AY-2025-2026

ODD SEM

Department of ECE

ANALOG ELECTRONIC CIRCUIT DESIGN
23EC2104

Topic:

HYBRID MODEL FOR BJT CONFIGURATIONS-CE

Session - 08

SESSION CONTENT

- Hybrid Model for BJT Configurations-CE

AIM OF THE SESSION

To analyze and understand the Hybrid-π model for the Common Emitter (CE) configuration of a BJT and apply it in small-signal amplifier circuit analysis.

INSTRUCTIONAL OBJECTIVES

The Session is designed to:

1. Explain the concept of the Hybrid-π model for BJTs.
2. Identify the key elements of the Hybrid-π equivalent circuit.
3. Describe the role of each parameter (rπ, gm, ro) in CE configuration.
4. Apply the model to analyze small-signal behavior of CE amplifiers.

LEARNING OUTCOMES

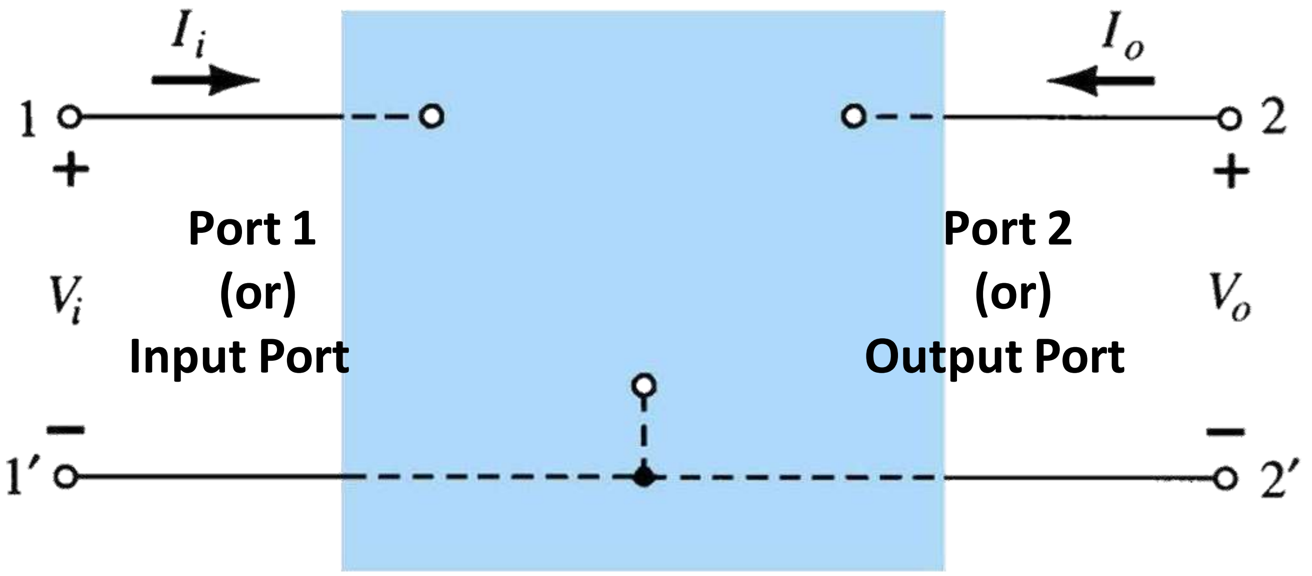
At the end of this session, learners will be able to:

1. Construct the Hybrid-π equivalent circuit for a given BJT CE configuration.
2. Use the model to calculate small-signal parameters and performance metrics.
3. Understand how the base-emitter resistance (rπ) and transconductance (gm) influence signal gain.

Basic BJT Amplifier Configurations

- Common-Emitter (CE) amplifier without and with emitter resistance
- Common-Base (CB) amplifier
- Common-Collector (CC) amplifier or Emitter Follower

Hybrid Equivalent Model



Two -Port Network

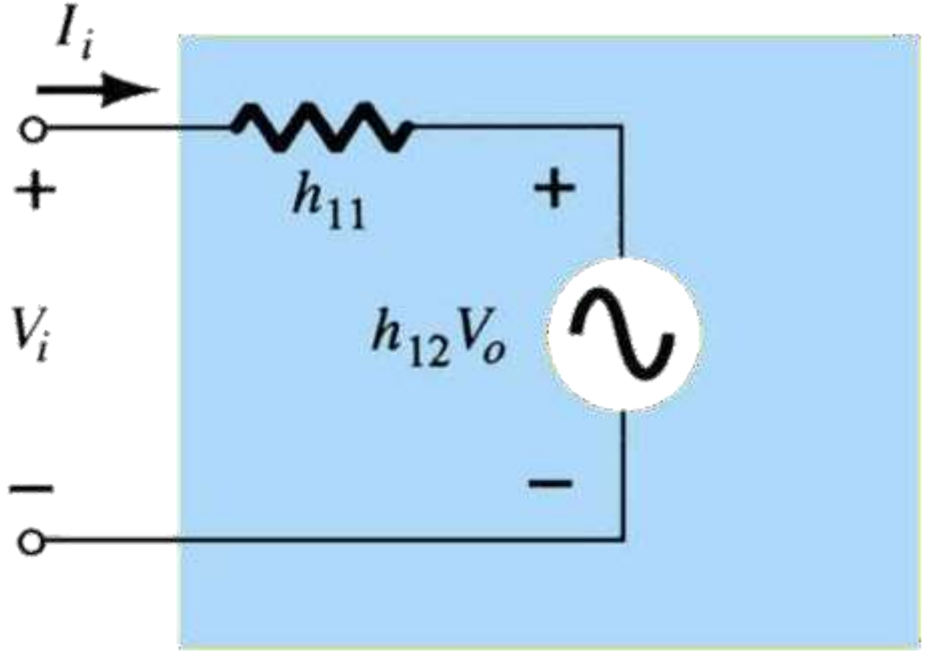
V_i = *Input Voltage*

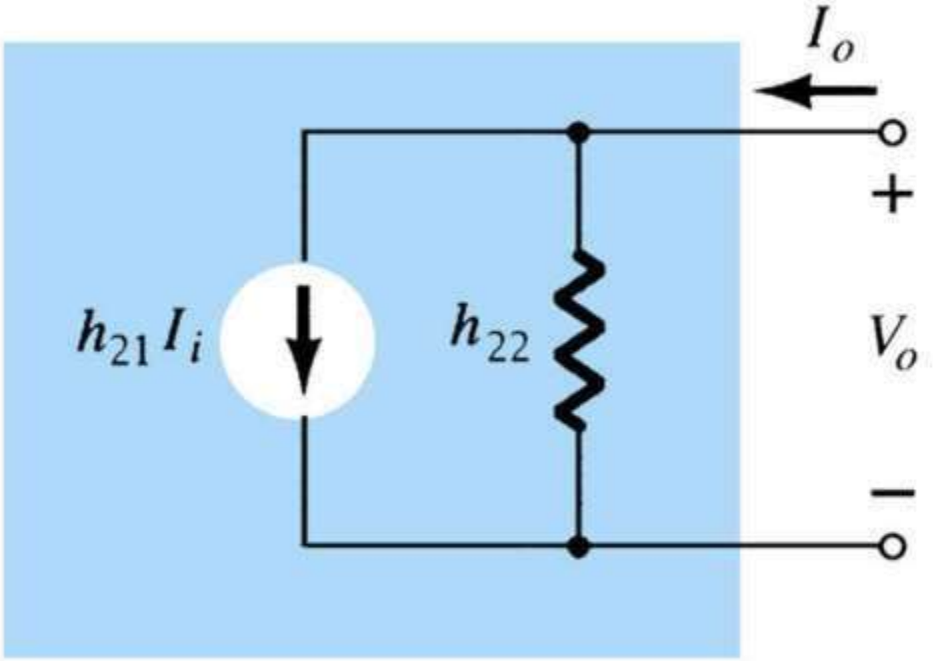
V_o = *Output Voltage*

I_i = *Input Current*

I_o = *Output Current*

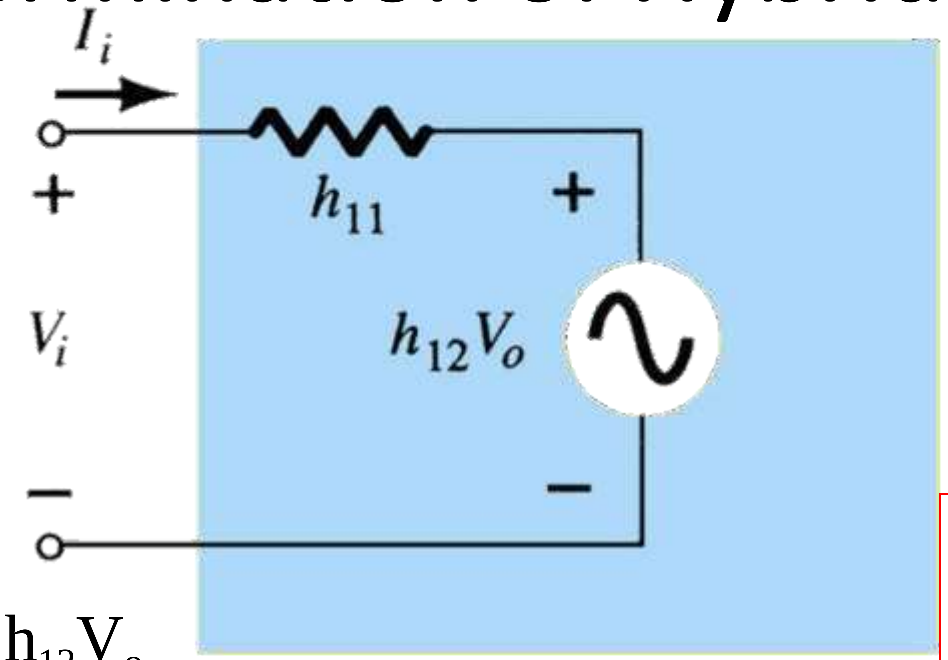
Determination of Hybrid Parameters





$$V_i = h_{11}I_i + h_{12}V_o \qquad I_O = h_{21}I_i + h_{22}V_o$$

Determination of Hybrid Parameters



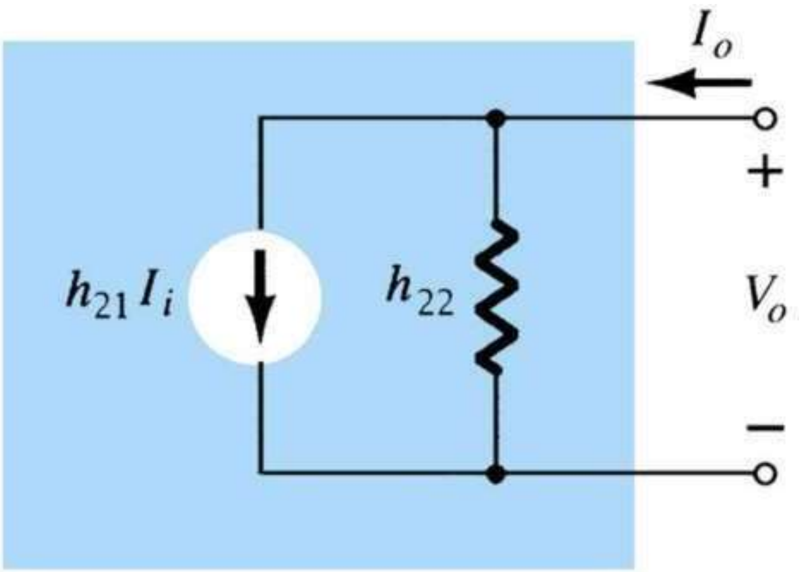
h_{11} - Ω and h_{22} – mhos
h12, h21 – Dimension Less.

