Fundumantal of Electronic II

Second Class

Chapter05: BJT AC Analysis
Lec05_p1

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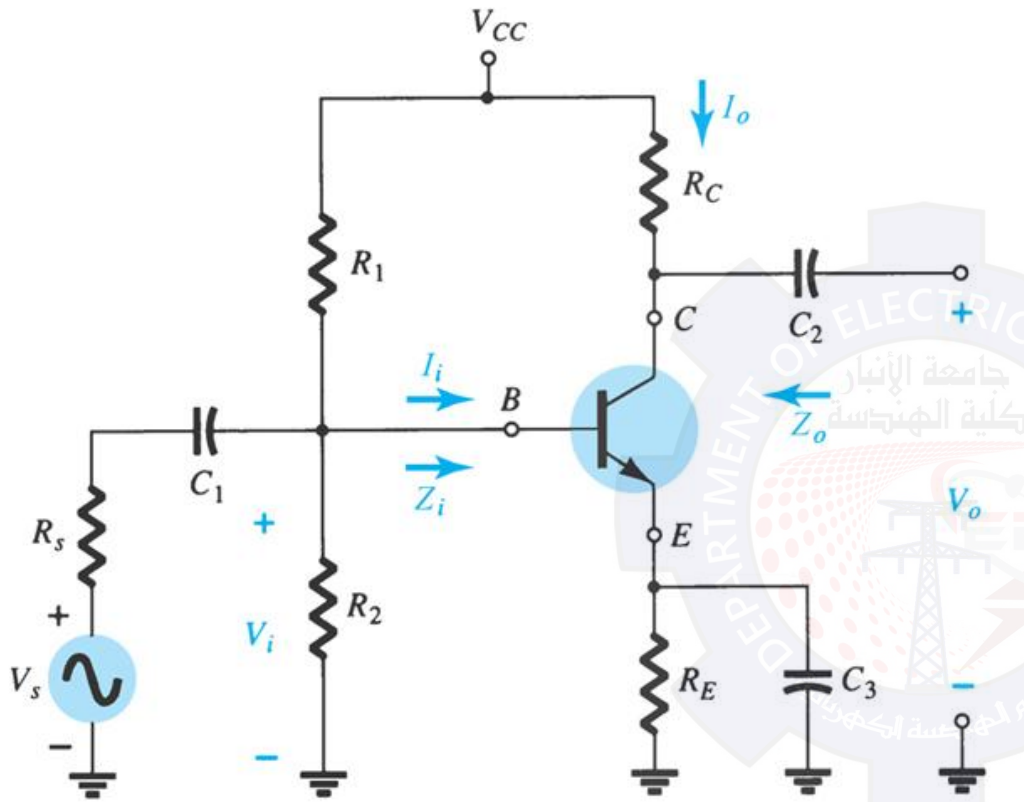
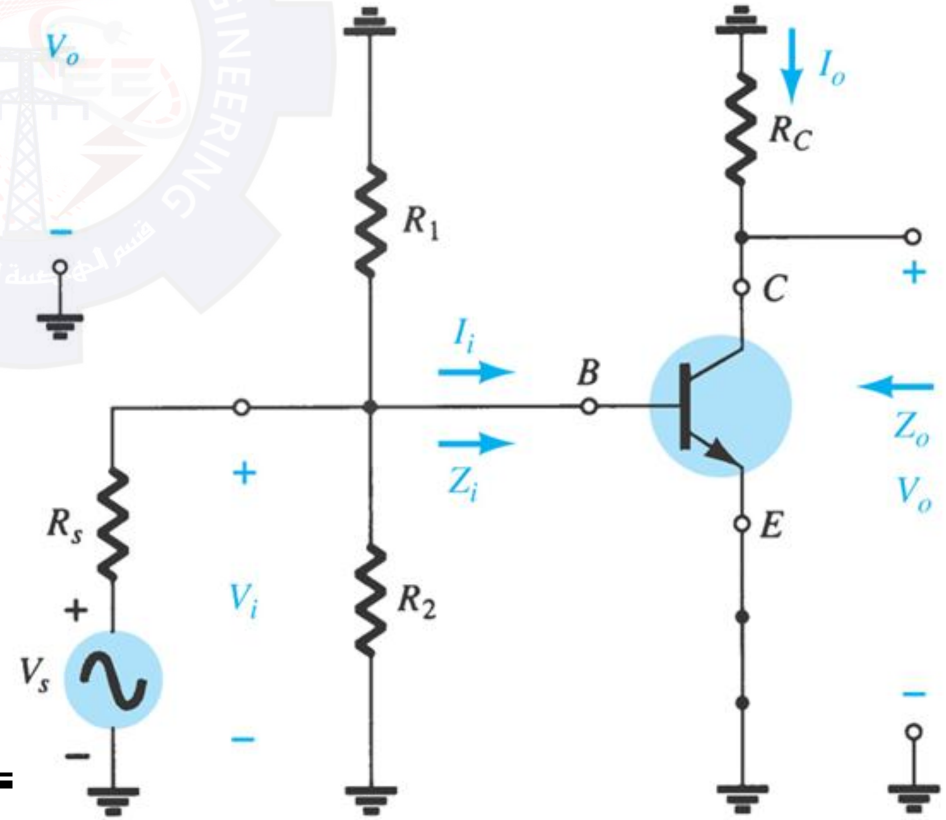
BJT Transistor Modeling

- A model is an equivalent circuit that represents the AC characteristics of the transistor.
- A model uses circuit elements that approximate the behavior of the transistor.
- There are two models commonly used in small signal AC analysis of a transistor:
  - **r_e model**
  - **Hybrid equivalent model**

