Bipolar Junction Transistor (BJT)

Dr Mohammad Abdur Rashid

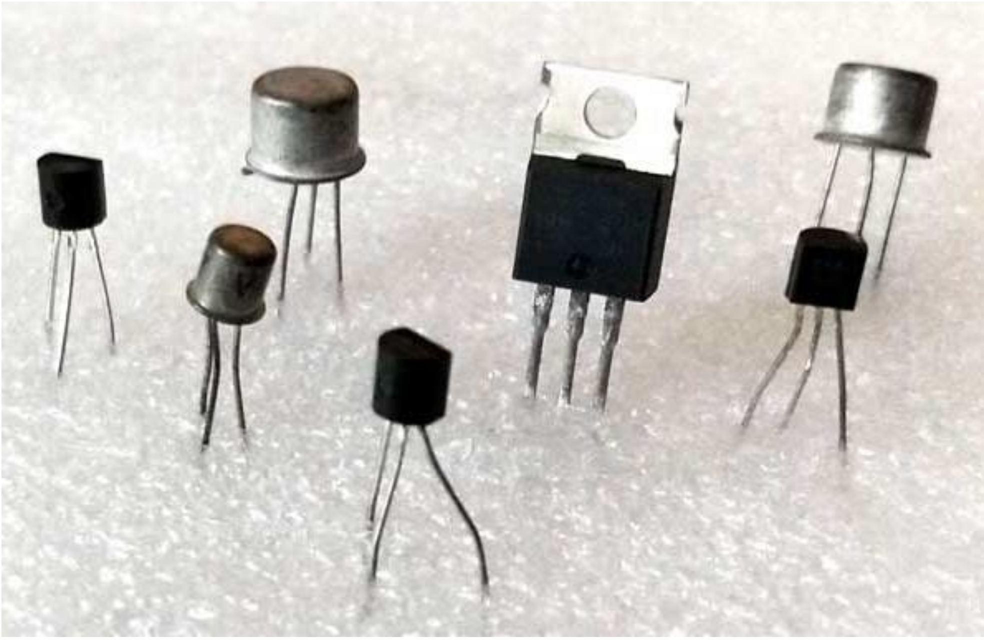
Bipolar Junction Transistor

BJT was invented in 1947

Nobel Prize in 1956

Dr. William Shockley (seated);
Dr. John Bardeen (left); Dr. Walter H. Brattain.

Vacuum tube and transistor

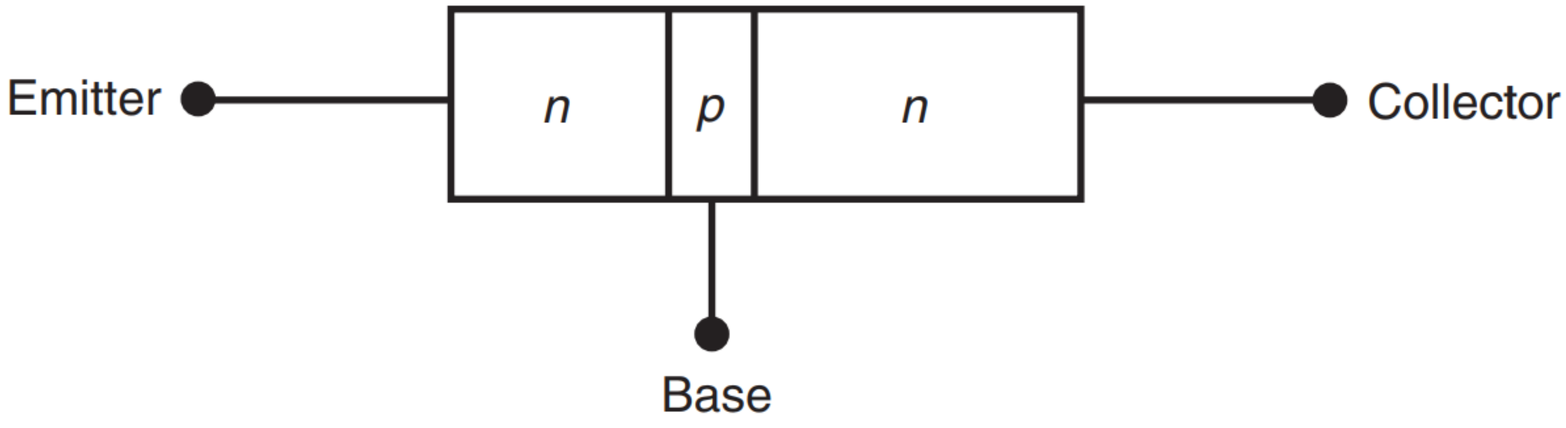


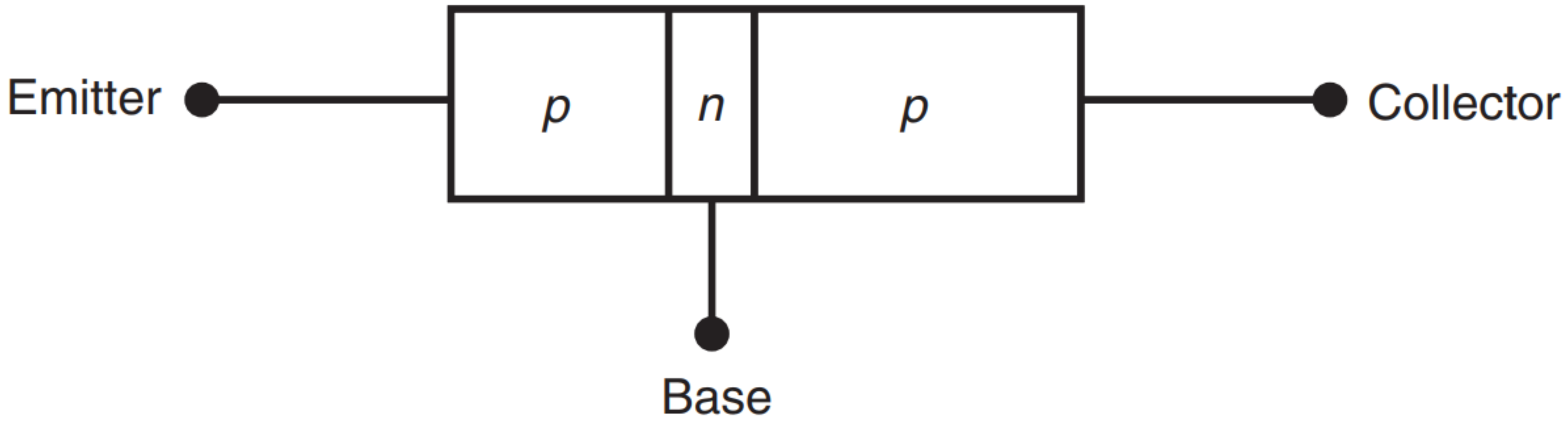
Antique radio

AMD Ryzen™ 9 3900X

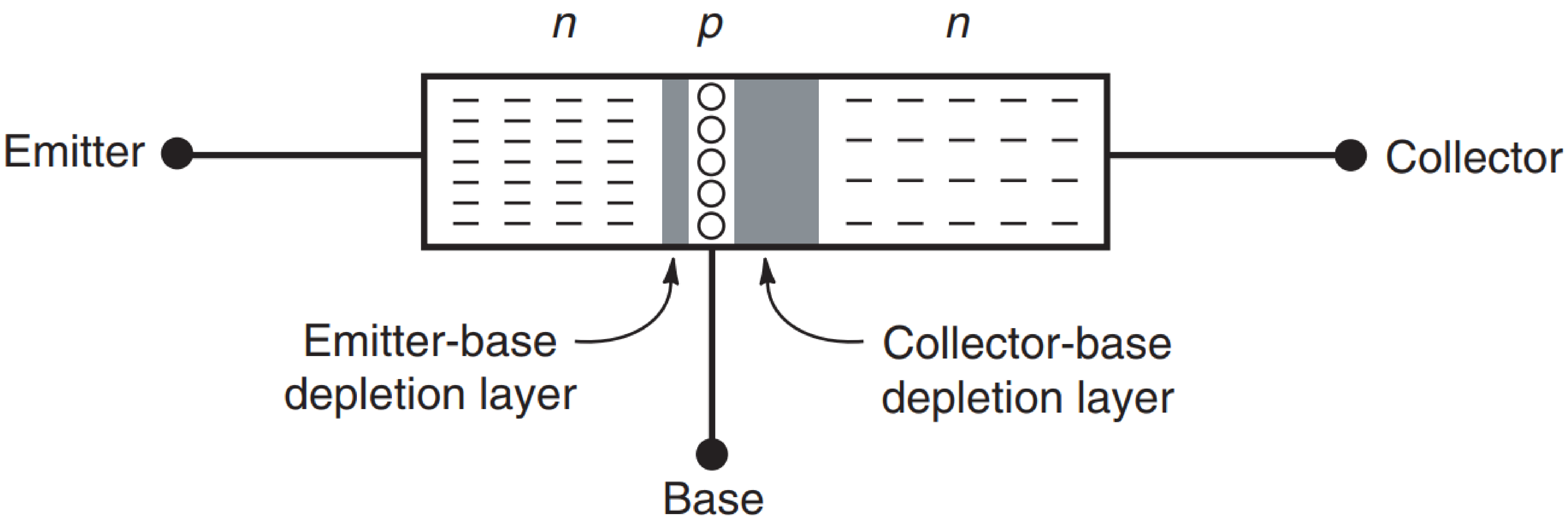
Cores	12
Threads	24
Transistors	19.2 billions
Dimensions	1.57 x 1.57 x 0.24 inches
Weight	45.1 g
Released	July 7, 2019

