Lecture 8

BIPOLAR JUNCTION TRANSISOR (BJT)

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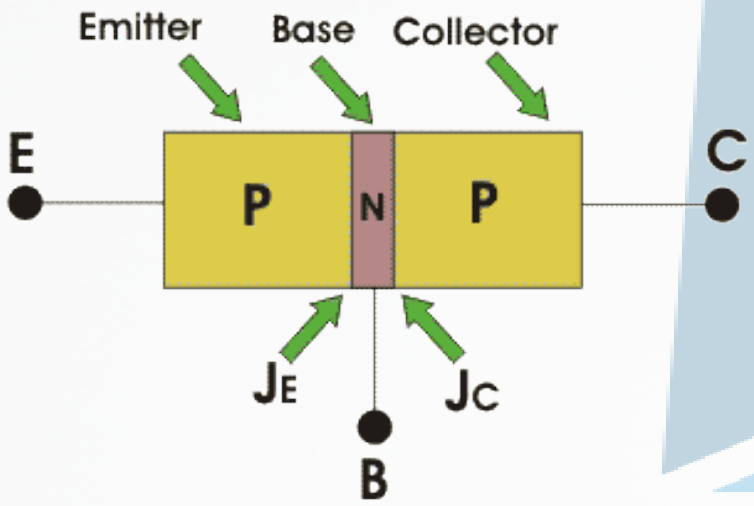
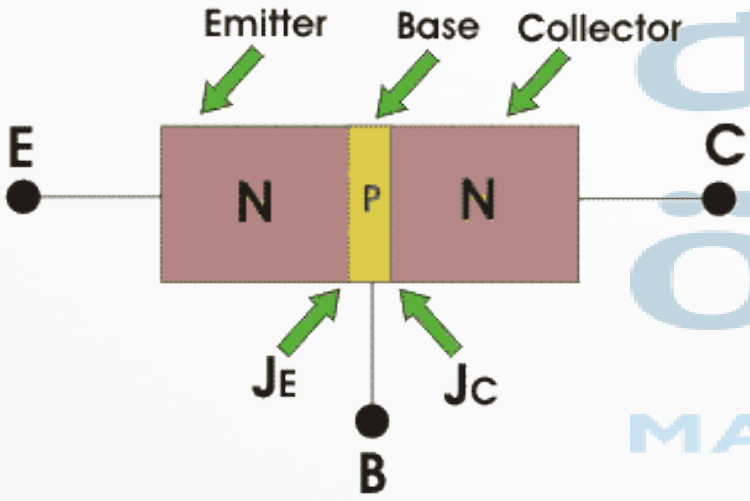
الترانزيستور ثنائي القطبية (BJT)

Bipolar Junction Transistor (BJT)





الترانزيستور هو عنصر إلكتروني ثلاثي الطبقات والنهايات . يكون الباعث مشاباً بشكل كبير في حين تكون طبقتا المجمع والقاعدة مشابتين إشابة قليلة.كما أن الطبقة الوسطى، والتي تمثل القاعدة في كلا النوعين، تكون ذات سماكة لا تتجاوز 1/10 من سماكة الطبقتين الأخريين.إن الإشابة المنخفضة للقاعدة يعطيها مقاومة عالية نظراً لقلة حوامل الشحنة الحرة فيها . تأتي تسمية هذا النوع من الترانزستورات بثنائي الوصلة أو التوصيل على أساس أن الإلكترونات والثقوب تحقن في المادة المستقطبة عكسياً .

