10k || Z_{i(base)}$

$= 10k || 2k$

$= 1.6k\Omega$

or $Z_{i(amp)} = 1.6k\Omega$

3.7 For the amplifier circuit shown in fig. calculate the voltage gain and input impedance of the amplifier when by-pass capacitor C_3 is removed from the circuit.



Solution:-

With by-pass capacitor C_3 (in fig.) removed, the gain of a amplifier falls and input impedance of the amplifier increases.

In case R_E is not by-passed, the magnitude of voltage gain A_V is

$$A_V = \frac{Z_l}{R_E} = \frac{3k}{2k} = 1.5$$

And,

$Z_{i(base)} = h_{ie} + (1 + h_{fe}) R_E$

$= 2k + (1 + 80) X 2k$

Or, $Z_{i(base)} = 164\ k\Omega$

And, input impedance of amplifier, $Z_{i(amp)}$ is

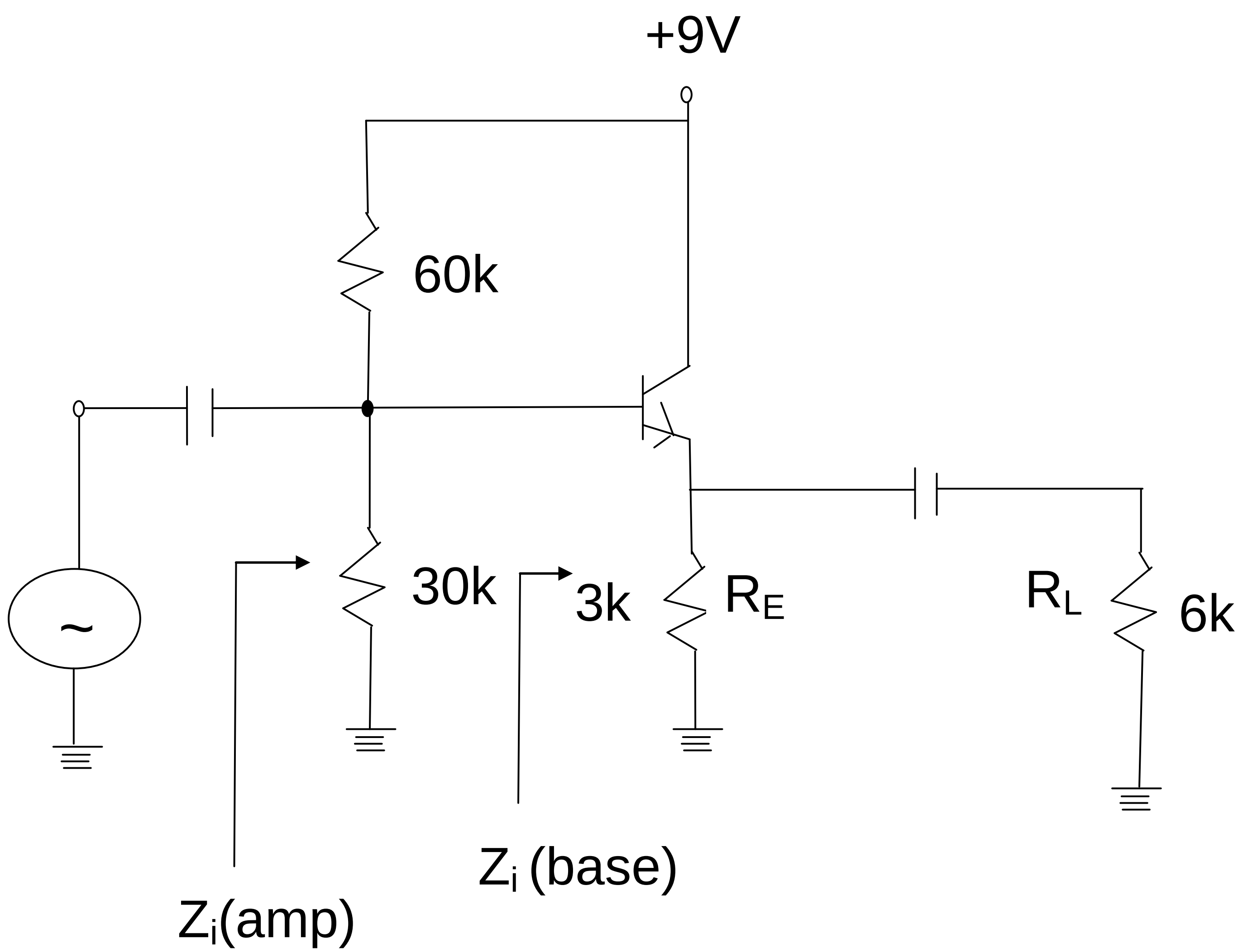
$Z_{i(amp)} = R_1 || R_2 || Z_{i(base)}$

$= 20k || 20k || 164\ k$

$10k || 164k \quad = 9.4\ k\Omega$

or $Z_{i(amp)} = 9.4\ k\Omega$

3.8 The emitter follower (common collector amplifier) shown in fig. uses a transistor with h-parameters h_{ie} = 4.5 kΩ, h_{fe} = 120. Other parameters h_{oe} and h_{re} have negligible effect on amplifier performance. Calculate voltage gain and input impedance of the amplifier. The coupling and by-pass capacitors may be assumed short at signal frequency.



Solution:-

Neglecting the effect of h_{oe} and h_{re} on amplifier performance, the voltage gain of emitter follower may be expressed as,

$$|A_V| = \frac{h_{fc} \times Z_e}{h_{ic} + h_{fc}.Z_e}$$

Where Z_e is the effective load seen by the emitter, and it is

$Z_e = R_E || R_L = 3k || 6k = 2\ k\Omega$

And using $h_{fc} \approx h_{fe}$ and $h_{ic} = h_{ie}$,

We have,

$$A_V = \frac{h_{fe} \times Ze}{h_{ie} + h_{fe} Z_e}$$

$$= \frac{120 \times 2k\Omega}{4k\Omega + (120 \times 2k\Omega)} = \frac{240}{244}$$

$$A_V = 0.98$$

The input impedance as seen at the base w.r.t ground is,

$Z_{i(base)} = h_{fc}.\ Z_e = h_{fe}.\ Z_e$

$= 120 \text{ X } 2\ k\Omega = 240\ k\Omega$

The input impedance of the amplifier (that is, after taking the effect of biasing resistors),

$Z_{i(amp)} = R_B || Z_{i(base)}$

And the effective base resistance R_B is,

$R_B = R_1 || R_2 = 60\ k || 30k = 20\ k\Omega$

Therefore,

$Z_{i(amp)} = 20k || 240k = 18.46\ k\Omega$

or $Z_{i(amp)} = 18.46\ k\Omega$