Transistor showing the three doped regions



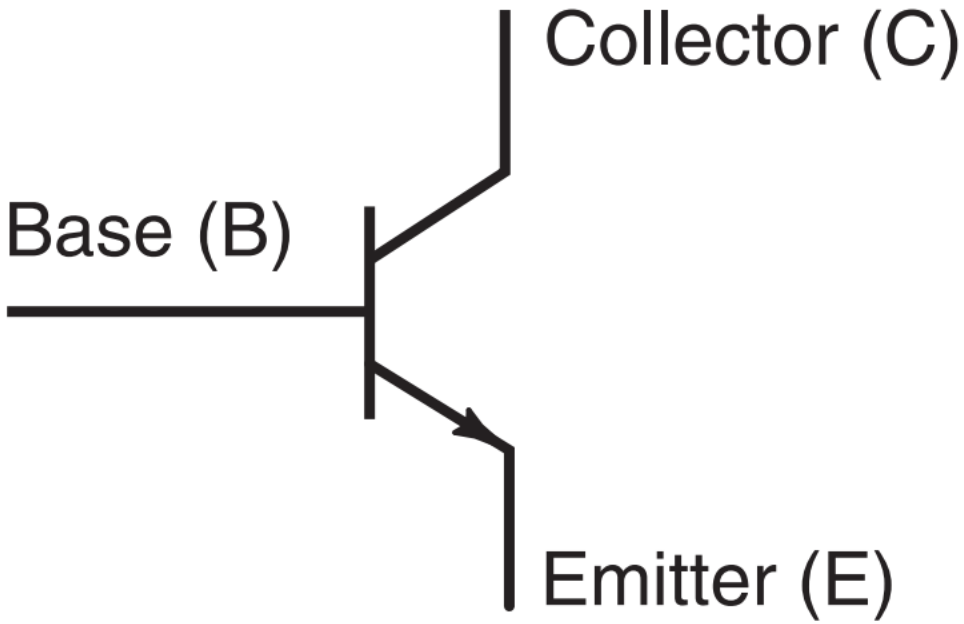


Depletion layers in an *npn* transistor

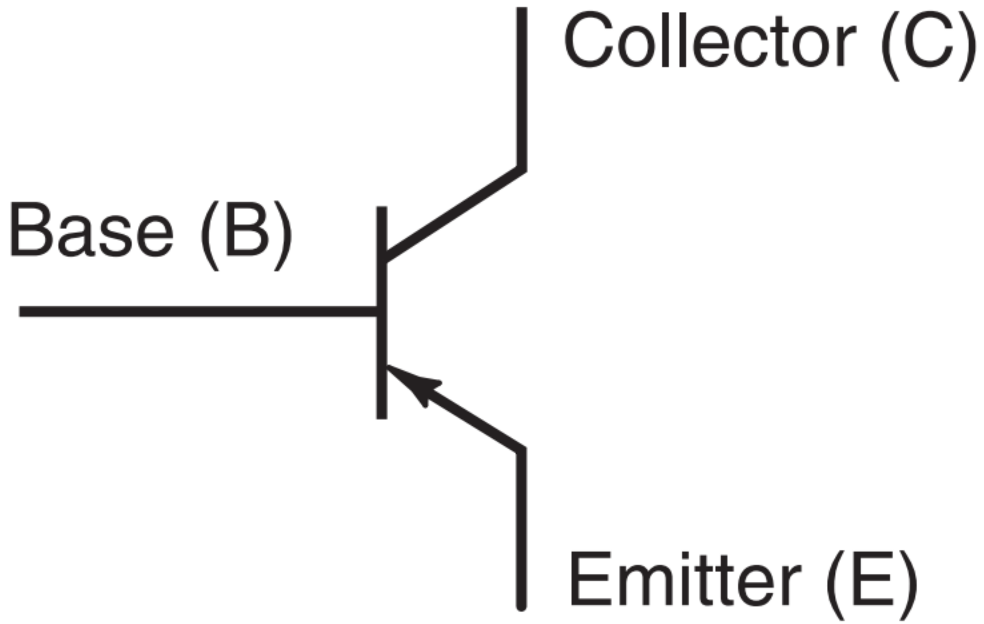


The **name transistor** is derived from "transfer resistor" it means that the resistance is changed.

