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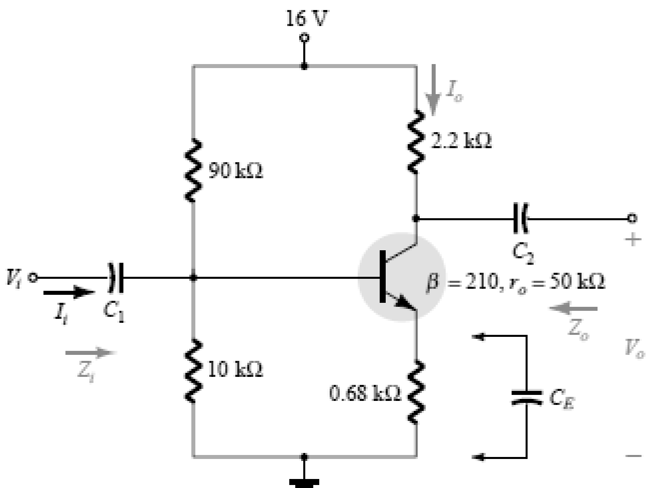
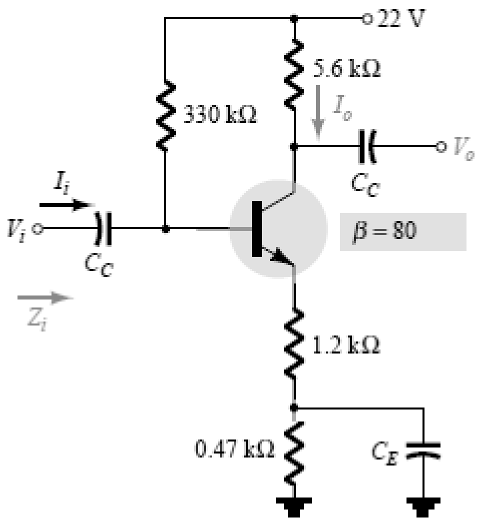
Internal Assesment Test – I								
Sub:	ANALOG ELECTRONICS						Code:	15EC32
Date:	18/ 09 / 2017	Duration:	90 mins	Max Marks:	50	Sem: III	Branch:	TCE (A)
Answer Any FIVE FULL Questions								

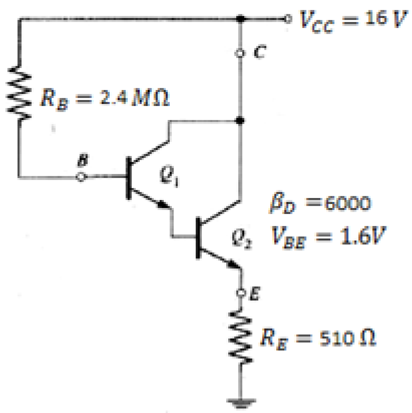
		Marks	OBE CO	OBE RBT
1	Derive an expression for input impedance, output impedance, voltage gain and current gain of transistor amplifier using complete hybrid-Model.	[10]	CO1	L2
2	Calculate the following for the network shown in (Fig 1) with and without C_E and compare the voltage gain. $(a) r_e$ $(b)\ Z_i$ $(c) Z_O$ $(d) A_V$ $(e) A_i$	[10]	CO1	L3
3	For the network shown in (Fig 2). Determine r_e, Z_i, Z_O, A_V, A_i	[10]	CO1	L3
4 (a)	Calculate the DC bias voltages and Currents for the given circuit (Fig 3).	[05]	CO1	L3
(b)	Draw and explain the hybrid- π model of transistor in CE configuration mentioning significance of each component in Model.	[05]	CO2	L5
5	Calculate the input impedance, output impedance, voltage gain and current gain for the given circuit (Fig 4).	[10]	CO1	L3
6 (a)	Determine the input impedance, output impedance, voltage gain and current gain for the circuit shown below (Fig 5).	[05]	CO1	L3
(b)	Analyze the r_e parameter model for emitter follower circuit and derive Z_i, Z_o, A_V, A_i	[05]	CO1	L4
7 (a)	Describe the h-parameter model for emitter bias circuit and derive Z_i, Z_o, A_V, A_i using approximate hybrid model.	[05]	CO1	L2
(b)	For the network shown below(Fig 6), determine V_{CC} for a voltage gain of $A_V = -180$	[05]	CO1	L3



