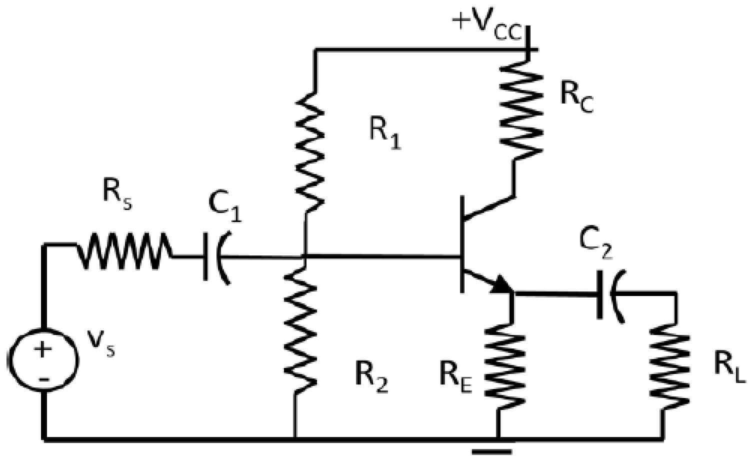
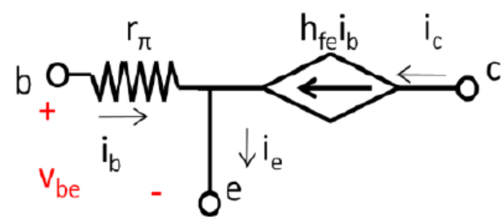
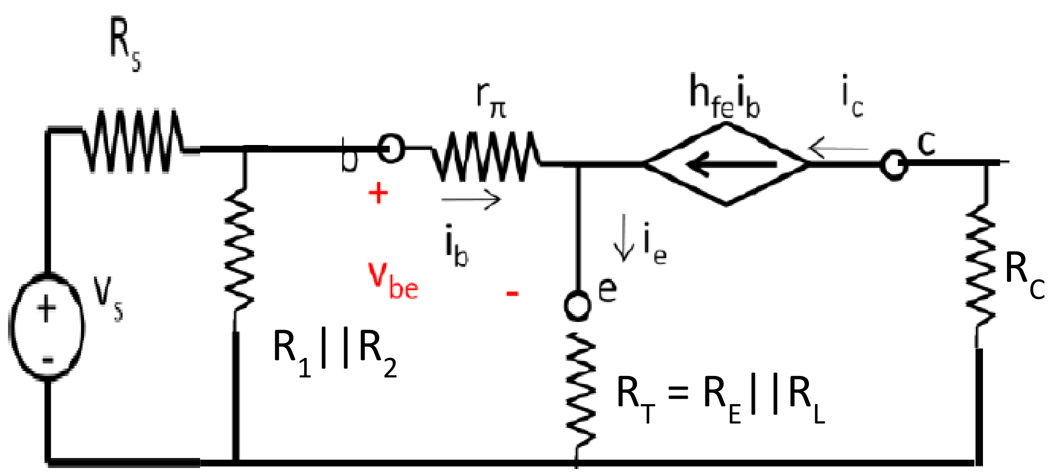
TUTORIAL 8 SOLUTIONS

Q 1)





The small signal equivalent of the circuit using small signal model of npn transistor given is as shown:



The output voltage v_o is the voltage across R_L i.e. $v_o = i_e R_T$.

