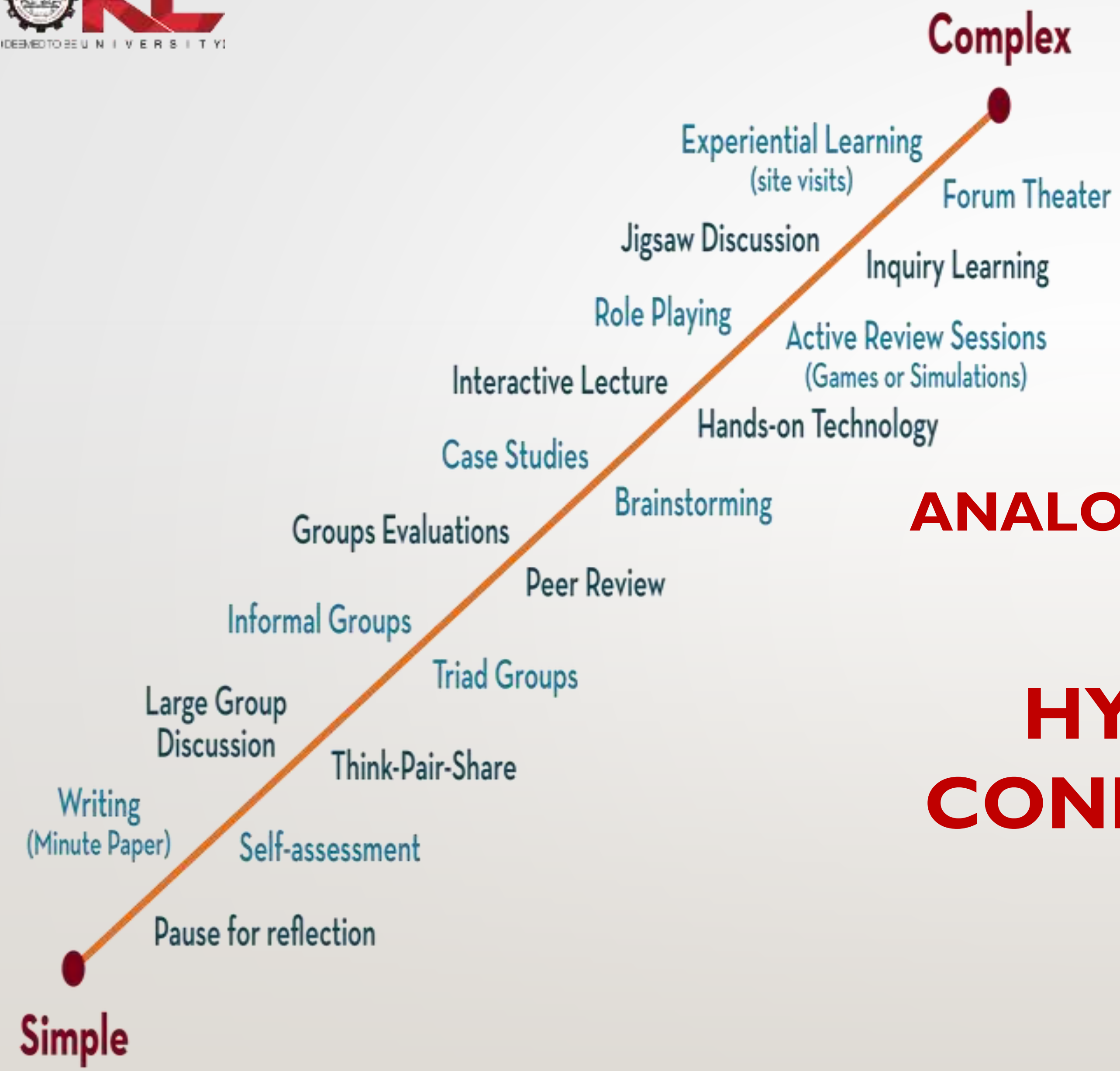


AY-2025-2026
ODD SEM

Department of ECE

ANALOG ELECTRONIC CIRCUIT DESIGN
23EC2104

Topic:

HYBRID MODEL FOR BJT CONFIGURATIONS-CE, CB,CC

Session - 09

SESSION CONTENT

- Hybrid Model for BJT Configurations-CE, CB, CC

AIM OF THE SESSION

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

INSTRUCTIONAL OBJECTIVES

The Session is designed to:

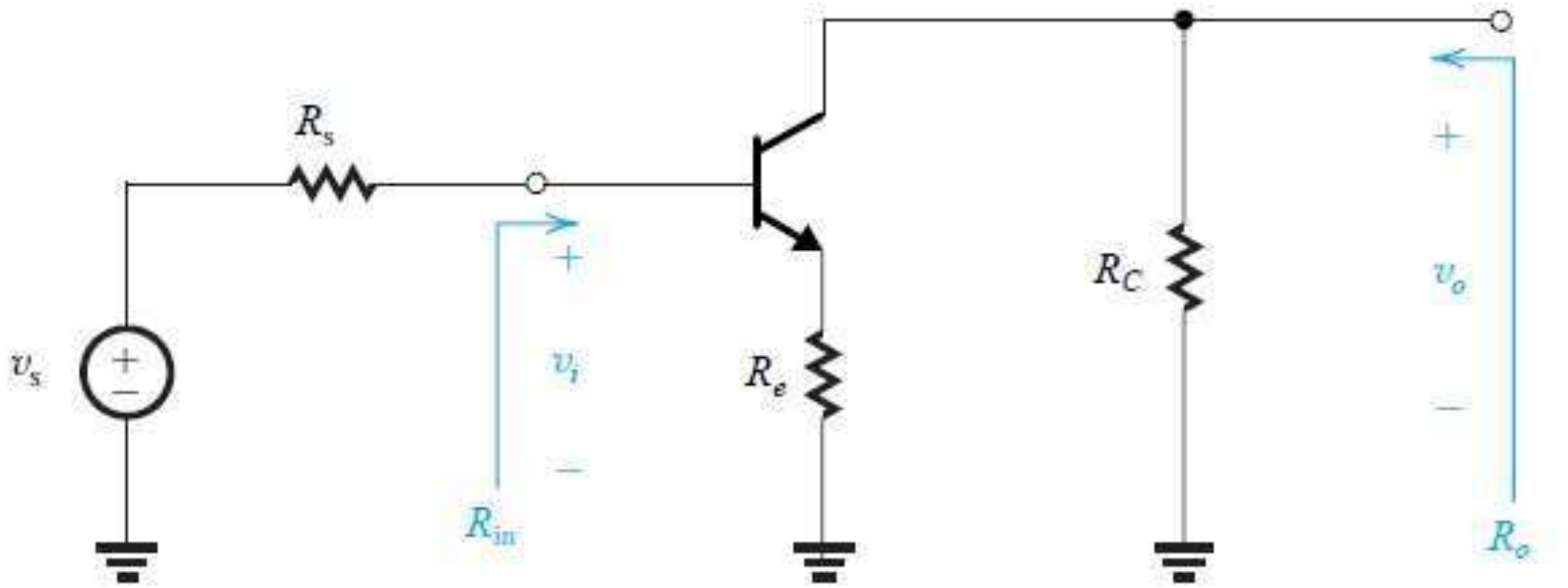
1. Explain the concept of the Hybrid-π model for BJTs.
2. Identify the key elements of the Hybrid-π equivalent circuit.
3. Describe the role of each parameter ($r\pi$, gm, ro) in CE,CB, CC configuration.
4. Apply the model to analyze small-signal behavior of CE, CB, CCamplifiers.