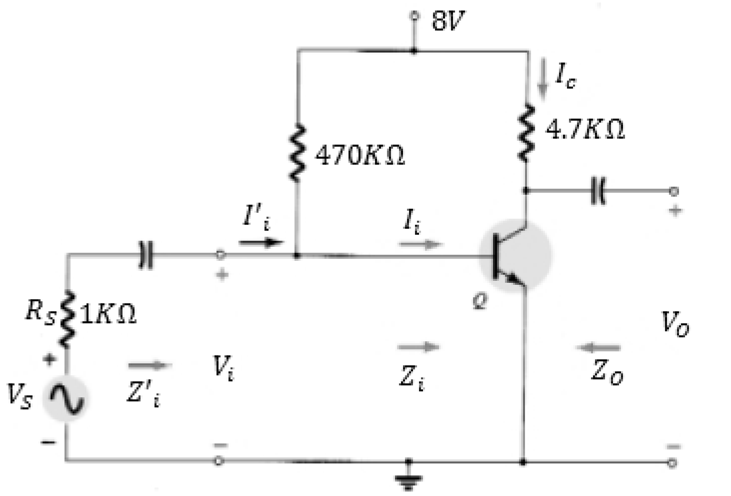
(Fig 1)



(Fig 2)

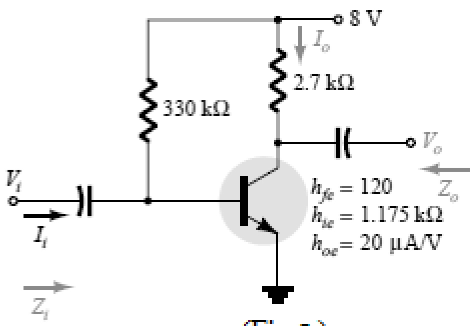


(Fig 3)

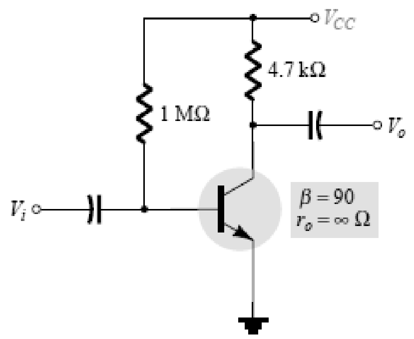


$h_{fe} = 110 \quad h_{ie} = 1.6K\Omega \quad h_{re} = 2 \times 10^{-4} \quad h_{oe} = 20\frac{\mu A}{V}$

(Fig 4)



(Fig 5)



(Fig 6)

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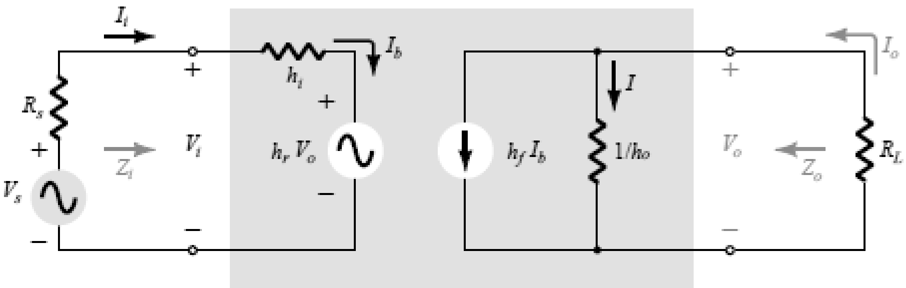
SOLUTION AND SCHEME OF EVALUATION

IAT-1: AEC

1. Derive an expression for input impedance, output impedance, voltage gain and current gain of transistor amplifier using complete hybrid-Model. [10 Marks]

COMPLETE HYBRID EQUIVALENT MODEL: [2 Marks]



Current Gain: [2 Marks]

Applying Kirchhoff's current law to the output circuit

$$I_o = h_f I_b + I = h_f I_i + \frac{V_o}{1/h_o} = h_f I_i + h_o V_o \quad as \;\; V_o = -I_o R_L \quad hence \;\; I_o = h_f I_i - h_o I_o R_L$$

$$I_o + h_o I_o R_L = h_f I_i => I_o(1 + h_o R_L) = h_f I_i => A_i = \frac{I_o}{I_i} = \frac{h_f}{1 + h_o R_L}$$

Voltage Gain: [2 Marks]

$$V_i = I_i h_i + V_O h_r \quad as \;\; I_i = \frac{(1 + h_o R_L) I_o}{h_f} \quad and \;\; I_o = \frac{-V_o}{R_L} \quad => V_i = \frac{-(1 + h_o R_L) h_i}{h_f R_L} V_o + V_O h_r$$

$$V_i = \frac{V_O h_r h_f R_L - (1 + h_o R_L) h_i V_o}{h_f R_L} => V_i = \frac{V_O h_r h_f R_L - h_i V_o - h_i V_o h_o R_L}{h_f R_L}$$

$$=> V_i = \frac{-V_o\left[h_i + \left(h_i h_o - h_r h_f\right) R_L\right]}{h_f R_L}$$

$$A_V = \frac{V_o}{V_i} => A_V = \frac{-h_f R_L}{h_i + \left(h_i h_o - h_r h_f\right) R_L}$$