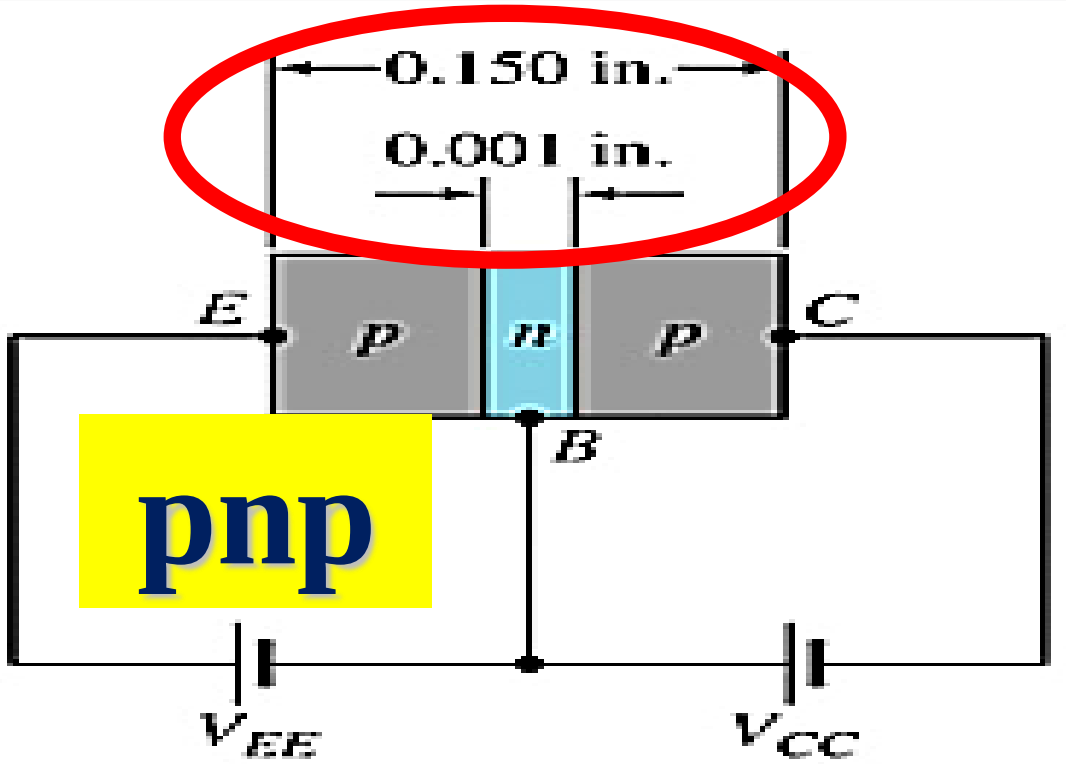
Transistor Construction

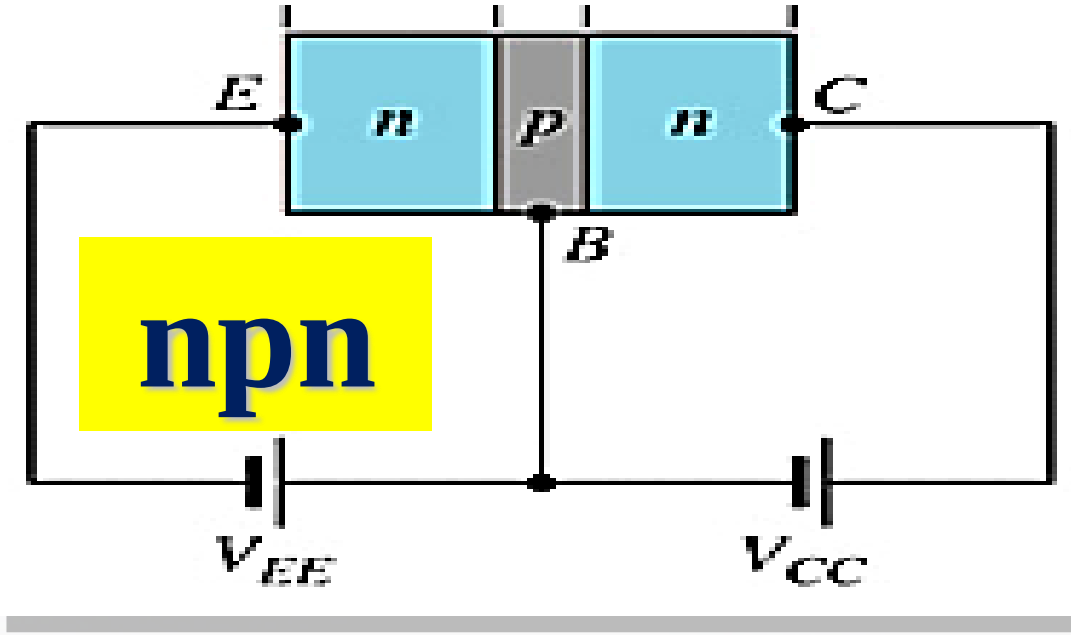
There are two types of transistors:

- pnp
- npn

The terminals are labeled:

- E - Emitter
- B - Base
- C - Collector

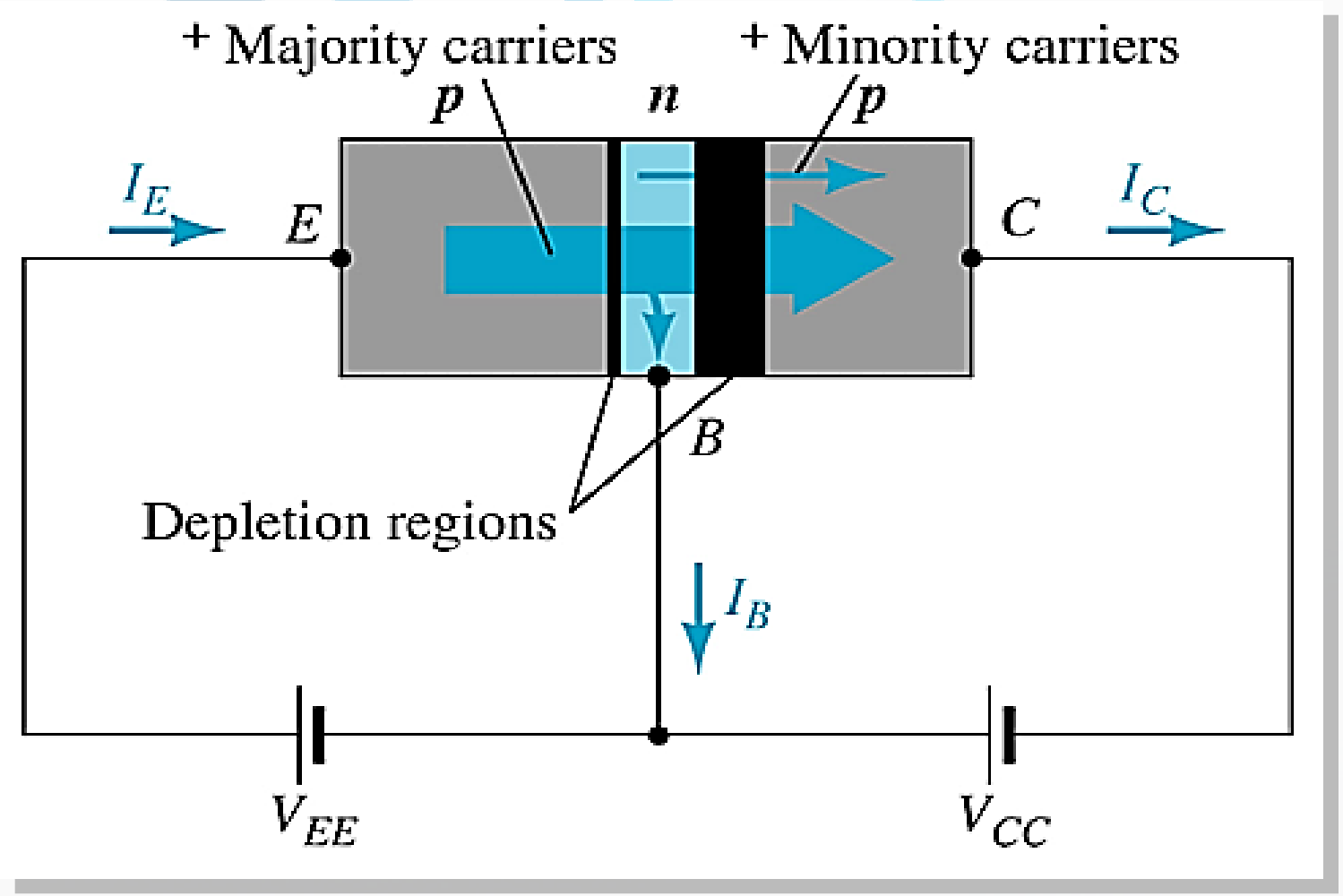




Transistor Operation

With the external sources, V_{EE} and V_{CC}, connected as shown:

- **The emitter-base junction is forward biased**
- **The base-collector junction is reverse biased**