$$V_i = h_{11}I_i + h_{12}V_o$$

$$h_{11} = \left.\frac{V_i}{I_i}\right|_{V_o = 0V} = \textbf{Input Impedance} \text{ with output part short circuited(} \Omega\text{)}$$

$$h_{12} = \left.\frac{V_i}{V_o}\right|_{I_i = 0V} = \textbf{ReverseVoltage Transfer Ratio} \text{ with input part open circuited}$$

Determination of Hybrid Parameters



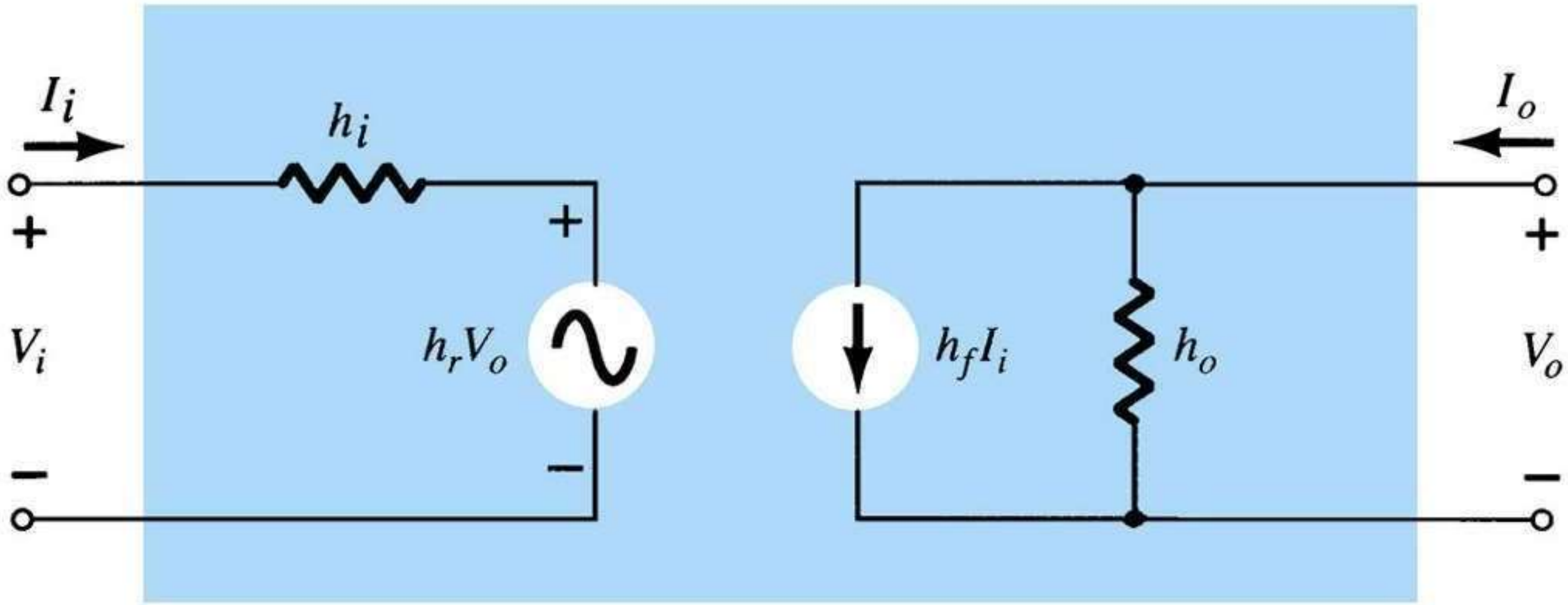
h_{11} - Ω and h_{22} – mhos
h12, h21 – Dimension Less.

$$I_O = h_{21}I_i + h_{22}V_o$$

$$h_{21} = \left.\frac{I_o}{I_i}\right|_{V_o = 0V}$$ = **Forward Current Gain** with output part short circuited

$$h_{22} = \left.\frac{I_o}{V_o}\right|_{I_i = 0A}$$ = **Output Adm ittance** with input part open circuited(mhos)

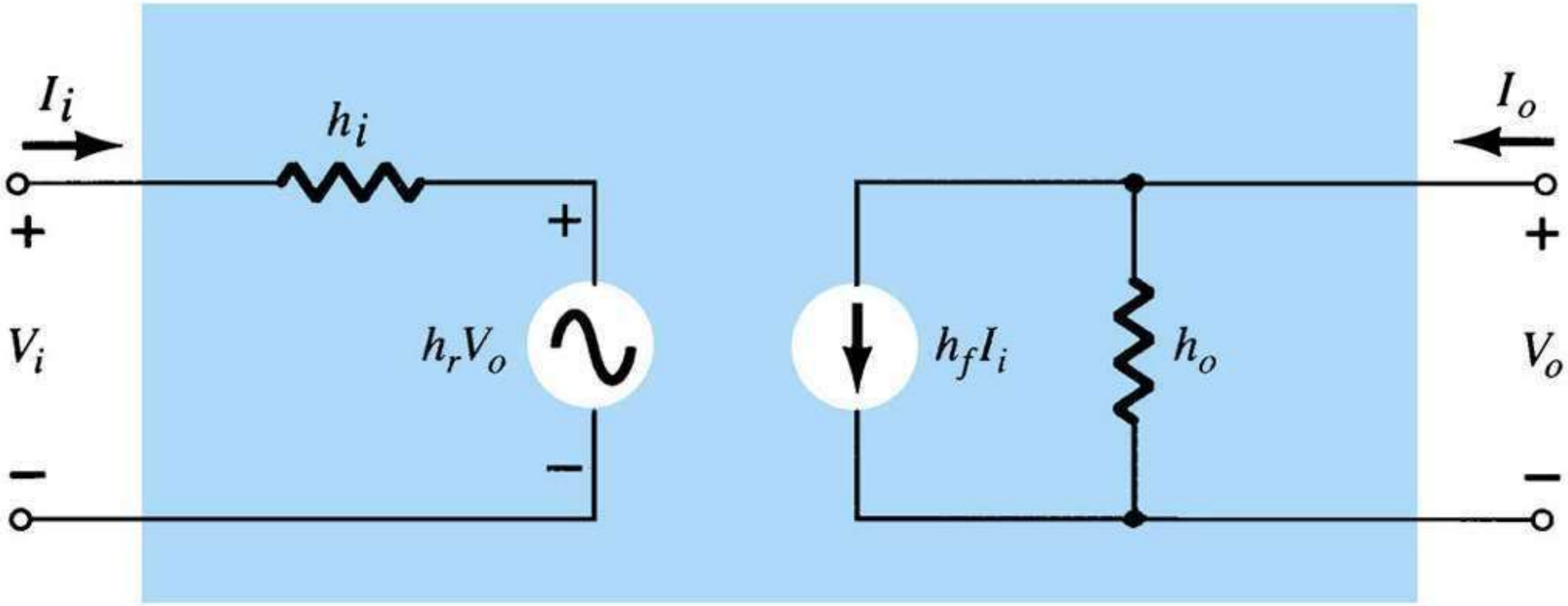
General h-Parameters for any Transistor Configuration



$$V_i = h_i\, I_i + h_r\, V_o$$
$$I_2 = h_f\, I_i + h_0\, V_o$$

hi = Input Resistance(Vi/Ii)
hr = Reverse Transfer Voltage Ratio (Vi/Vo)
hf = Forward Transfer Current Ratio (Io/Ii)
ho = Output Conductance(Io/Vo)

General h-Parameters for any Transistor Configuration



$$h_f = \left.\frac{I_o}{I_i}\right|_{V_o=0V}$$

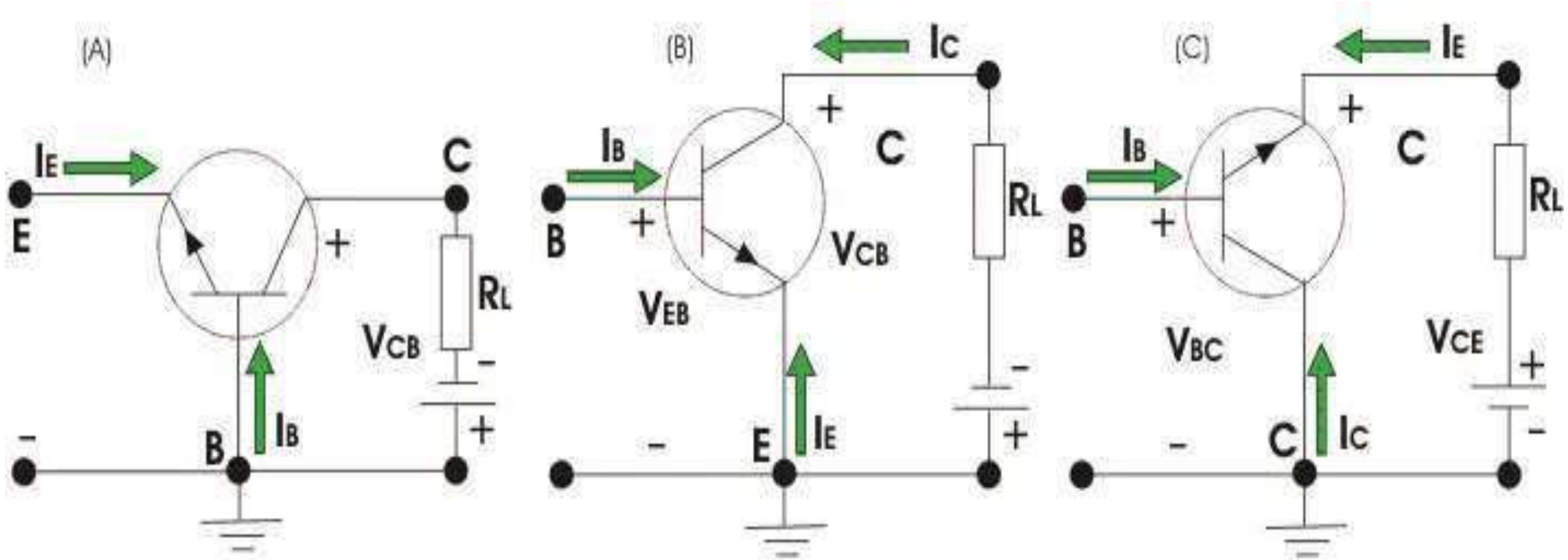
$$V_i = h_i\, I_i + h_r\, V_o$$
$$I_o = h_f\, I_i + h_0\, V_o$$