Schematic symbols for transistors

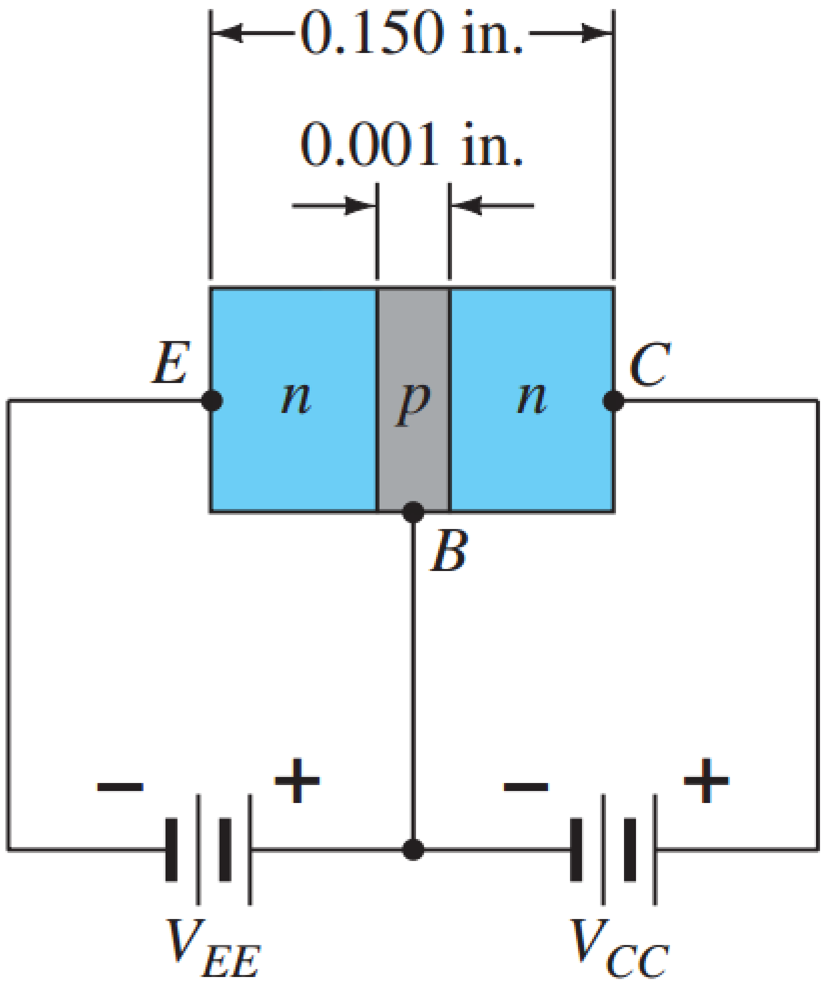


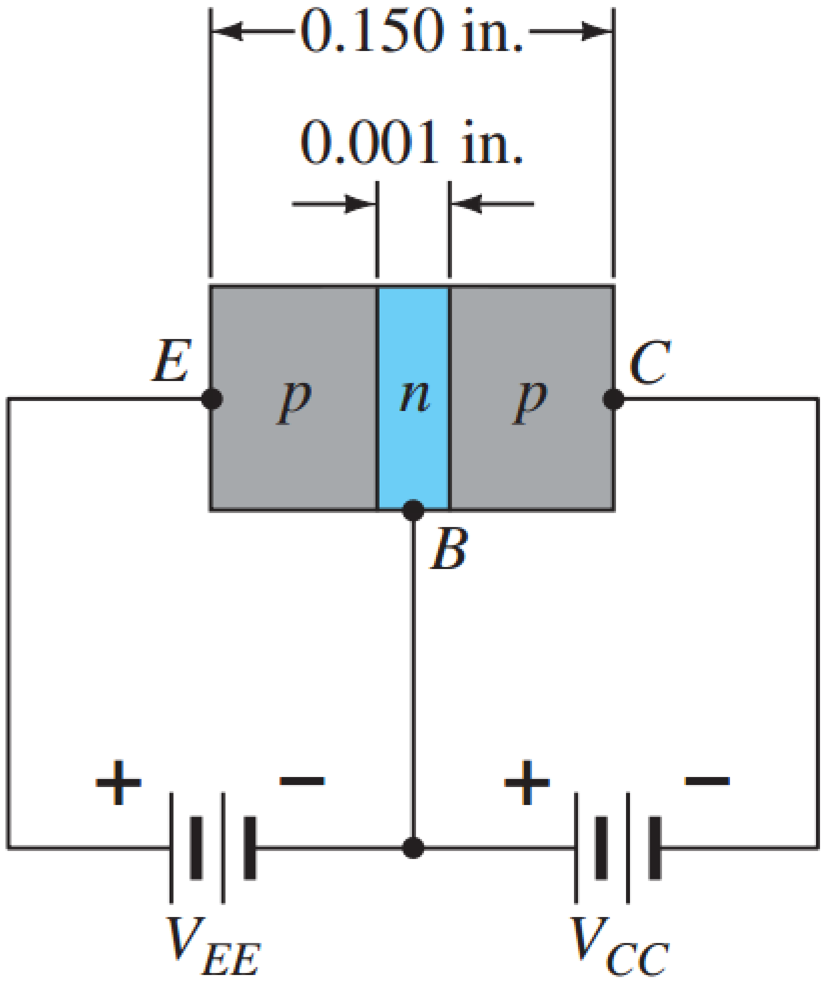
(a) *npn* transistor



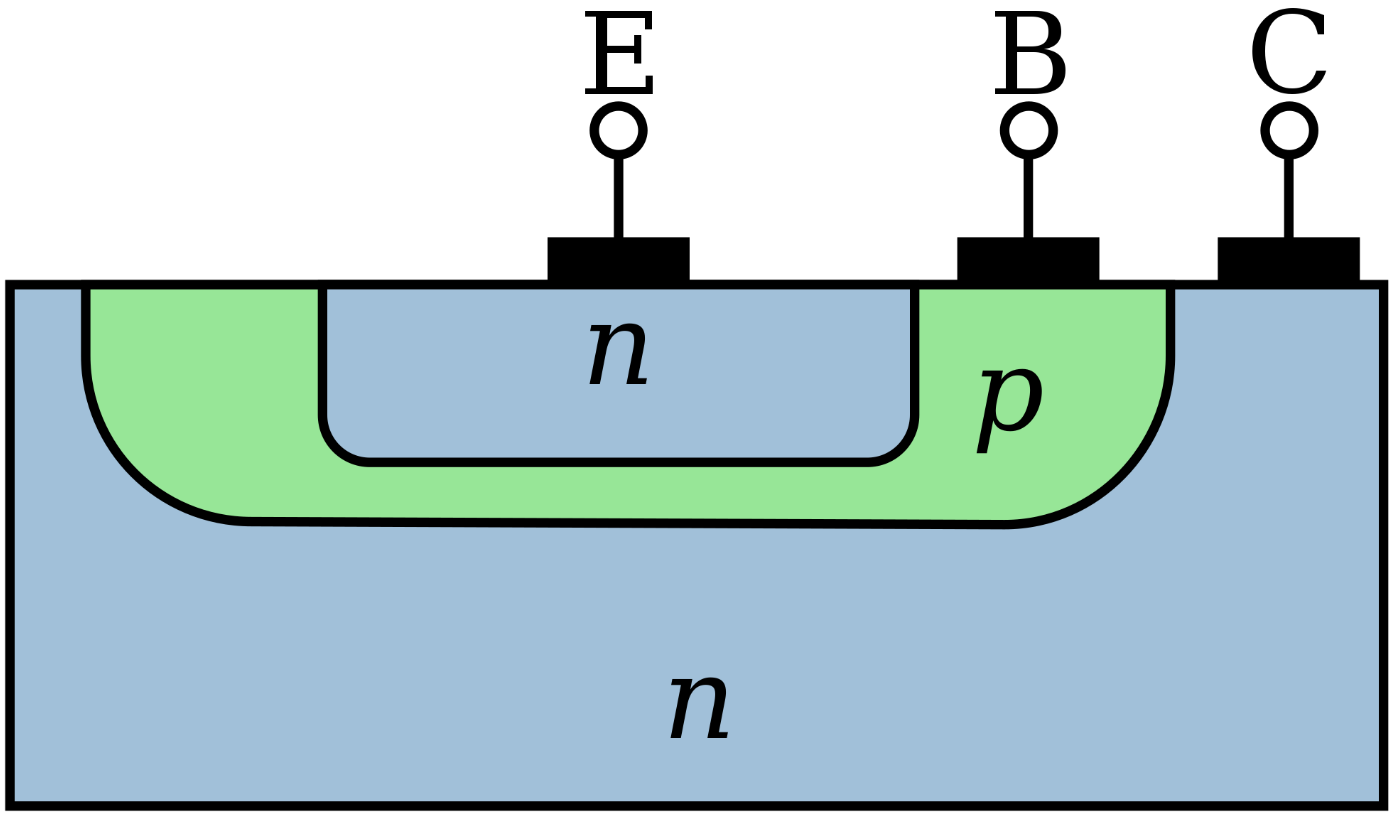
(b) *pnp* transistor

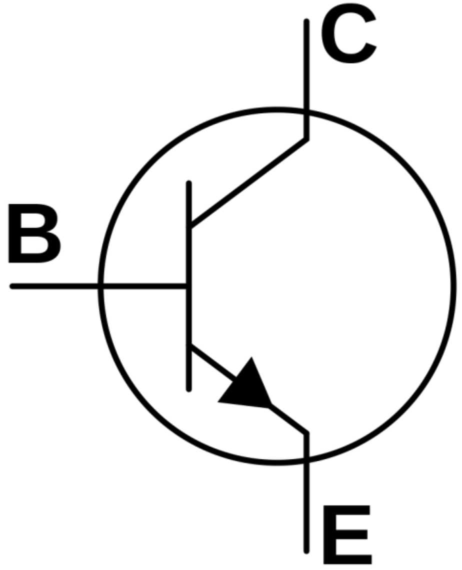
Bipolar Junction Transistor



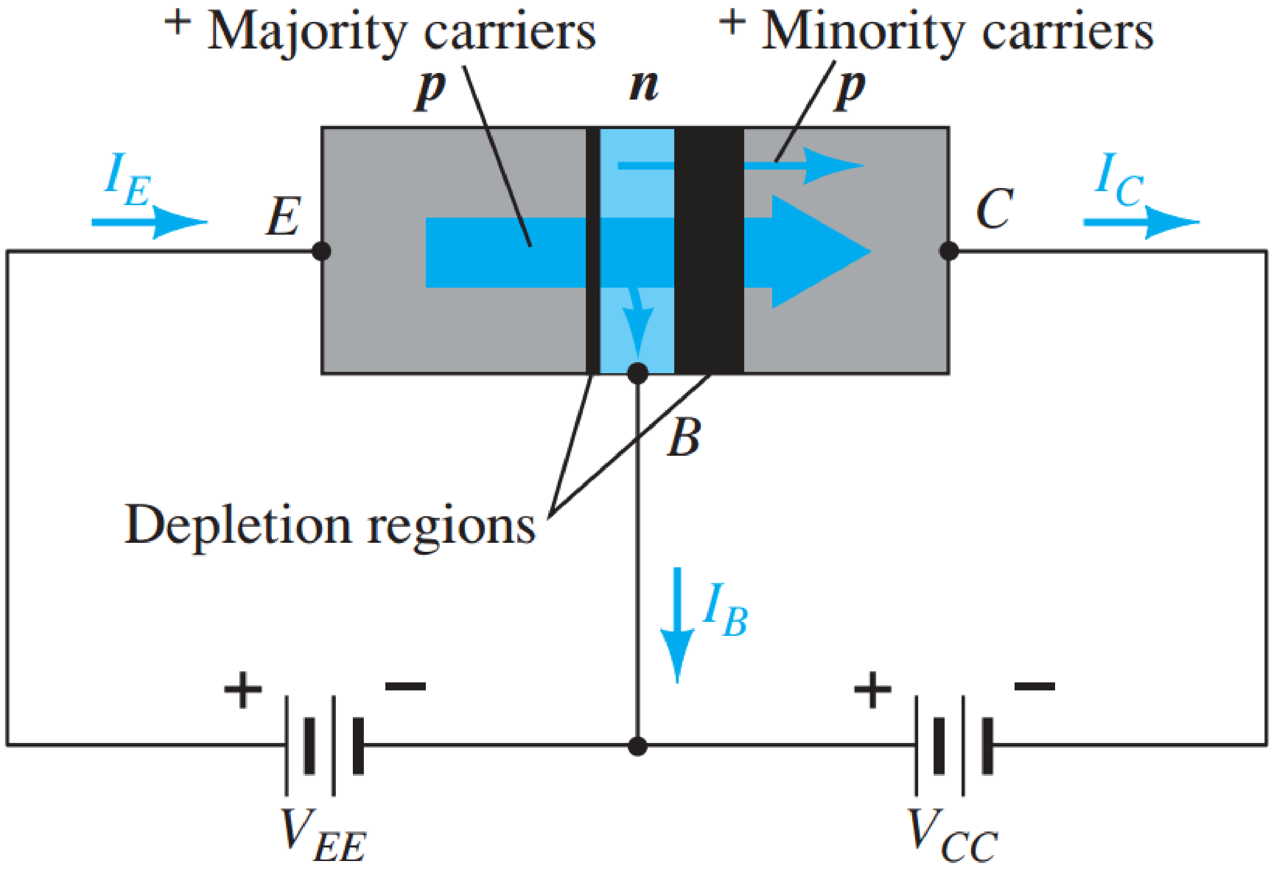


Cross sectional view of *npn* transistor





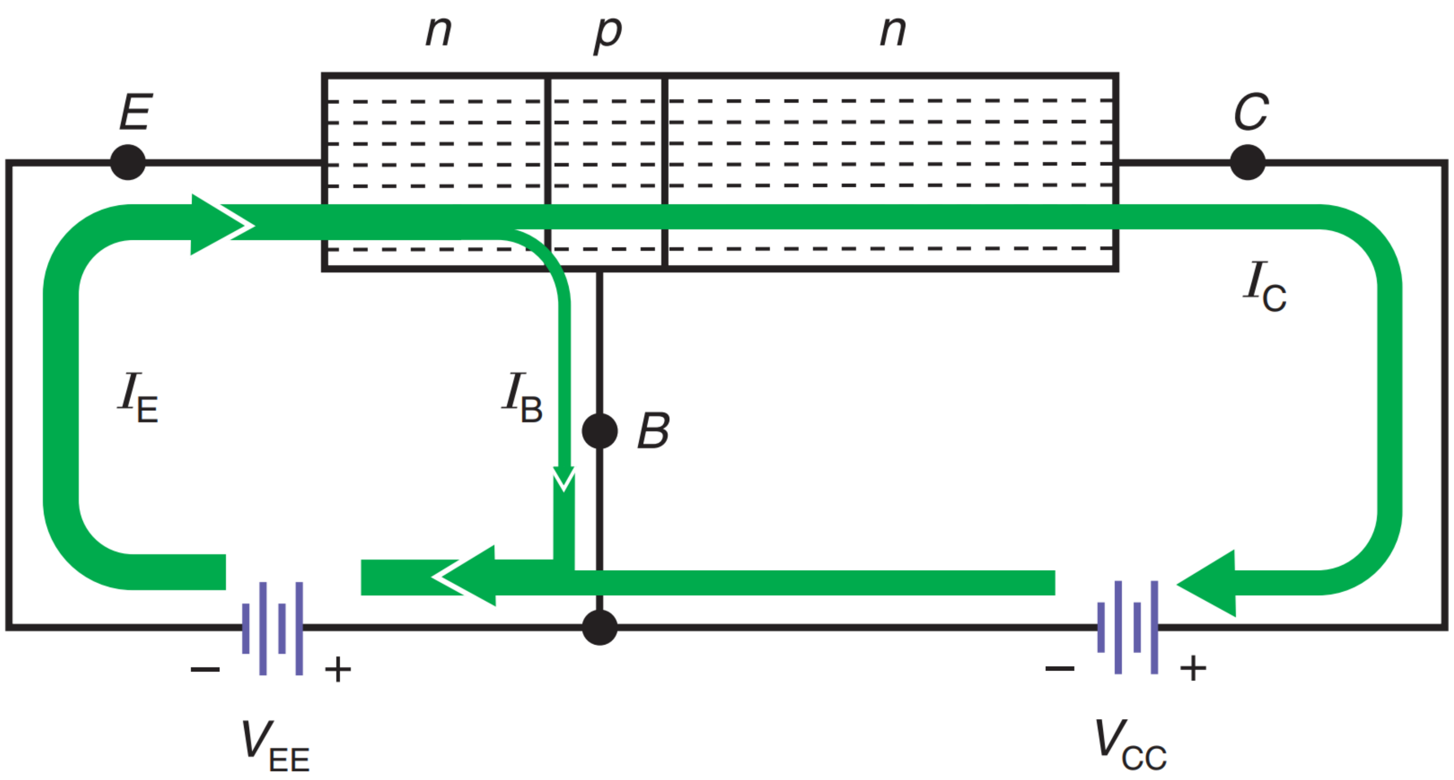
Majority and minority carrier flow of a *pnp* transistor