Input Impedance: [2 Marks]

$$V_i = I_i h_i + h_r V_o \qquad and \;\; V_o = -I_o R_L \quad hence \;\; V_i = I_i h_i - I_o R_L h_r \quad as \;\; I_o = A_i I_i$$

$$V_i = I_i h_i - R_L h_r A_i I_i \quad and \;\; Z_i = \frac{V_i}{I_i} = h_i - R_L h_r A_i \quad as \;\; A_i = \frac{h_f}{1 + h_o R_L} \quad hence \;\; Z_i = h_i - \frac{R_L h_r h_f}{1 + h_o R_L}$$

output Impedance: The output impedance od an amplifier is defined to be the ratio of the output voltage to the output current with the signal V_S set to zero. **[2 Marks]**

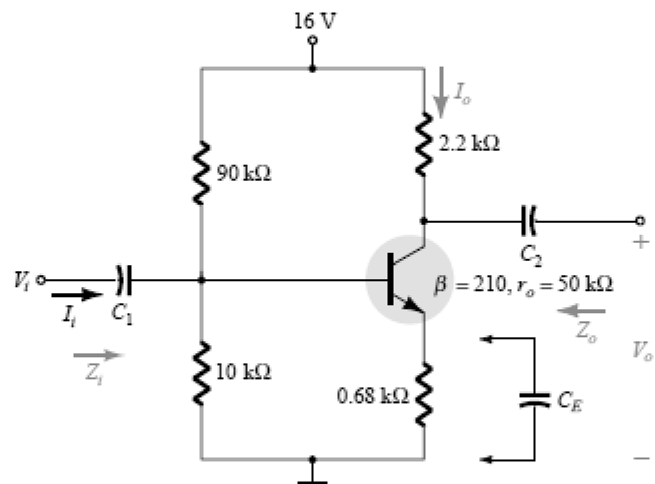
$$V_S - I_i R_S - I_i h_i - h_r V_o = 0 \quad for\ calculating\ Z_o;\ V_S\ has\ to\ be\ set\ to\ zero \ => I_i(R_S + h_i) = -h_r V_o$$

$$I_i = \frac{-h_r V_o}{R_S + h_i}$$

$$I_o = h_f I_i + h_o V_o => I_o = \frac{-h_r h_f V_o}{R_S + h_i} + h_o V_o$$

$$Z_o = \frac{V_o}{I_o} = \frac{1}{h_o - \left[\frac{h_r h_f}{(R_S + h_i)}\right]}$$

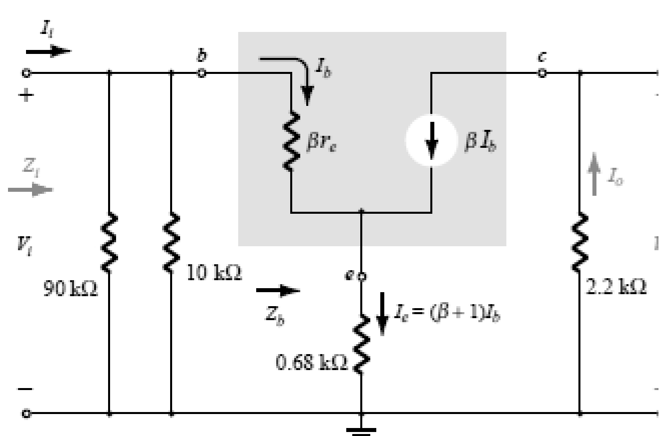
2. **Calculate the following for the network shown in (Fig 1) with and without C_E and compare the voltage gain.$(a) r_e$ (b) Z_i $(c) Z_O$ $(d) A_V$ $(e) A_i$** **[10 Marks]**



(Fig **1**)

<u>ANSWER:</u> (Without C_E) **[5 Marks]**

$$\beta R_E \geq 10 R_2 \quad => 210 \times 0.68K\Omega \geq 10 \times 10K\Omega => 142.8K\Omega \geq 100K\Omega (Satisfied)$$



$$V_B = \frac{V_{CC} R_2}{R_1 + R_2} = \frac{16 \times 10K\Omega}{90K\Omega + 10K\Omega} = 1.6V$$

$$V_E = V_B - V_{BE} = 1.6 - 0.7 = 0.9V$$

$$I_E = \frac{V_E}{R_E} = \frac{0.9}{0.68K\Omega} = 1.32mA$$

$$r_e = \frac{26mV}{I_E} = \frac{26mV}{1.32mA} = 19.69\Omega$$

$$Z_b = \beta r_e + (\beta + 1)R_E = 210 \times 19.69\Omega + (210 + 1)0.68K\Omega = 147.6K\Omega$$

$$R' = \frac{R_1 R_2}{R_1 + R_2} = \frac{90K\Omega \times 10K\Omega}{90K\Omega + 10K\Omega} = 9K\Omega$$