BJT Transistor Modeling



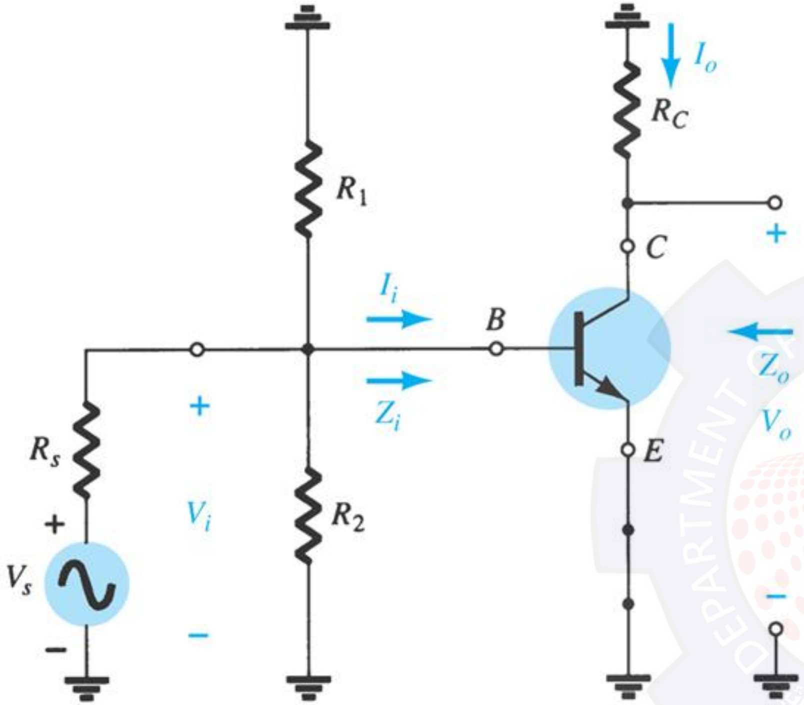
Capacitors chosen with very small reactance at the frequency of application → replaced by low-resistance or short circuit.

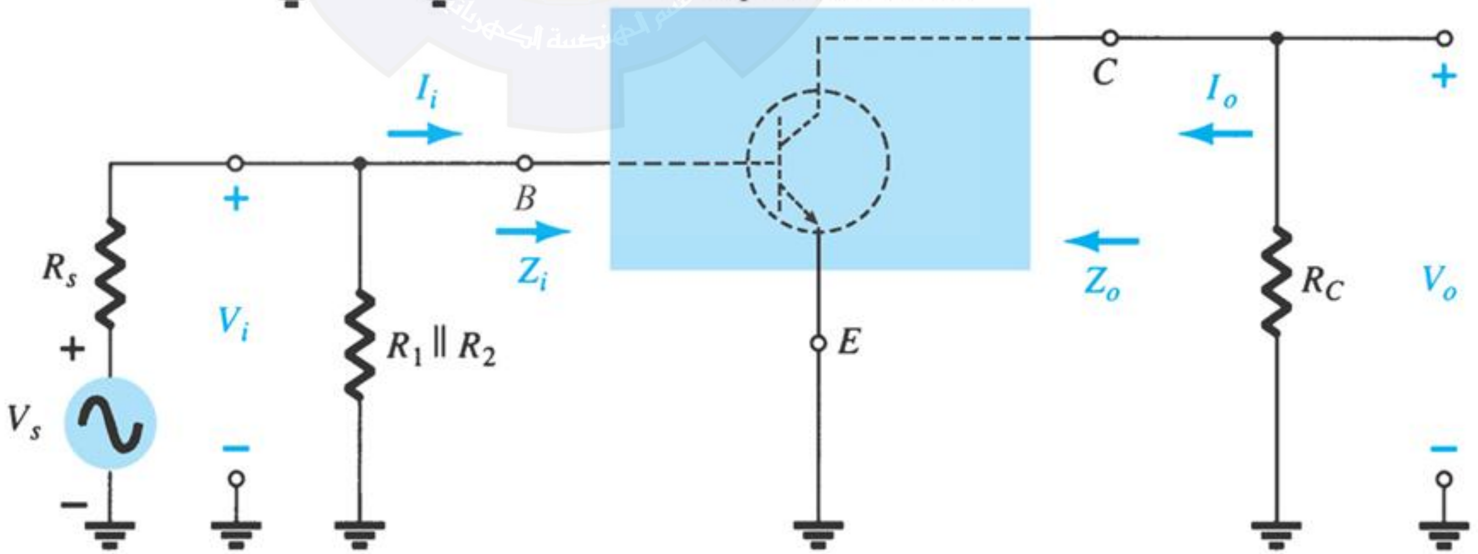


Removal of the dc supply and insertion of the short-circuit equivalent for the capacitors.