LEARNING OUTCOMES

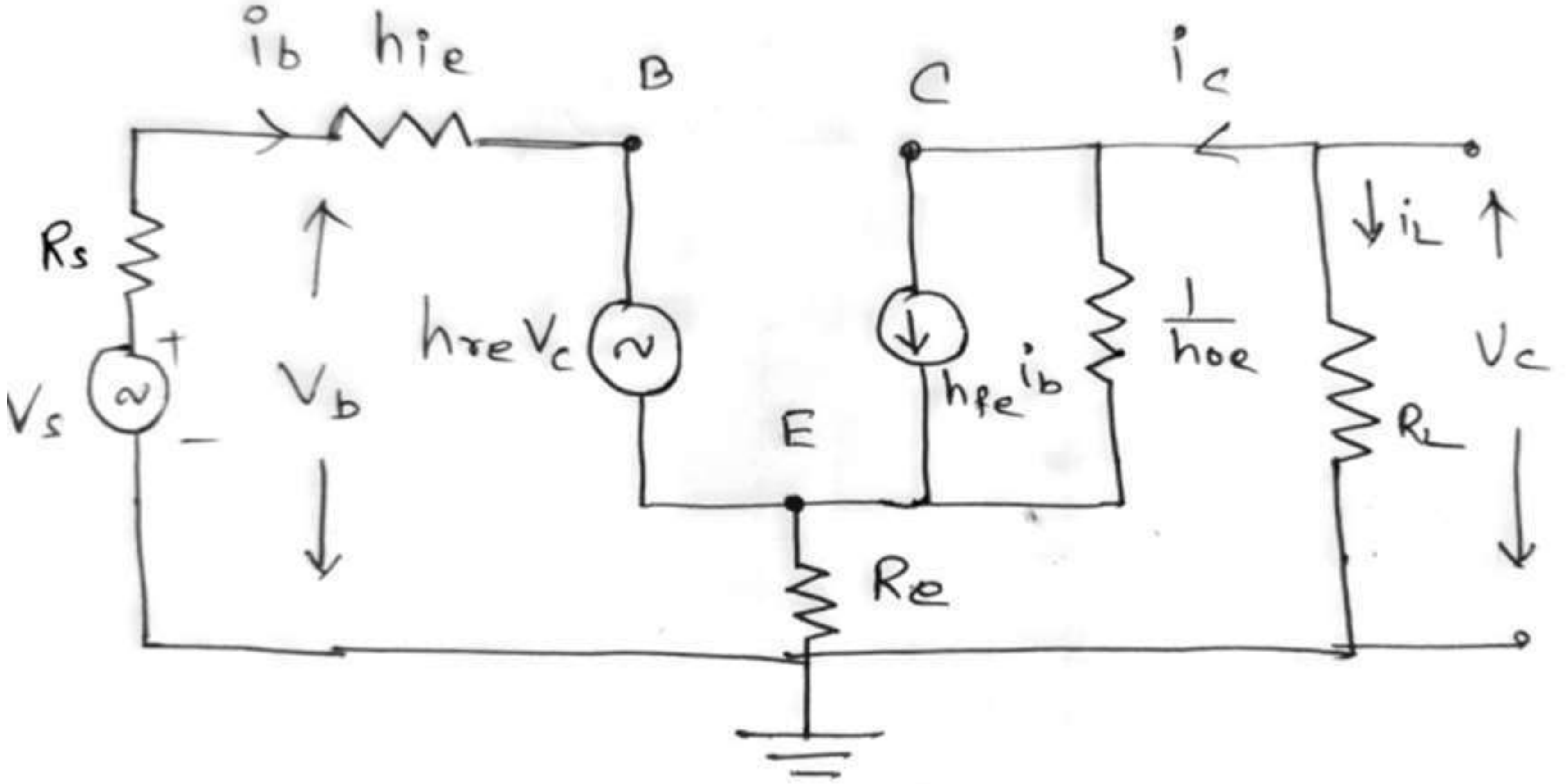
At the end of this session, learners will be able to:

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

CE Amplifier With Emitter Resistance



CE Amplifier With Emitter Resistance
(Using Hybrid Model)



CE Amplifier With Emitter Resistance
(Using Hybrid Model)

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

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

$$A_v = \frac{A_i R_L}{R_i}$$

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

$$A_i = \frac{h_{oe} R_e - h_{fe}}{1 + h_{oe}(R_L + R_e)}$$

$$R_i = h_{ie} + h_{re} A_i (R_L + R_e) + R_e (1 - A_i) - R_e h_{re}$$

$$A_v = \frac{A_i R_L}{R_i}$$

$$R_0 = \frac{1 + h_{fe}}{h_{oe}} + \frac{(R_s + h_{ie})(1 + h_{oe} R_e)}{h_{oe} R_e} \text{ and } Y_0 = \frac{1}{R_0}$$

Hybrid model

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

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

$$\boxed{A_v = \frac{A_i R_L}{R_i}}$$

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

Approximate Hybrid model

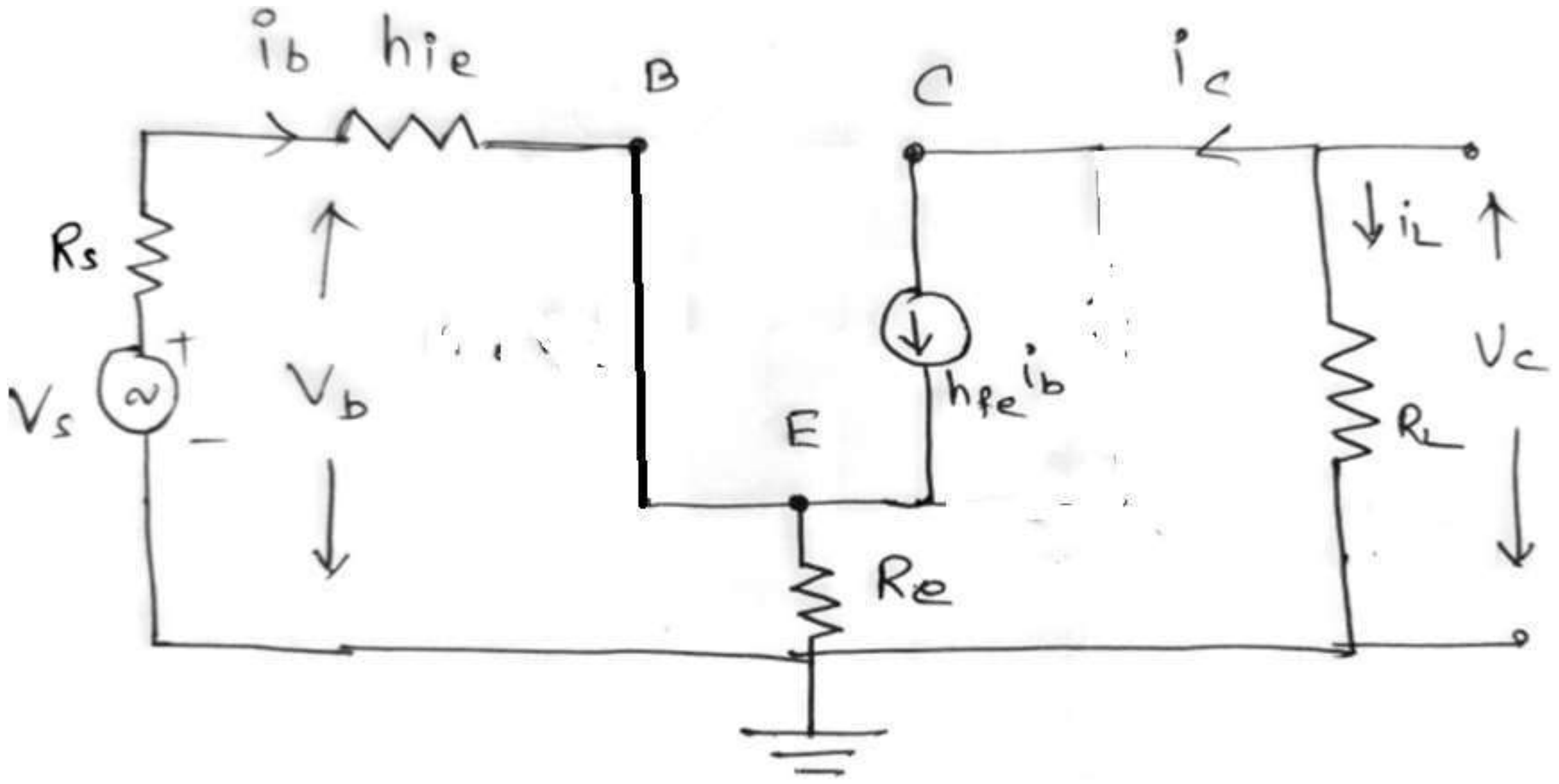
$$\boxed{A_i = -h_{fe}}$$

$$\boxed{R_i = h_{ie} + (1+h_{fe})R_e}$$

$$\boxed{A_v = \frac{A_i R_L}{R_i} = \frac{-h_{fe}R_L}{h_{ie} + (1+h_{fe})R_e}}$$

$$\boxed{Y_0 = 0, \text{ and } R_0 = \infty}$$

CE Amplifier With Emitter Resistance
(Using Approximate Hybrid Model)