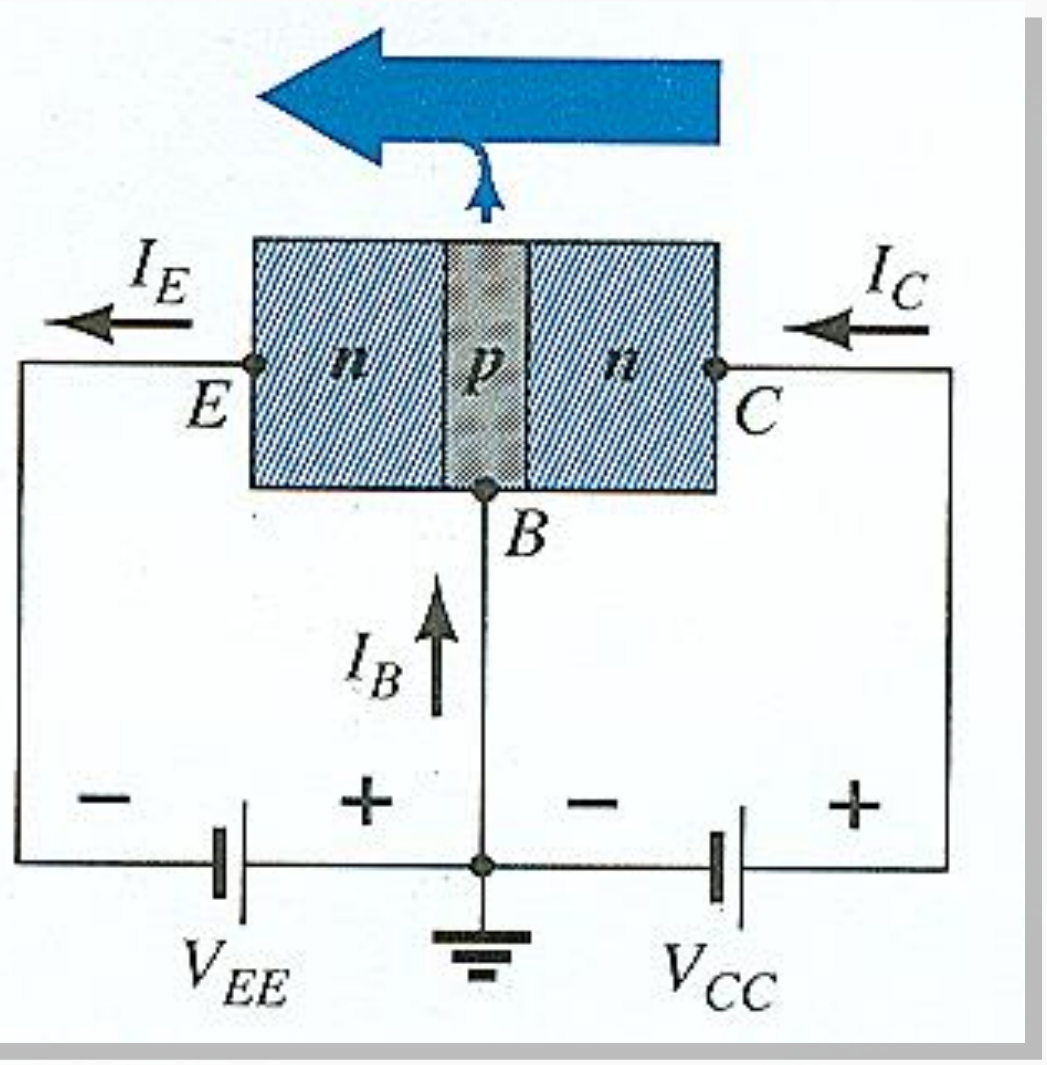
Currents in a Transistor

Emitter current is the sum of the collector and base currents:

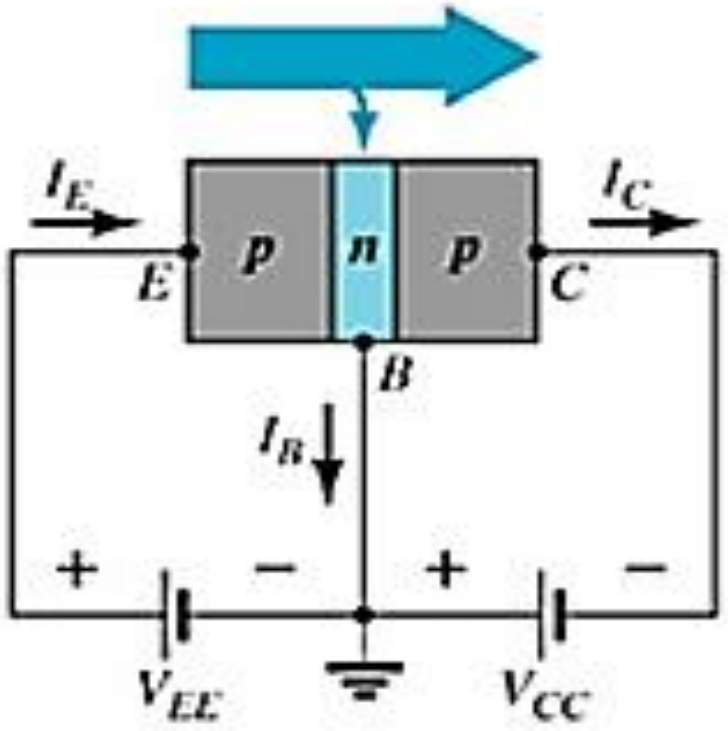
$$I_E = I_C + I_B$$

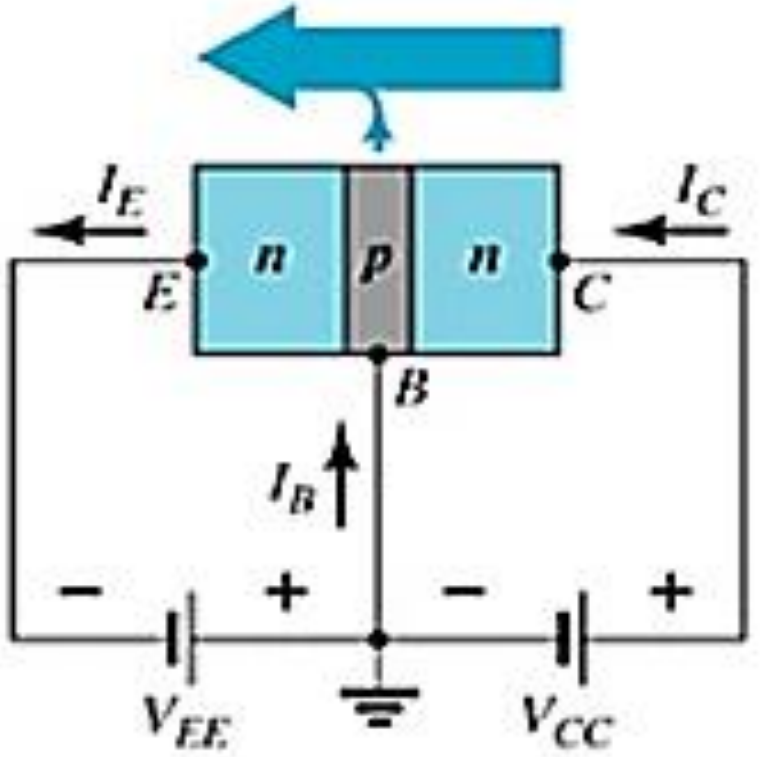
The collector current is comprised of two currents:

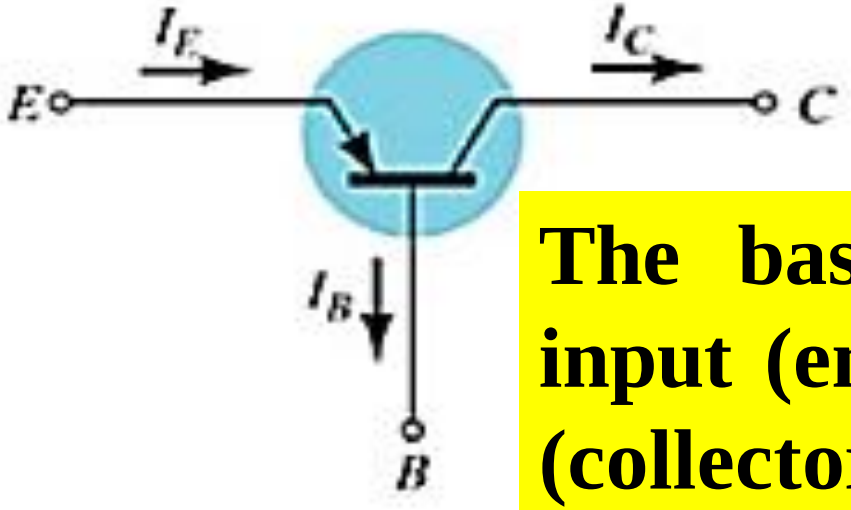
$$I_C = I_{C_{majority}} + I_{CO_{minority}}$$

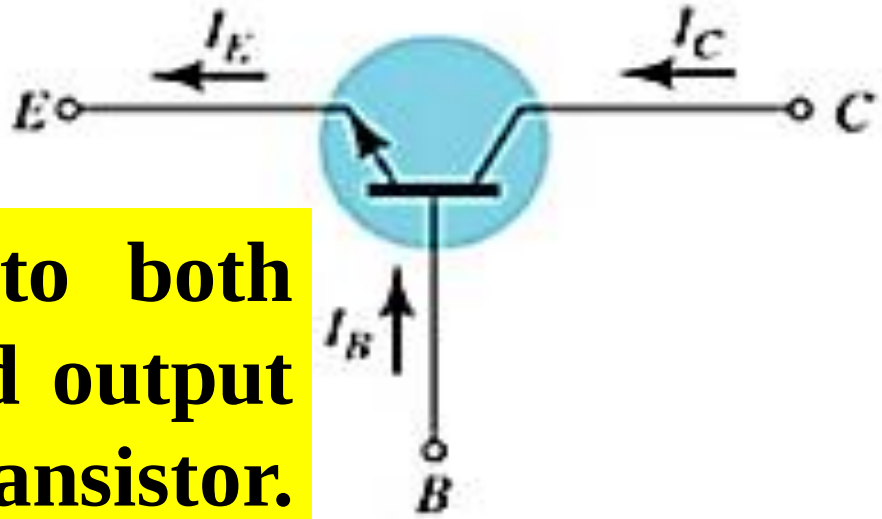


Common-Base Configuration







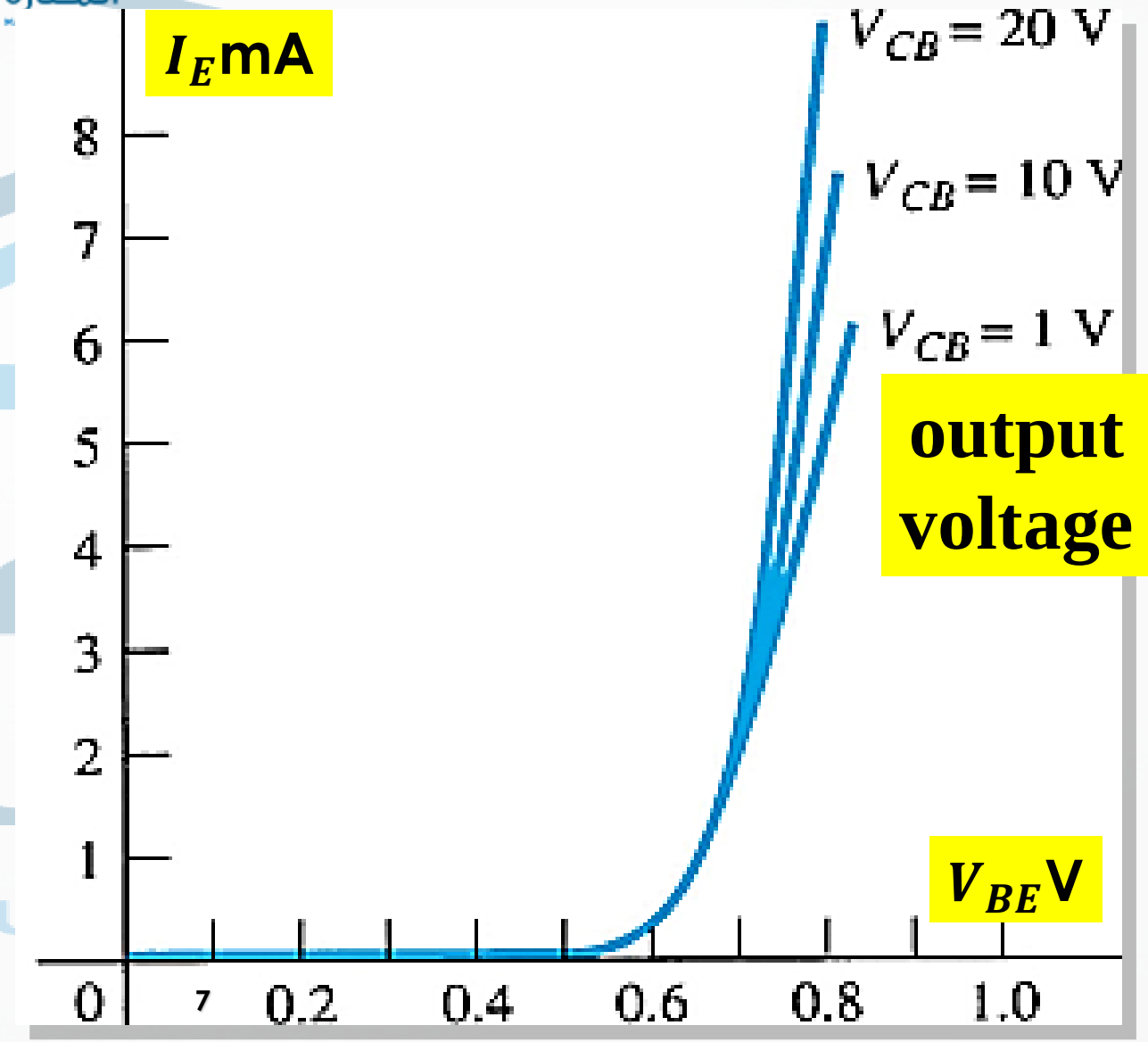


The base is common to both input (emitter–base) and output (collector–base) of the transistor.