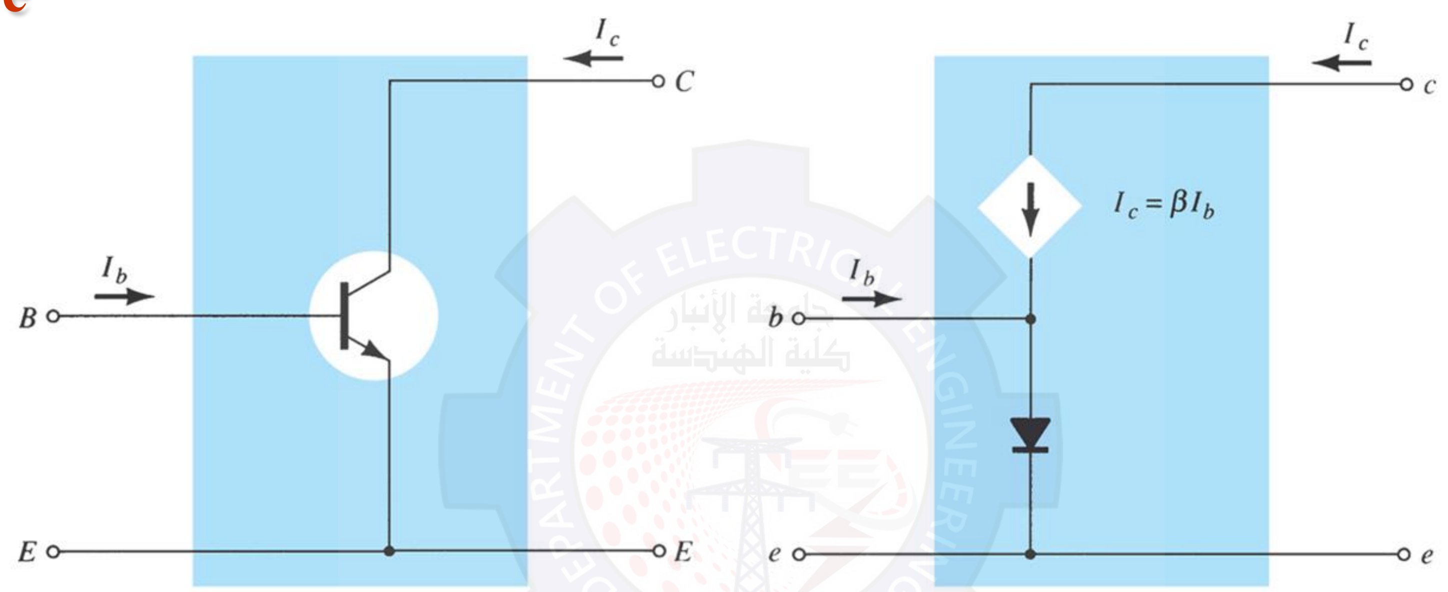
BJT Transistor Modeling

Circuit redrawn for small-signal ac analysis





The r_e Transistor Model Common Emitter Configuration

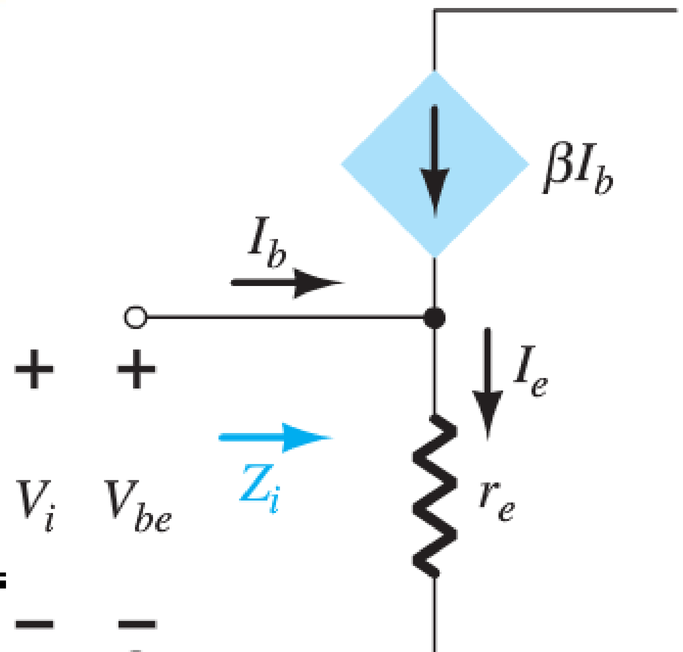


$$Z_i = \frac{V_i}{I_b} = \frac{V_{be}}{I_b}$$