$i_e = i_c + i_b$ and $i_c = h_{fe}\, i_b$ => $i_e = h_{fe}\, i_b + i_b = (1+h_{fe})\, i_b$

hence, $v_o = (1+h_{fe})\, i_b R_T$ -(1)

Similarly, in input loop

$$v_b = i_b r_\pi + (1+h_{fe}) i_b R_T \qquad \text{-(2)}$$

From (1) and (2), **Voltage gain,** $A_v = \dfrac{v_o}{v_b} = \dfrac{(1+h_{fe})R_T}{r_\pi + (1+h_{fe})R_T}$

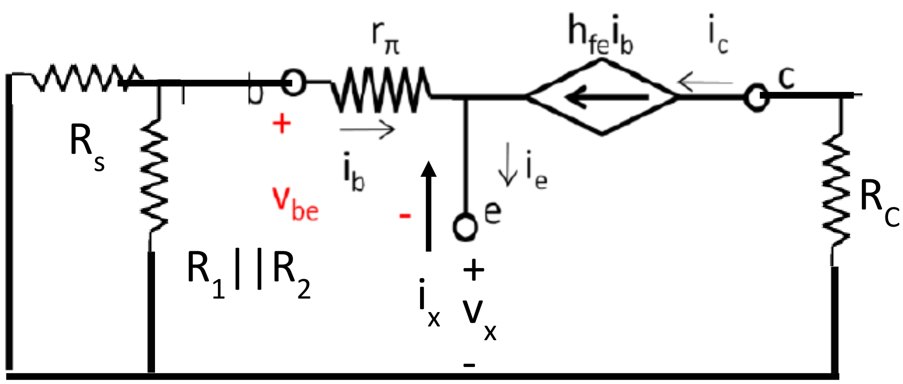
Input Resistance is given as $R_{in} = R_1 \,||\, R_2 \,||\, R_i$ where $R_i = \dfrac{v_b}{i_b}$

From equation (2) it can be directly calculated

$$R_i = \frac{v_b}{i_b} = r_\pi + (1+h_{fe})R_T \text{ and } R_{in} = R_1 \,||\, R_2 \,||\, R_i$$

Output Resistance is calculated using Thevenin equivalent resistance across the output (emitter).

Consider a voltage source v_x applied across output supplying current i_x. The input voltage source is shorted according to Thevenin's theorem.



Shortening of input source makes equivalent resistance at input node as

$$R_s' = R_s \,||\, R_1 \,||\, R_2$$

Applying KVL in input loop,

$$i_b R_s' + i_b r_\pi + v_x = 0$$

$$\Rightarrow v_x = -i_b (R_s' + r_\pi)$$

KCL at node E gives $i_x + i_b + h_{fe} i_b = 0$

$$\Rightarrow i_b = -\frac{i_x}{1+h_{fe}}$$

Combining both the above results,

$$v_x = i_x \frac{R_s^{'} + r_\pi}{1+h_{fe}} \qquad \Rightarrow R_o = \frac{v_x}{i_x} = \frac{R_s^{'} + r_\pi}{1+h_{fe}}$$

Q 2) The values given in the question can be put in the derived expressions in question 1 to get the various parameters,

$$R_T = R_E \,||\, R_L = \frac{R_E R_L}{R_E + R_L} = \frac{1*9}{1+9} = \frac{9}{10} k\Omega$$

Voltage gain, $A_v = \dfrac{(1+h_{fe})R_T}{r_\pi + (1+h_{fe})R_T}$

Since $r_\pi << (1+h_{fe})R_T$ because the value of r_π is in several ohms which is much less than several kilo ohms $\Rightarrow A_V \cong 1$

Input resistance $R_i \cong (1+h_{fe})R_T = (1+100)*\frac{9}{10} = \frac{909}{10} = 90.9k\Omega$

$R_1 \,||\, R_2 = \dfrac{R_1 R_2}{R_1 + R_2} = 200k\Omega$ $\Rightarrow R_{in} = R_1 \,||\, R_2 \,||\, R_i = \dfrac{200*90.9}{200+90.9} = \dfrac{18180}{290.9} = 62.5k\Omega$

Current gain $A_I = \dfrac{i_L}{i_b} = 1 + h_{fe} = 101$

The expression for current gain can be obtained by applying KCL at node E in the small signal equivalent.