$$I_E = I_C + I_B$$

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

Transistor Biasing



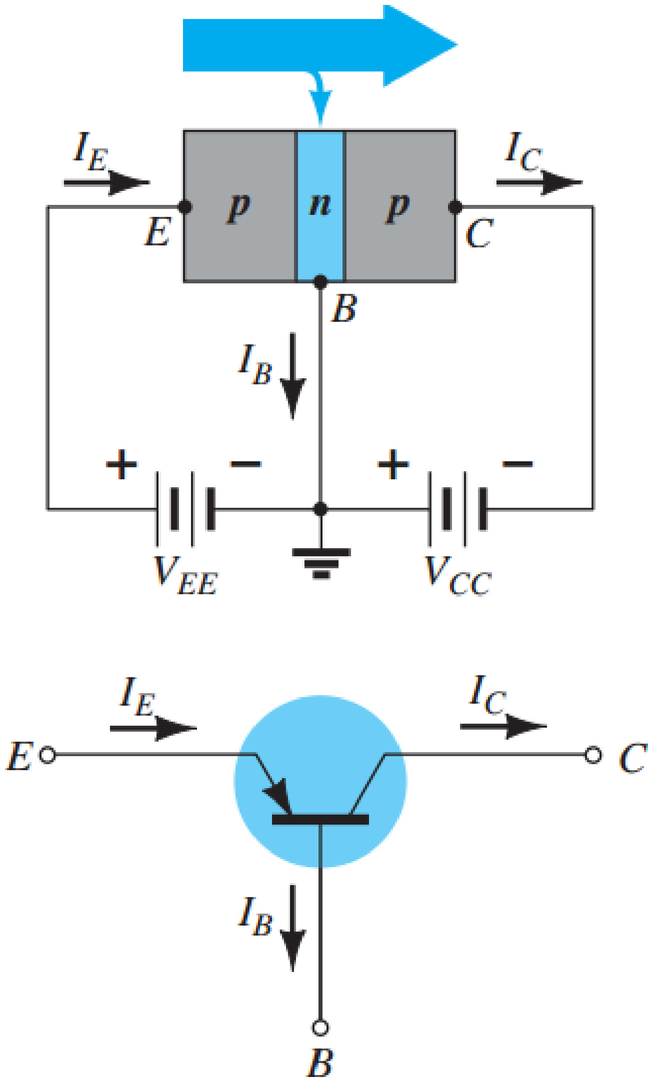
$$I_E = I_B + I_C$$

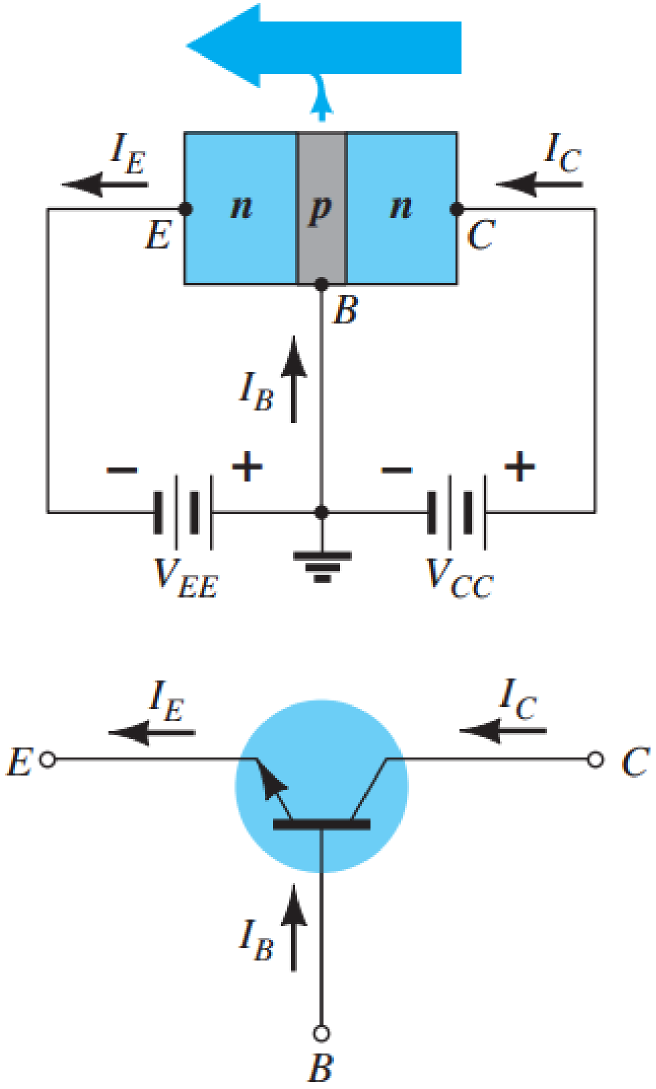
$$I_C = I_E - I_B$$

$$I_B = I_E - I_C$$

Transistor biasing for the common-base connection

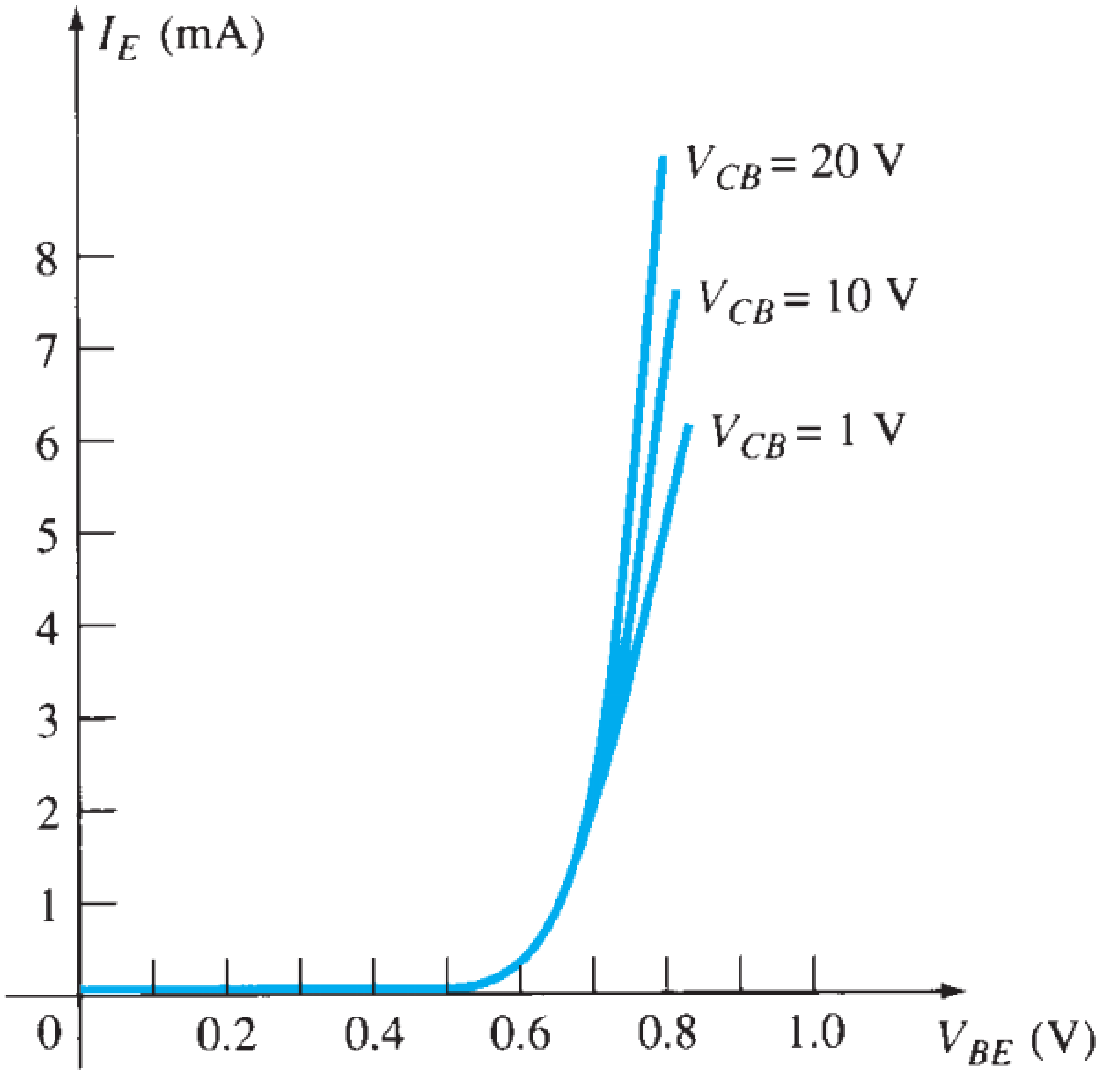
pnp
transistor





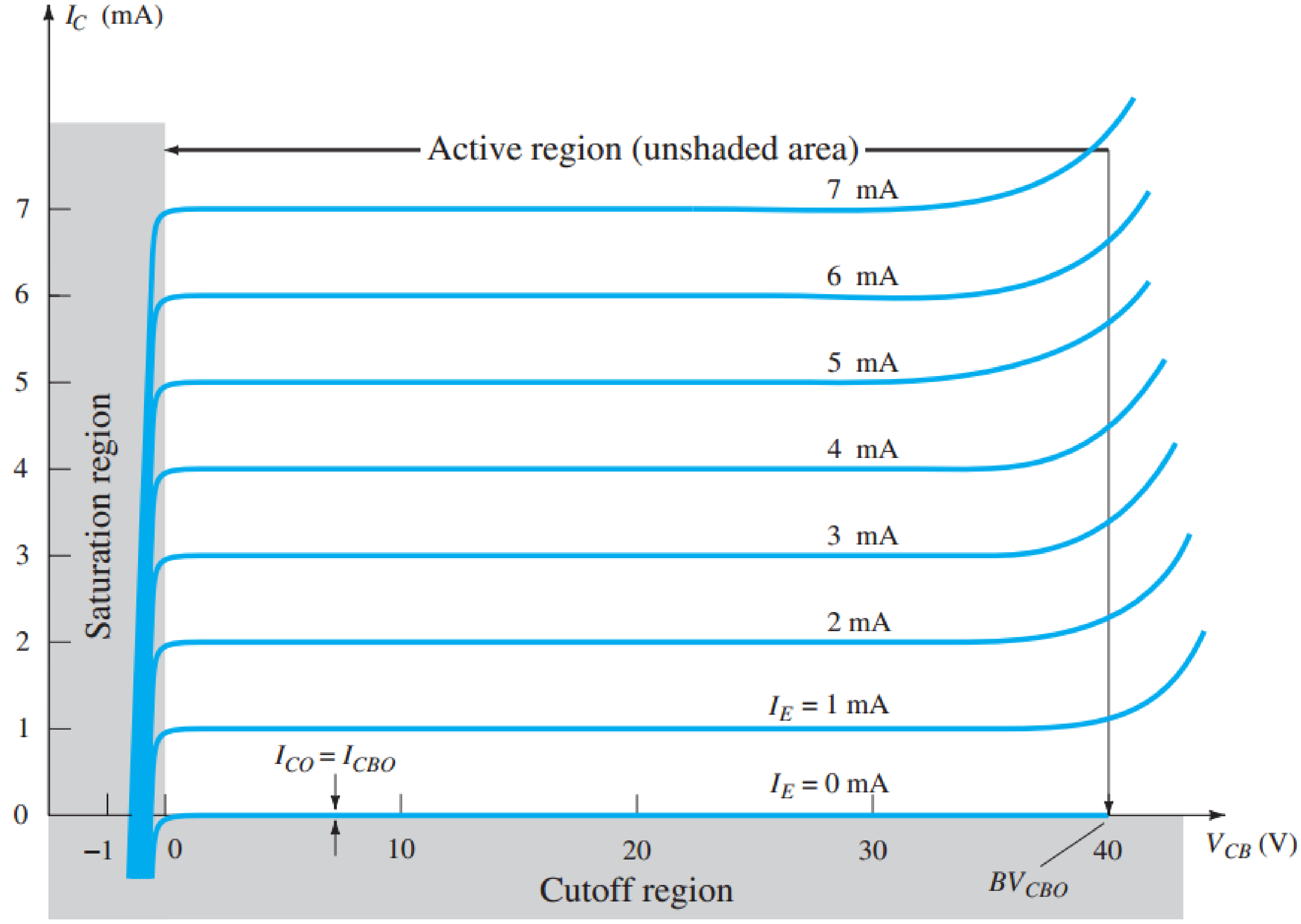
npn
transistor

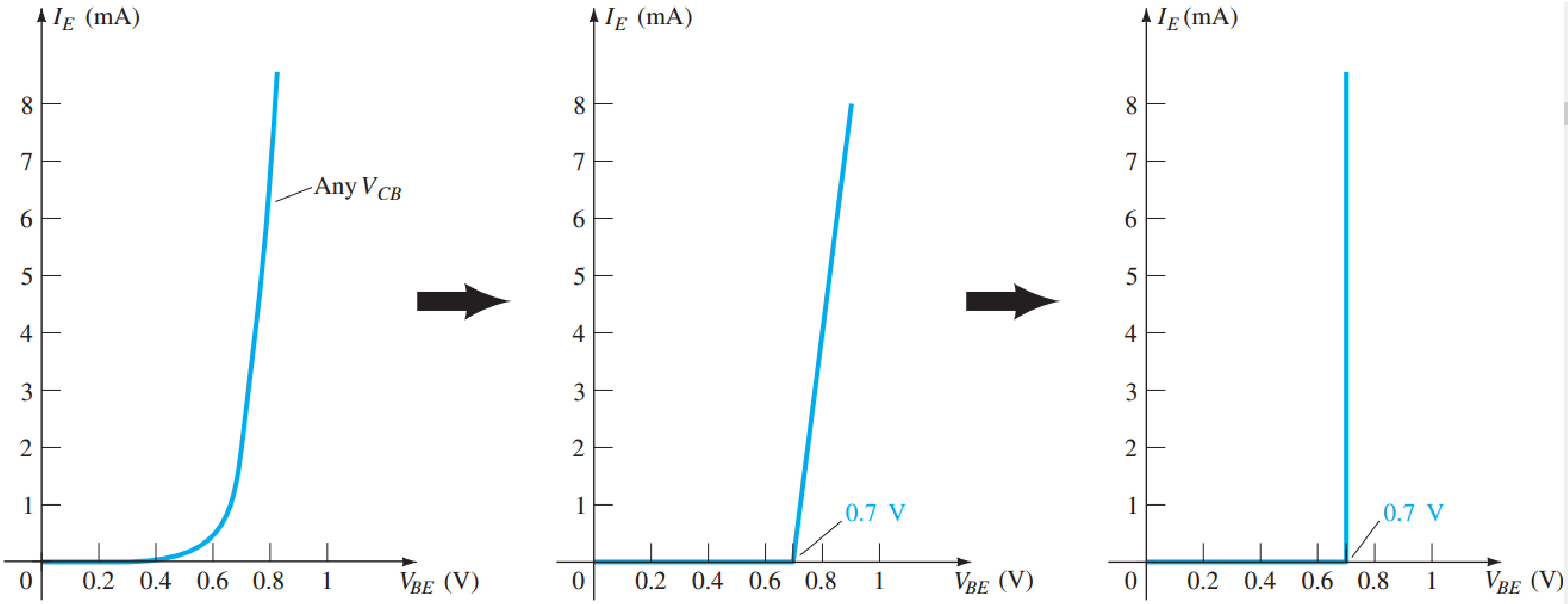
Input or driving point characteristics for a common-base silicon transistor amplifier



Output or collector characteristics for a common-base transistor amplifier

$$I_C \cong I_E$$





Developing the equivalent model to be employed for the base-to-emitter region of an amplifier in the dc mode

Alpha (α)