$$h_i = \left.\frac{V_i}{I_i}\right|_{V_o=0V}$$

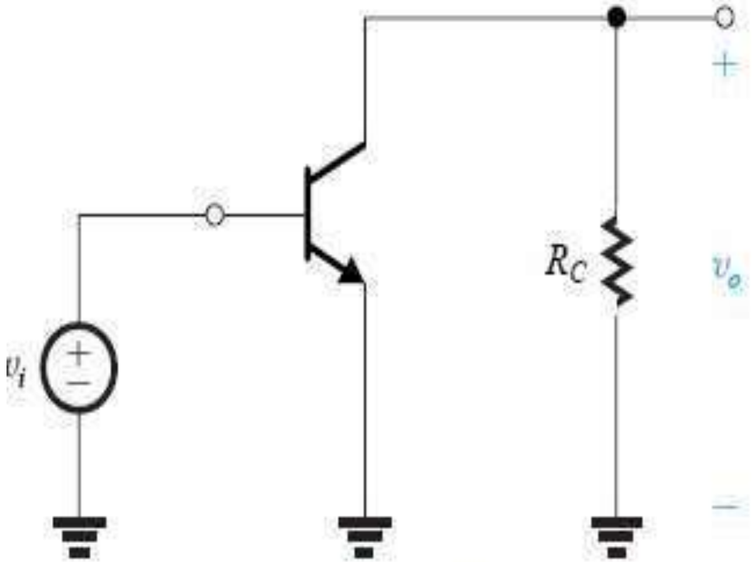
$$h_r = \left.\frac{V_i}{V_o}\right|_{I_i=0\ A}$$

$$h_o = \left.\frac{I_o}{V_o}\right|_{I_i=0\ A}$$

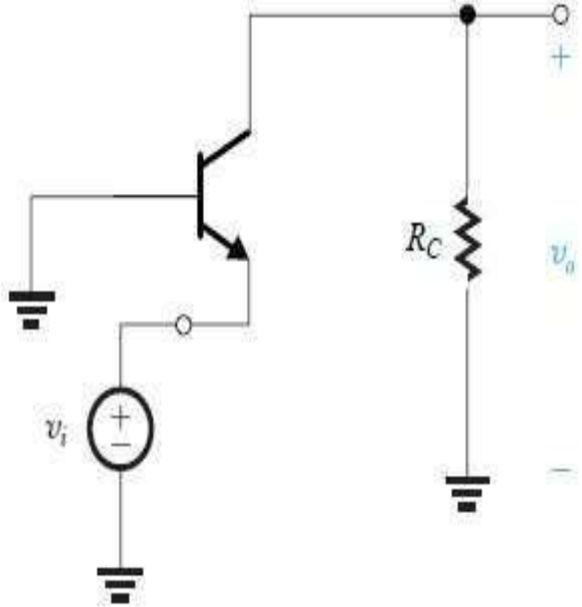
Three Basic Configurations of BJT Amplifier



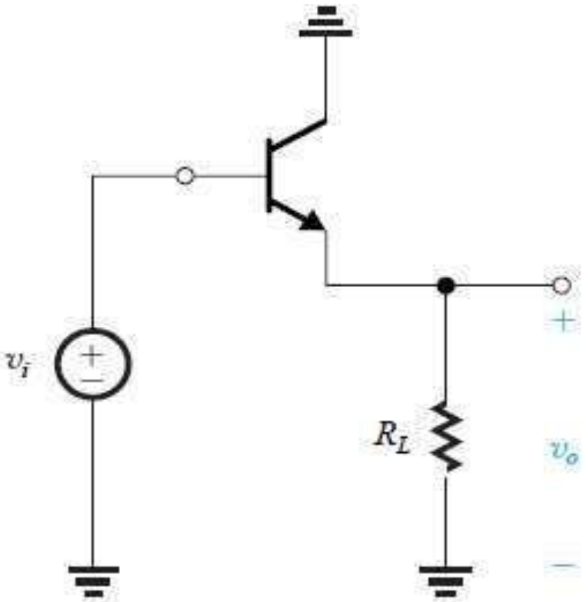
Three Basic Configurations of BJT Amplifier



(a) Common-Emitter (CE)

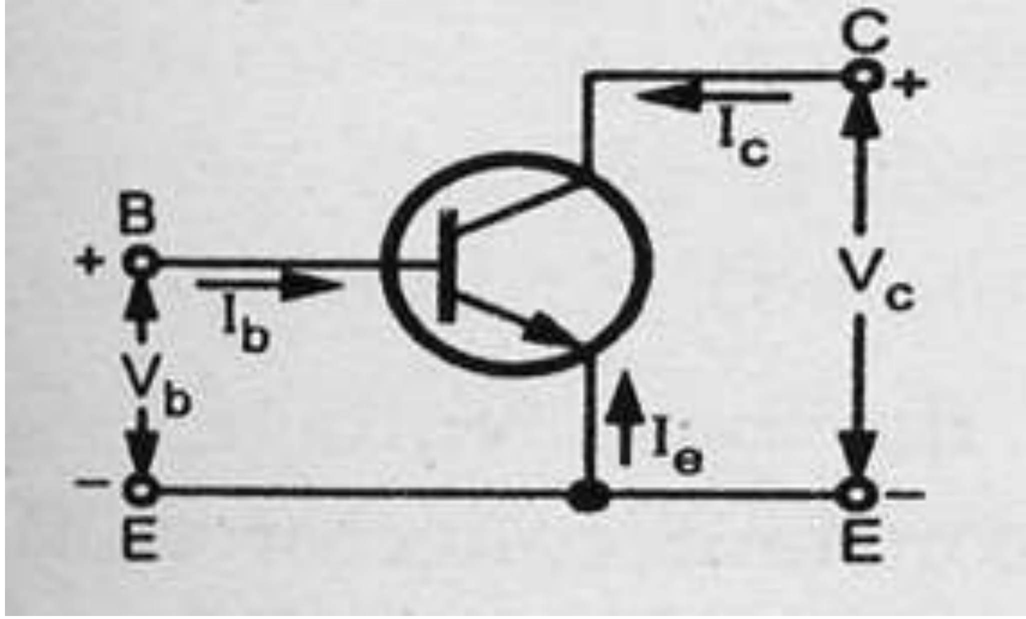


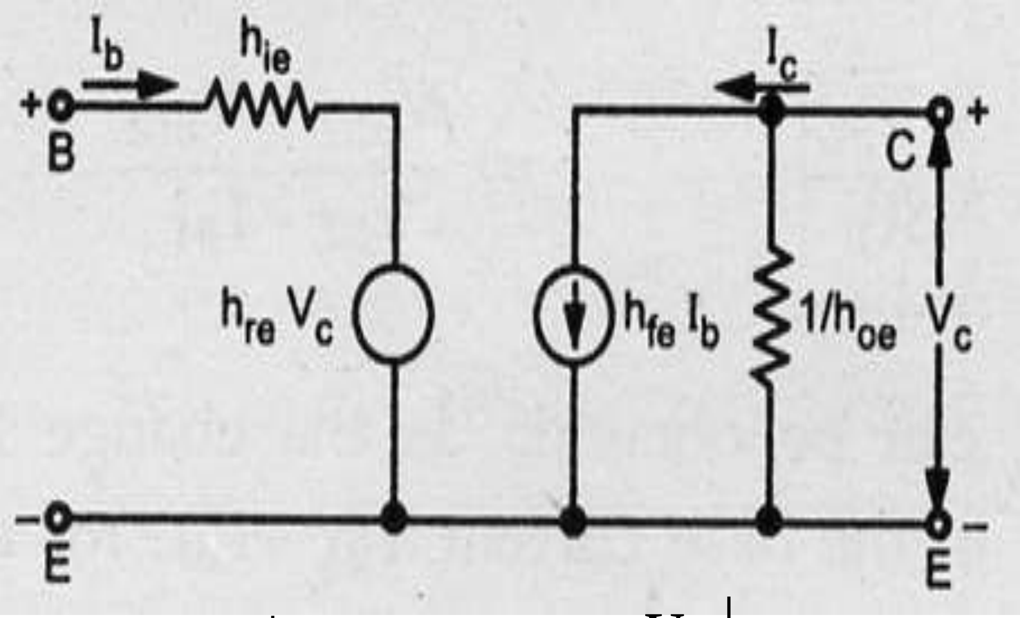
(b) Common-Base (CB)