$$V_{be} = I_e r_e = (I_c + I_b) r_e = (\beta I_b + I_b) r_e$$

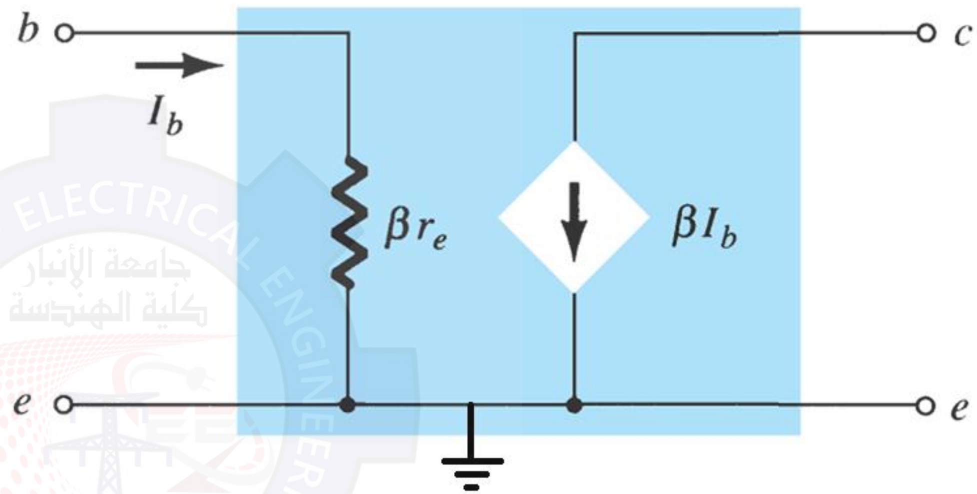
$$= (\beta + 1) I_b r_e$$

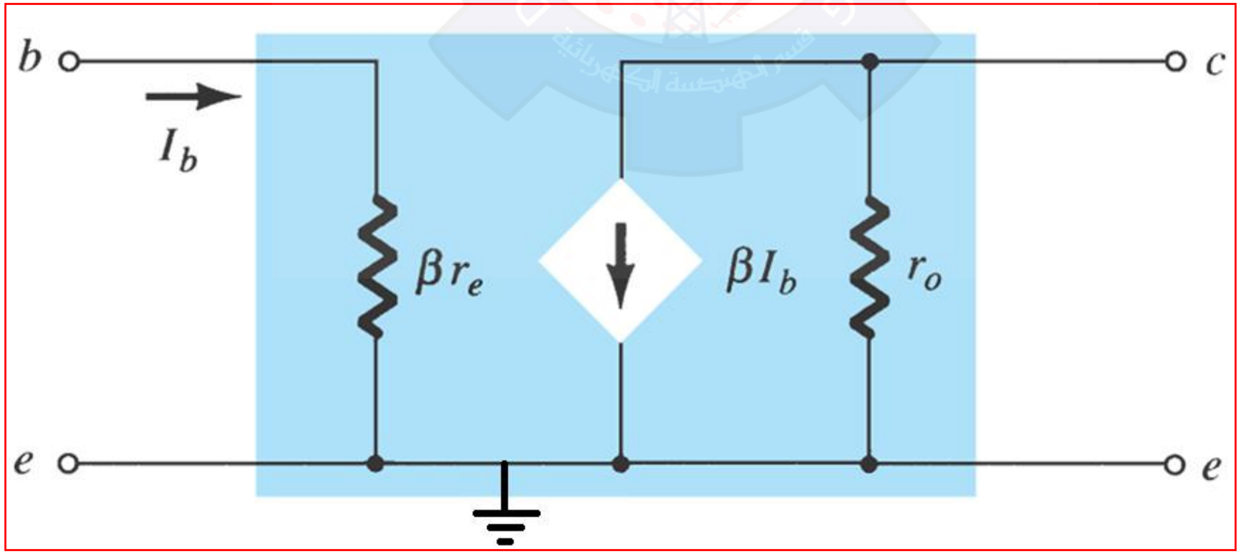
$$Z_i = \frac{V_{be}}{I_b} = \frac{(\beta + 1) I_b r_e}{I_b} = (\beta + 1) r_e \simeq \beta r_e$$