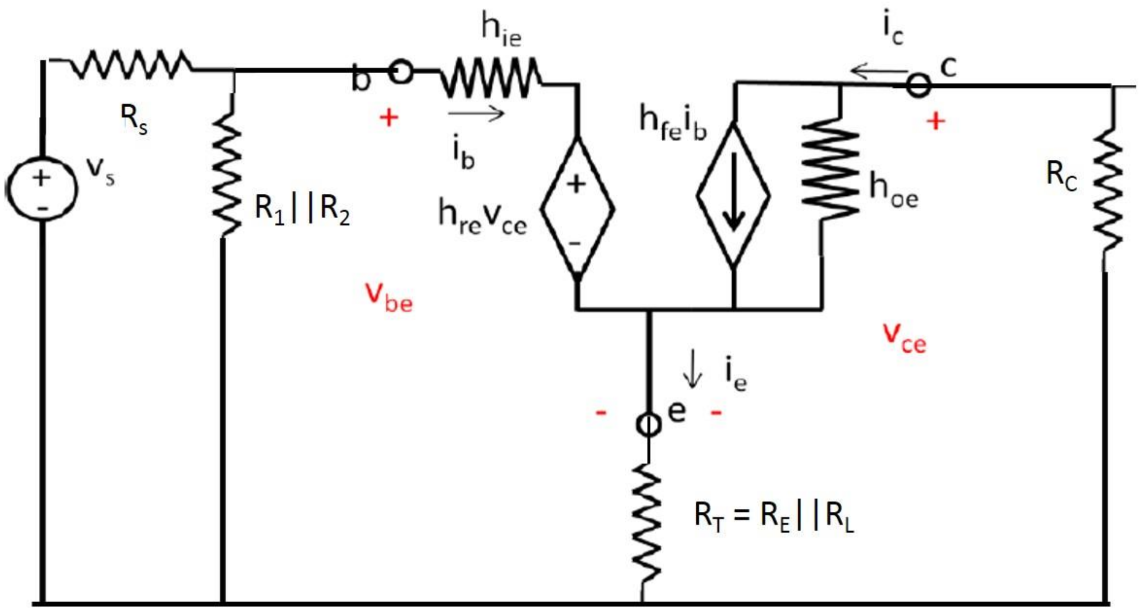
Output Resistance $R_o = \dfrac{R_s^{'} + r_\pi}{1+h_{fe}}$

Since $R_s^{'} = R_1 \,||\, R_2 \,||\, R_s = \dfrac{200*1}{200+1} \cong 1k\Omega$, as value of r_π is in several ohms hence maximum value is considered to be 1 kilo ohm,

$$\Rightarrow R_o = \frac{2000}{(1+100)} \cong 20\Omega$$

It is clear from above calculations that it acts as unity gain amplifier with high input resistance and low output resistance.

Q 3) The small signal equivalent is shown as:



Since this is a CC amplifier, therefore, by analogy to the h parameter model of the CE amplifier,

$A_I = \dfrac{-h_{fc}}{1+h_{oc}R_T}$, $R_i = h_{ic} + h_{rc}A_I R_T$ and $A_v = \dfrac{A_I R_T}{R_i}$ where h_{ic}, h_{fc}, h_{rc} and h_{oc} are CC h-parameters.

The relation between CE and CC h-parameters is

$h_{fc} = -(1+h_{fe})$, $h_{ic} = h_{ie}$, $h_{rc} = 1 - h_{re}$ and $h_{oc} = h_{oe}$

Using these expressions,

h_{fc}=-101 h_{ic}=840ohm $h_{rc} = 1 - 10^{-4} \cong 1$ and $h_{oc} = 10^{-5}\Omega^{-1}$

Therefore,

$$A_I = \frac{101}{1+10^{-5}*0.9*10^3} = \frac{101}{1+0.009} = \frac{101}{1.009} = 100.09$$

$$R_i = 840 + 100*0.9*10^3\Omega = (0.84+90)k\Omega = 90.84k\Omega$$

$$A_v = \frac{100*0.9}{90.84} = \frac{90}{90.84} \cong 1$$

The values obtained are almost same as obtained in question 2.