CE Amplifier With Emitter Resistance

(Using Approximate Hybrid Model)

$$A_i = \frac{h_{oe} R_e - h_{fe}}{1 + h_{oe}(R_L + R_e)}$$

$$R_i = h_{ie} + h_{re} A_i (R_L + R_e) + R_e(1 - A_i) - R_e h_{re}$$

$$A_v = \frac{A_i R_L}{R_i}$$

$$R_0 = \frac{1 + h_{fe}}{h_{oe}} + \frac{(R_s + h_{ie})(1 + h_{oe} R_e)}{h_{oe} R_e} \quad and \quad Y_0 = \frac{1}{R_0}$$

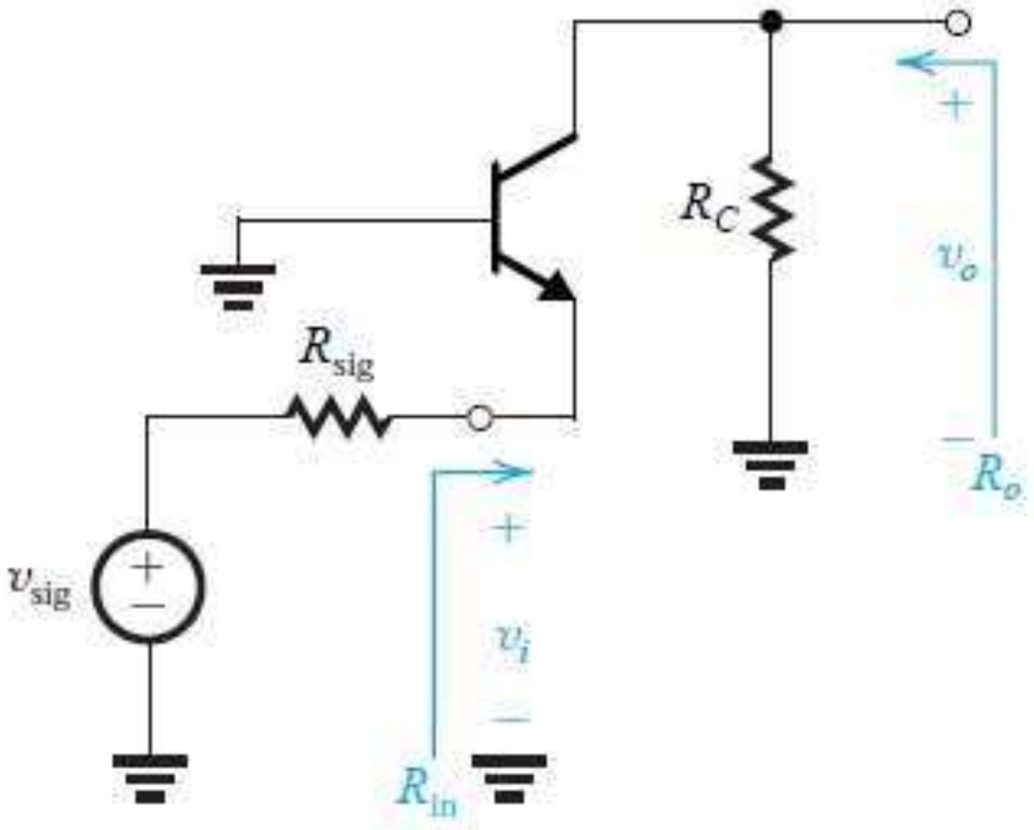
$$A_i = -h_{fe}$$

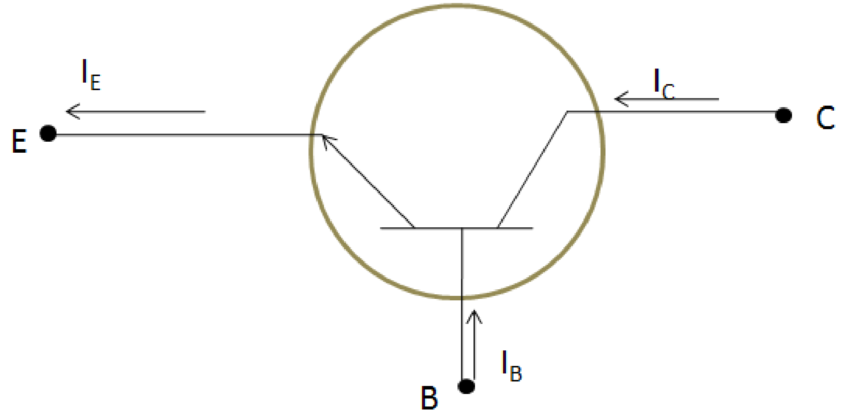
$$R_i = h_{ie} + (1 + h_{fe}) R_e$$

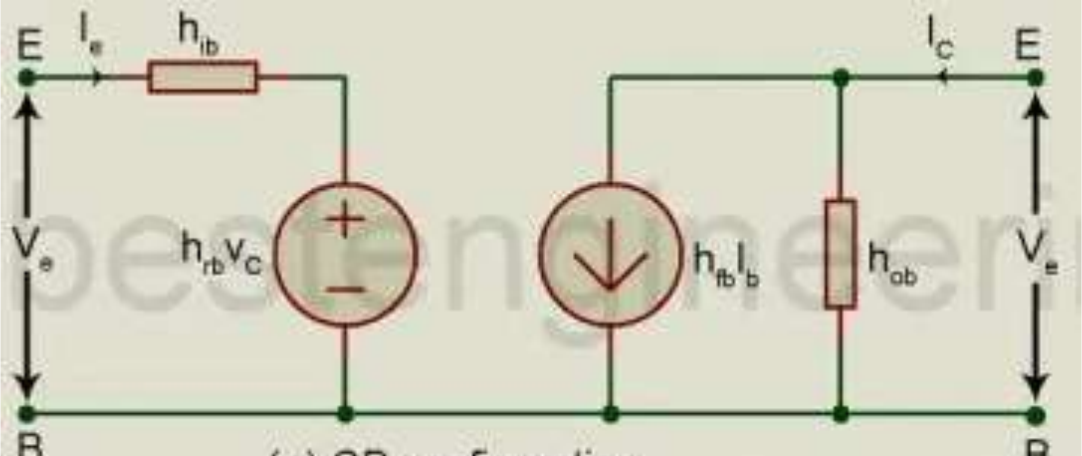
$$A_v = \frac{A_i R_L}{R_i} = \frac{-h_{fe} R_L}{h_{ie} + (1 + h_{fe}) R_e}$$