The r_e Transistor Model Common Emitter Configuration

$$r_e = \frac{26\ mV}{I_E}$$





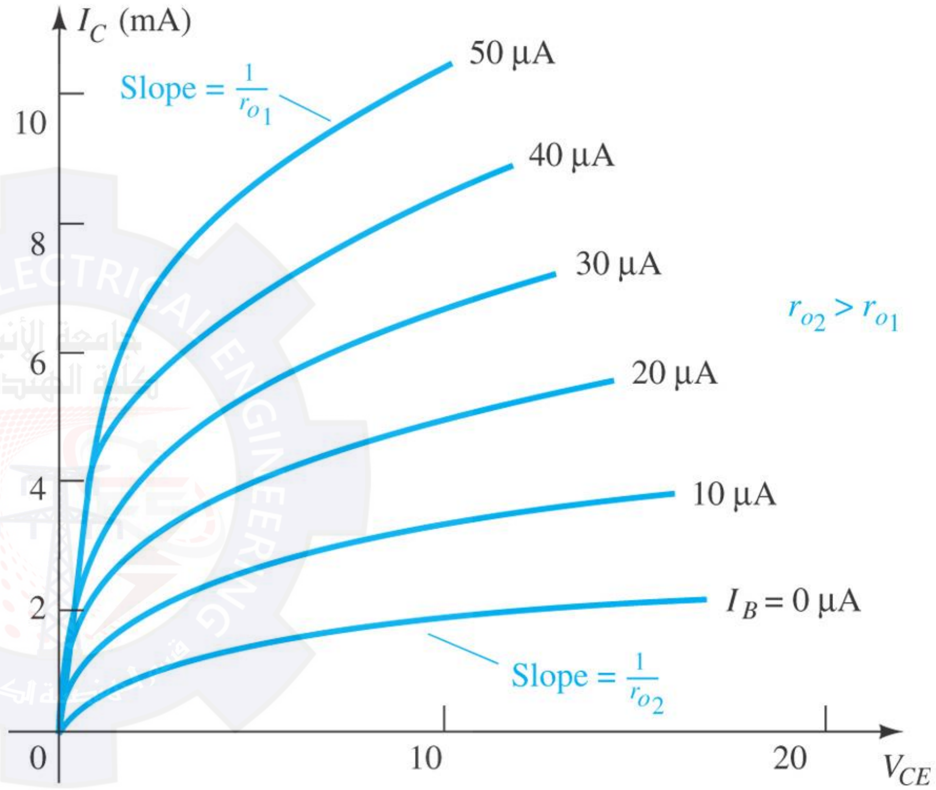
The r_e Transistor Model

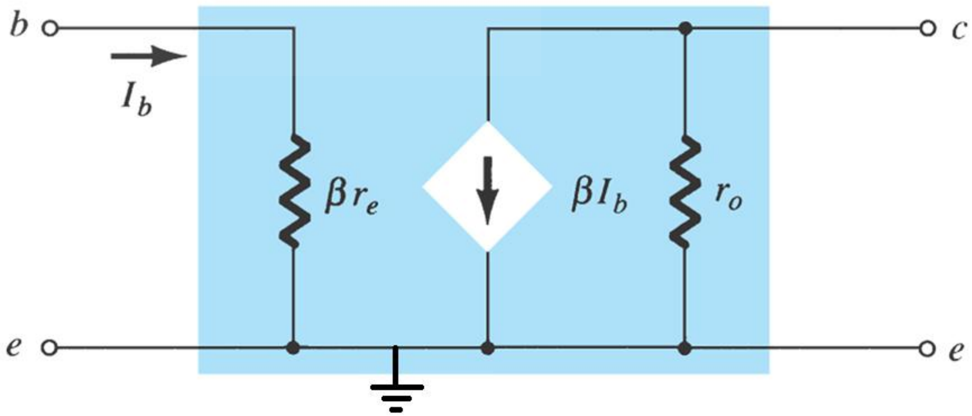
Common Emitter Configuration

$$slope = \frac{\Delta I_C}{\Delta V_{CE}} = \frac{1}{r_0}$$

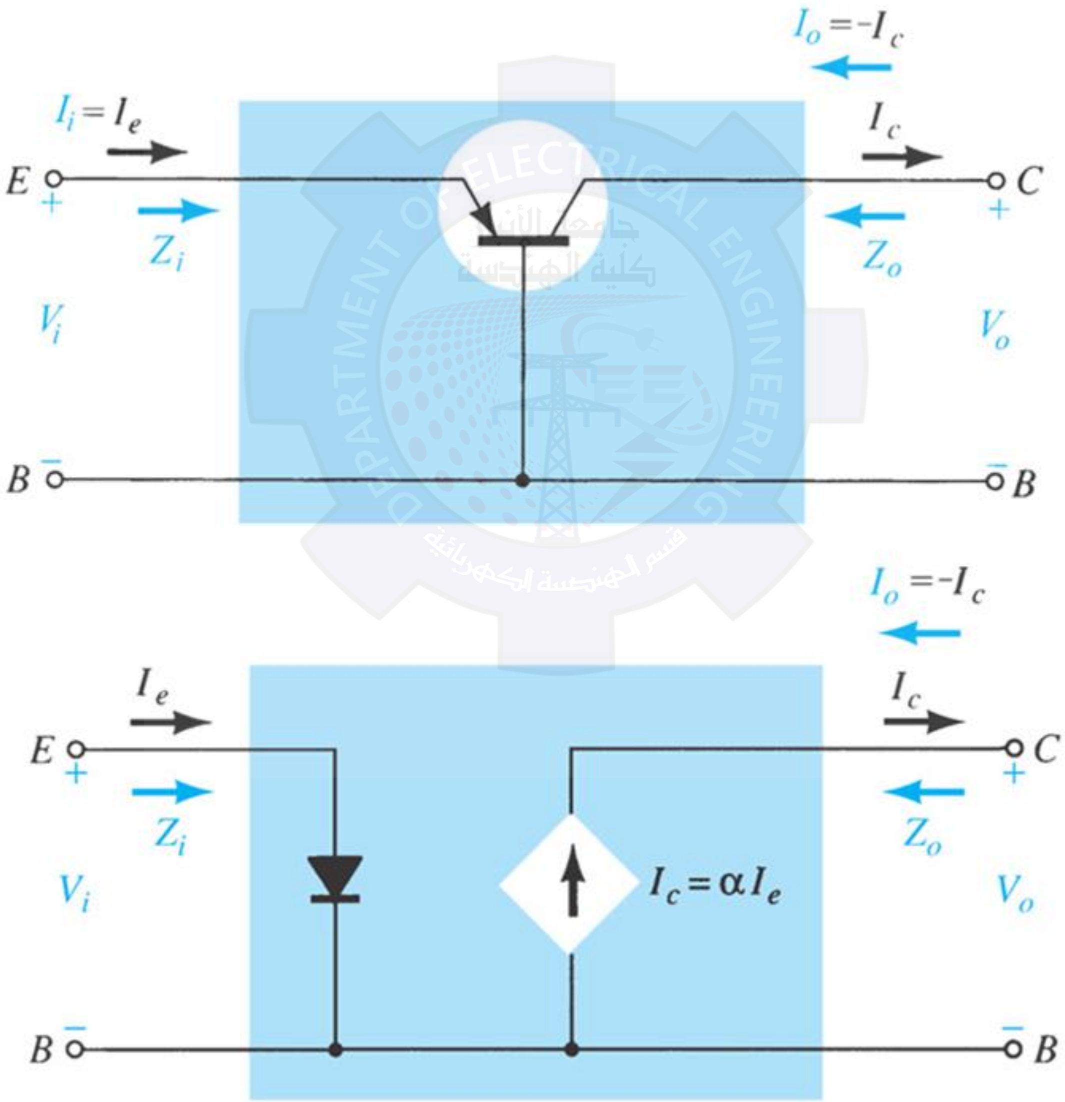
$$r_0 = \frac{\Delta V_{CE}}{\Delta I_C}$$