DC Mode

$$\alpha_{\text{dc}} = \frac{I_C}{I_E}$$

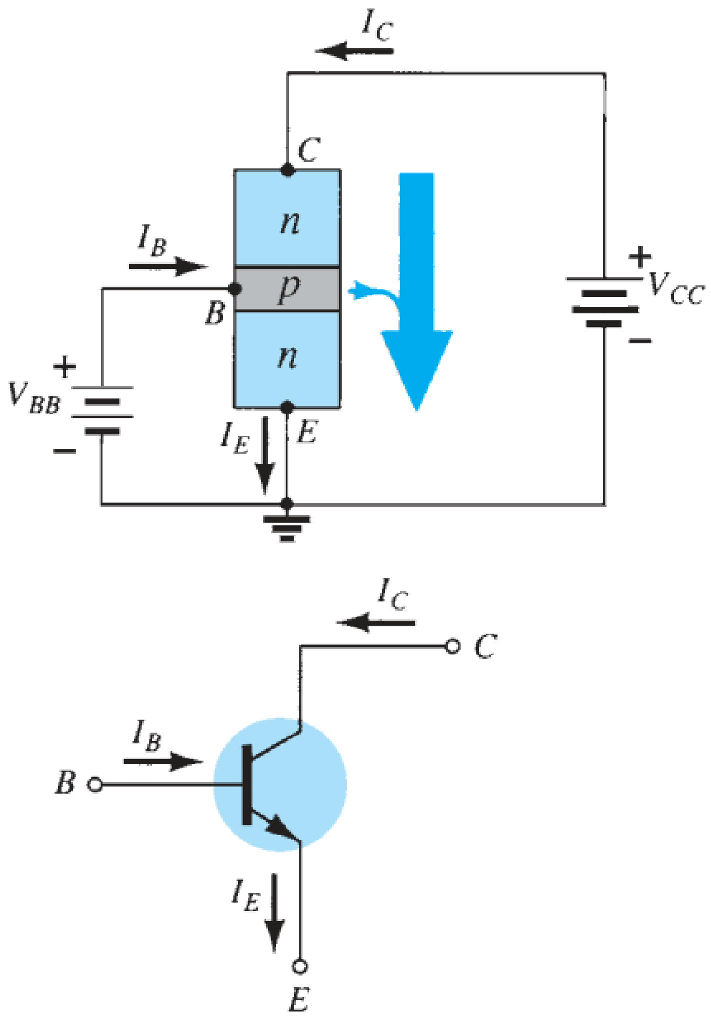
$$I_C = \alpha I_E + I_{CBO}$$

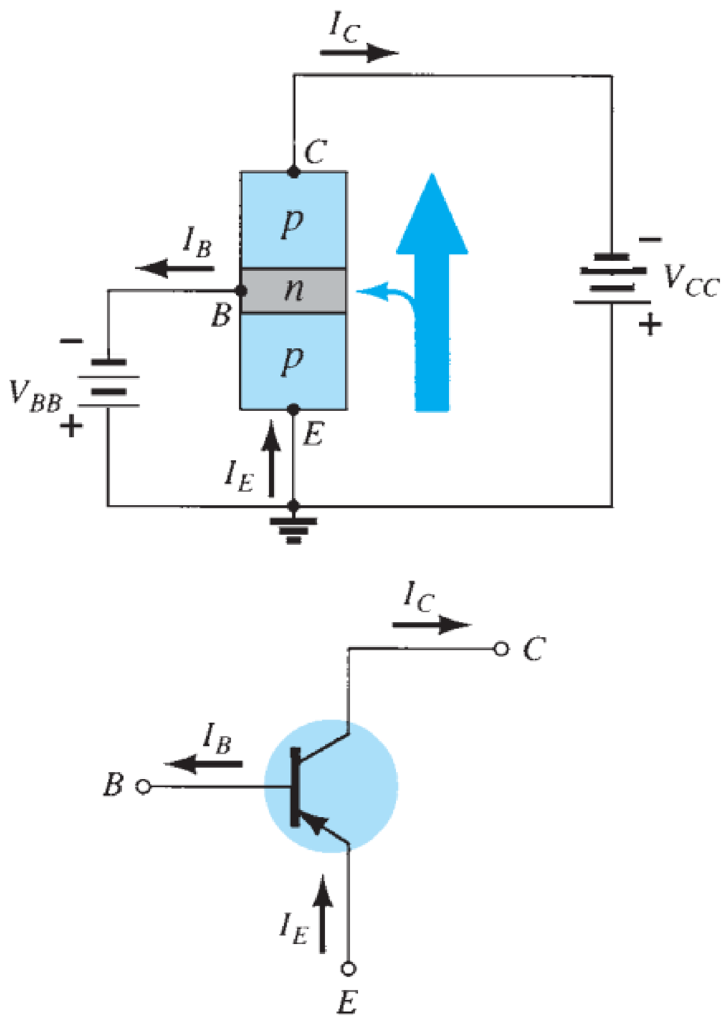
AC Mode

$$\alpha_{\text{ac}} = \left.\frac{\Delta I_C}{\Delta I_E}\right|_{V_{CB}=\text{constant}}$$

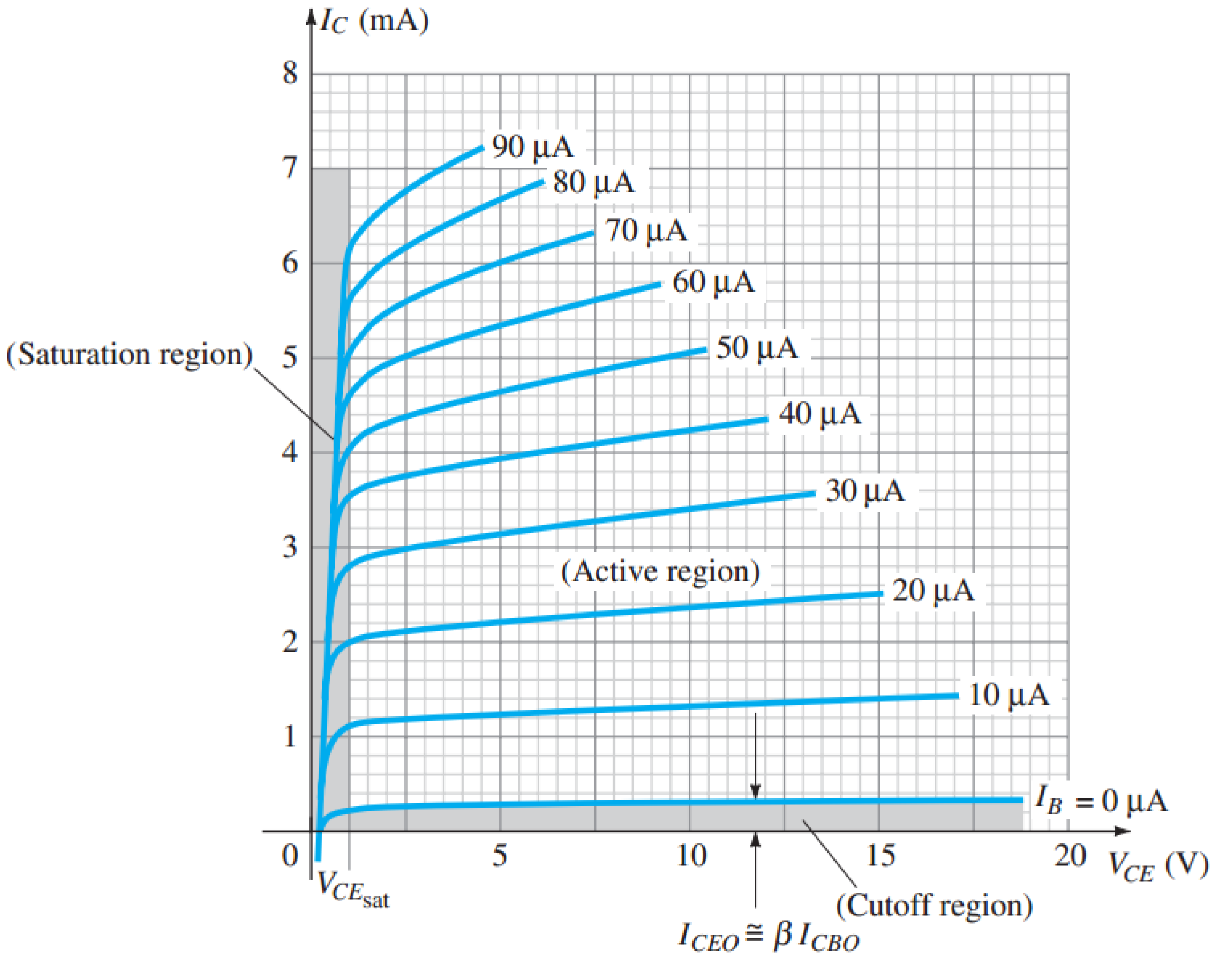
The ac alpha is formally called the common-base, short-circuit, amplification factor.

Common-emitter configuration

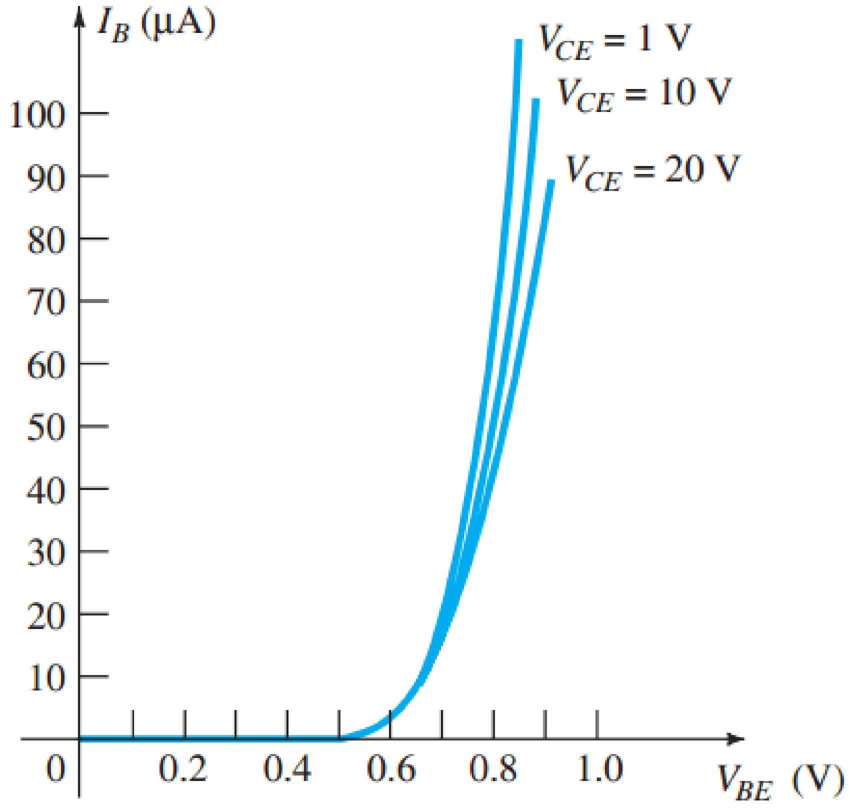




Characteristics in the common-emitter configuration



Collector characteristics



Base characteristics

Beta (β)