Common-Base Amplifier

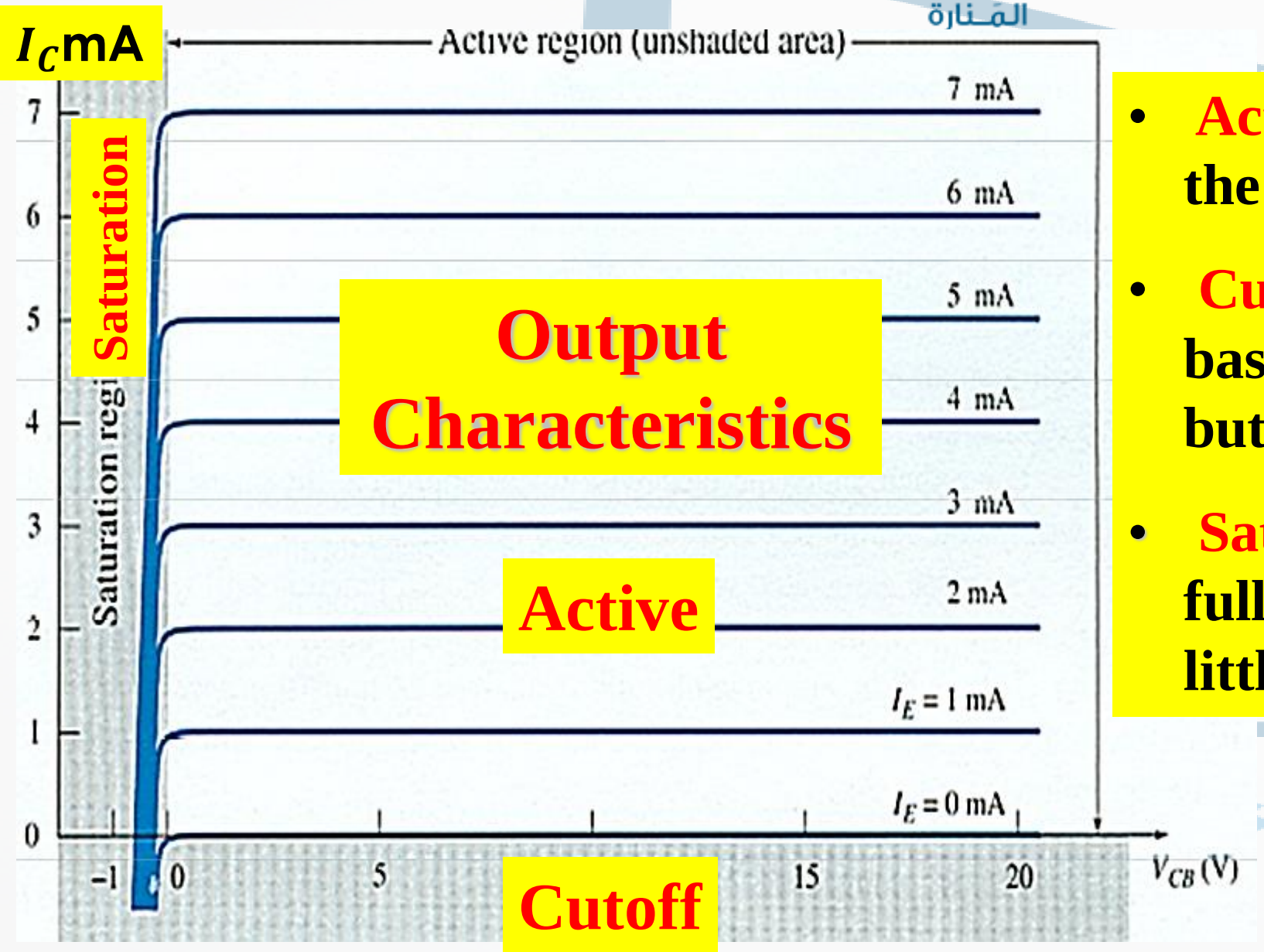
Input Characteristics

This curve shows the relationship between of input current (I_E) to input voltage (V_{BE}) for three output voltage (V_{CB}) levels.



Common-Base Amplifier

Operating Regions



- **Active** – Operating range of the amplifier.
- **Cutoff** – The amplifier is basically off. There is voltage, but little current.
- **Saturation** – The amplifier is full on. There is current, but little voltage.

Approximations

Emitter and collector currents: $I_C \cong I_E$

Base-emitter voltage: $V_{BE} = 0.7\,V$ (for Silicon)

Alpha (α)

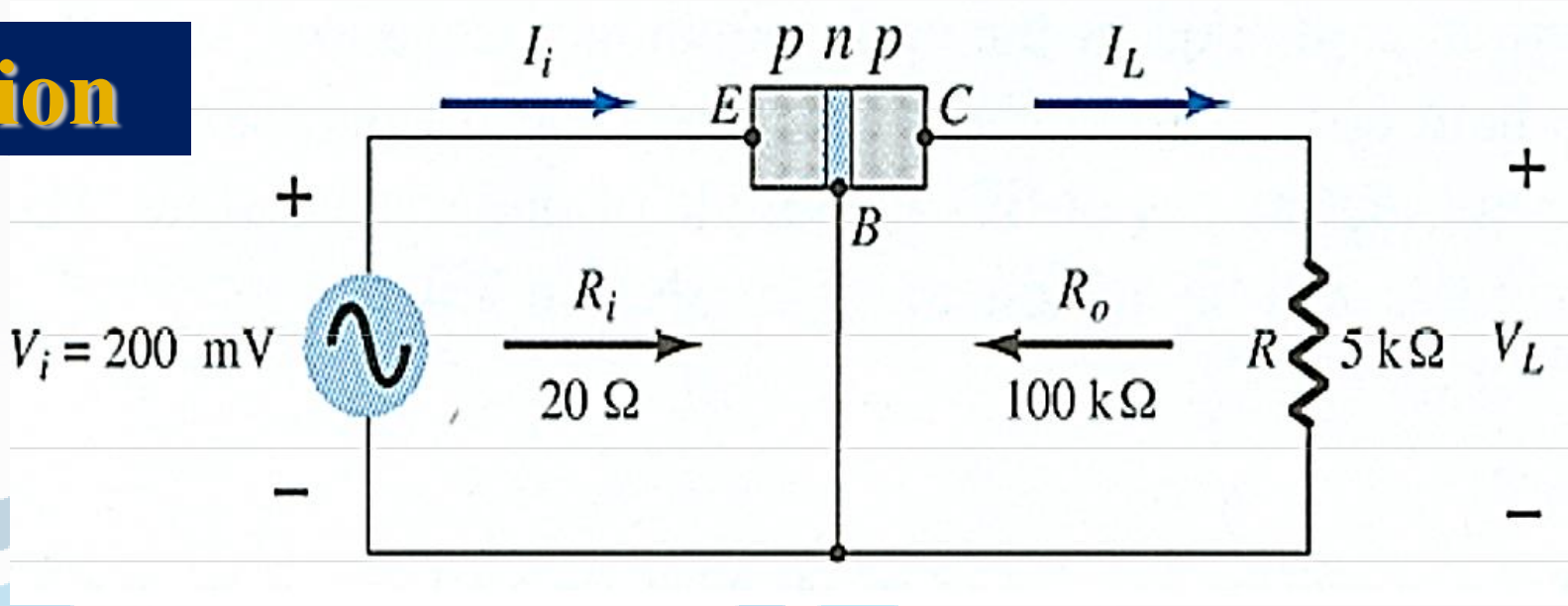
Alpha (α) is the ratio of I_C to I_E : $\alpha_{dc} = \frac{I_C}{I_E}$