The output resistance *r* is typically in the range of 40 kΩ to 50 kΩ

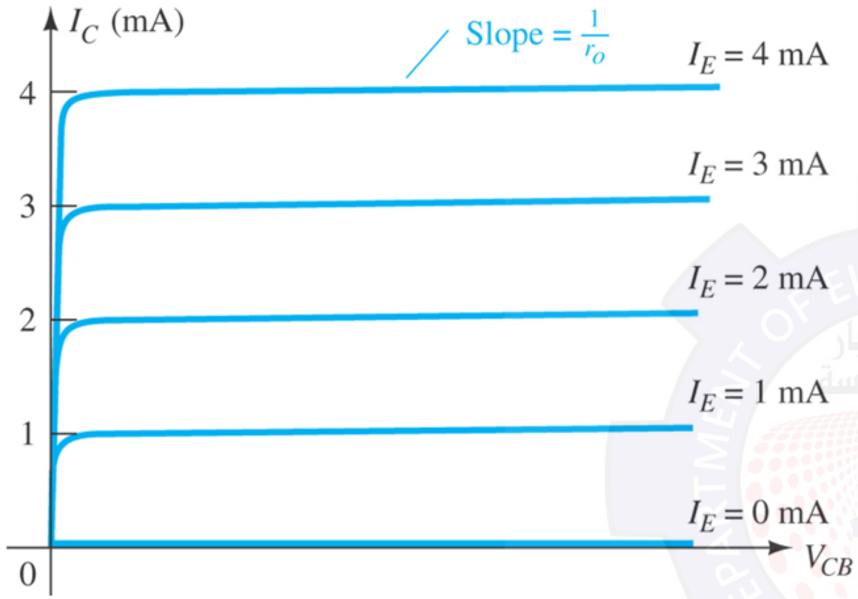


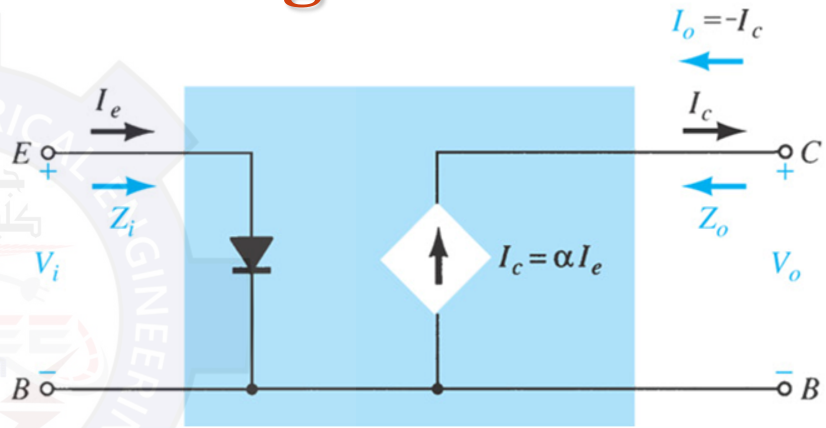


Common-Base Configuration



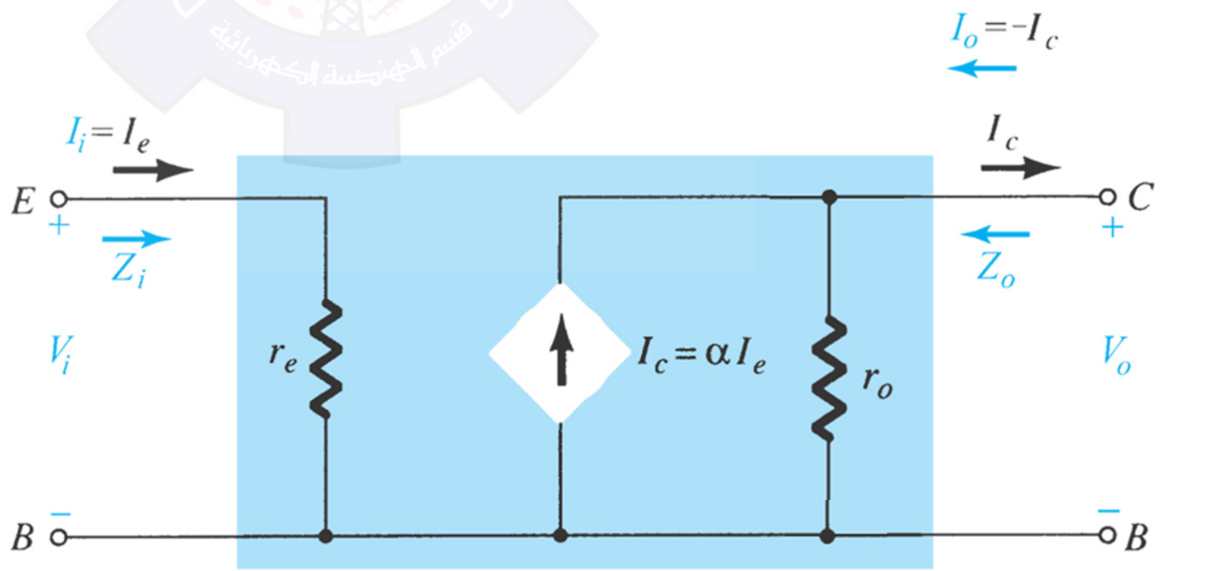
Common-Base Configuration



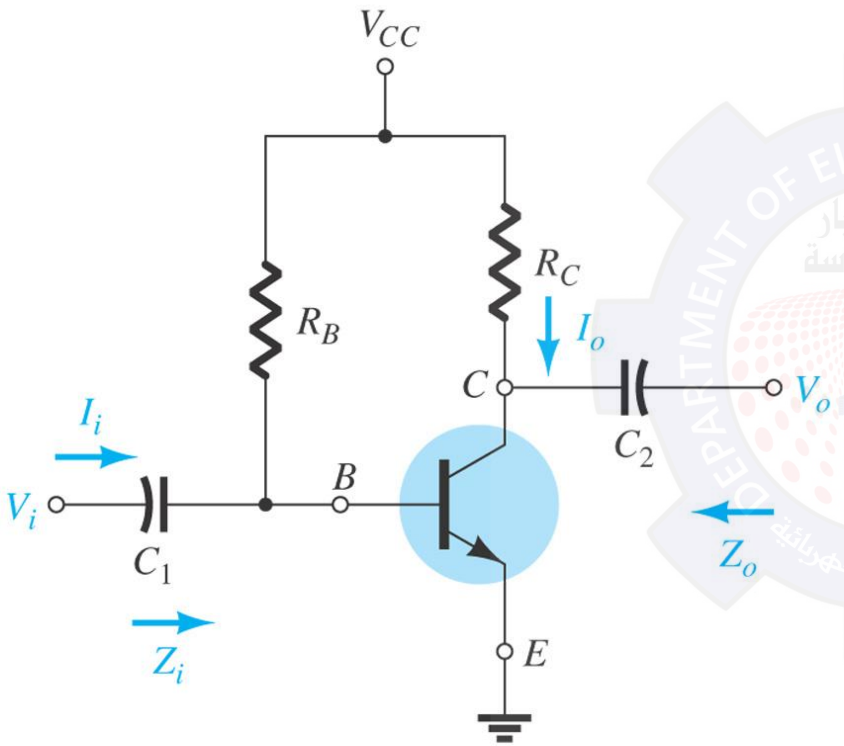


The output resistance r_0 is quite high. typically extend into the megaohm range.