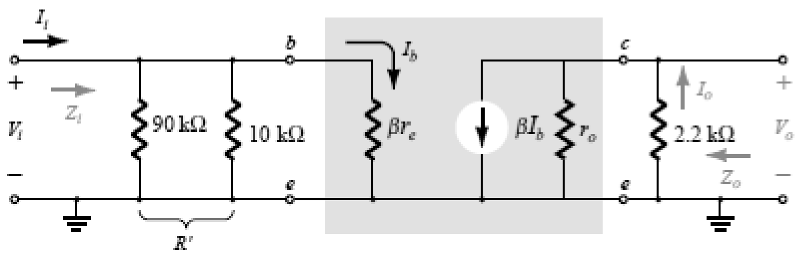
$$Z_i = R' || Z_b = 9K\Omega || 147.6K\Omega = 8.48K\Omega$$

$$Z_o = R_C = 2.2K\Omega$$

$$A_V = \frac{-R_C}{(R_E + r_e)} = \frac{-2.2K\Omega}{(19.69\Omega + 0.68K\Omega)} = -3.14$$

$$A_i = -A_V \frac{Z_i}{R_C} = 3.14 \times \frac{8.48K\Omega}{2.2K\Omega} = 12.10$$

(With C_E) **[5 Marks]**



$$R' = \frac{R_1 R_2}{R_1 + R_2} = \frac{90K\Omega \times 10K\Omega}{90K\Omega + 10K\Omega} = 9K\Omega$$

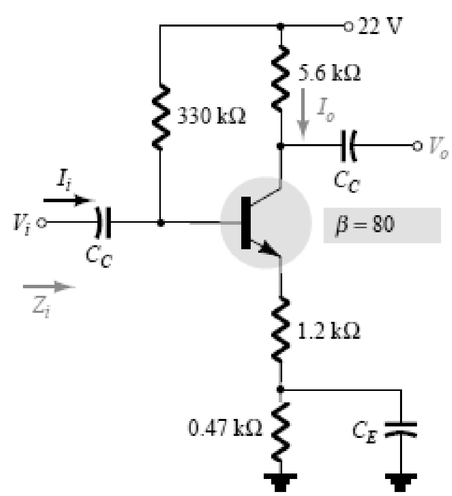
$$Z_i = R' || \beta r_e = 9K\Omega || 4.135K\Omega = 2.83K\Omega$$

$$Z_o = R_C = 2.2K\Omega$$

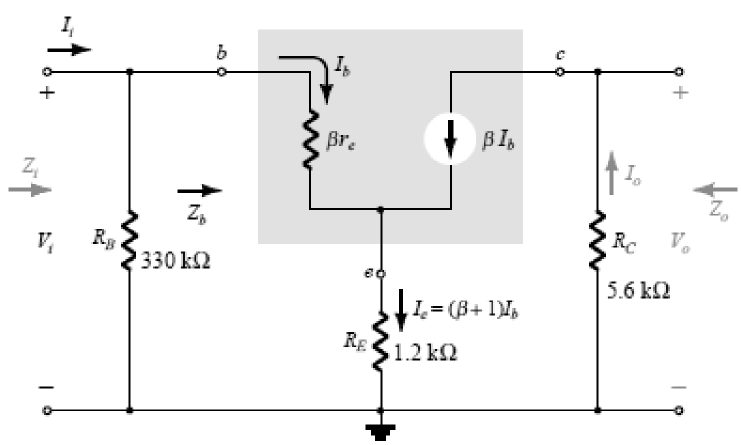
$$A_V = \frac{-R_C}{r_e} = \frac{-2.2K\Omega}{19.69\Omega} = -111.73$$

$$A_i = -A_V \frac{Z_i}{R_C} = 111.73 \times \frac{2.83K\Omega}{2.2K\Omega} = 143.72$$

3. **For the network shown in (Fig 2). Determine r_e, Z_i, Z_O, A_V, A_i** **[10 Marks]**



(Fig 2)



$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \frac{22 - 0.7}{330 \times 10^3 + (80 + 1)(1.2 + 0.47) \times 10^3} = 45.77\mu A$$

$$I_E = (\beta + 1)I_B = (80 + 1)45.77\mu A = 3.708mA$$

$$r_e = \frac{26mV}{I_E} = \frac{26mV}{3.708mA} = 7.01\Omega$$ **[2 Marks]**

$$Z_b = \beta r_e + (\beta + 1)R_E = (80 \times 7.01\Omega) + (80 + 1)1.2K\Omega = 97.76K\Omega$$