DC Mode

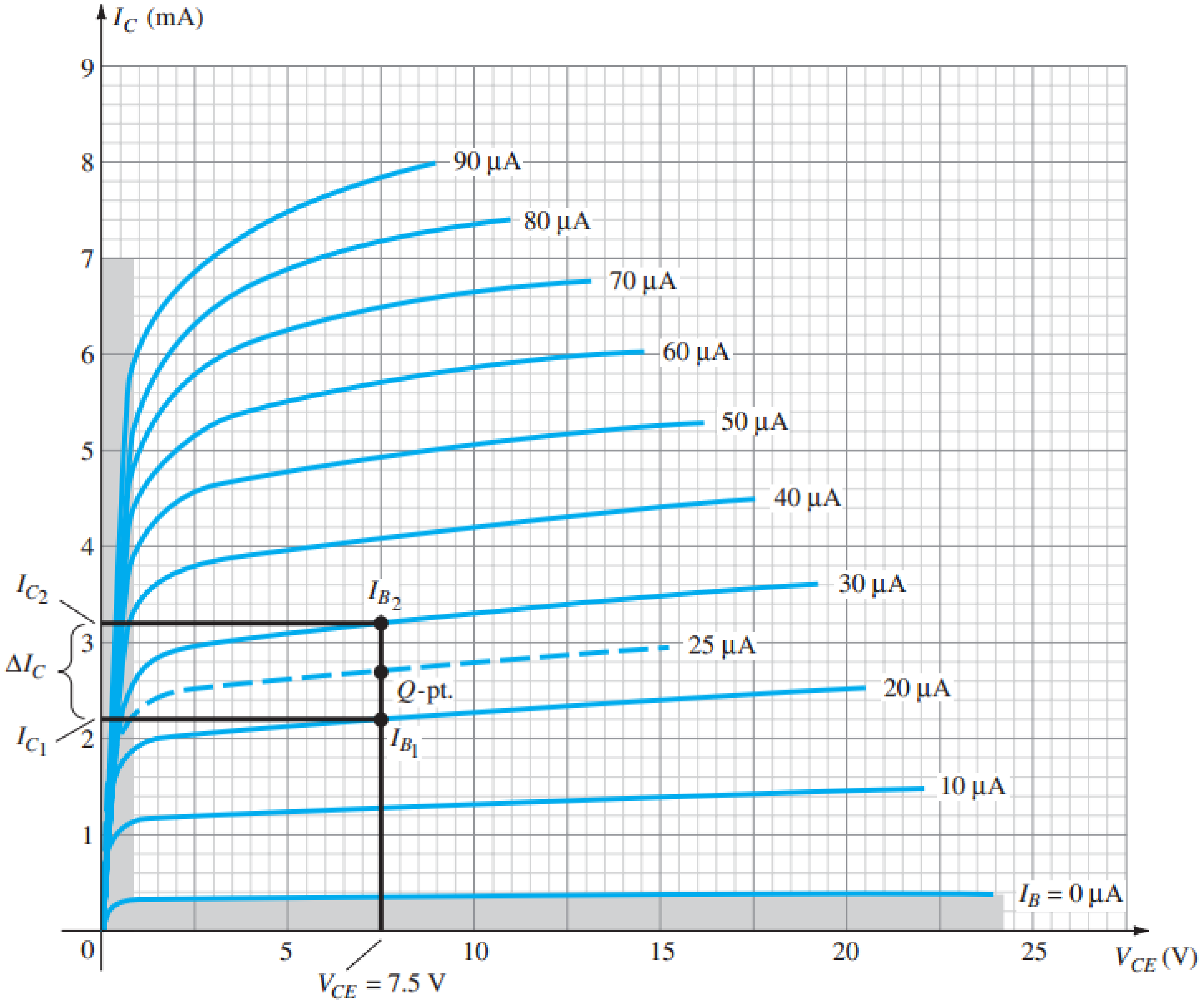
$$\beta_{dc} = \frac{I_C}{I_B}$$

AC Mode

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

The ac beta is formally called the common-emitter, forward-current, amplification factor.

Determining β_{ac} and β_{dc} from the collector characteristics



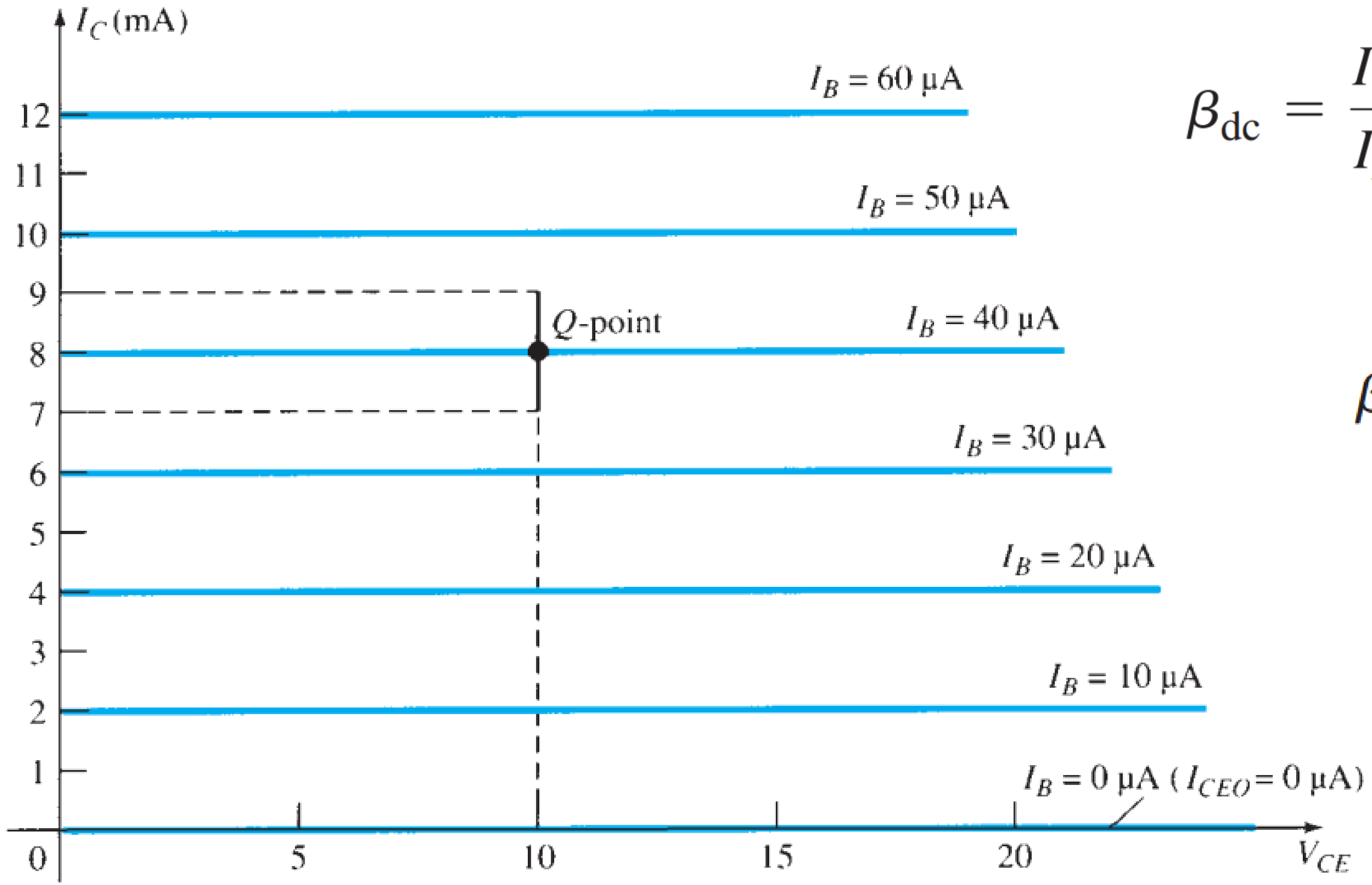
$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE=\text{constant}}} = \frac{I_{C_2} - I_{C_1}}{I_{B_2} - I_{B_1}}$$

$$= \frac{3.2\text{ mA} - 2.2\text{ mA}}{30\ \mu\text{A} - 20\ \mu\text{A}} = \frac{1\text{ mA}}{10\ \mu\text{A}}$$

$$= \mathbf{100}$$

$$\beta_{dc} = \frac{I_C}{I_B} = \frac{2.7\text{ mA}}{25\ \mu\text{A}} = \mathbf{108}$$

Characteristics in which β_{ac} is the same everywhere



$$\beta_{dc} = \frac{I_C}{I_B} = \frac{8\text{ mA}}{40\ \mu\text{A}} = \mathbf{200}$$