Ideally: $\alpha = 1$

In reality: α is between 0.9 and 0.998

Alpha (α) in the AC mode: $\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}$

Transistor Amplification



Currents and Voltages:

$$I_E = I_i = \frac{V_i}{R_i} = \frac{200\text{mV}}{20\Omega} = 10\text{mA}$$

$$I_C \cong I_E$$

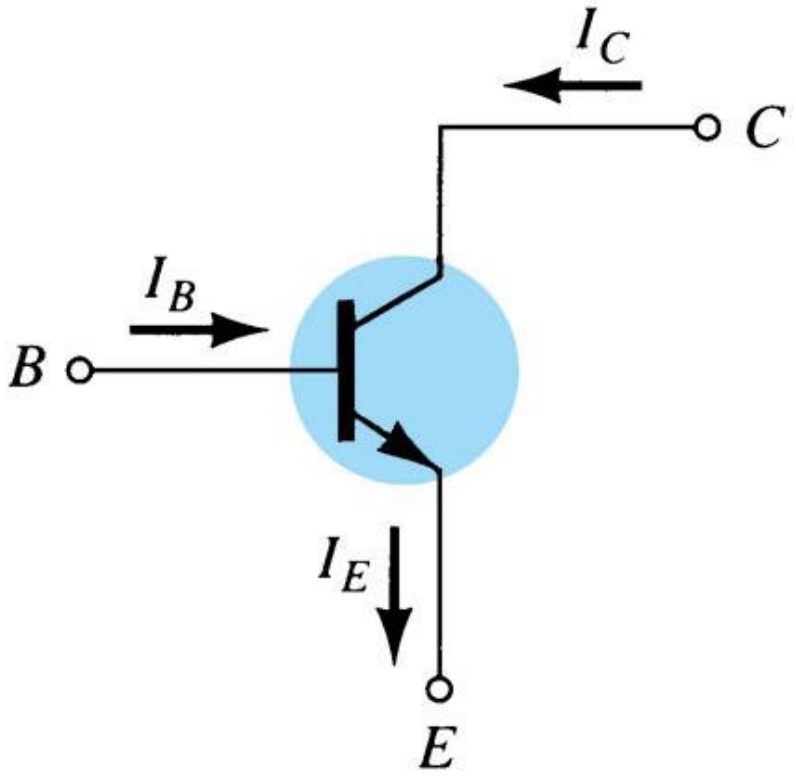
$$I_L \cong I_i = 10\text{ mA}$$

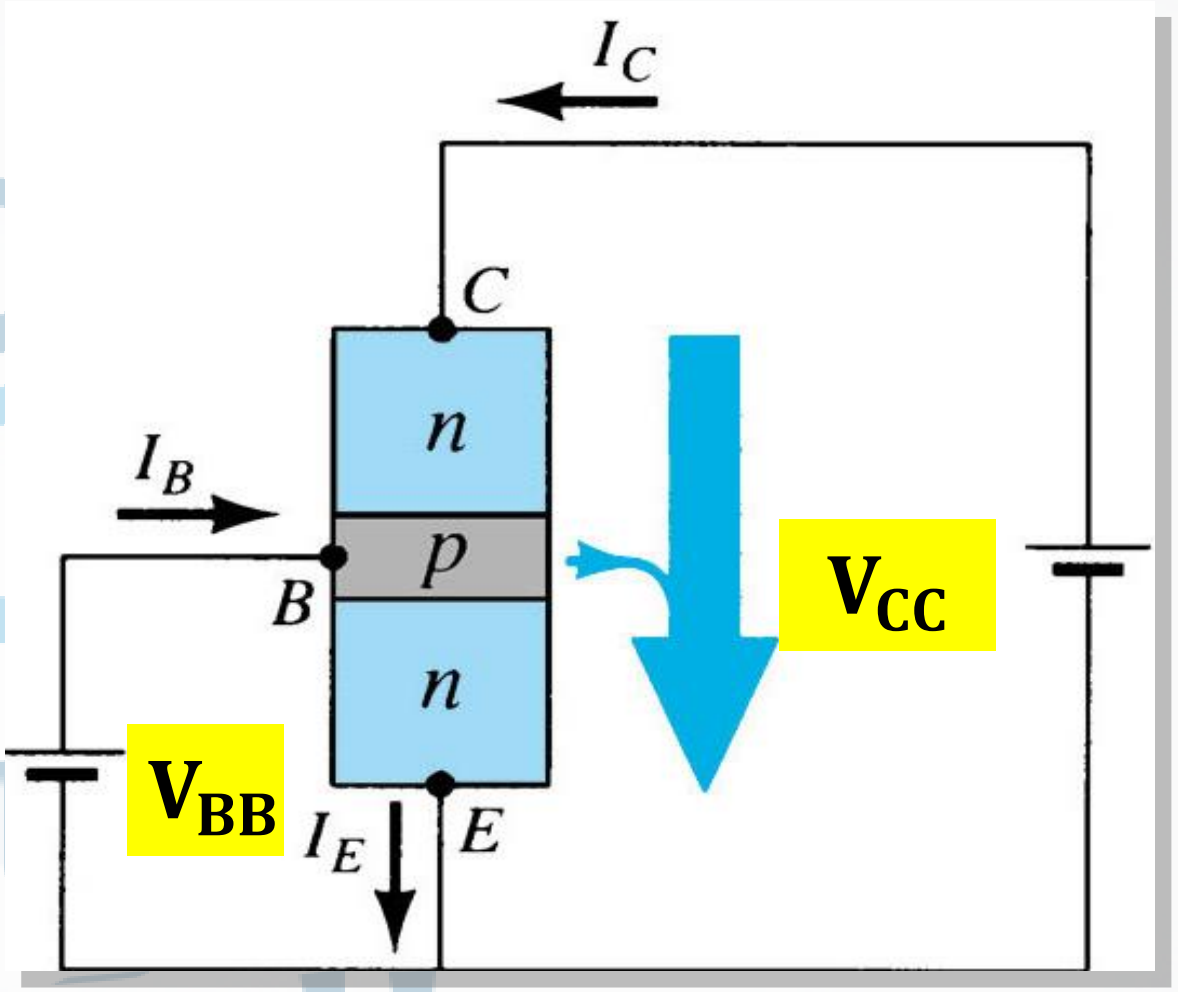
$$V_L = I_L R = (10\text{ mA})(5\text{ k}\Omega) = 50\text{ V}$$