$$Y_0 = 0, \; and \; R_0 = \infty$$

CB Amplifier(**Using Hybrid Model)**

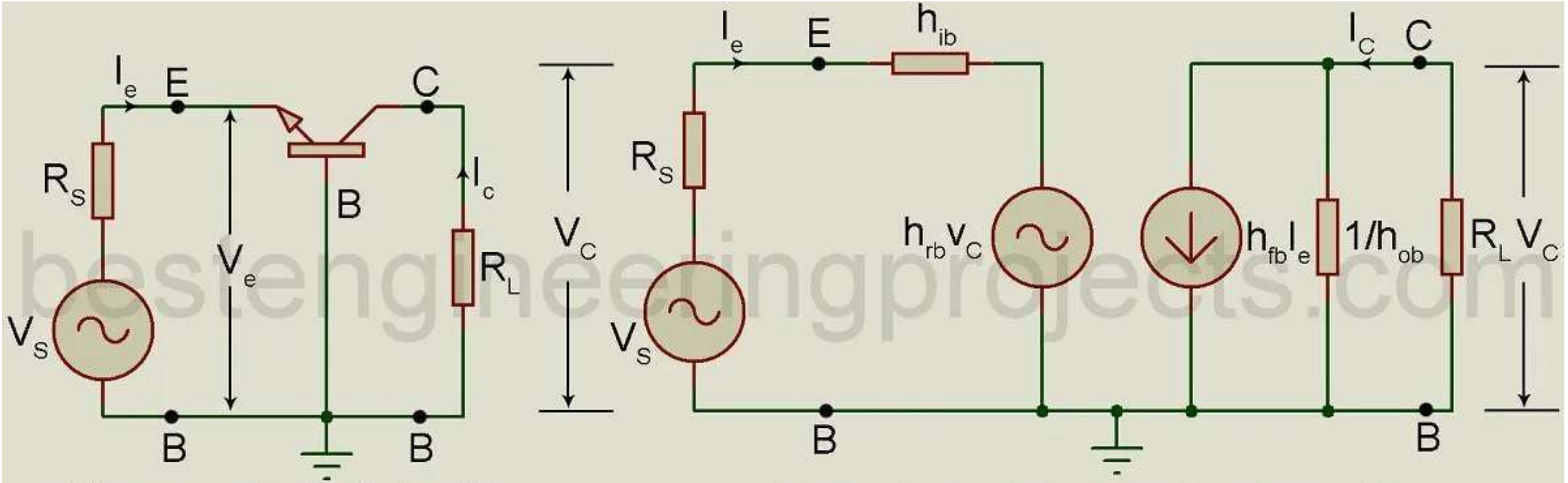






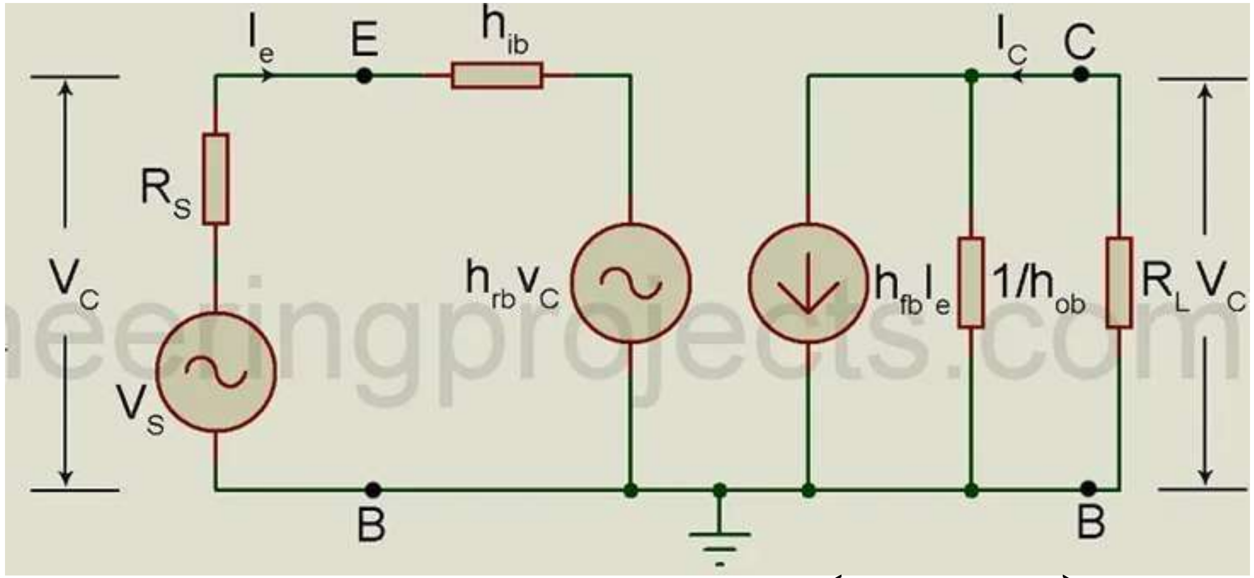
(a) CB configuration

CB Amplifier(**Using Hybrid Model)**



(a) a.c. equivalent circuit (b) Equivalent circuit using h-model

CB Amplifier **(Using Hybrid Model)**



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

$$i_c = h_{fb} i_e + h_{ob} v_c$$

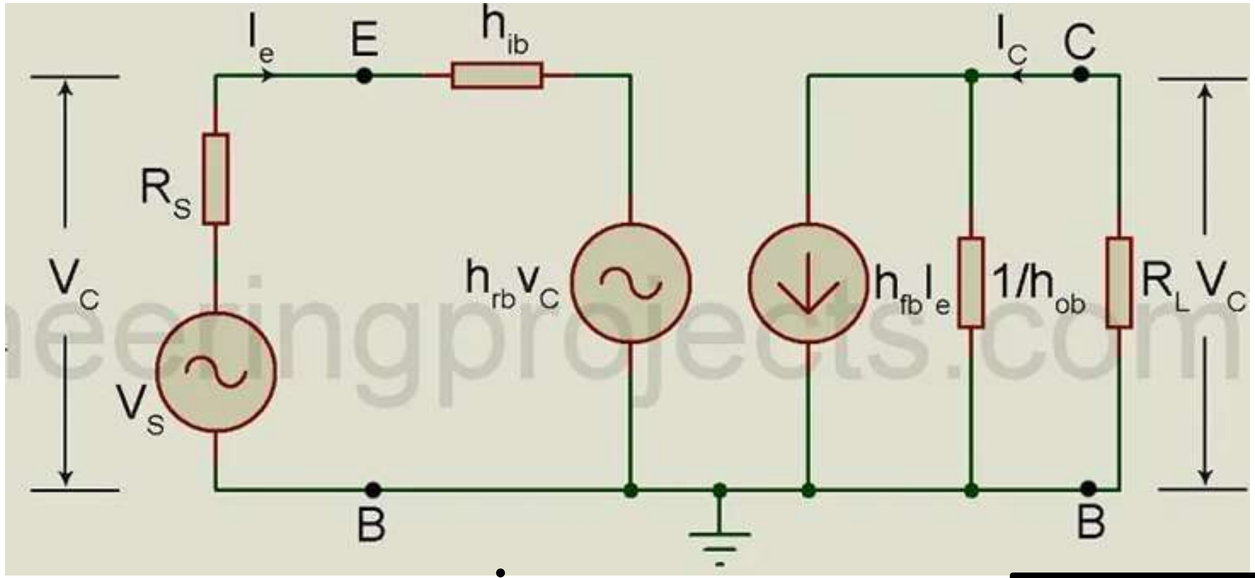
$$v_c = i_L R_L = -i_c R_L$$

$$i_c = h_{fb} i_e + h_{ob}(-i_c R_L)$$

$$i_c(1 + h_{ob} R_L) = h_{fb} i_e$$

$$\boxed{A_i = \frac{i_c}{i_e} = -\frac{h_{fb}}{1 + h_{ob} R_L}}$$

CB Amplifier **(Using Hybrid Model)**



$$\boxed{R_i = \frac{v_e}{i_e}}$$

$$\boxed{v_e = h_{ib} i_e + h_{rb} v_c}$$

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

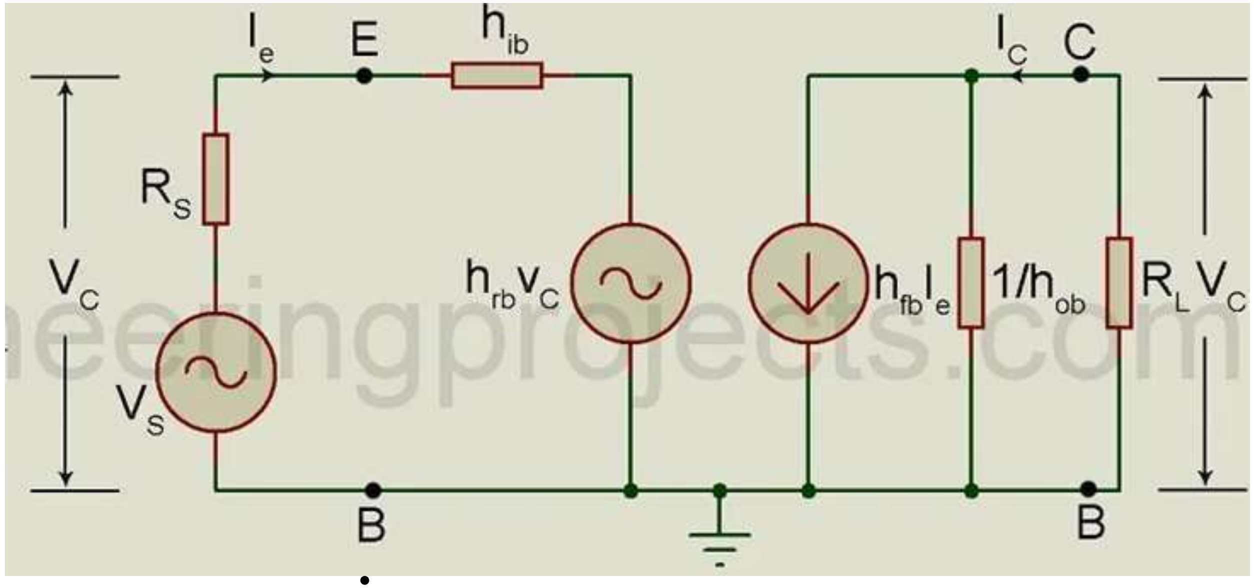
$$\boxed{v_c = i_L R_L = -i_c R_L = A_i i_e R_L}$$