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

$$= \frac{9\text{ mA} - 7\text{ mA}}{45\ \mu\text{A} - 35\ \mu\text{A}}$$

$$= \frac{2\text{ mA}}{10\ \mu\text{A}} = \mathbf{200}$$

Relation between α and β

$$\alpha = \frac{I_C}{I_E}$$

$$\beta = \frac{I_C}{I_B}$$

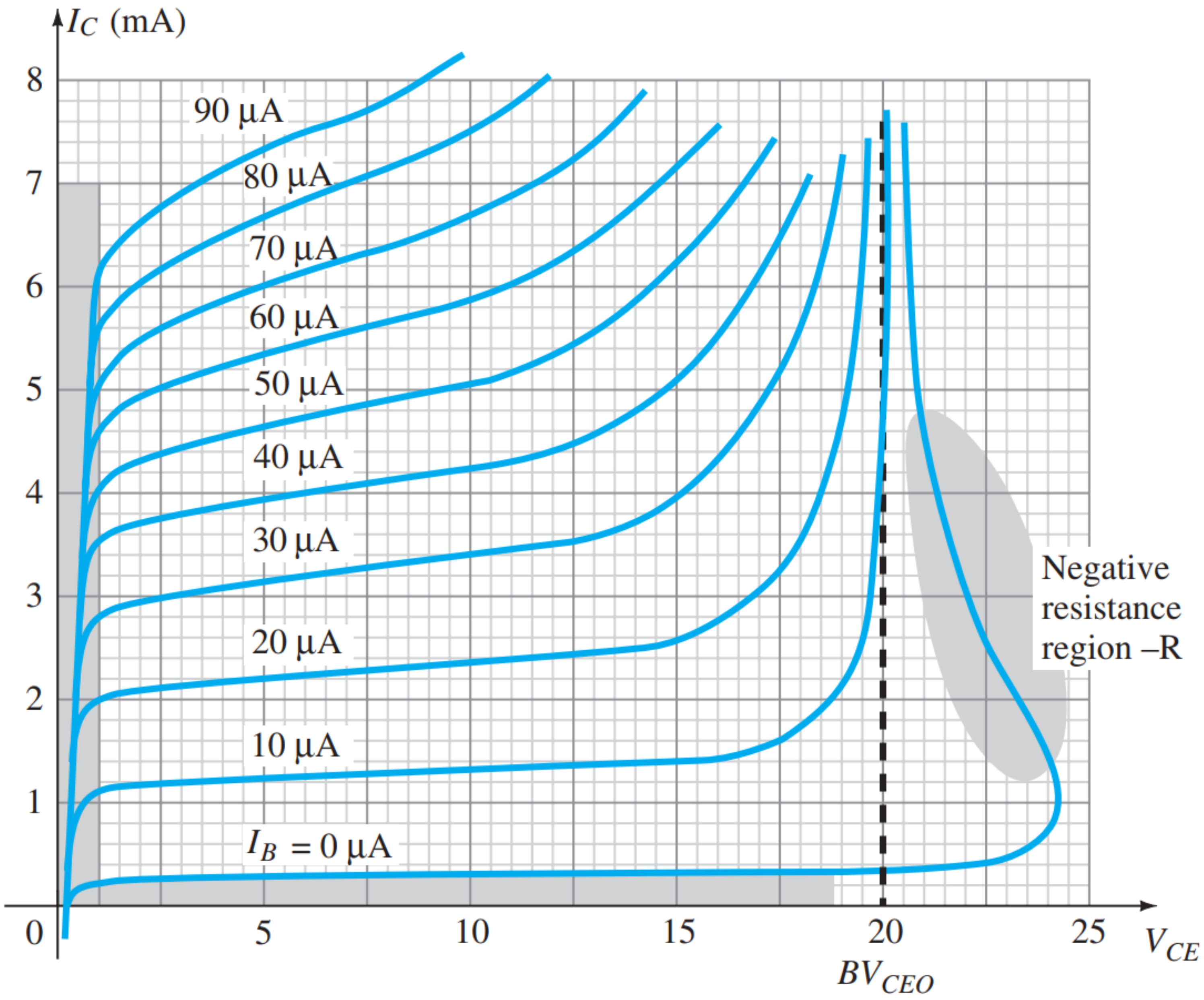
$$I_E = I_C + I_B$$

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

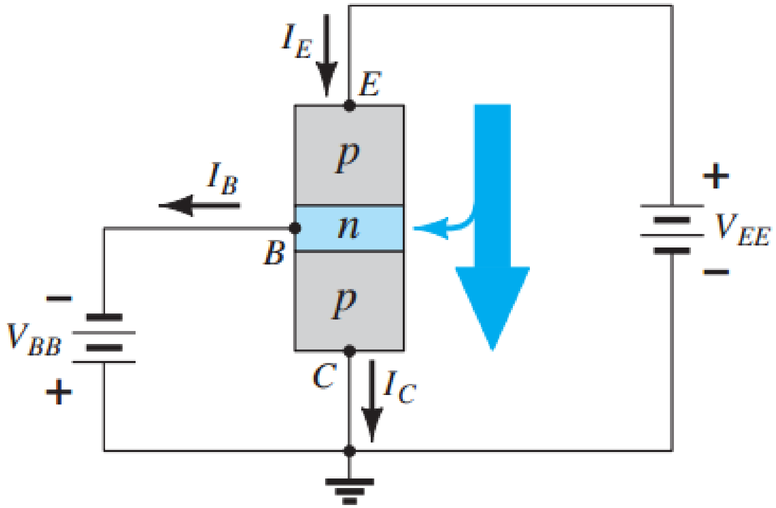
$$\beta = \frac{\alpha}{1 - \alpha}$$

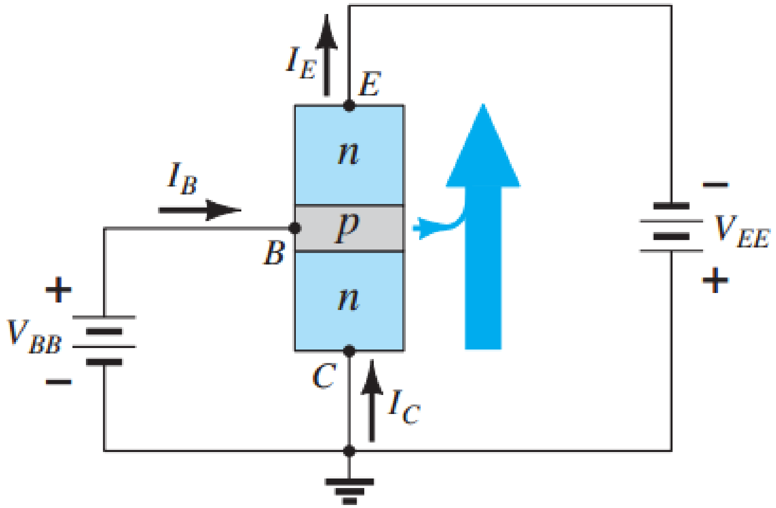
$$I_E = (\beta + 1)I_B$$

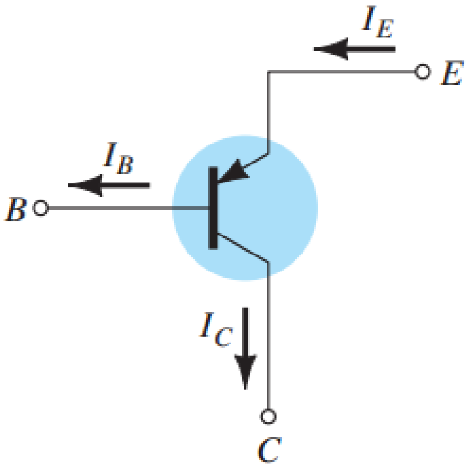
Breakdown region in the common-emitter configuration

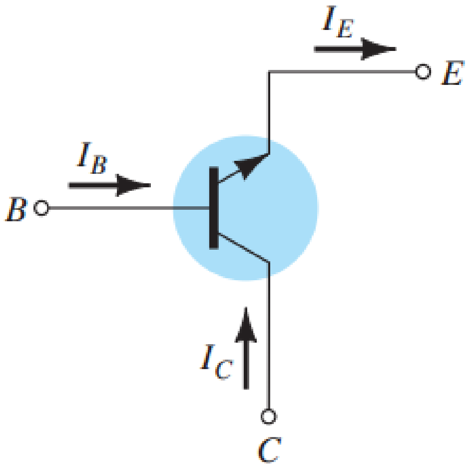


Common-collector configuration

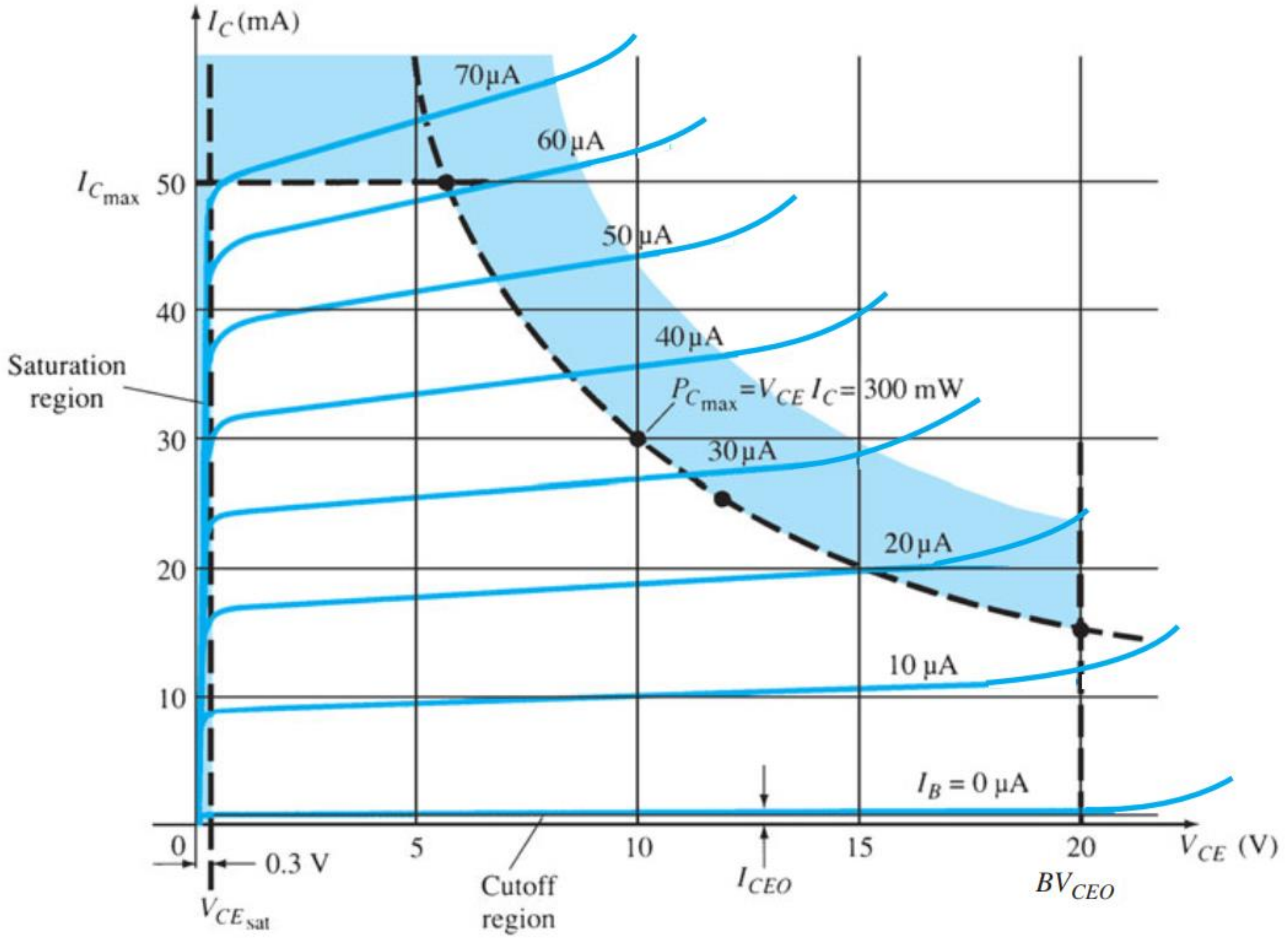




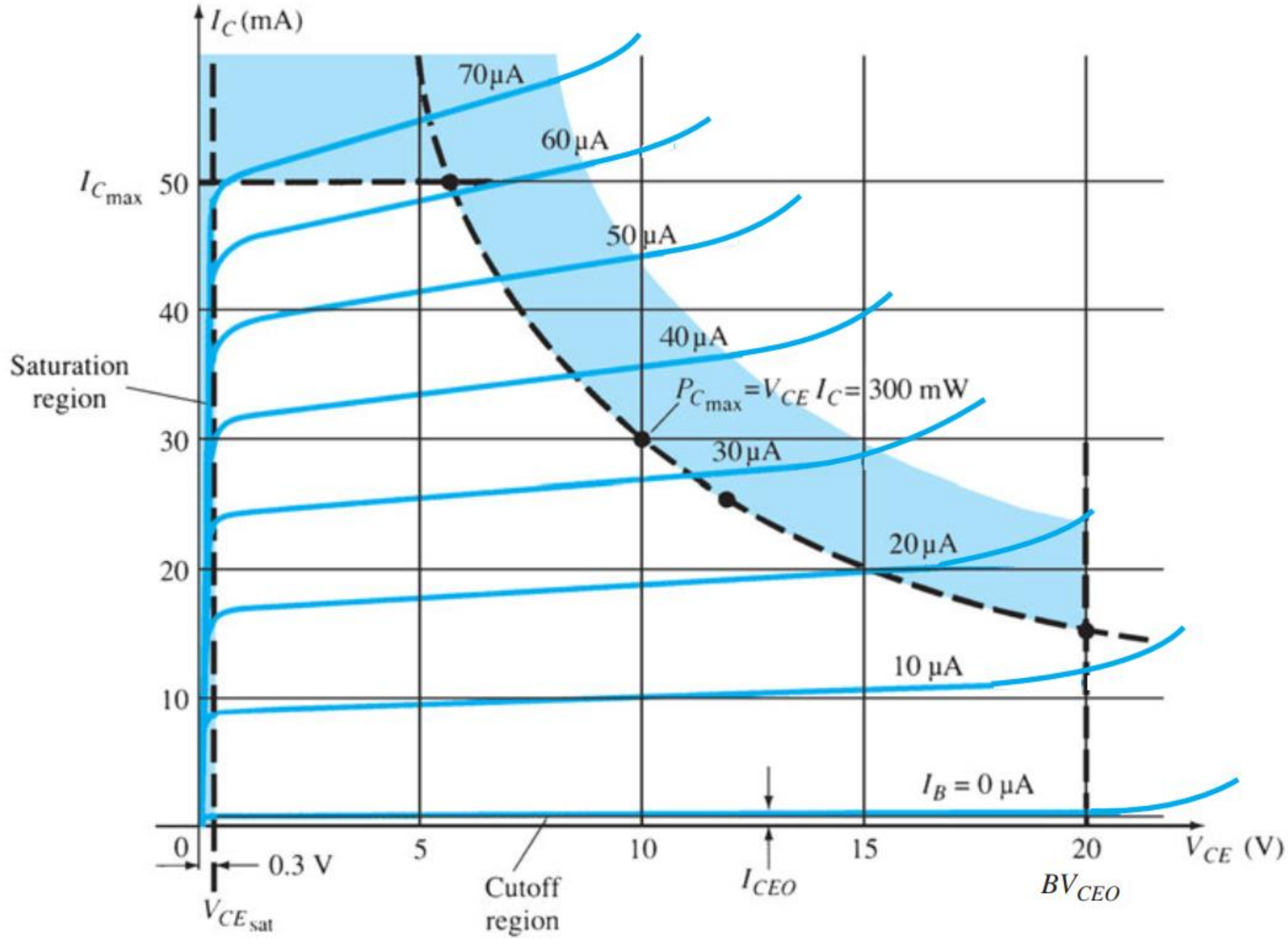




Linear (undistorted) region of operation for a transistor



Linear (undistorted) region of operation for a transistor



Transistor specification sheet

MAXIMUM RATINGS

Rating	Symbol	2N4123	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CBO}	40	Vdc
Emitter-Base Voltage	V_{EBO}	5.0	Vdc
Collector Current – Continuous	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	625 5.0	mW mW°C
Operating and Storage Junction Temperature Range	T_j, T_{stg}	–55 to +150	°C

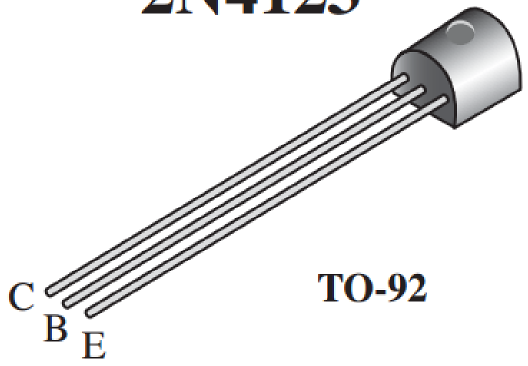
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C W
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C W