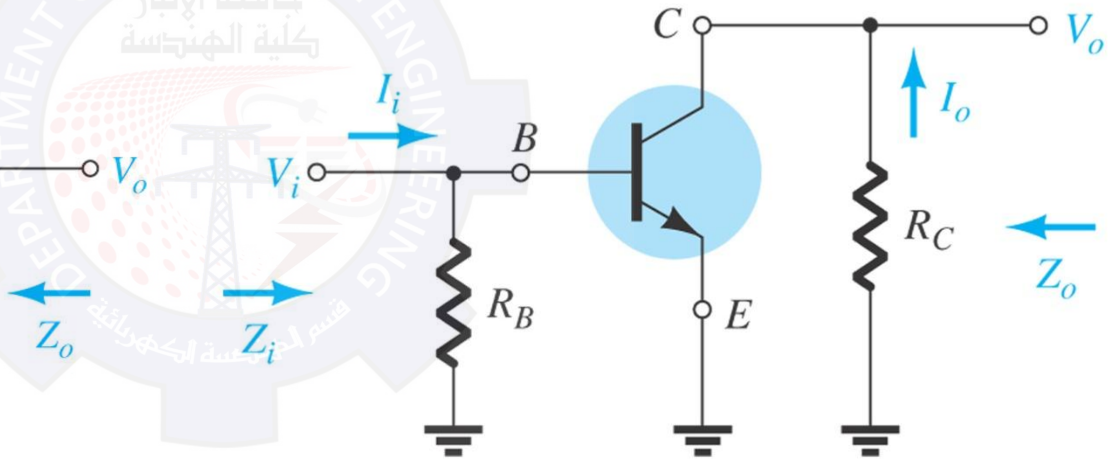
Common Base r_e equivalent circuit



Common Emitter Fixed Bias Configuration

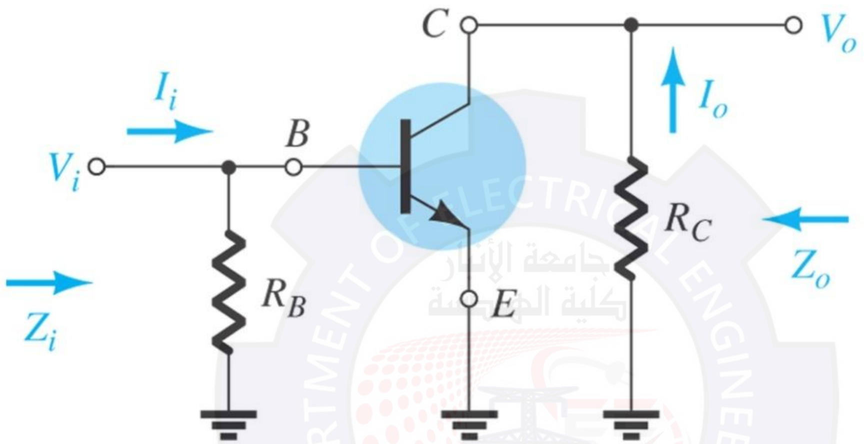


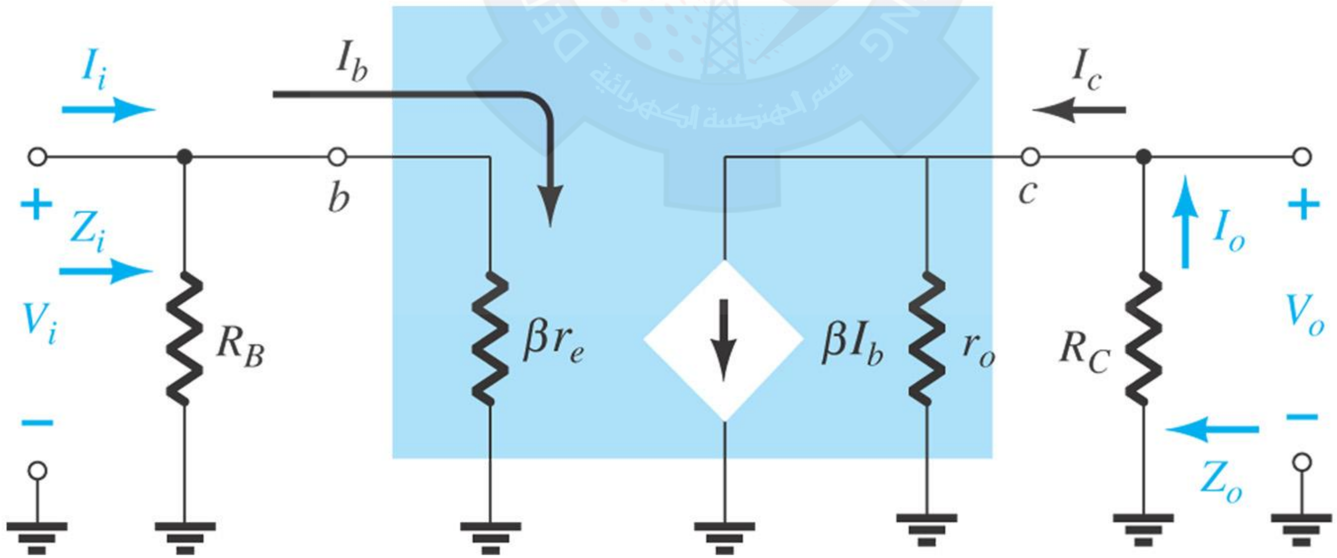
Common-emitter fixed-bias configuration.



Network after the removal of the effects of V_{CC}, C_1 and C_2.

Common Emitter Fixed Bias Configuration





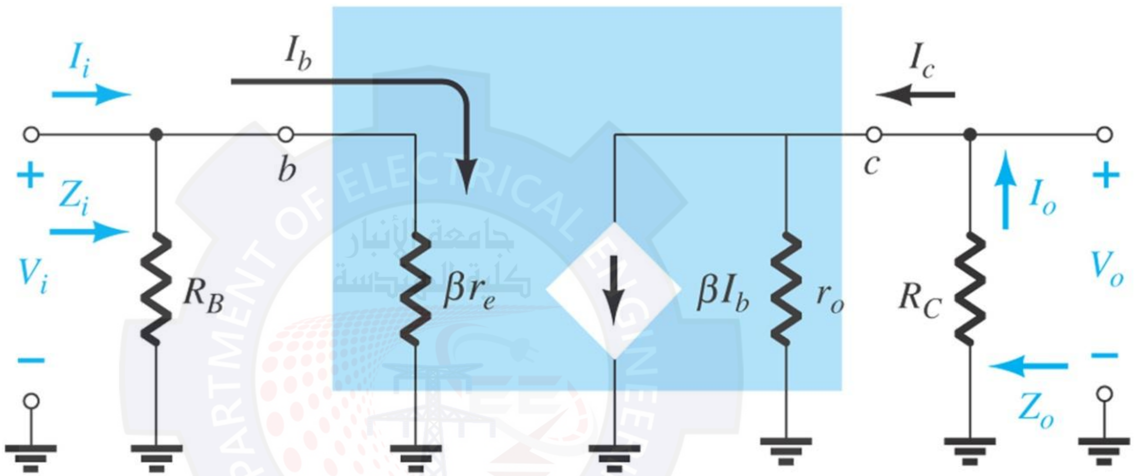
Substituting the r_e model into the network.