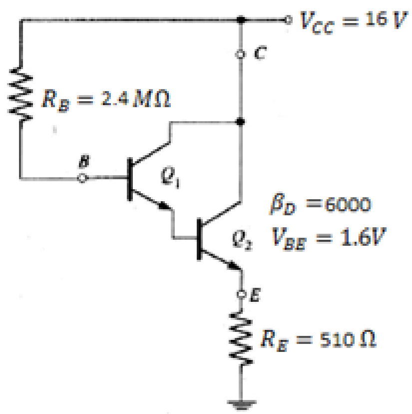
$$Z_i = R_B||Z_b = 330K\Omega||97.76K\Omega = 75.41K\Omega$$ **[2 Marks]**

$$Z_o = R_C = 5.6K\Omega$$ **[2 Marks]**

$$A_V = \frac{-R_C}{(R_E + r_e)} = \frac{-5.6K\Omega}{(1.2K\Omega + 7.01\Omega)} = -4.639$$ **[2 Marks]**

$$A_i = -A_V \frac{Z_i}{R_C} = 4.639 \times \frac{75.41K\Omega}{5.6K\Omega} = 62.469$$ **[2 Marks]**

4. (a)Calculate the DC bias voltages and Currents for the given circuit (Fig 3). [5 Marks]



(Fig 3)

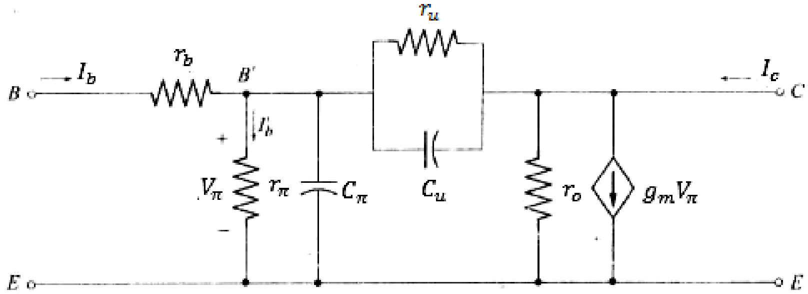
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta_D + 1)R_E}$$ **[2 Marks]**

$$I_B = \frac{16 - 1.6}{2.4 \times 10^6 + (6000 + 1)510} = 2.637\mu A$$

$$I_E = (\beta_D + 1)I_B = (6000 + 1)2.637\mu A = 15.82mA$$ **[2 Marks]**

$$V_E = I_E R_E = 15.82 \times 10^{-3} \times 510 = 8.0709V$$ **[1 Mark]**

(b) Draw and explain the hybrid- π model of transistor in CE configuration mentioning significance of each component in Model. [5 Marks]



[1 Mark]

<u>HYBRID π MODEL:</u> It is the more accurate model for High frequency effects. For low frequency approximations, the model can be made with the r_e model. **[4 Marks]**

The capacitors appear in the hybrid π model are stray capacitors. The capacitive effect only come into play at high frequencies. For low and mid frequencies their reactance is very large, and they can be considered open circuit. The capacitance value is in few pico farad(pf) to few tens of pico farad (pf).

r_u, r_π & r_o are the resistance between the indicated terminals of the device, when the device is in the active region.

u provides the union, it provides between collector and base terminals.

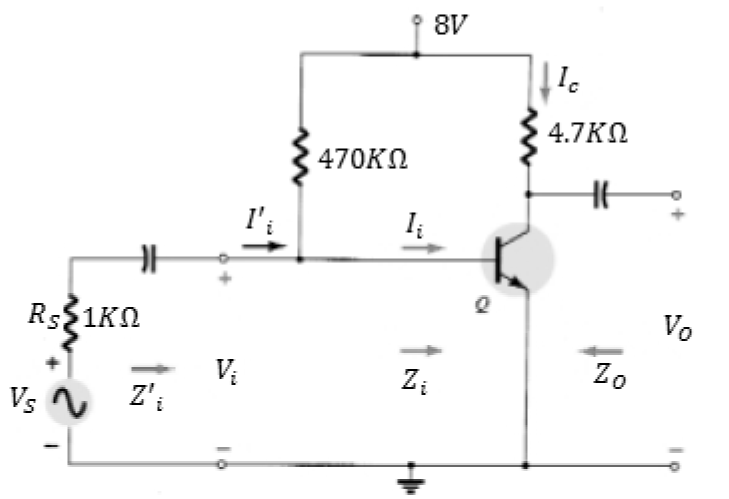
r_b is usually very small it can be replaced by a short-circuit equivalent.

r_u is usually so large it can be ignored for most applications.

$$r_\pi = \beta r_e \quad g_m = \frac{1}{r_e} \quad r_o = \frac{1}{h_{oe}} \quad h_{re} = \frac{r_\pi}{r_\pi + r_u} = \frac{r_\pi}{r_\mu}$$