FAIRCHILD

SEMICONDUCTOR ™

2N4123



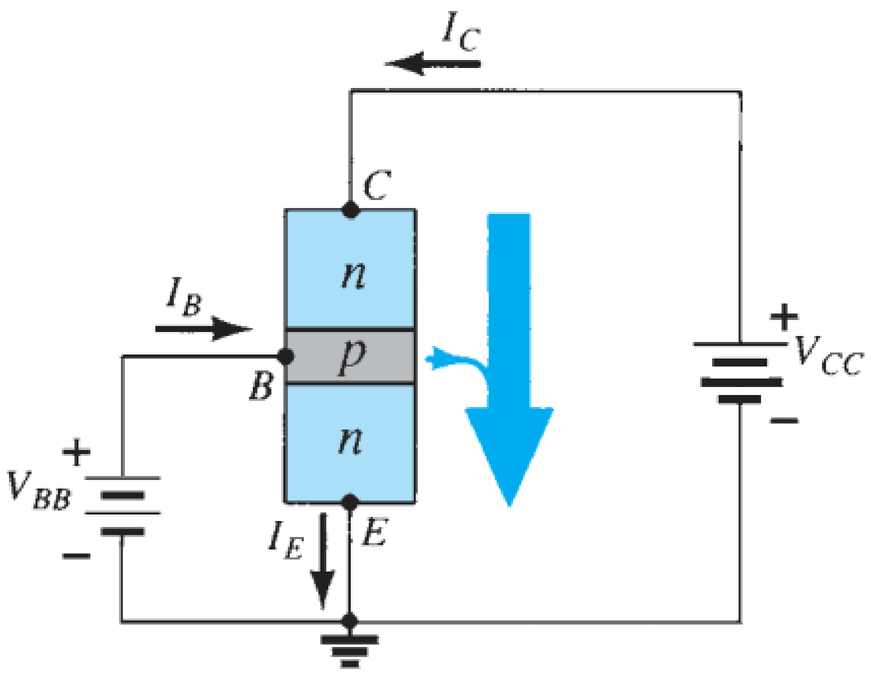
TO-92

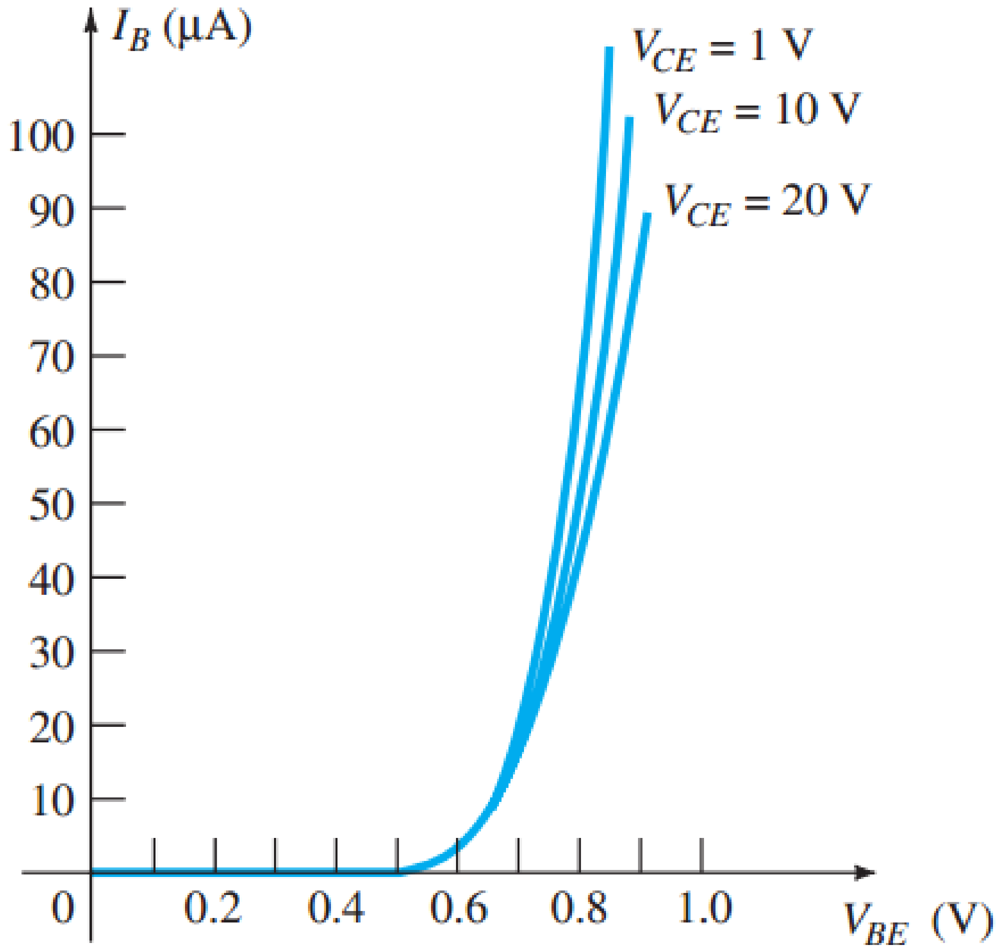
General Purpose Transistor NPN Silicon

Applications and uses of transistor

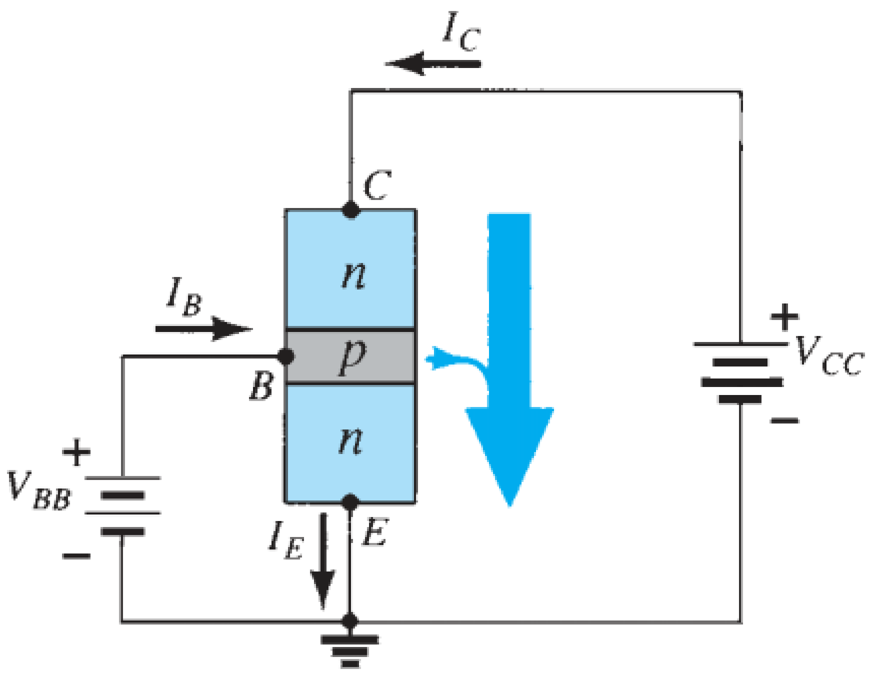
- The core use of transistors include switching applications or both as amplification and switching.
- There is a kind of transistors which produce current flow depending on the amount of light shined upon them, those are known as phototransistors.
- Bipolar Junction Transistors (BJT) can cause a greater current flow from the emitter to collector when a small amount of current is passed through the base.
- Field Effect Transistors acts as voltage-controlled devices. Field Effect Transistors (FETs) have very high input impedance and it helps to run very little current through them. This is helpful for not causing the power source to load down as they are not disturbing the original circuit power elements on which they are connected to. FETs are cheaper and easier to manufacture and cause less loading.

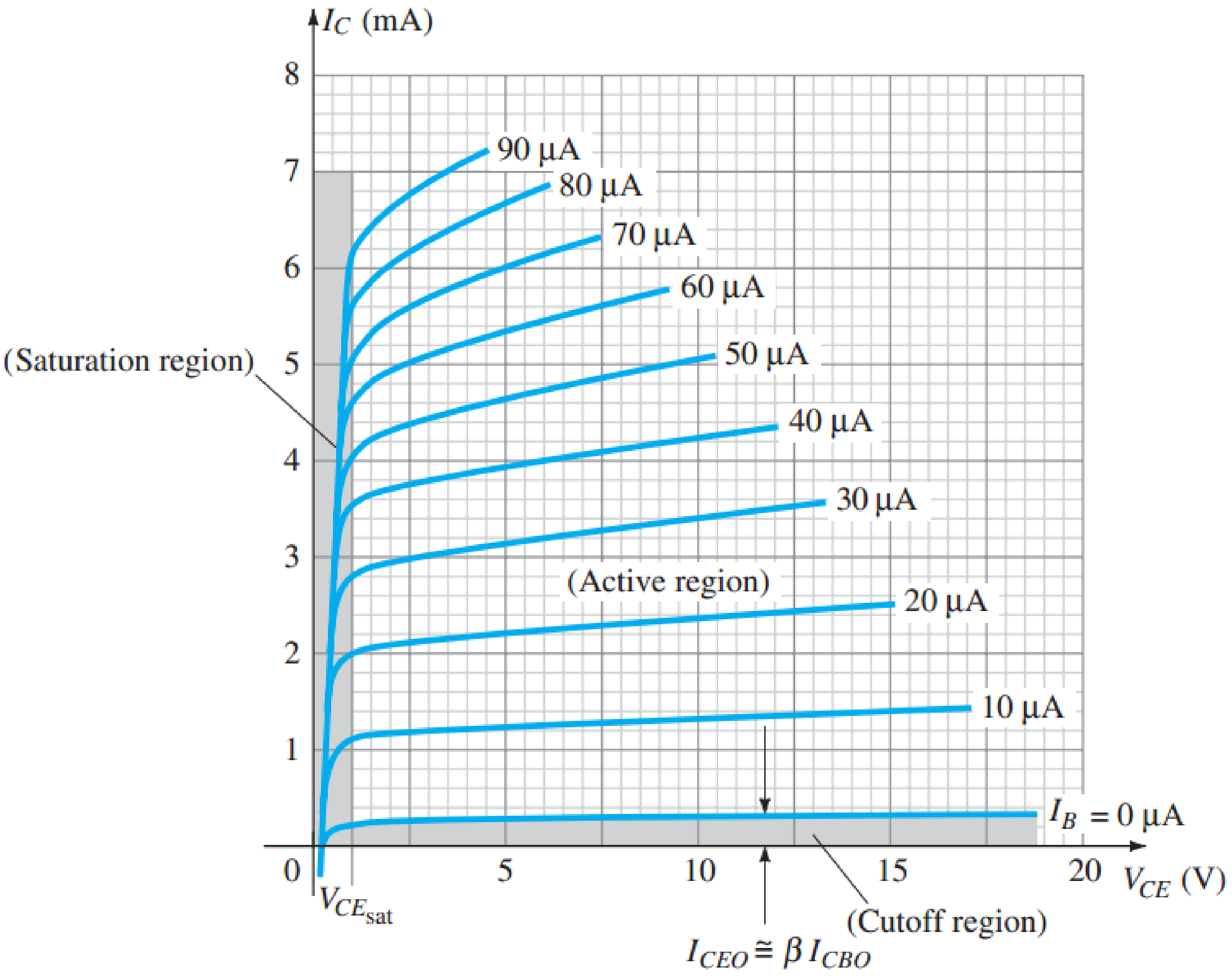
Transistor as a switch





Transistor as a switch





Readings

Electronic Devices and Circuit Theory
– Boylestad, Nashelsky

Chapter 3: Bipolar Junction Transistors