$$\boxed{v_e = h_{ib} i_e + h_{rb} (A_i i_e R_L)}$$

$$\boxed{v_e = i_e (h_{ib} + h_{rb} A_i R_L)}$$

$$\boxed{\Rightarrow R_i = \frac{v_e}{i_e} = h_{ib} + h_{rb} A_i R_L}$$

CB Amplifier **(Using Hybrid Model)**



$$A_v = \frac{v_c}{v_e}$$

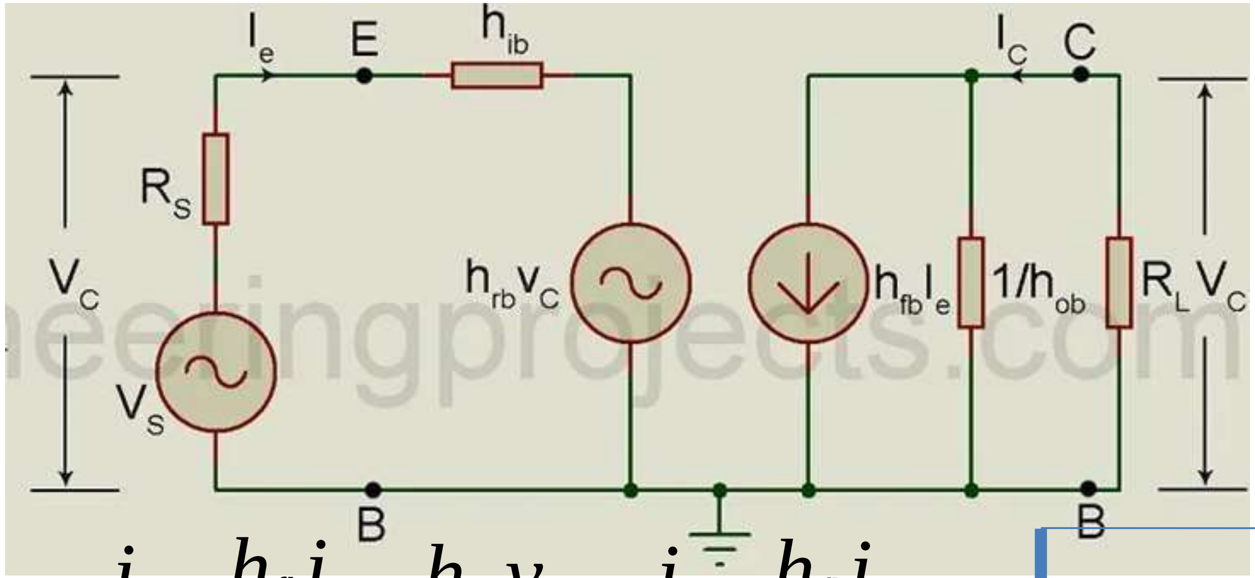
But, $A_i = -\frac{i_c}{i_e} \Rightarrow i_c = -A_i\, i_e$

$$v_c = i_L R_L = -i_c R_L = A_i i_e R_L$$

$$\frac{1}{R_i} = \frac{i_e}{v_e}$$

$$\Rightarrow A_v = \frac{v_c}{v_e} = \frac{A_i i_e R_L}{v_e} = \frac{A_i R_L}{R_i}$$

CB Amplifier **(Using Hybrid Model)**



$$\frac{i_c}{v_c} = \frac{h_{fb} i_e}{v_c} + \frac{h_{ob} v_c}{v_c} \Rightarrow \frac{i_c}{v_c} = \frac{h_{fb} i_e}{v_c} + h_{ob}$$