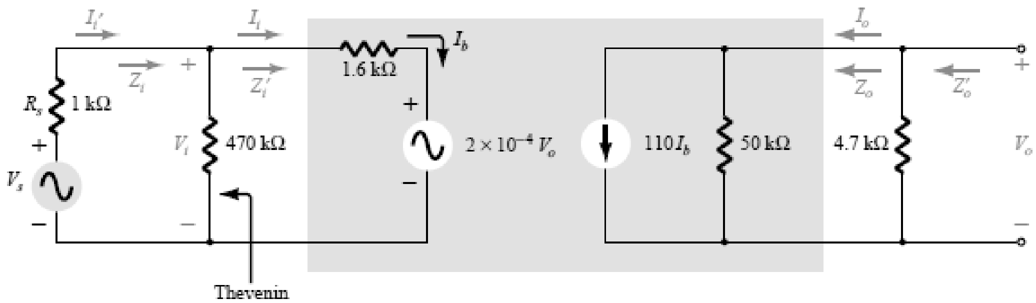
CE amplifier is most widely used becauseCE transistor have high gain than any other configuration.

5. **Calculate the input impedance, output impedance, voltage gain and current gain for the given circuit (Fig 4).** **[10 Marks]**

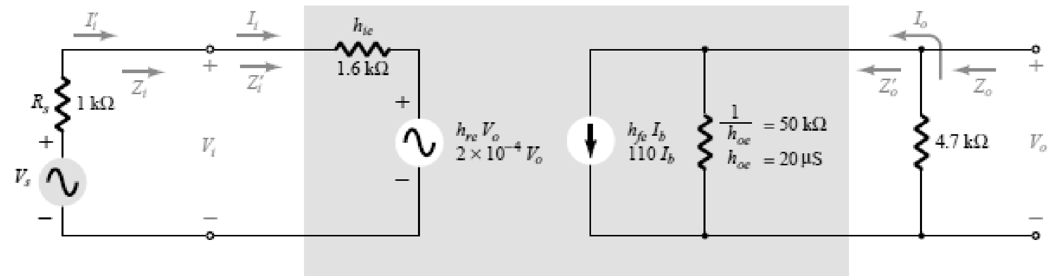


$h_{fe} = 110 \quad h_{ie} = 1.6K\Omega \quad h_{re} = 2 \times 10^{-4} \quad h_{oe} = 20\frac{\mu A}{V}$

(Fig 4)



[2 marks]



[2 marks]

$$Z'_i = h_{ie} - \frac{R_L h_{re} h_{fe}}{1 + h_{oe} R_L} => Z'_i = 1.6K\Omega - \frac{(4.7K\Omega)(2 \times 10^{-4})110}{1 + (20\mu S \times 4.7K\Omega)} = 1.505K\Omega$$

$Z_i = 470K\Omega || Z_i => Z_i = 1.5K\Omega$ **[2 marks]**

$$A_V = \frac{-h_{fe} R_L}{h_{ie} + (h_{ie} h_{oe} - h_{re} h_{fe}) R_L} => A_V = \frac{-110(4.7K\Omega)}{1.6K\Omega + (1.6K\Omega \times 20\mu S - (2 \times 10^{-4}) \times 110)(4.7K\Omega)}$$

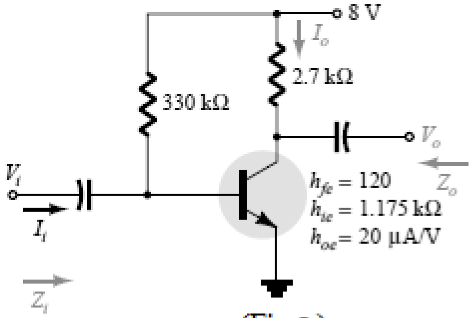
$A_V = -313.9$ **[1 mark]**

$$A_i = \frac{I_o}{I_i} = \frac{h_{fe}}{1 + h_{oe} R_L} = \frac{110}{1 + (20\mu S \times 4.7K\Omega)} = 100.54$$ **[1 mark]**

$$Z'_o = \frac{1}{h_{oe} - \left[\frac{h_{re} h_{fe}}{(R_S + h_{ie})}\right]} = \frac{1}{20\mu S - \left[(2 \times 10^{-4}) \times \frac{110}{(1K\Omega + 1.6K\Omega)}\right]} = 86.67K\Omega$$

$Z_O = R_C || Z_o => Z_O = 4.7K\Omega || 86.67K\Omega => Z_O = 4.45K\Omega$ **[2 marks]**

6. (a) Determine the input impedance, output impedance, voltage gain and current gain for the circuit shown below (Fig 5). **[5 Marks]**



(Fig 5)

(a) $Z_i = R_B \| h_{ie} = 330\ \text{k}\Omega \| 1.175\ \text{k}\Omega$
$\cong h_{ie} = \mathbf{1.171\ k\Omega}$ **[1 mark]**

(b) $r_o = \dfrac{1}{h_{oe}} = \dfrac{1}{20\ \mu\text{A/V}} = 50\ \text{k}\Omega$