(c) Common-Collector (CC)
or Emitter Follower

Hybrid Model for BJT Configurations-CE



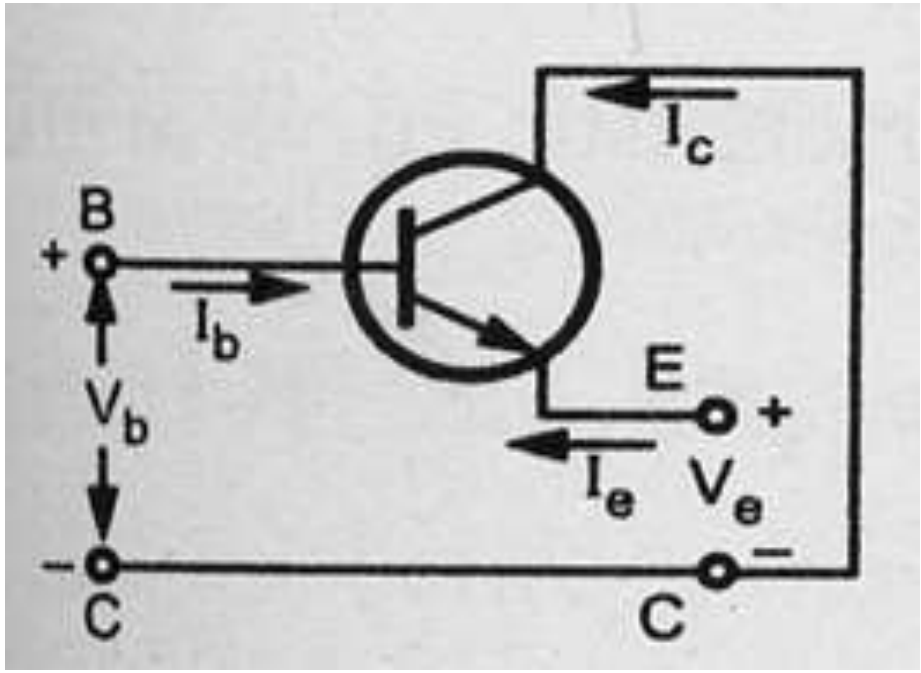


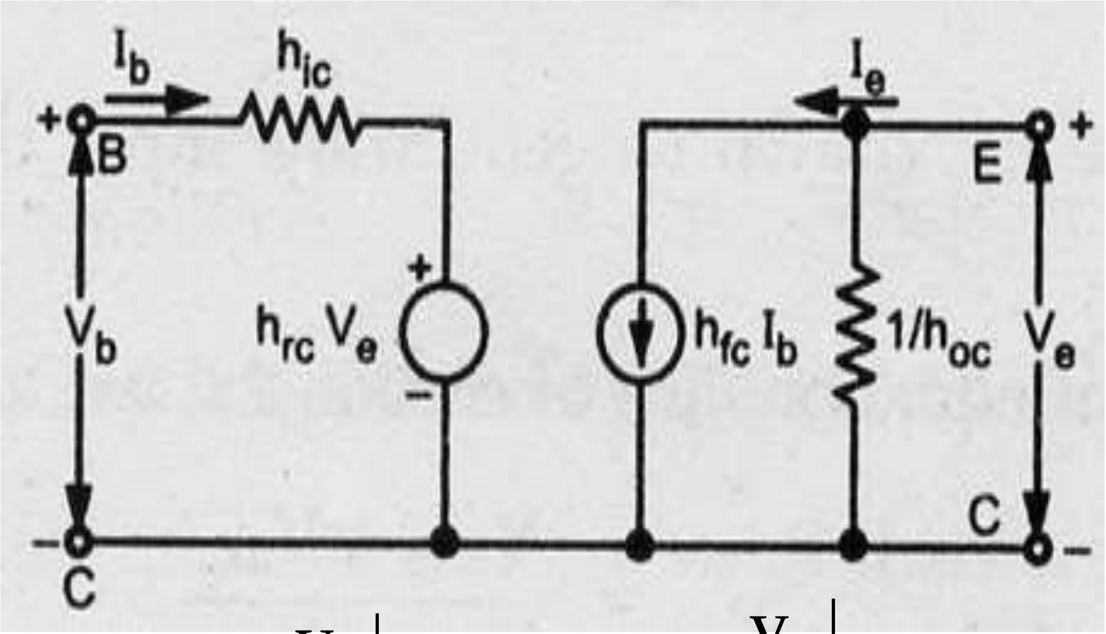
$$\boxed{\begin{aligned} v_b &= h_{ie} i_b + h_{re} v_c \\ i_c &= h_{fe} i_b + h_{oe} v_c \end{aligned}}$$

$$h_{ie} = \left.\frac{v_b}{i_b}\right|_{V_c = 0V} \qquad h_{re} = \left.\frac{v_b}{v_c}\right|_{i_b = 0\,A}$$

$$h_{fe} = \left.\frac{i_c}{i_b}\right|_{V_c = 0V} \qquad h_{oe} = \left.\frac{i_c}{v_c}\right|_{i_b = 0\,A}$$

Hybrid Model for BJT Configurations-CC



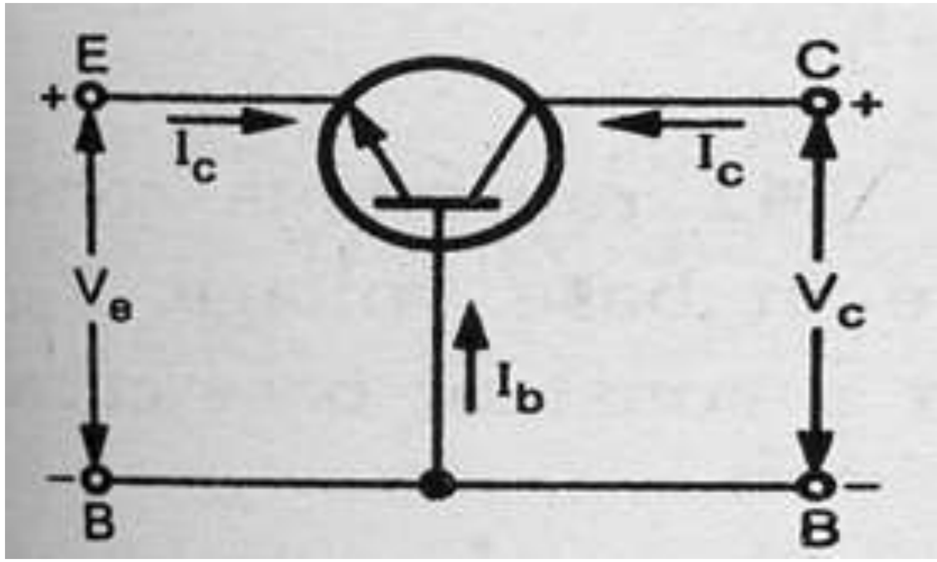


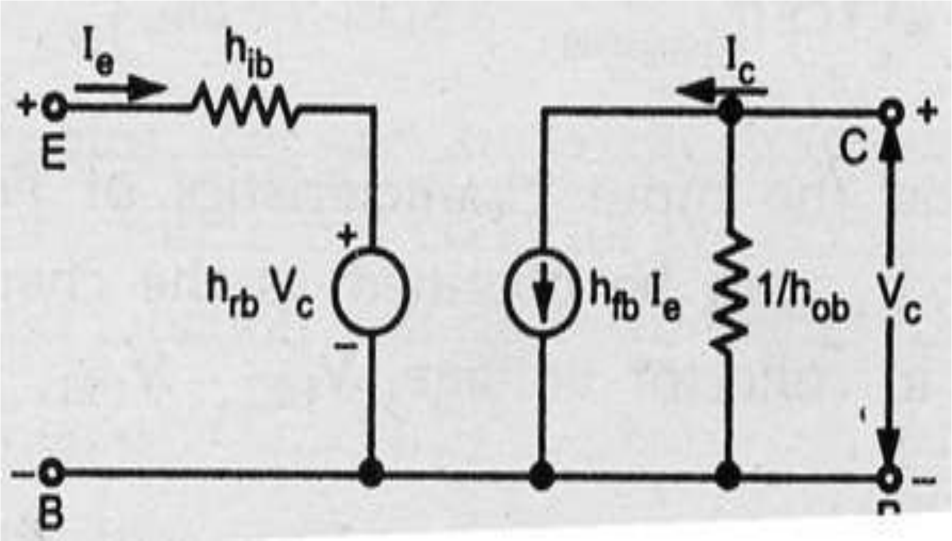
$$\boxed{\begin{aligned} v_b &= h_{ic} i_b + h_{rc} v_e \\ i_e &= h_{fc} i_b + h_{oc} v_e \end{aligned}}$$

$$h_{ic} = \left.\frac{v_b}{i_b}\right|_{V_e = 0V} \qquad h_{rc} = \left.\frac{v_b}{v_e}\right|_{i_b = 0\,A}$$

$$h_{fc} = \left.\frac{i_e}{i_b}\right|_{V_e = 0V} \qquad h_{oe} = \left.\frac{i_e}{v_e}\right|_{i_b = 0\,A}$$

Hybrid Model for BJT Configurations-CB



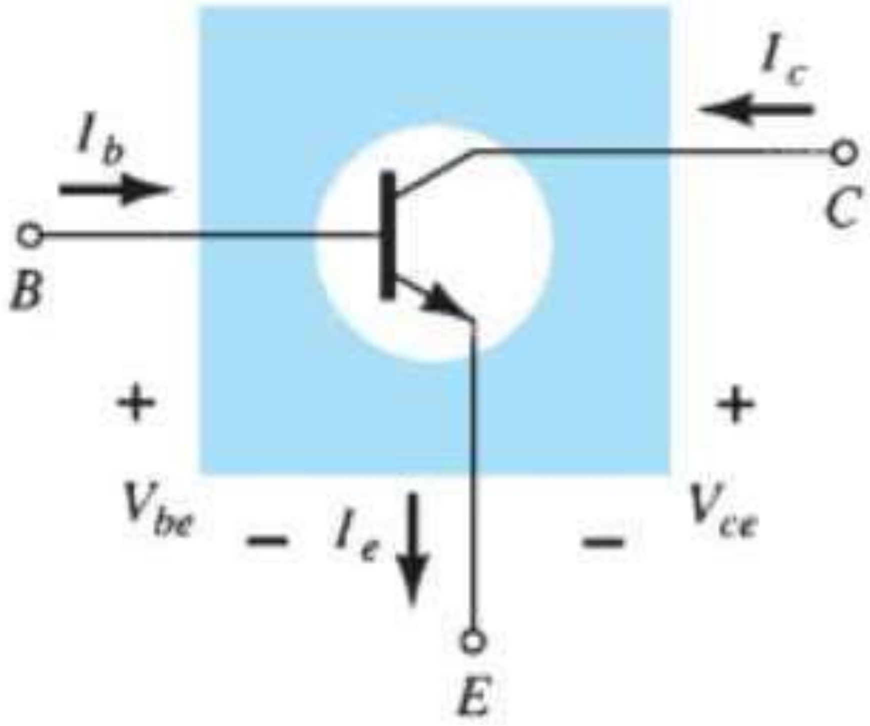


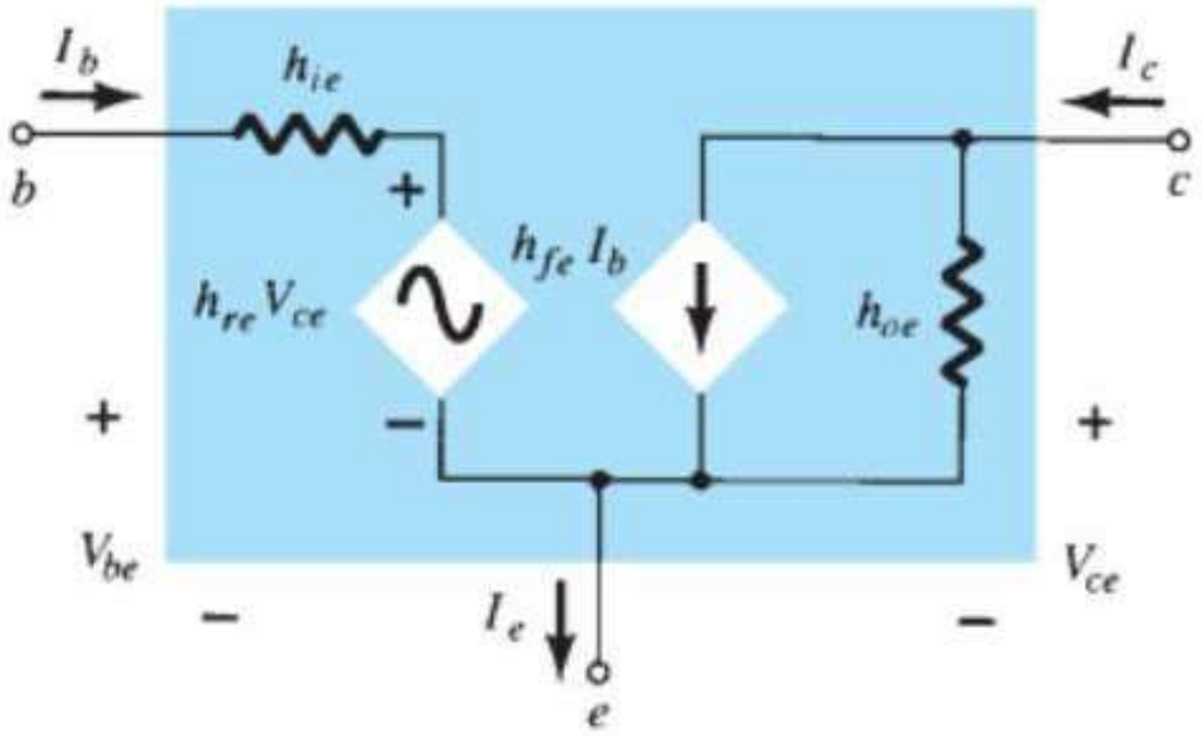
$$\boxed{\begin{aligned} v_e &= h_{ib} i_e + h_{rb} v_c \\ i_c &= h_{fb} i_e + h_{ob} v_c \end{aligned}}$$

$$h_{ib} = \left.\frac{v_e}{i_c}\right|_{V_c=0V} \qquad h_{rb} = \left.\frac{v_e}{v_c}\right|_{i_e=0\ A}$$