Voltage Gain:

$$A_v = \frac{V_L}{V_i} = \frac{50\text{V}}{200\text{mV}} = 250$$

Common–Emitter Configuration



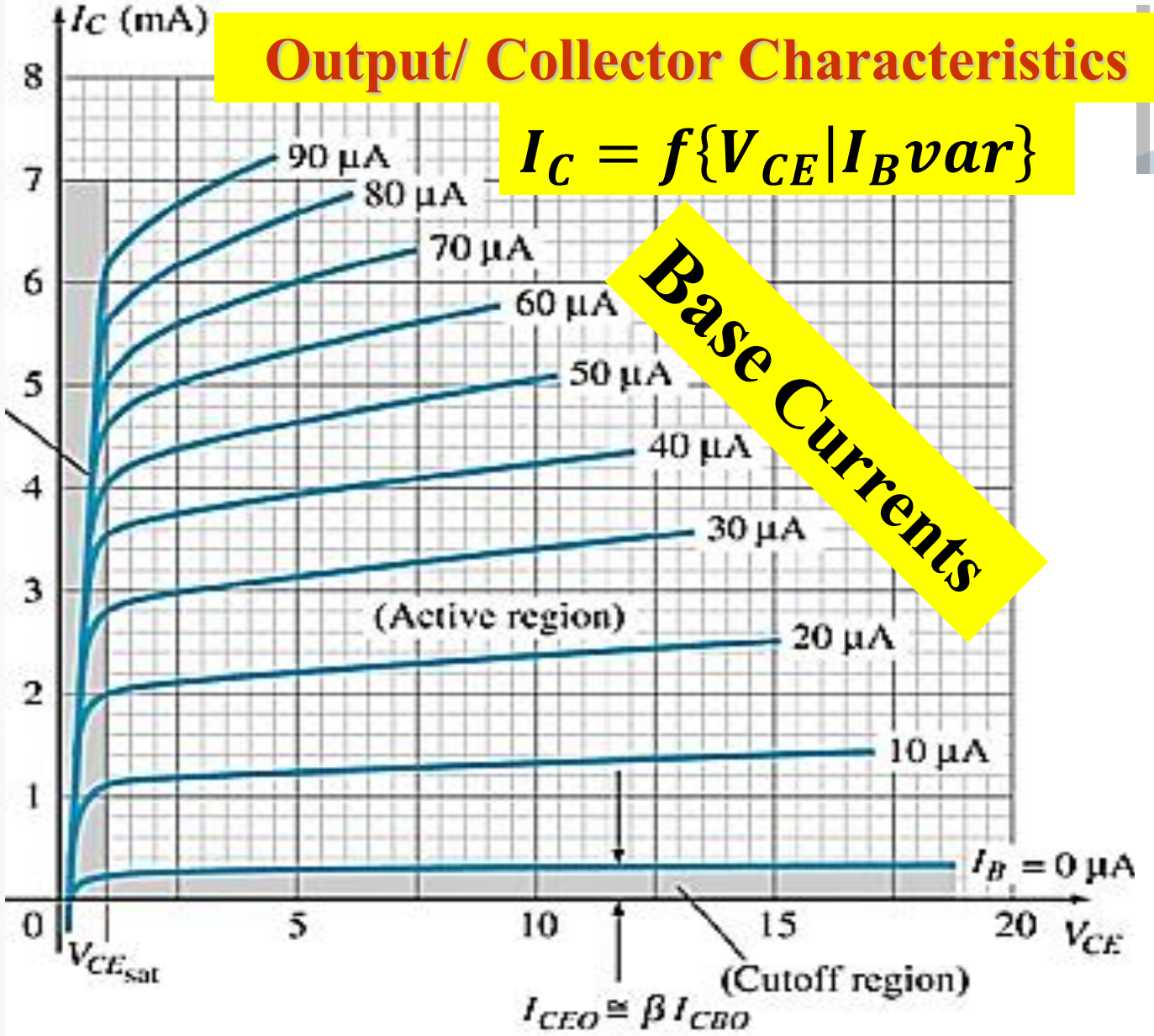


- **The emitter is common to both input (base-emitter) and output (collector-emitter).**
- **The input is on the base and the output is on the collector.**