$Z_o = \dfrac{1}{h_{oe}} \| R_C = 50\ \text{k}\Omega \| 2.7\ \text{k}\Omega = \mathbf{2.56\ k\Omega} \cong R_C$ **[1 mark]**

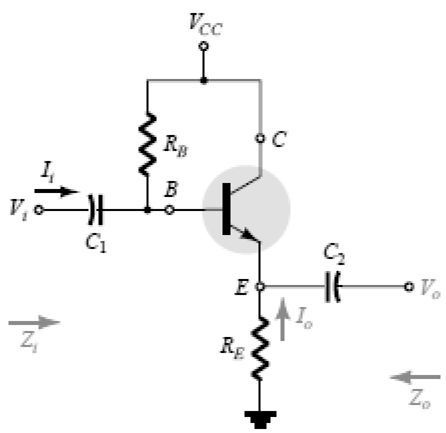
(c) $Av = -\dfrac{h_{fe}(R_C \| 1/h_{oe})}{h_{ie}} = -\dfrac{(120)(2.7\ \text{k}\Omega \| 50\ \text{k}\Omega)}{1.171\ \text{k}\Omega} = \mathbf{-262.34}$

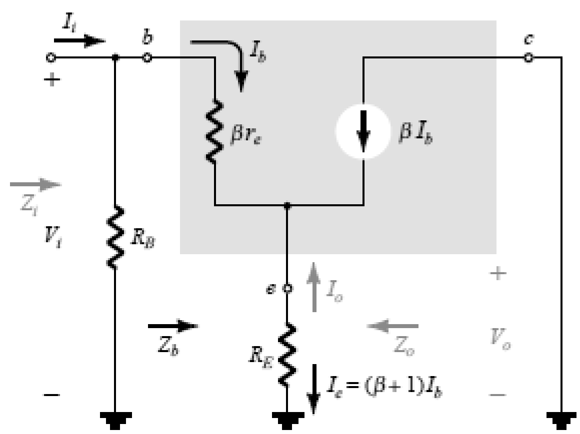
[1 mark]

$$A_i = -A_V \frac{Z_i}{R_C} = 262.34 \times \frac{1.171K\Omega}{2.7K\Omega} = 113.77$$ [**1 Mark**]

(b) Analyze the r_e parameter model for emitter follower circuit and derive Z_i , Z_o , A_V , A_i **[5 Marks]**

EMITTER FOLLOWER CIRCUIT/COMMON COLLECTOR CONFIGURATION:





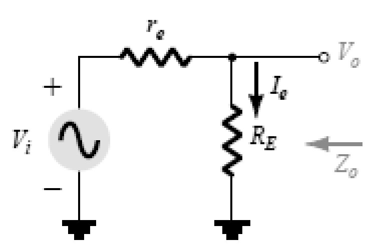
[1 Mark]

For emitter follower circuit the output is taken from the emitter terminal. The output is slightly less than the input signal hence $A_V \approx 1$

$$V_i = I_b \beta r_e + I_e R_E \Rightarrow V_i = I_b \beta r_e + (\beta + 1) I_b R_E$$

$$Z_b = \frac{V_i}{I_b} \Rightarrow Z_b = \beta r_e + (\beta + 1) R_E$$

$$\Rightarrow Z_b \approx \beta(r_e + R_E)$$



$Z_i = R_B || Z_b$ [**1 Mark**]

Output impedance is calculated by setting V_i to zero hence $Z_o = R_E || r_e$ [**1 Mark**]

$$V_o = \frac{V_i R_E}{R_E + r_e} \Rightarrow A_V = \frac{V_o}{V_i} = \frac{R_E}{R_E + r_e} \quad as\ R_E + r_e \approx R_E \quad \Rightarrow A_V \approx 1$$ [**1 Mark**]

the + ve sign indicates there is no phase shift between V_o & V_i

$$I_b = \frac{I_i R_B}{R_B + Z_b} => I_i = \frac{(R_B + Z_b)I_b}{R_B} \quad and\ \ I_o = -I_e = -(\beta + 1)I_b$$