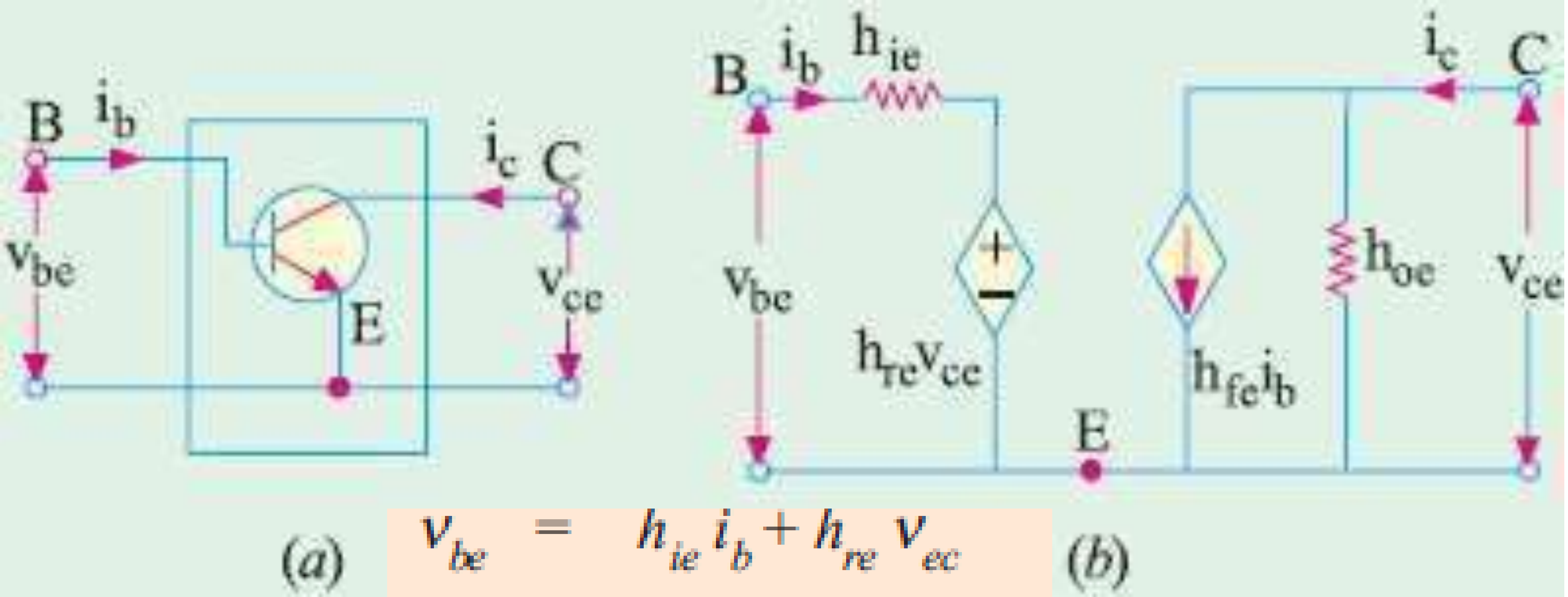
$$h_{fb} = \left.\frac{i_c}{i_e}\right|_{V_c=0V} \qquad h_{ob} = \left.\frac{i_c}{v_c}\right|_{i_e=0\ A}$$

Hybrid Model for BJT Configurations-CE



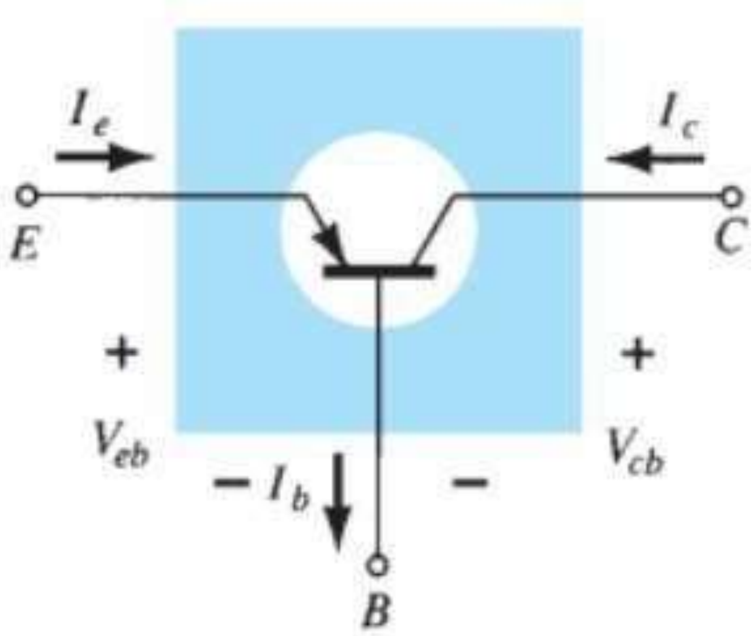


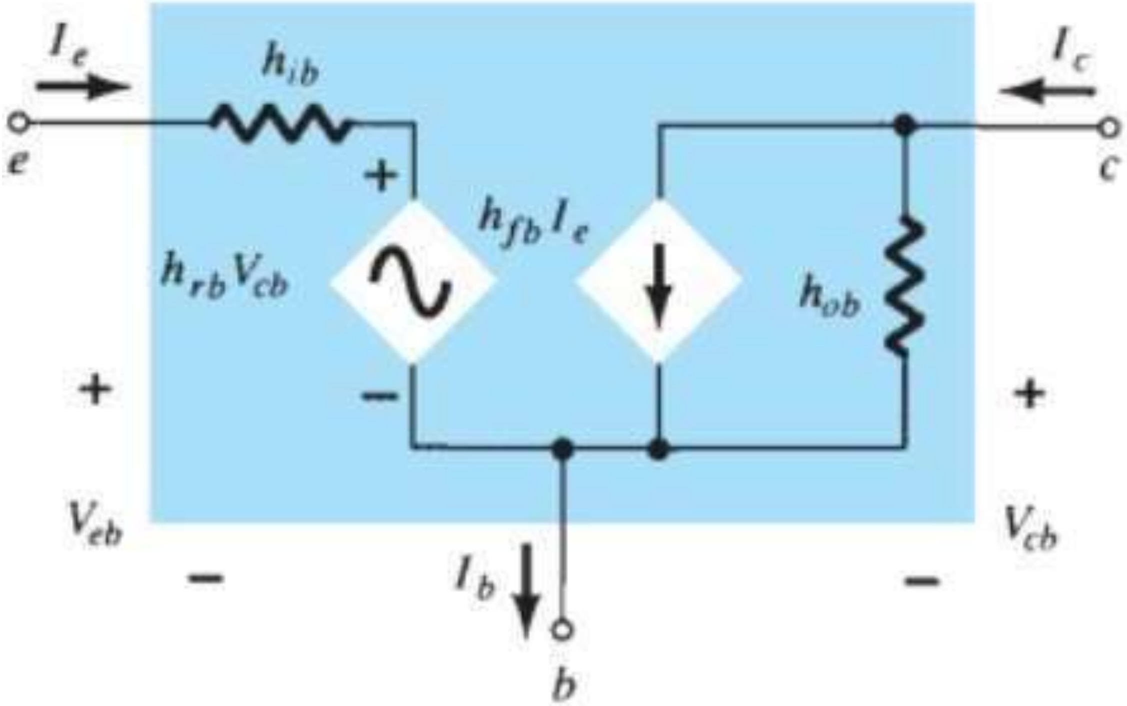
Hybrid Model for BJT Configurations-CE



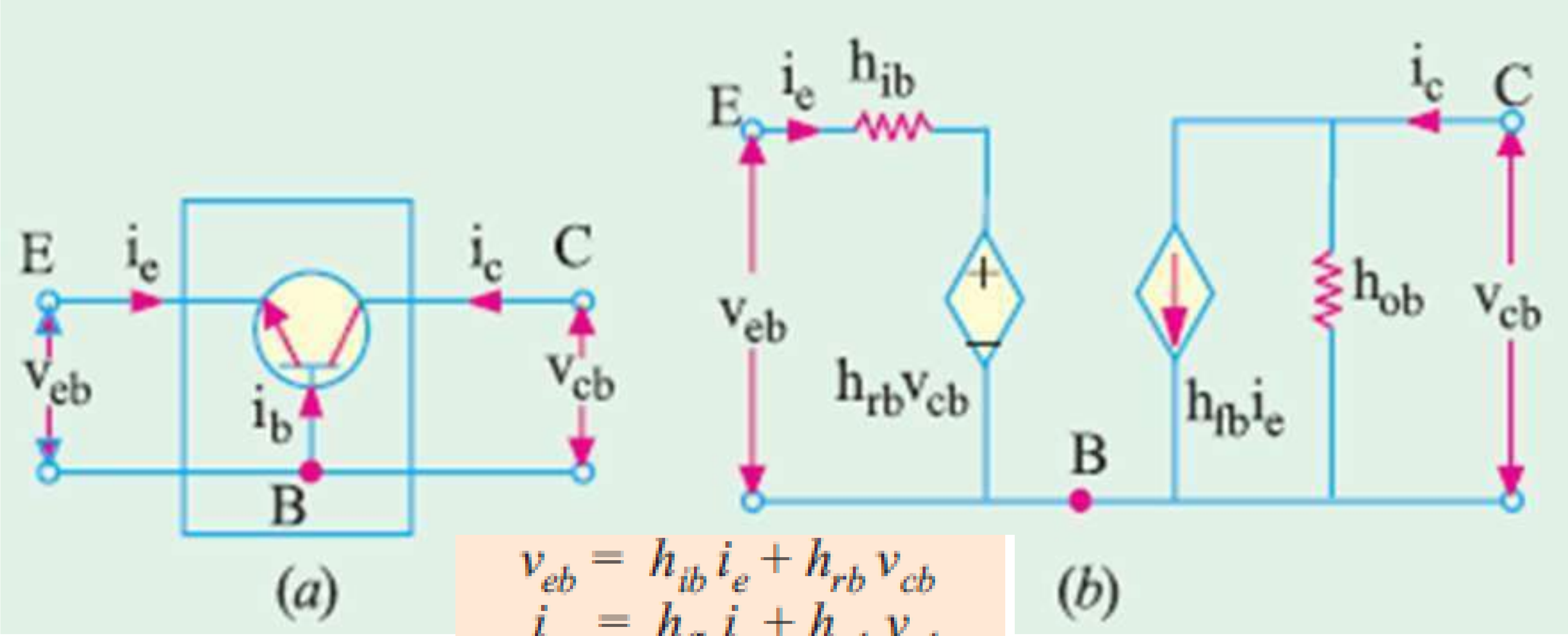
$$
\begin{aligned}
v_{be} &= h_{ie}\, i_b + h_{re}\, v_{ec} \\
i_e &= h_{fb}\, i_b + h_{oe}\, v_{ec}
\end{aligned}
$$