$$v_s = 0, R_s i_e + h_{ib} i_e + h_{rb} v_c = 0$$

$$(R_s + h_{ib}) i_e = -h_{rb} v_c$$

Output Admittance Y_o

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

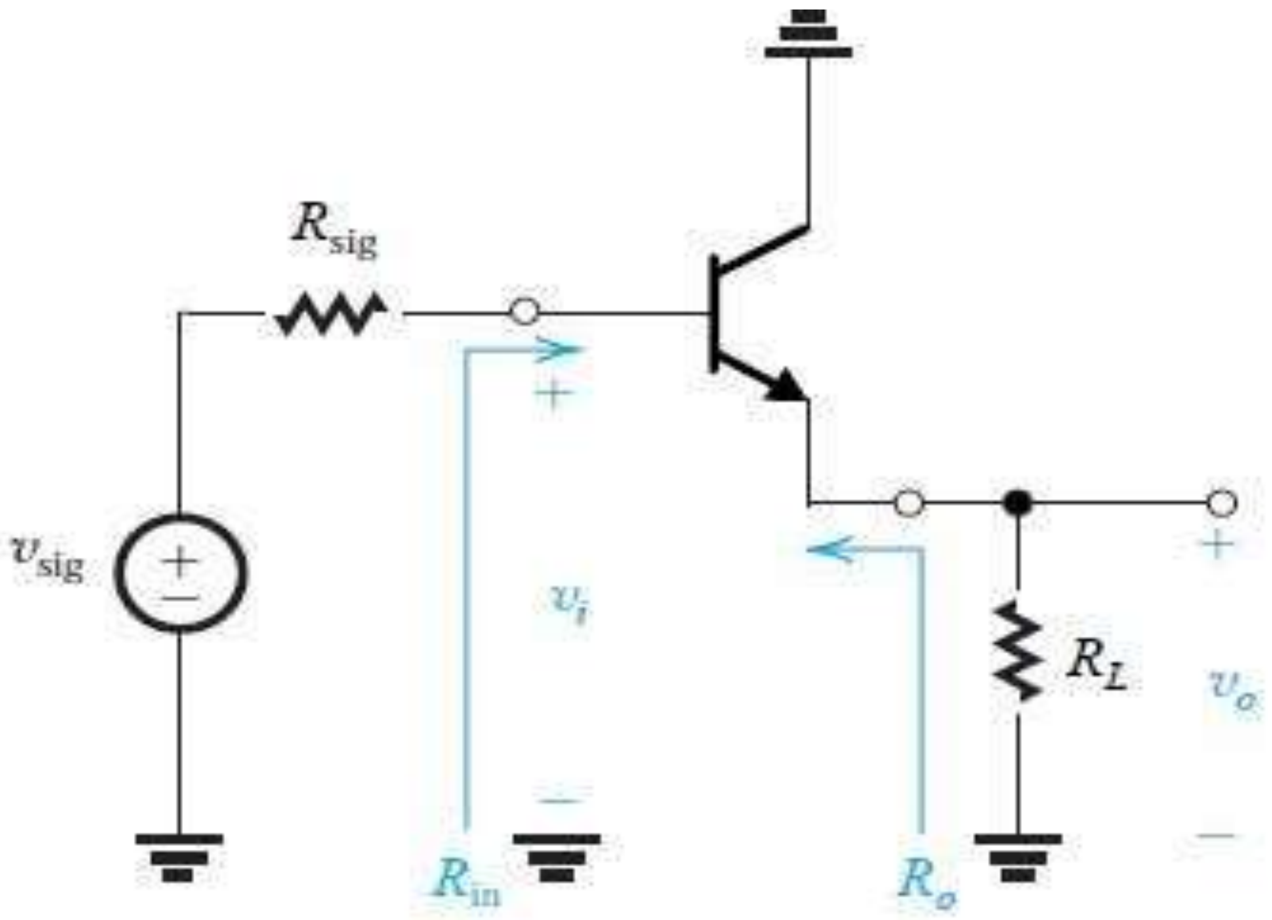
$$i_c = h_{fb} i_e + h_{ob} v_c$$

Dividing By V_c

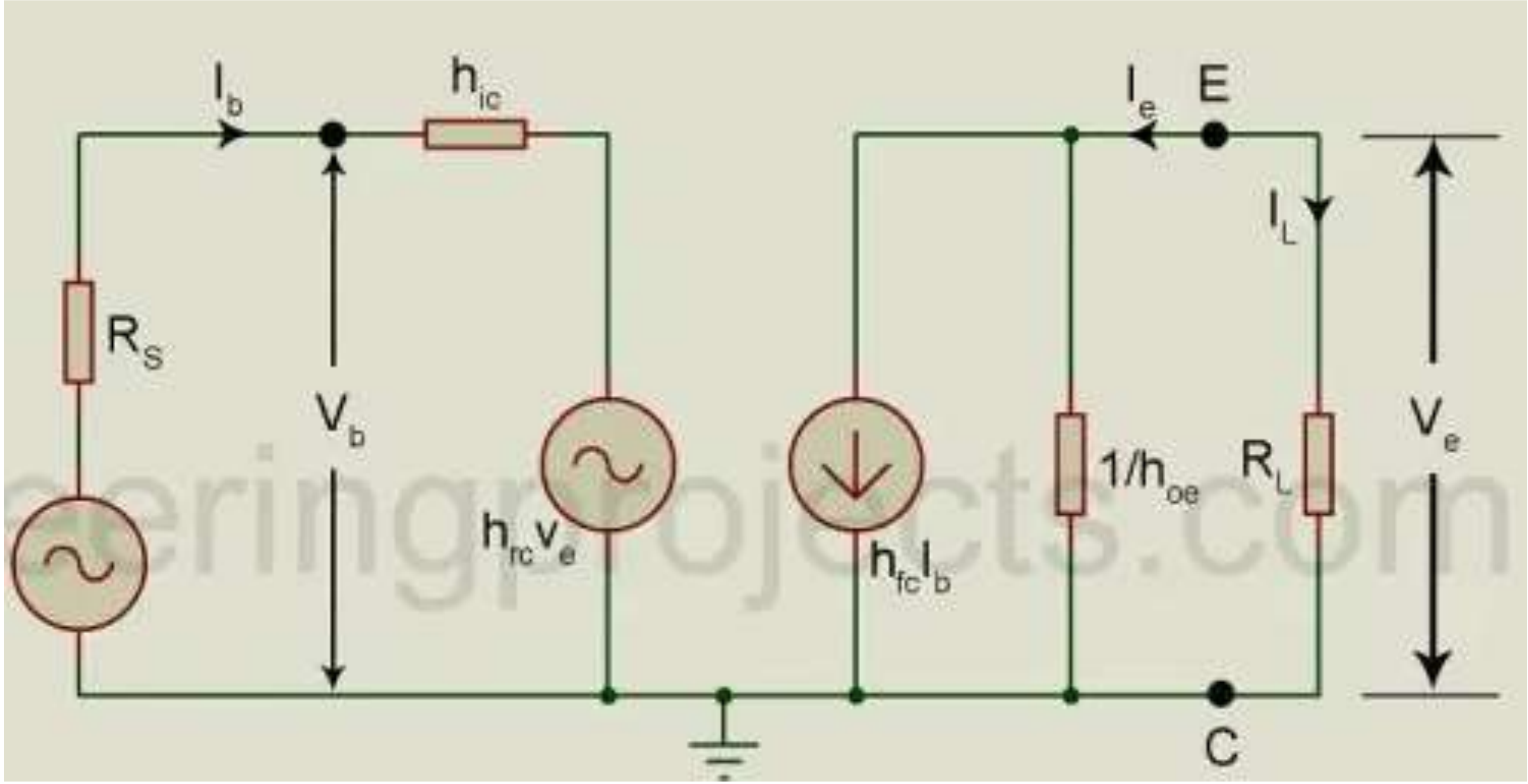
$$\boxed{\Rightarrow \frac{i_e}{v_c} = -\frac{h_{rb}}{R_s + h_{ib}}}$$

$$\boxed{\Rightarrow Y_0 = h_{ob} - \frac{h_{fb} h_{rb}}{R_s + h_{ib}} \text{ and } R_0 = \frac{1}{Y_0}}$$