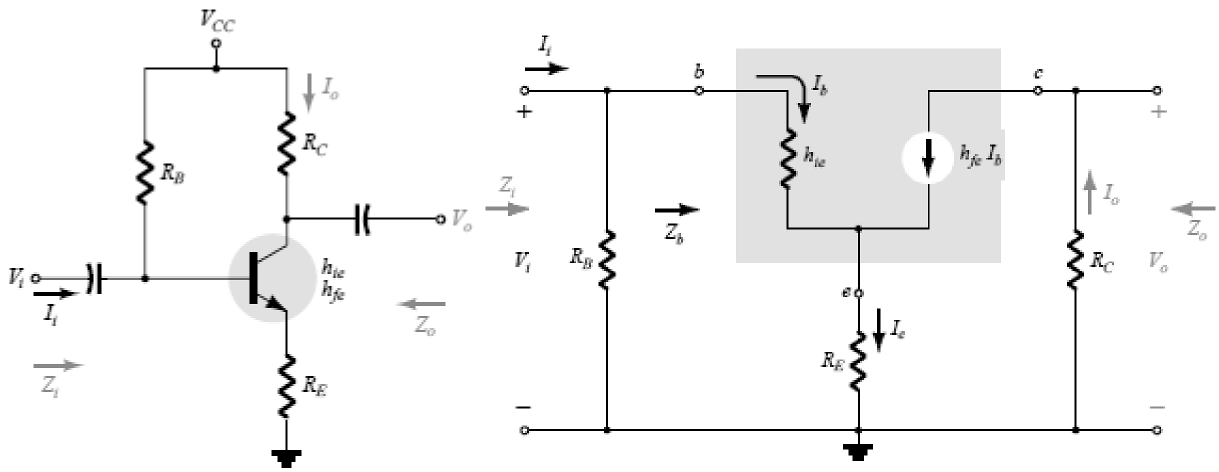
$$A_i = \frac{I_o}{I_i} = \frac{-(\beta + 1)I_b}{\left[\frac{(R_B + Z_b)I_b}{R_B}\right]} = -(\beta + 1)I_b \times \frac{R_B}{(R_B + Z_b)I_b} = \frac{-(\beta + 1)R_B}{R_B + Z_b} = \frac{-\beta R_B}{R_B + Z_b} \quad as\ \ \beta + 1 \approx \beta$$

The current gain can also be calculated as

$$A_i = -A_V \frac{Z_i}{R_E}$$ **[1 Mark]**

7. **(a) Describe the h-parameter model for emitter bias circuit and derive Z_i , Z_o , A_V , A_i using approximate hybrid model.** **[5 Marks]**

<u>EMITTER BIAS CONFIGURATION:</u>



$$Z_b = h_{ie} + (h_{fe} + 1)R_E$$

$$Z_i = R_B || Z_b$$

$$Z_O = R_C$$

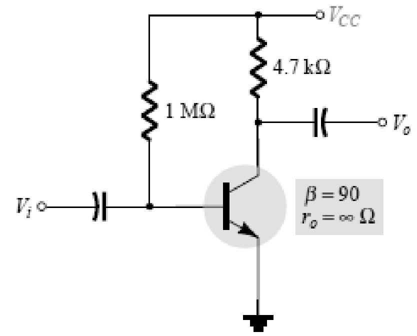
$$A_V = \frac{V_o}{V_i} = \frac{-h_{fe} R_C I_b}{Z_b I_b} => A_V = \frac{-h_{fe} R_C}{h_{fe} R_E} => A_V = \frac{-R_C}{R_E}$$

$$I_o = h_{fe} I_b \quad and \qquad and\ \ I_b = \frac{I_i R_B}{R_B + Z_b} => I_i = \frac{(R_B + Z_b)I_b}{R_B}$$

$$A_i = \frac{I_o}{I_i} = \frac{[h_{fe} I_b]}{\left[\frac{(R_B + Z_b)I_b}{R_B}\right]} = h_{fe} I_b \times \frac{R_B}{(R_B + Z_b)I_b} = \frac{h_{fe} R_B}{Z_b + R_B}$$

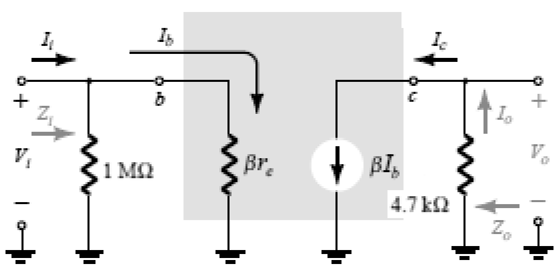
The current gain can also be calculated as $A_i = -A_V \frac{Z_i}{R_C}$

(b) For the network shown below (Fig 6), determine V_{CC} for a voltage gain of $A_V = -180$



(Fig 6)

[5 Marks]



[1 Mark]

$As\ r_o \geq 10R_C \quad (Satisfied)$

$Hence\ A_V = \frac{-R_C}{r_e} = -180 => r_e = \frac{R_C}{180} => r_e = 26.11\Omega$ **[1 Mark]**

$r_e = \frac{26mV}{I_E} => I_E = \frac{26mV}{26.11\Omega} = 0.9957mA$ **[1 Mark]**

$I_B = \frac{I_E}{(\beta + 1)} = 10.94\mu A$ **[1 Mark]**

$I_B = \frac{V_{CC} - V_{BE}}{R_B} => V_{CC} = I_B R_B + V_{BE} => V_{CC} = 11.64V$ **[1 Mark]**