Hybrid Model for BJT Configurations-CB



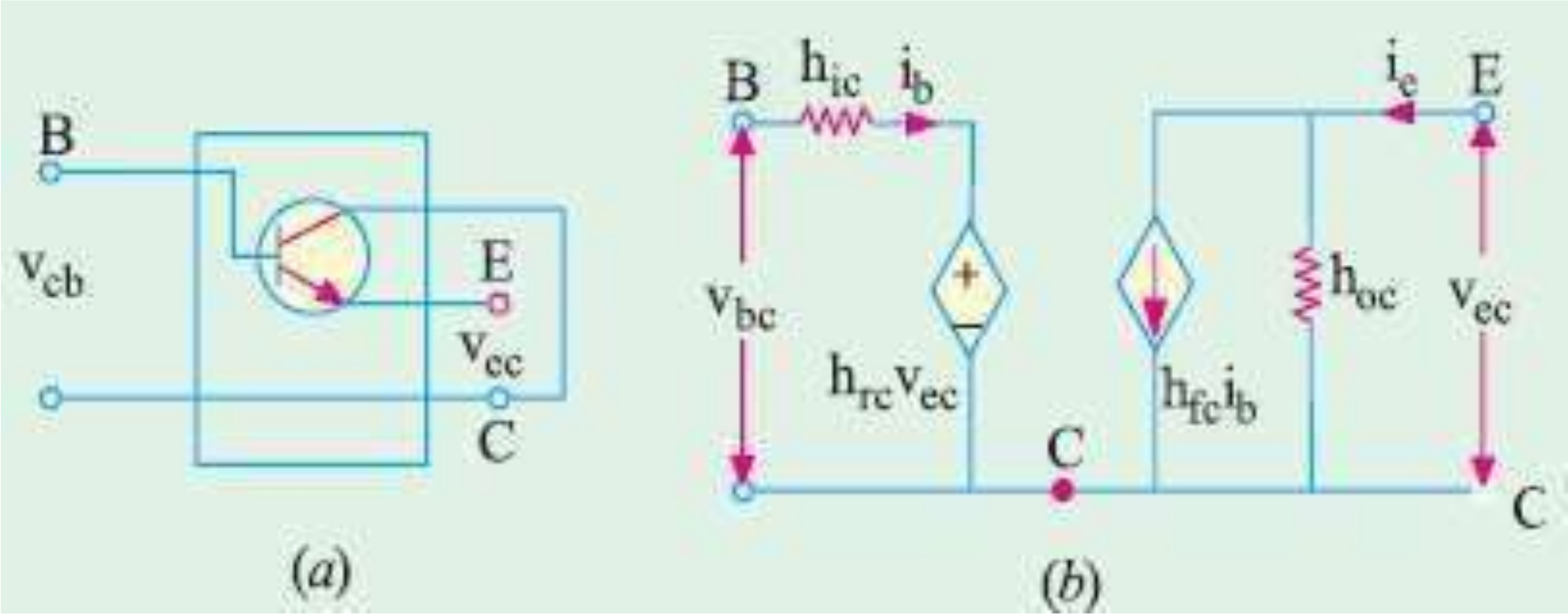


Hybrid Model for BJT Configurations-CB



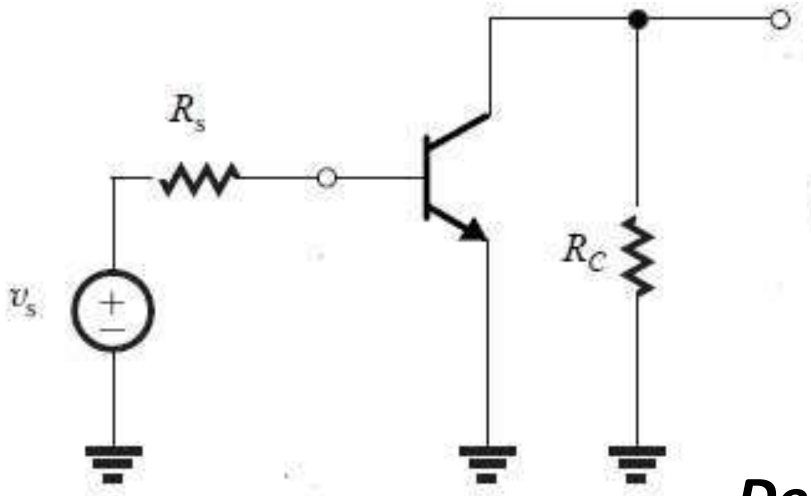
$$v_{eb} = h_{ib}\, i_e + h_{rb}\, v_{cb}$$
$$i_e = h_{fb}\, i_e + h_{ob}\, v_{eb}$$

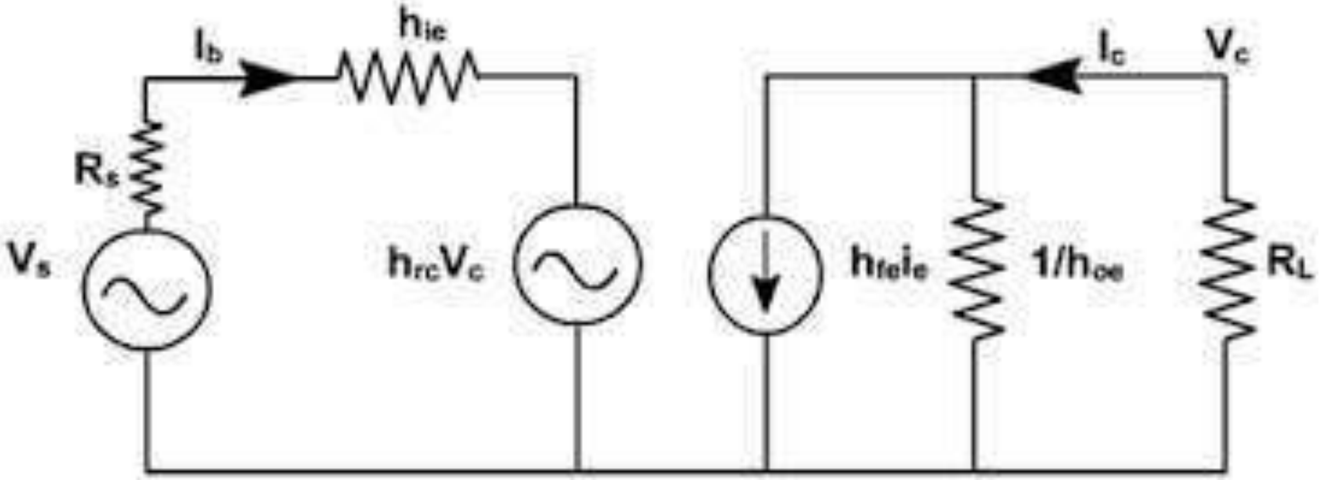
Hybrid Model for BJT Configurations-CC



$$
\begin{aligned}
v_{be} &= h_{ie}\, i_b + h_{re}\, v_{ec} \\
i_e &= h_{fe}\, i_b + h_{oc}\, v_{ce}
\end{aligned}
$$

CE Amplifier Without Emitter Resistance
(Using Hybrid Model)

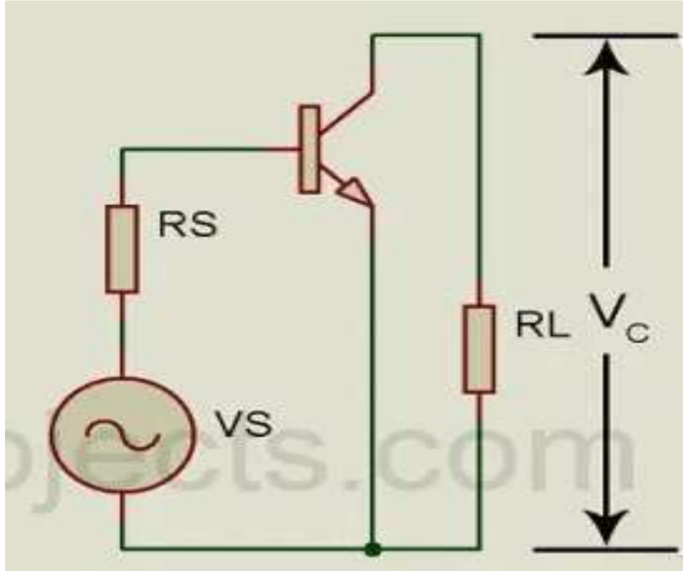


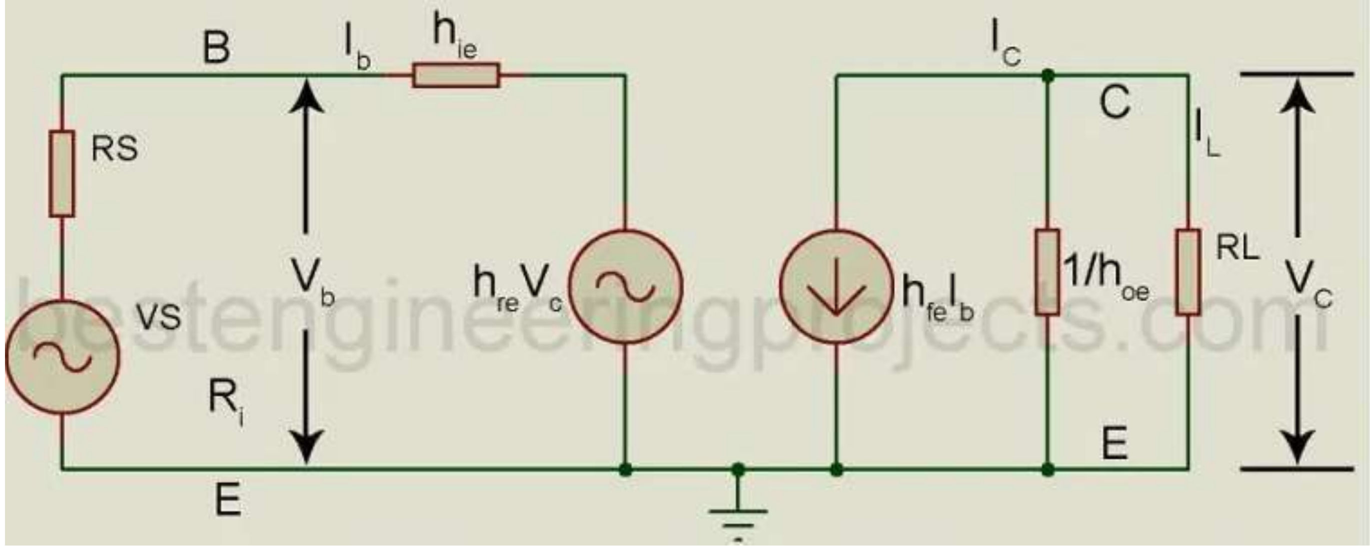


Determine :