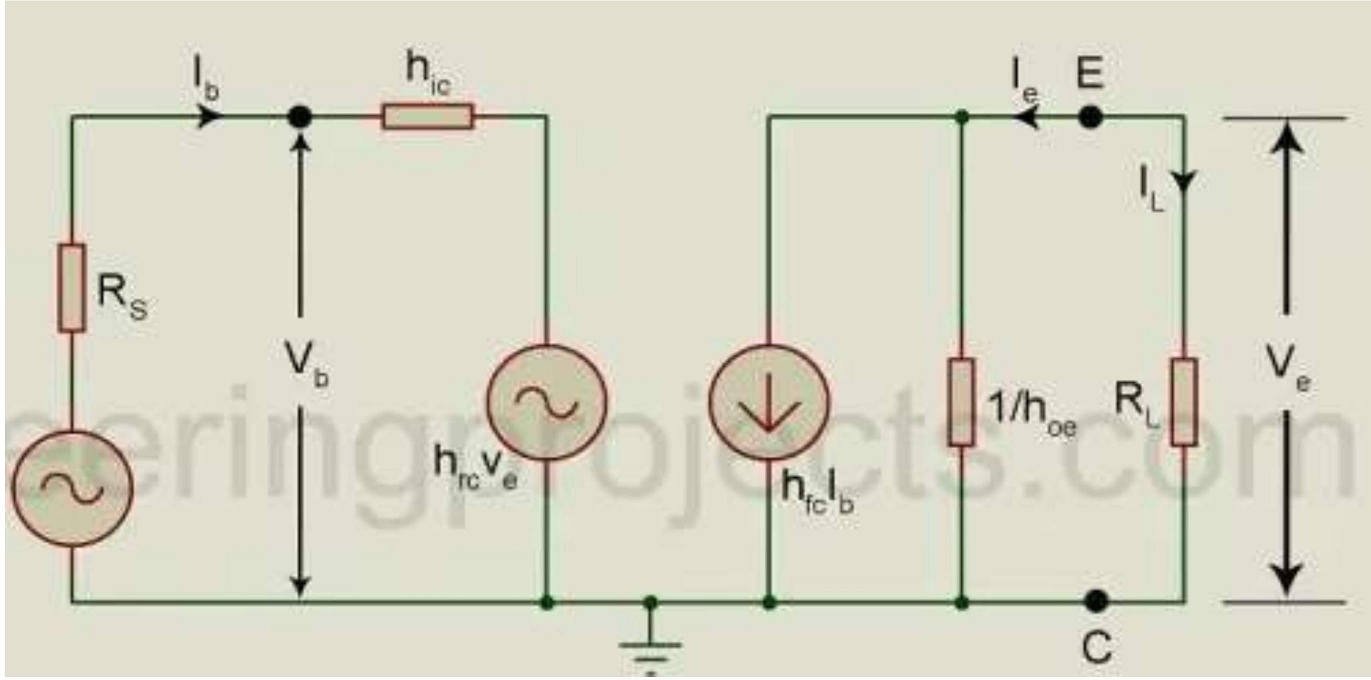
CC Amplifier(**Using Hybrid Model)**



CB Amplifier(**Using Hybrid Model)**



CB Amplifier **(Using Hybrid Model)**



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

$$i_e = h_{fc} i_b + h_{oc} v_e$$

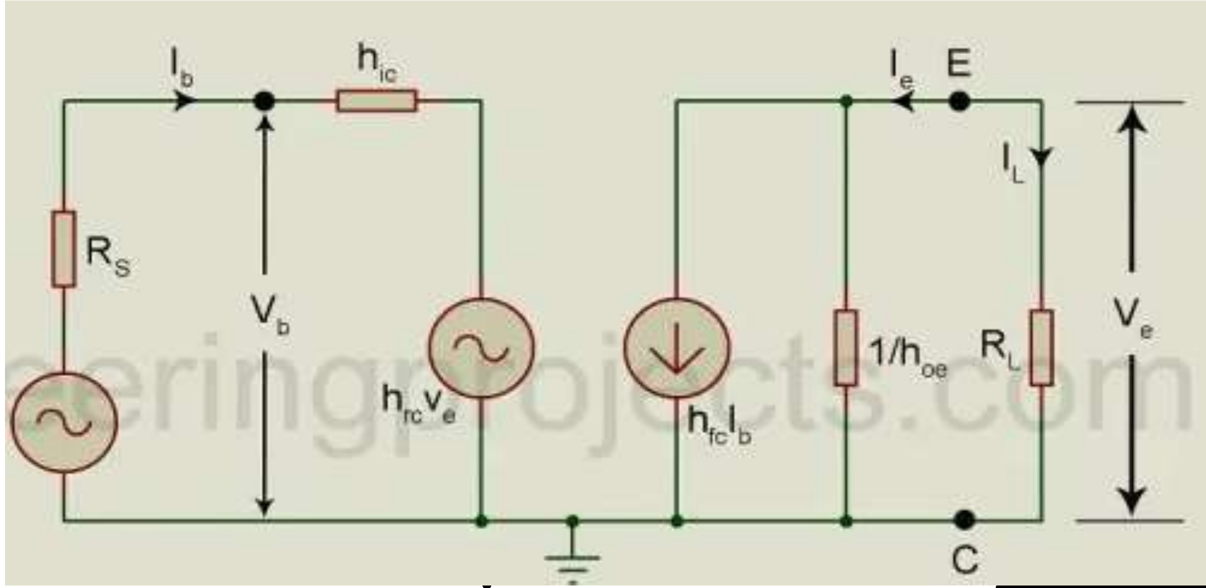
$$v_c = i_L R_L = -i_e R_L$$

$$i_e = h_{fc} i_b + h_{oc}\left(-i_e R_L\right)$$

$$i_e\left(1 + h_{oc} R_L\right) = h_{fc} i_b$$

$$\boxed{A_i = \frac{i_e}{i_b} = -\frac{h_{fc}}{1 + h_{oc} R_L}}$$

CB Amplifier **(Using Hybrid Model)**



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

$$v_b = h_{ic} i_b + h_{rc} v_e$$

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

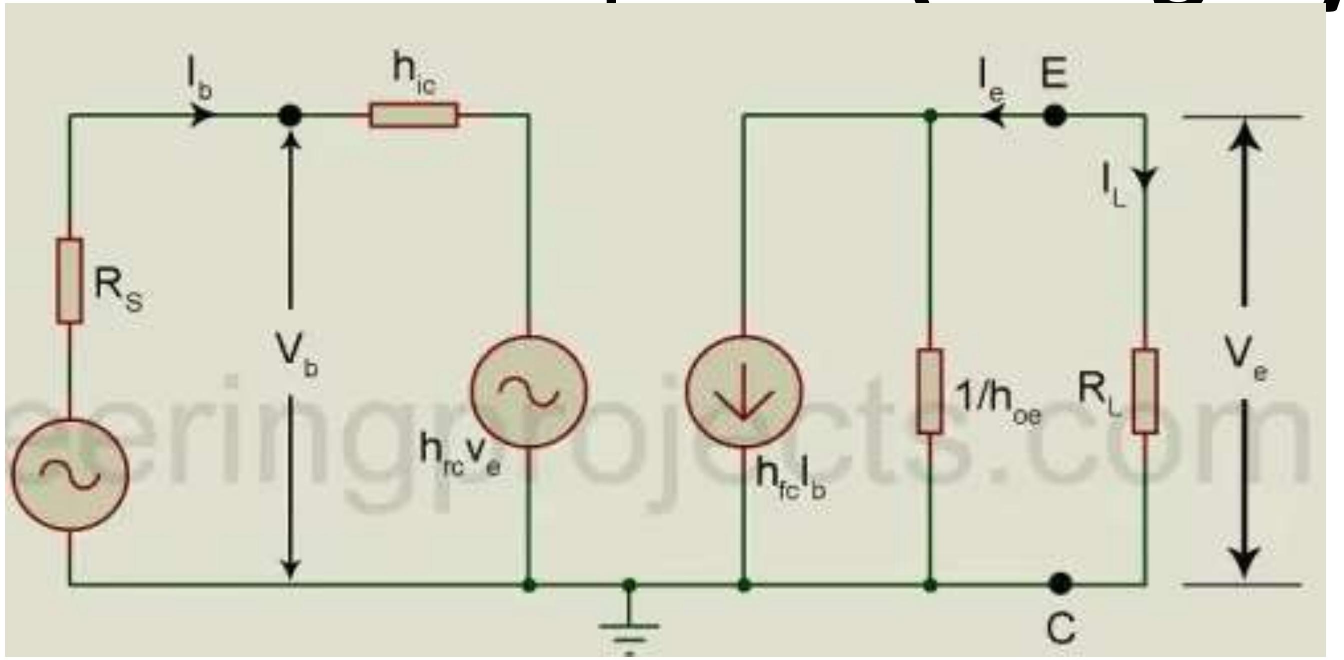
$$v_e = i_L R_L = -i_e R_L = A_i i_b R_L$$

$$v_b = h_{ic} i_b + h_{rc}(A_i i_b R_L)$$

$$v_b = i_b (h_{ic} + h_{rc} A_i R_L)$$

$$\Rightarrow R_i = \frac{v_b}{i_b} = h_{ic} + h_{rc} A_i R_L$$

CB Amplifier **(Using Hybrid Model)**



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

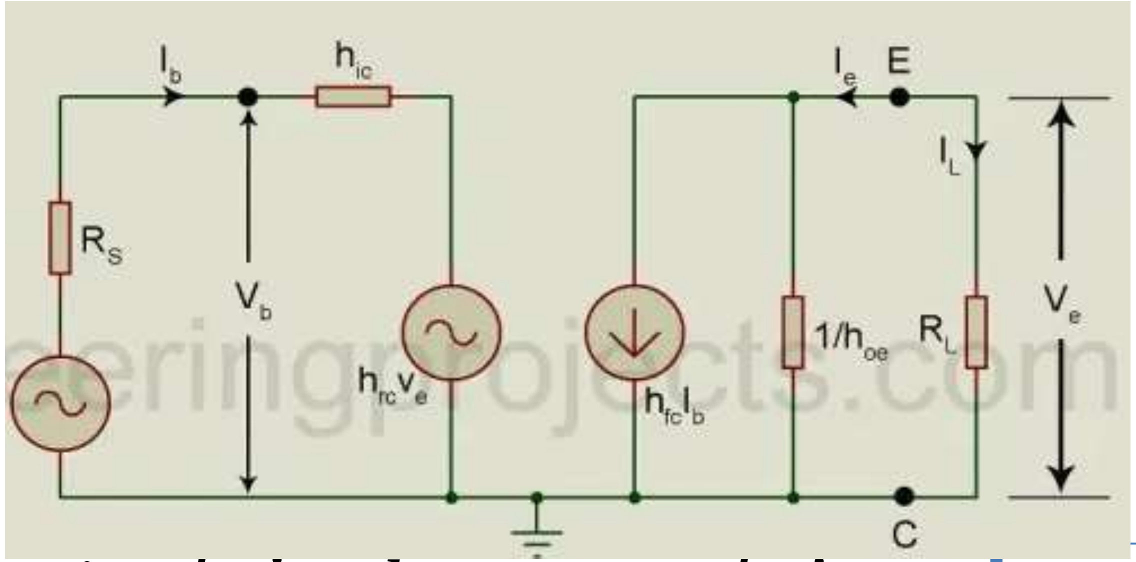
$$\text{But, } A_i = -\frac{i_e}{i_b} \Rightarrow i_e = -A_i\, i_b$$

$$\boxed{v_e = i_L R_L = -i_e R_L = A_i i_b R_L}$$

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

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

CB Amplifier **(Using Hybrid Model)**



Output Admittance Y_o

$$\boxed{Y_o = \frac{i_e}{v_e}}$$

$$i_e = h_{fc} i_b + h_{oc} v_e$$

Dividing By V_e

$$\frac{i_e}{v_e} = \frac{h_{fc} i_b}{v_e} + \frac{h_{ob} v_e}{v_e} \Rightarrow \frac{i_e}{v_e} = \frac{h_{fc} i_b}{v_e} + h_{oc}$$