Common–Emitter Configuration Characteristics

Output/ Collector Characteristics

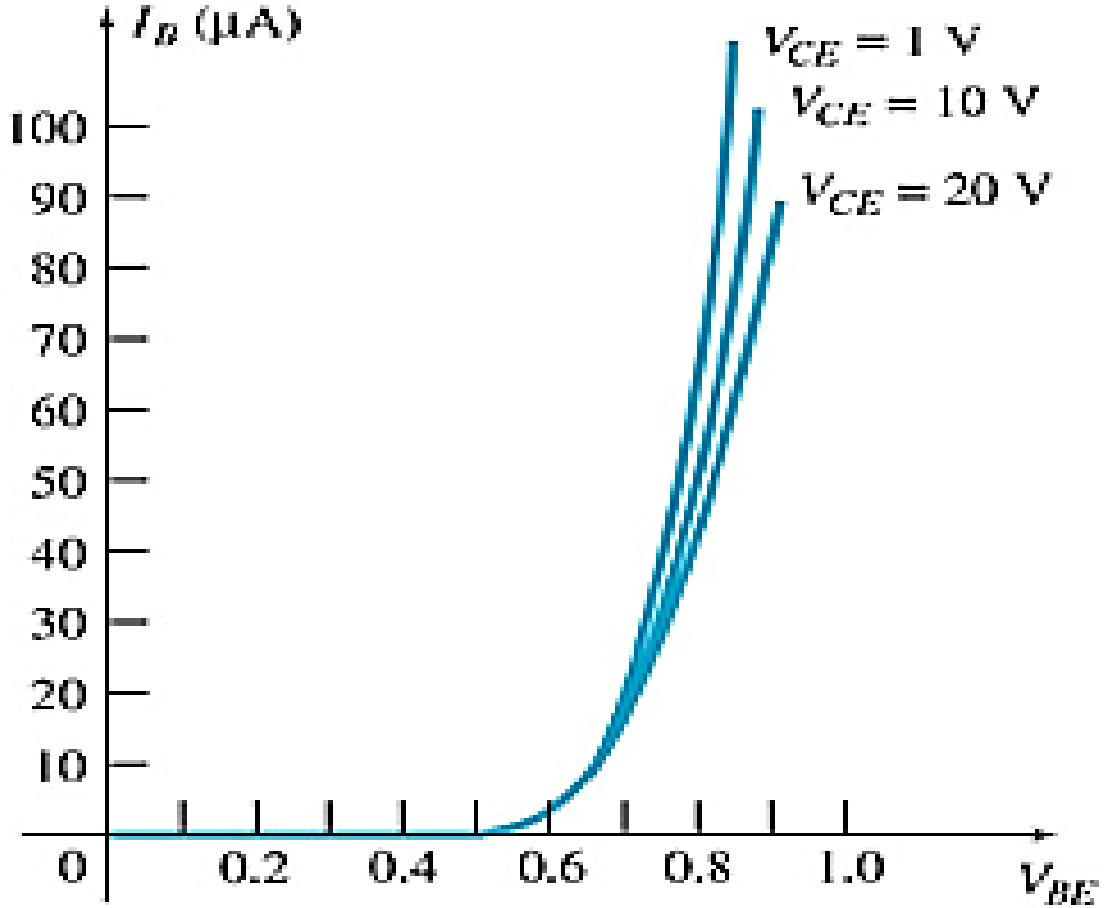
$$I_C = f\{V_{CE}|I_B var\}$$



Base Currents

Input/ Base Characteristics

$$I_B = f\{V_{BE}|V_{CE} var\}$$



Common-Emitter Amplifier Currents

Ideal Currents $I_E = I_C + I_B \qquad I_C = \alpha I_E$

Actual Currents $I_C = \alpha I_E + I_{CBO}$

where I_{CBO} = minority collector current

I_{CBO} is usually so small that it can be ignored, except in high power transistors and in high temperature environments.

- When I_B = 0 μA the transistor is in cutoff, but there is some minority current flowing called I_{CEO}.

In AC mode:

$$I_{CEO} = \frac{I_{CBO}}{1-\alpha}\bigg|_{I_B = 0\,\mu A}$$

Common-Emitter Amplifier Currents

- **Beta (β)**

β represents the amplification factor of a transistor. (β is sometimes referred to as h_{fe}, a term used in transistor modeling calculations)

In DC mode:

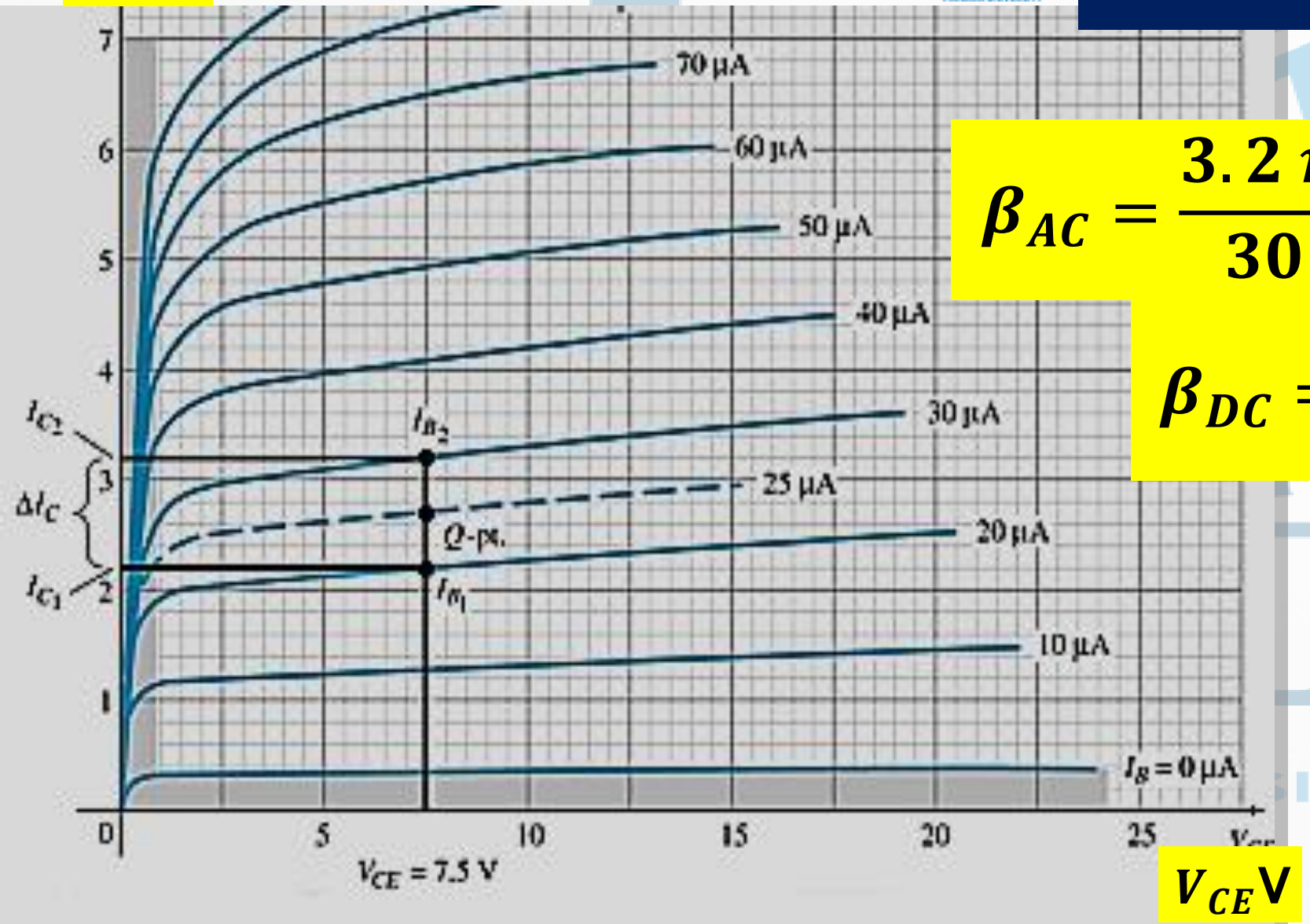
$$\beta_{dc} = \frac{I_C}{I_B}$$

In AC mode:

$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}=\text{constant}}$$

- **Beta (β)**

Determining β from a Graph



$$\beta_{AC} = \frac{3.2\ mA - 2.2\ mA}{30\ \mu A - 20\ \mu A} = 100$$

$$\beta_{DC} = \frac{2.7\ mA}{25\ \mu A} = 108$$

Common-Emitter Amplifier Currents

Relationship between amplification factors β and α

$$\alpha = \frac{\beta}{\beta + 1}$$

$$\beta = \frac{\alpha}{\alpha - 1}$$

Relationship Between Currents

$$I_C = \beta I_B$$

$$I_E = (\beta + 1) I_B$$

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