1. ***Current Gain or Current Amplification A_i***
2. ***Input Resistance R_i***
3. ***Voltage Gain or Voltage Amplification A_v***
4. ***Output Admittance Y_0***
5. ***Output Resistance R_o***

CE Amplifier Without Emitter Resistance
(Using Hybrid Model)

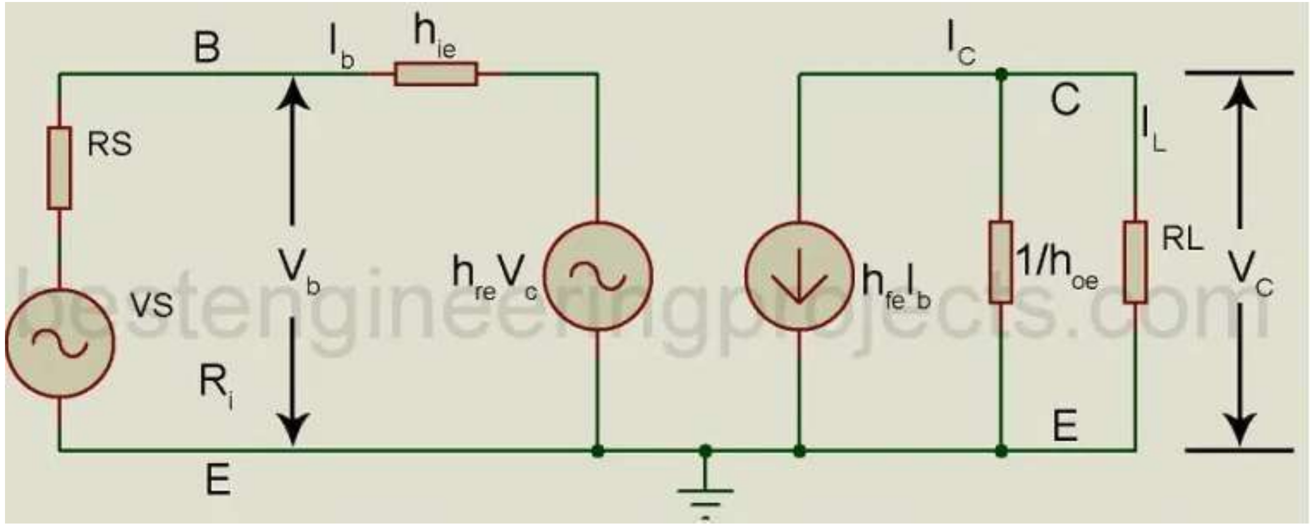




Determine :

1. ***Current Gain or Current Amplification A_i***
2. ***Input Resistance R_i***
3. ***Voltage Gain or Voltage Amplification A_v***
4. ***Output Admittance Y_0***
5. ***Output Resistance R_o***

CE Amplifier Without Emitter Resistance (Using Hybrid Model)



- ***Current Gain or Current Amplification:***
- Current gain is defined as the ratio of the load current I_L to the input current I_b.

$$A_i = \frac{i_L}{i_b} = -\frac{i_c}{i_b}$$

$$i_c = h_{fe} i_b + h_{oe} v_c$$

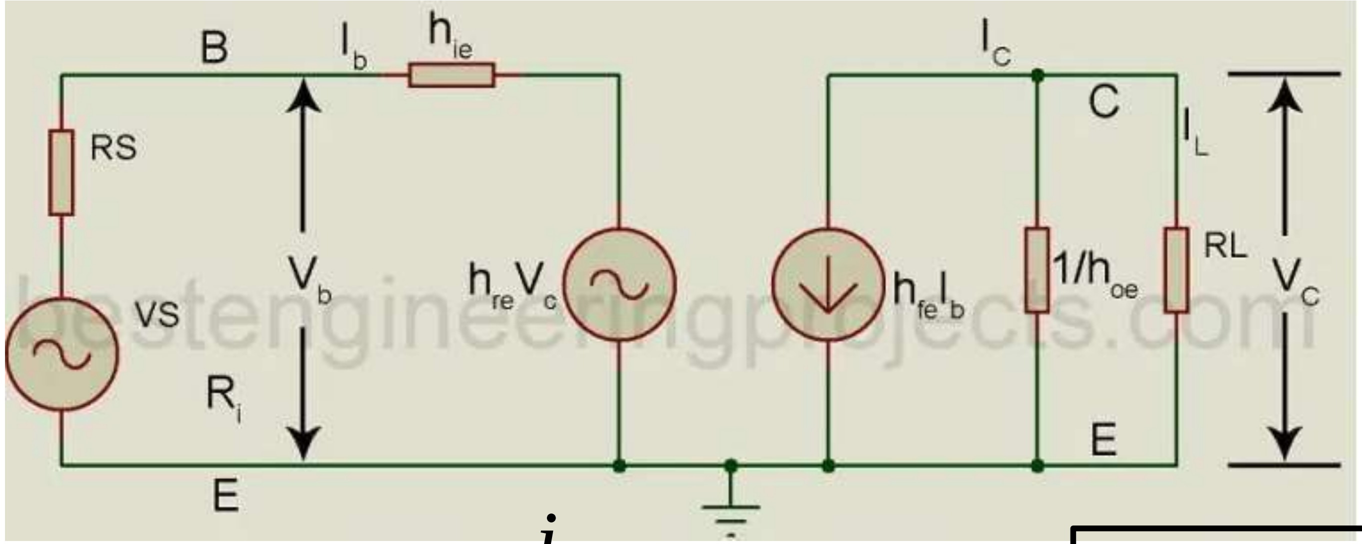
$$v_c = i_L R_L = -i_c R_L$$

$$i_c = h_{fe} i_b + h_{oe}\left(-i_c R_L\right)$$

$$i_c\left(1 + h_{oe} R_L\right) = h_{fe} i_b$$

$$\boxed{A_i = \frac{i_c}{i_b} = -\frac{h_{fe}}{1 + h_{oe} R_L}}$$

CE Amplifier Without Emitter Resistance
(Using Hybrid Model)



Input Resistance R_i

$$\boxed{R_i = \frac{v_b}{i_b}}$$

$$\boxed{v_b = h_{ie} i_b + h_{re} v_c}$$

$$\boxed{v_c = i_L R_L = -i_c R_L = A_i i_b R_L}$$

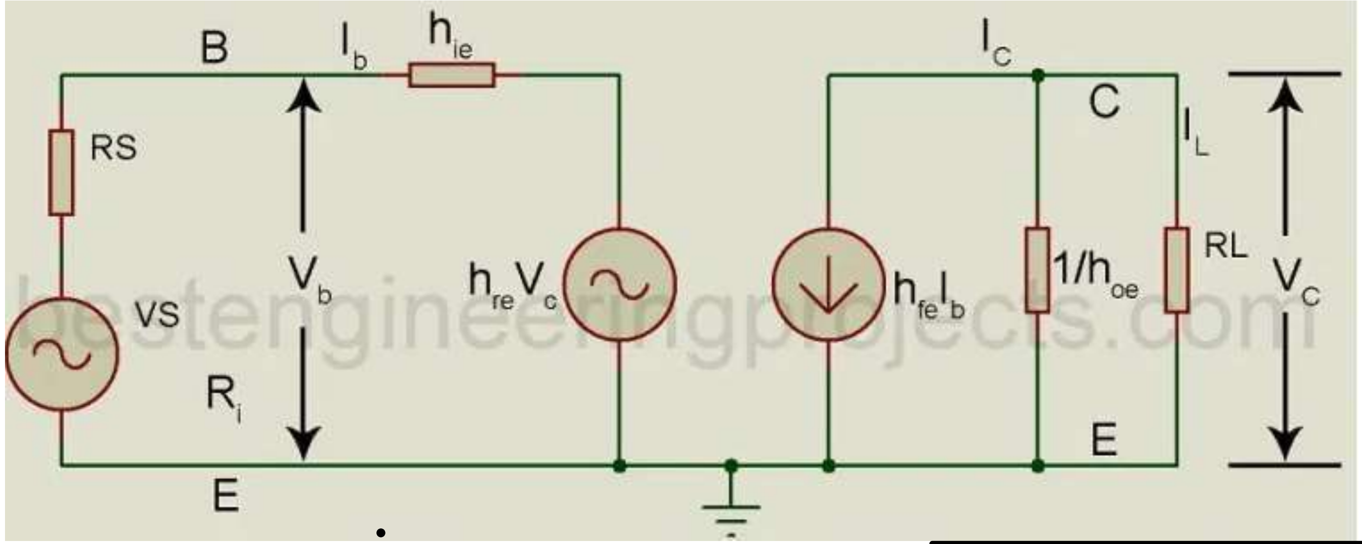
But, $A_i = -\frac{i_c}{i_b} \Rightarrow i_c = -A_i i_b$

$$\boxed{v_b = h_{ie} i_b + h_{re} (A_i i_b R_L)}$$

$$\boxed{v_b = i_b (h_{ie} + h_{re} A_i R_L)}$$

$$\boxed{\Rightarrow R_i = \frac{v_b}{i_b} = h_{ie} + h_{re} A_i R_L}$$

CE Amplifier Without Emitter Resistance
(Using Hybrid Model)



Voltage Gain A_v

$$\boxed{A_v = \frac{v_c}{v_b}}$$

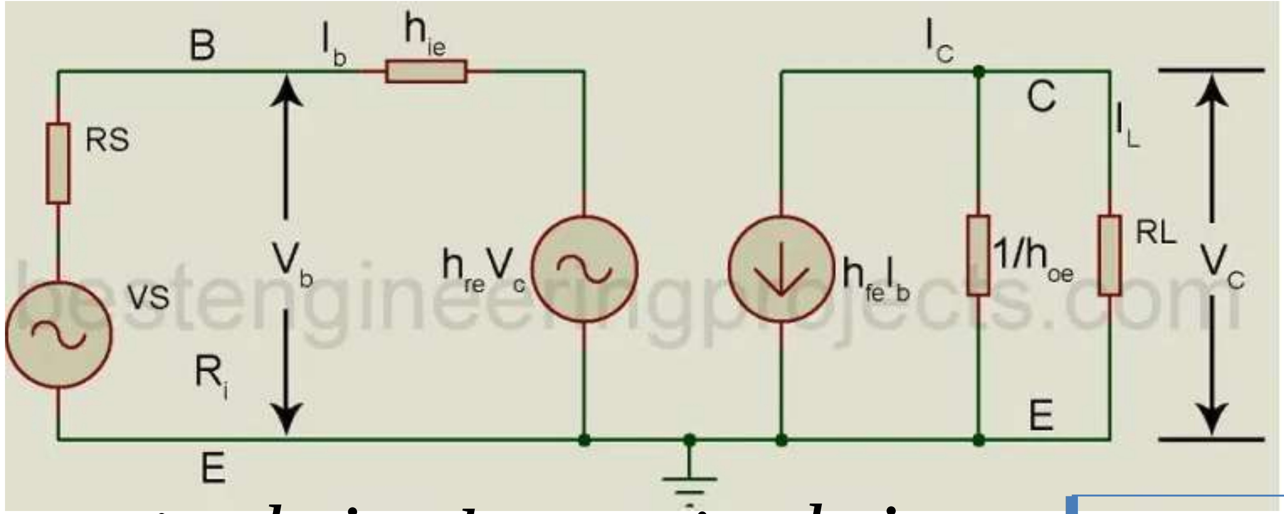
$$\boxed{v_c = i_L R_L = -i_c R_L = A_i i_b R_L}$$

