ELA – 2110

ELECTRONICS DEVICES AND CIRCUITS

HOME ASSIGNMENT 2

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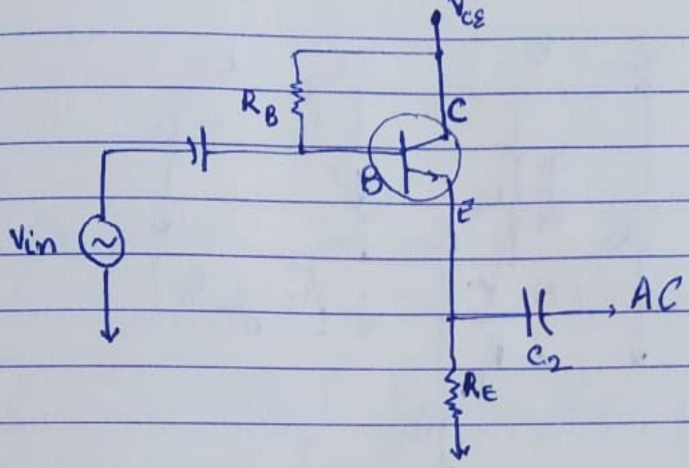
HOME ASSIGNMENT

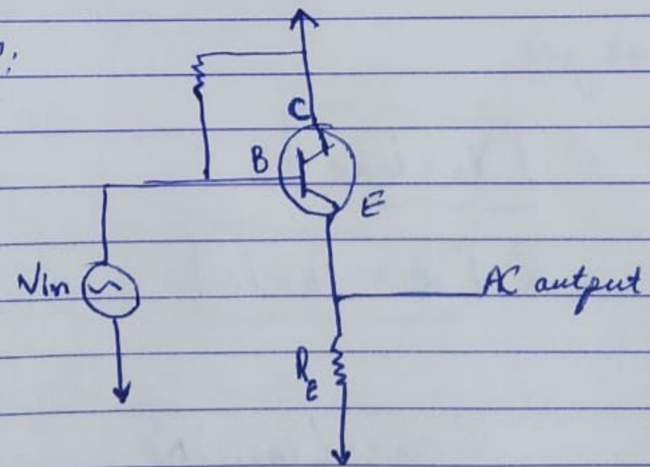
Q Find the small voltage gain and I/O impedance of common Collector amplifier using hybrid-π model of transistor.

Sol:



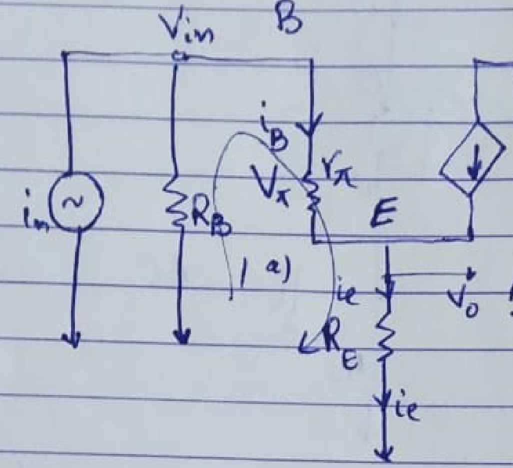
A.C signal procedure :→ all DC signals being grounded and all Coupling Capacitors being short circuited.

Equivalent of AC:



Small signal Analysis of Common Emitter BJT

Hybrid-π-Model



$$\boxed{i_c = g_m v_\pi}$$

Calculating the voltage gain,

we get,

$$\boxed{V_o = i_e R_E}$$

& $\boxed{i_e = i_B + i_c}$

$\therefore$

$$V_o = (i_B + i_c) R_E$$

we know,

$$\boxed{V_\pi = i_B r_\pi}$$

$$\therefore \boxed{i_B = \frac{V_\pi}{r_\pi}}$$

$$v_o = \left(\frac{V_\pi}{r_\pi} + i_c\right) R_E$$

$\therefore$ we get, $V_o = V_\pi \left[\frac{1}{r_\pi} + g_m \right] R_E$ as $\boxed{i_c = g_m V_\pi}$ $\rightarrow$ (2)

Since, $\boxed{r_\pi = \frac{\beta}{g_m}} \Rightarrow \frac{1}{r_\pi} = \frac{g_m}{\beta}$

on substitute $\frac{g_m}{\beta}$ in (2)

$V_o = V_\pi \left[\frac{g_m}{\beta} + g_m \right] R_E$ & $\frac{g_m}{\beta} << g_m$

we can neglect it

$\therefore \boxed{V_o = V_\pi [g_m] R_E}$ - (3)

Applying KVL in (a)

$V_{in} - V_\pi = V_o$

$\therefore \boxed{V_{in} = V_o + V_\pi}$ - (4)

Substituting V_π from (4) in (3)

$V_o = (V_{in} - V_o)[g_m] R_E$

$\therefore V_o + g_m R_E V_o = V_{in} g_m R_E$

$V_o [1 + g_m R_E] = V_{in} g_m R_E$

Voltage gain $= \frac{V_o}{V_{in}} = \frac{g_m R_E}{1 + g_m R_E} \Rightarrow \boxed{\frac{R_E}{\frac{1}{g_m} + R_E}}$

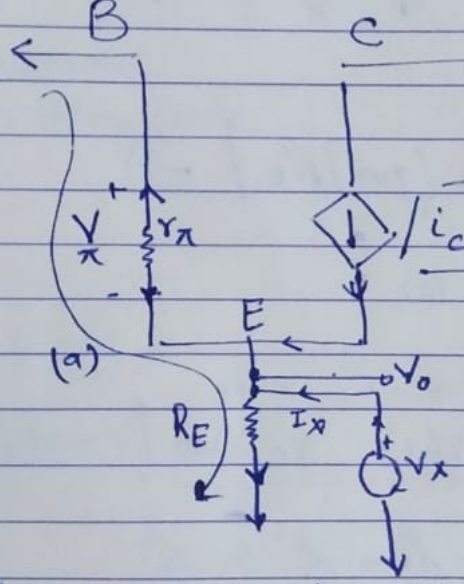
Since

$g_m << R_E$, hence A_v (voltage gain) $\simeq \frac{R_E}{R_E} \simeq 1$

Since no negative signs therefore Input-output signals are in phase.