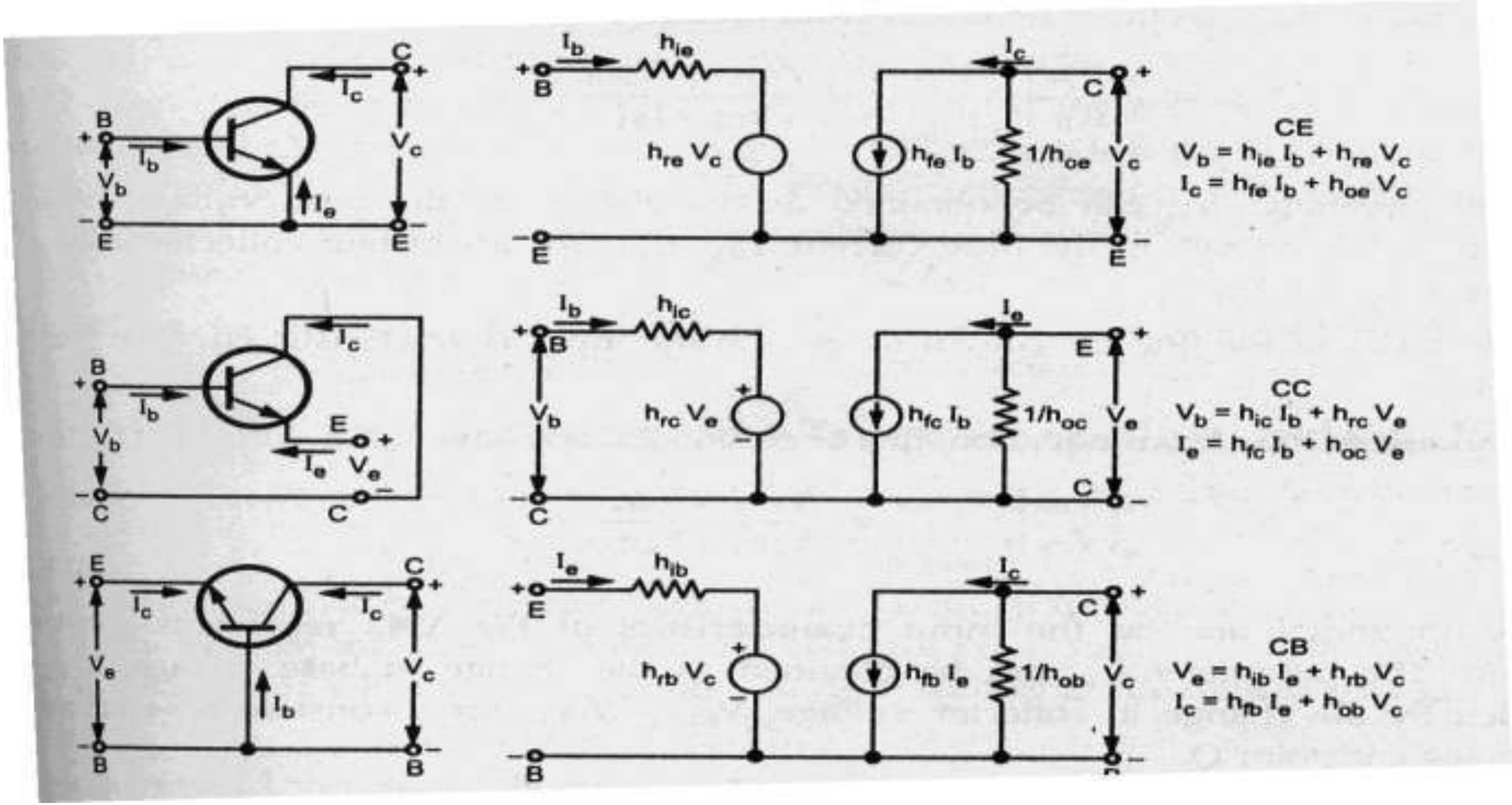
$$v_s = 0, R_s i_b + h_{ic} i_b + h_{rc} v_e = 0$$

$$(R_s + h_{ic}) i_b = -h_{rc} v_e$$

$$\boxed{\Rightarrow \frac{i_b}{v_e} = -\frac{h_{rc}}{R_s + h_{ic}}}$$

$$\boxed{\Rightarrow Y_0 = h_{oc} - \frac{h_{fc} h_{rc}}{R_s + h_{ic}} \; and \; R_0 = \frac{1}{Y_0}}$$

Hybrid Model and Equations for the transistor in three different configurations are are given below.



Conversion Formulae for Hybrid Parameters

CE to CB h-parameters	CE to CC h-parameters	CE h-parameters to r-parameters
$h_{ib} \approx \dfrac{h_{ie}}{1 + h_{fe}}$	$h_{ic} = h_{ie}$	$\alpha \approx \dfrac{h_{fe}}{1 + h_{fe}}$
$h_{rb} \approx \dfrac{h_{ie}\, h_{oe}}{1 + h_{fe}} - h_{re}$	$h_{rc} = 1 - h_{re}$	$r_c = \dfrac{1 + h_{fe}}{h_{oe}}$
$h_{fb} \approx \dfrac{h_{fe}}{1 + h_{fe}}$	$h_{fc} = 1 + h_{fe}$	$r_e = \dfrac{h_{ie}}{1 + h_{fe}} \approx r'_e$
$h_{ob} \approx \dfrac{h_{oe}}{1 + h_{fe}}$	$h_{oc} = h_{oe}$	$r_b = h_{ie} - \dfrac{h_{re}(1 + h_{fe})}{h_{oe}}$
		$r_\pi = h_{ie}$
		$\beta = h_{fe}$

TABLE 11.4

Configuration / Parameter	Common Emitter, CE	Common Base, CB	Common Collector, CC	Equivalent T-Circuit
h_{ie}	1.1 kΩ	$\frac{h_{ib}}{1+h_{fb}}$	h_{ic}*	$r_b + \frac{r_e}{1-a}$
h_{re}	2.5×10^{-4}	$\frac{h_{ib}\,h_{ob}}{1+h_{fb}} - h_{rb}$	$1 - h_{rc}$*	$\frac{r_e}{r_c\,(1-a)}$
h_{fe}	50	$-\frac{h_{fb}}{1+h_{fb}}$	$-(1+h_{fc})$*	$\frac{a}{1-a}$
h_{oe}	25 μS (μA/V)	$\frac{h_{ob}}{1+h_{fb}}$	h_{oc}*	$\frac{1}{r_c\,(1-a)}$
h_{ib}	$\frac{h_{ie}}{1+h_{fe}}$	21.6 Ω	$-h_{ic}/h_{fc}$	$r_e + (1-a)\,r_b$
h_{rb}	$\frac{h_{ie}\,h_{oe}}{1+h_{fe}} - h_{re}$	$2.9. \times 10^{-4}$	$h_{rc} - \frac{h_{ic}\,h_{oc}}{h_{fc}} - 1$	r_b/r_c
h_{fb}	$\frac{-h_{fe}}{1+h_{fe}}$	−0.98	$-\frac{1+h_{fc}}{h_{fc}}$	$-a$
h_{ob}	$\frac{h_{oe}}{1+h_{fe}}$	0.49 μS (μA/V)	$\frac{-h_{oc}}{h_{fc}}$	$1/r_c$
h_{ic}	h_{ie}*	$\frac{h_{ib}}{1+h_{fb}}$	1.1 kΩ	$r_b + \frac{r_e}{1-a}$
h_{rc}	$1 - h_{re} = 1$*	1	1	$1 - \frac{r_e}{r_c\,(1-a)}$
h_{fc}	$-(1+h_{fe})$*	$\frac{-1}{1+h_{fb}}$	−51	$-\frac{1}{1-a}$
h_{oc}	h_{oe}*	$\frac{h_{ob}}{1+h_{fb}}$	25 μS (μA/V)	$\frac{1}{r_c\,(1-a)}$
a	$\frac{h_{fe}}{1+h_{fe}}$	$-h_{fb}$	$\frac{1+h_{fc}}{h_{fc}}$	0.98
r_c	$\frac{1+h_{fe}}{h_{oe}}$*	$\frac{1}{h_{ob}}$	$\frac{-h_{fc}}{h_{oc}}$*	2.04 MΩ
r_e	$\frac{h_{re}}{h_{oe}}$*	$h_{ib} - \frac{h_{rb}}{h_{ob}}\,(1+h_{fb})$*	$\frac{1-h_{rc}}{h_{oc}}$*	10 Ω
r_b	$h_{ie} - \frac{h_{re}}{h_{oe}}\,(1+h_{fe})$*	$\frac{h_{rb}}{h_{ob}}$*	$h_{ic} + \frac{h_{fc}}{h_{oc}}\,(1-h_{rc})$*	590 Ω

* Stands for exact.