But, $A_i = -\frac{i_c}{i_b} \Rightarrow i_c = -A_i\, i_b$

$$\boxed{\frac{1}{R_i} = \frac{i_b}{v_b}}$$

$$\boxed{\Rightarrow A_v = \frac{v_c}{v_b} = \frac{A_i i_b R_L}{v_b} = \frac{A_i R_L}{R_i}}$$

CE Amplifier Without Emitter Resistance
(Using Hybrid Model)



Output Admittance Y_o

$$\boxed{Y_o = \frac{i_c}{v_c}}$$

$$i_c = h_{fe} i_b + h_{oe} v_c$$

Dividing By V_c

$$\frac{i_c}{v_c} = \frac{h_{fe} i_b}{v_c} + \frac{h_{oe} v_c}{v_c} \Rightarrow \frac{i_c}{v_c} = \frac{h_{fe} i_b}{v_c} + h_{oe}$$

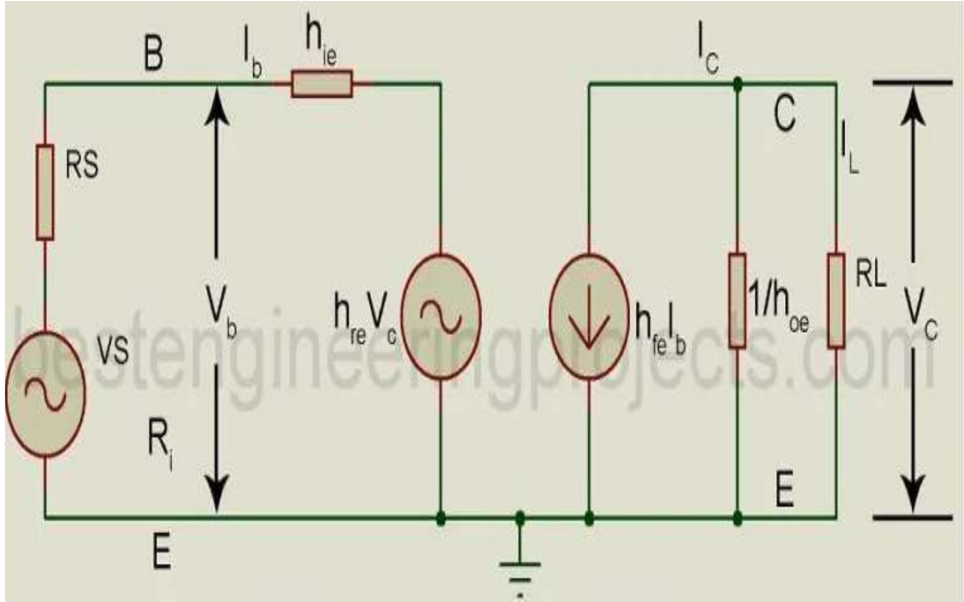
$$v_s = 0, R_s i_b + h_{ie} i_b + h_{re} v_c = 0$$

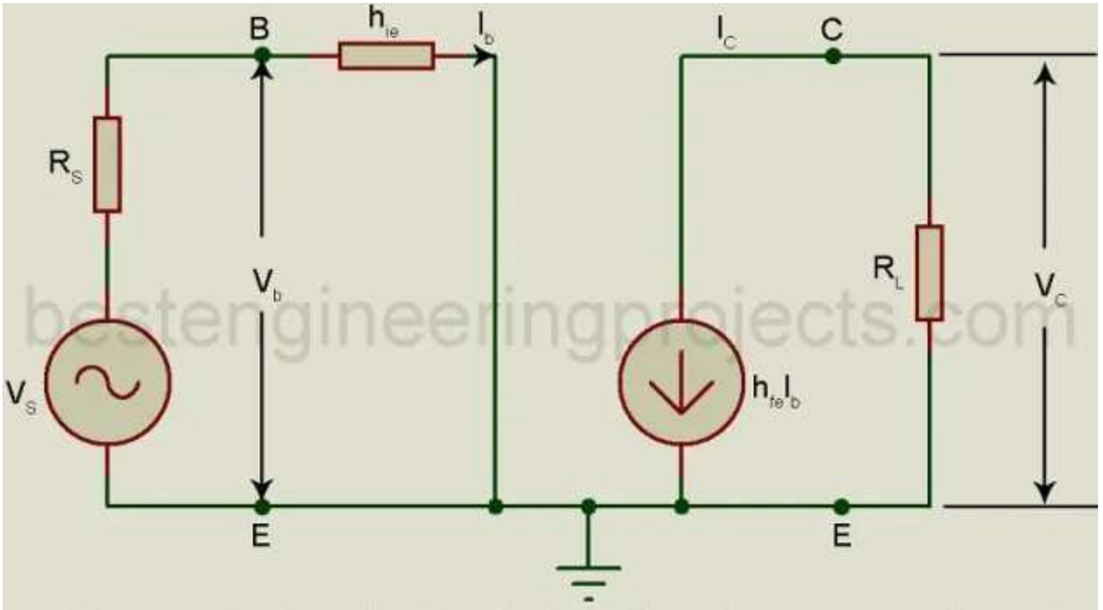
$$(R_s + h_{ie}) i_b = -h_{re} v_c$$

$$\boxed{\Rightarrow \frac{i_b}{v_c} = -\frac{h_{re}}{R_s + h_{ie}}}$$

$$\boxed{\Rightarrow Y_0 = h_{oe} - \frac{h_{fe} h_{re}}{R_s + h_{ie}} \text{ and } R_0 = \frac{1}{Y_0}}$$

CE Amplifier Without Emitter Resistance
(Using Approximate Hybrid Model)





$$A_i = \frac{i_c}{i_b} = -\frac{h_{fe}}{1 + h_{oe}R_L}$$

$$R_i = \frac{v_b}{i_b} = h_{ie} + h_{re}A_i R_L$$

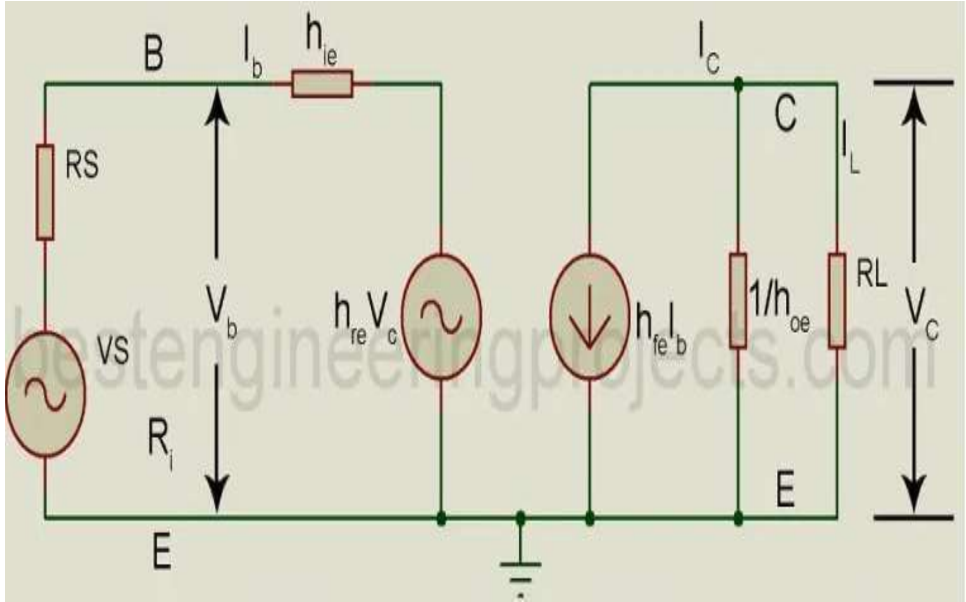
Neglecting

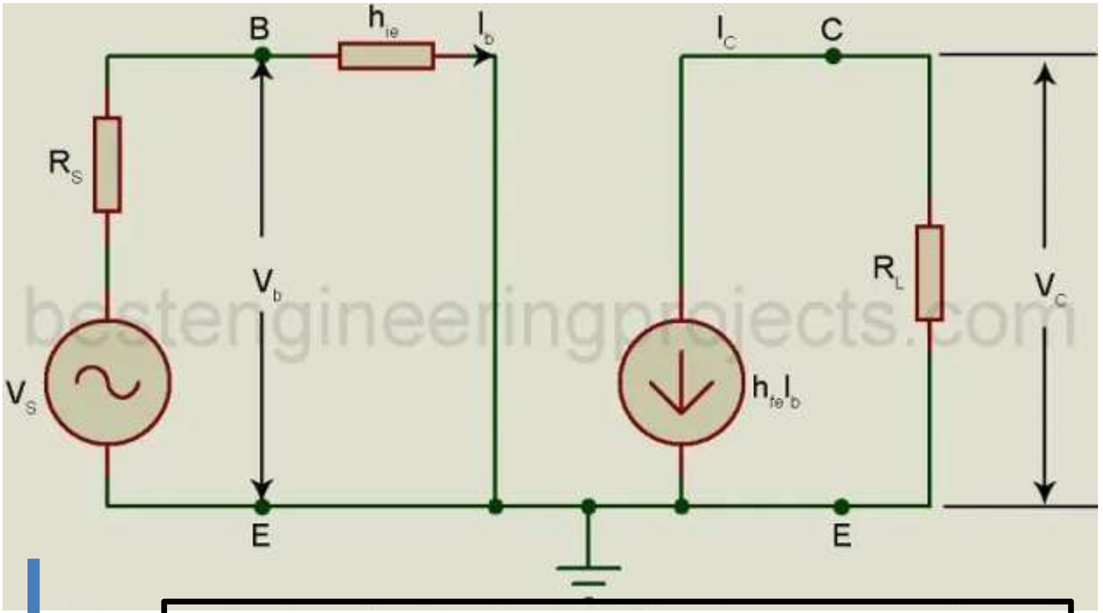
$$h_{oe} = 0, and\ h_{re} = 0$$

$$A_i = \frac{i_c}{i_b} = -h_{fe}$$

$$\Rightarrow R_i = h_{ie}$$

CE Amplifier Without Emitter Resistance
(Using Approximate Hybrid Model)





$$\Rightarrow A_v = \frac{A_i R_L}{R_i} = \frac{A_i R_L}{h_{ie}}$$

$$\Rightarrow Y_0 = h_{oe} - \frac{h_{fe} h_{re}}{R_s + h_{ie}} \text{ and } R_0 = \frac{1}{Y_0}$$

$$\Rightarrow Y_0 = 0 \text{ and } R_0 = \frac{1}{Y_0} = \infty$$