For Output Impedance:

On shortckt all independt sources and Resistor, Eq ckt, we get.



$$\boxed{\frac{V_x}{I_x} = Z_o}$$ (output Impedance)

Applying KCL at E junction,

$$\frac{V_x}{r_\pi} + \frac{V_x}{R_E} = I_x + i_c$$

$$\frac{V_x}{r_\pi} + \frac{V_x}{R_E} = I_x + g_m V_\pi$$ & $\boxed{V_\pi = -V_x}$ from KVL in (a

$$\cancel{I_x - g} \quad \frac{V_\pi}{R_E} + \frac{V_\pi}{r_\pi} = I_x - g_m V_\pi$$

$$I_x = \frac{V_\pi}{R_E} + \frac{V_\pi}{r_\pi} + g_m V_\pi$$

$$I_x = V_\pi \left[\frac{1}{R_E} + \frac{1}{r_\pi} + g_m \right]$$

$$\boxed{\frac{I_x}{V_\pi} = \frac{1}{R_E} + \frac{1}{r_\pi} + g_m}$$

&

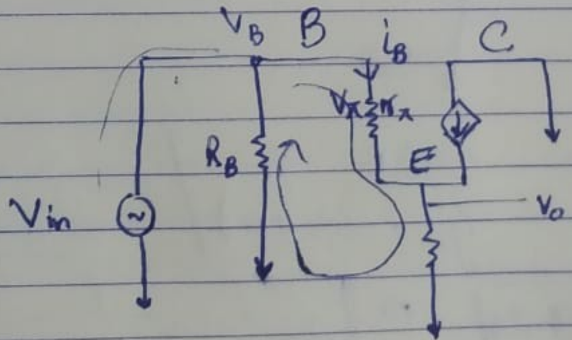
$$\frac{1}{r_\pi} << g_m$$

$\therefore$

$$\boxed{\frac{I_x}{V_\pi} = \frac{1}{R_E} + g_m}$$

$$\Rightarrow \boxed{R_o = \frac{1}{R_e} + \frac{1}{1/g_m}} \quad \text{ie} \quad \frac{1}{R_e} \text{ in parralle with } g_m$$

For Input Impedance:



$$\boxed{i_c = g_m V_\pi}$$

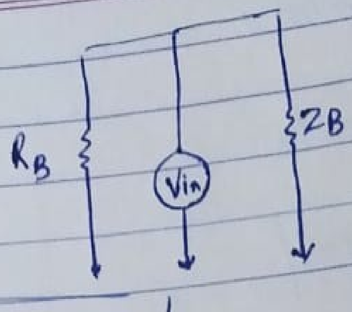
$$V_B = V_{in}$$

$$\boxed{V_B = V_\pi + V_e}$$

$$V_B = i_B r_\pi + (\beta+1) i_B R_E$$

$$\boxed{\frac{V_B}{i_B} = r_\pi + (\beta+1) R_E = Z_B}$$

Eqt. ckt:



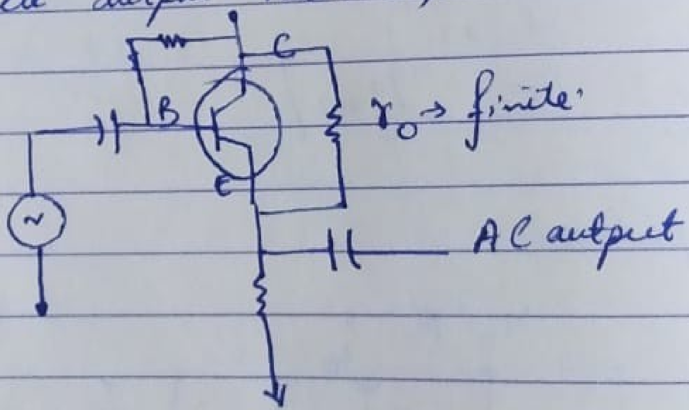
$$\boxed{Z_{in} = R_B \parallel Z_B}$$

$$\frac{1}{Z_{in}} = \frac{1}{R_B} + \frac{1}{Z_B} \Rightarrow \boxed{\frac{1}{R_B} + \frac{1}{r_\pi + (\beta+1)R_E}}$$

Said,

$$Z_B = \boxed{r_\pi + (\beta+1)R_E}$$

If for a finite output resistance,



Then,

$$\boxed{\text{Voltage gain} = \frac{R_E \parallel r_o}{1/g_m + (R_E \parallel r_o)}}$$

$$\boxed{Z_{in} = R_B \parallel Z_B} \Rightarrow \boxed{\frac{1}{R_B} + \frac{1}{r_\pi + (\beta+1)(R_E \parallel r_o)}}$$

$$\therefore \boxed{Z_o = \left(\frac{1}{g_m}\right) \parallel (R_E \parallel r_o)}$$