Common Emitter Fixed Bias Configuration

Input impedance:

$$Z_i = R_B \,||\, \beta r_e$$

$$Z_i \cong \beta r_e \Big|_{R_E \geq 10\beta r_e}$$



Output impedance:

$$Z_o = R_C \,||\, r_o$$

$$Z_o \cong R_C \Big|_{r_o \geq 10 R_C}$$

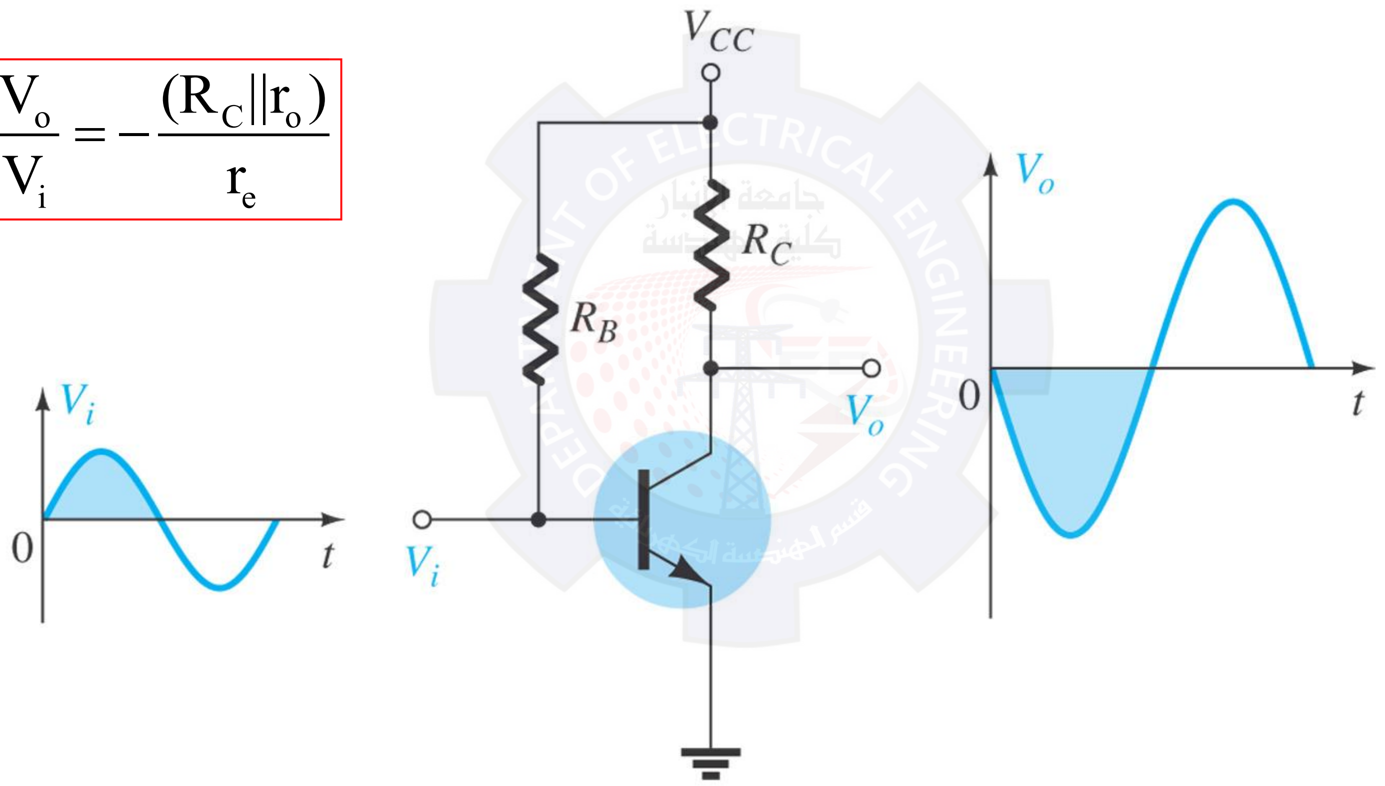
Voltage gain:

$$V_o = -\beta I_b (R_C || r_o) \;\; , \;\; I_b = \frac{V_i}{\beta r_e} \;\; , V_o = -\beta \left(\frac{V_i}{\beta r_e} \right) (R_C || r_o)$$

$$A_v = \frac{V_o}{V_i} = -\frac{(R_C || r_o)}{r_e} \quad , \quad A_v = -\frac{R_C}{r_e} \Big|_{r_o \geq 10R}$$

Common Emitter Fixed Bias Configuration

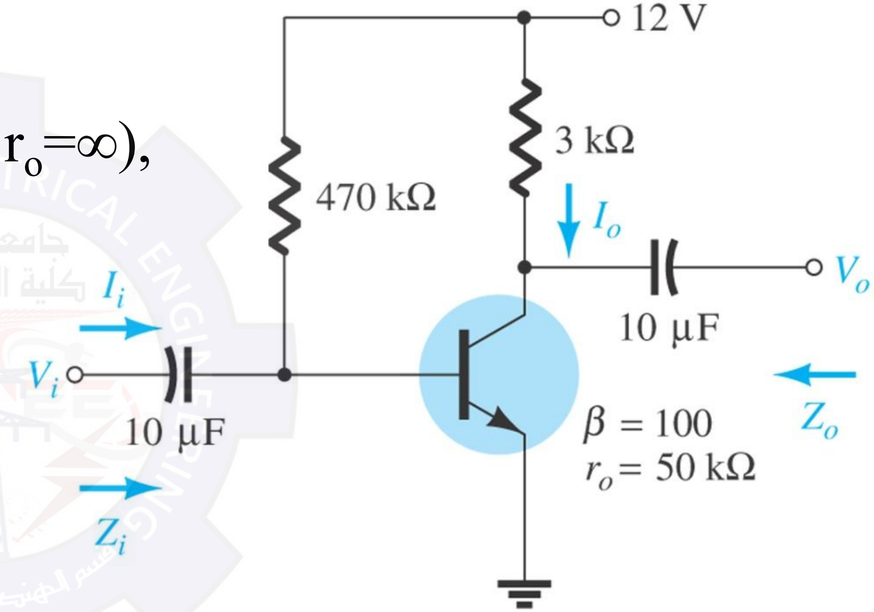
$$A_v = \frac{V_o}{V_i} = -\frac{(R_C \| r_o)}{r_e}$$



Demonstrating the 180° phase shift between input and output waveforms.

Example 5.1

Determine r_e, Z_i (with $r_o=\infty$), Z_o (with $r_o=\infty$), A_v (with $r_o=\infty$).
Repeat with $r_o=50\ k\Omega$.



Example 5.1 - Solution