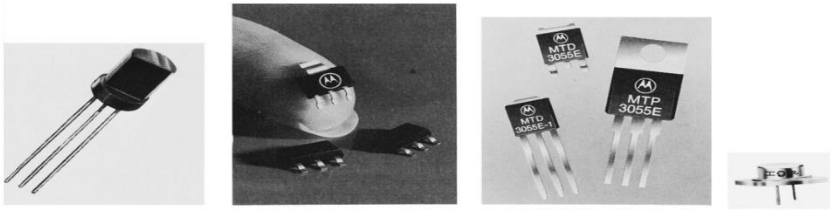
Transistor - Introduction to Bipolar Junction Transistor (BJT)

Introduction

- Beside diodes, the most popular semiconductor devices is transistors. Eg: Bipolar Junction Transistor (BJT)
- Transistors are more complex and can be used in many ways
- Most important feature: can amplify signals and as switch
- Amplification can make weak signal strong (make sounds louder and signal levels greater), in general, provide function called *Gain*



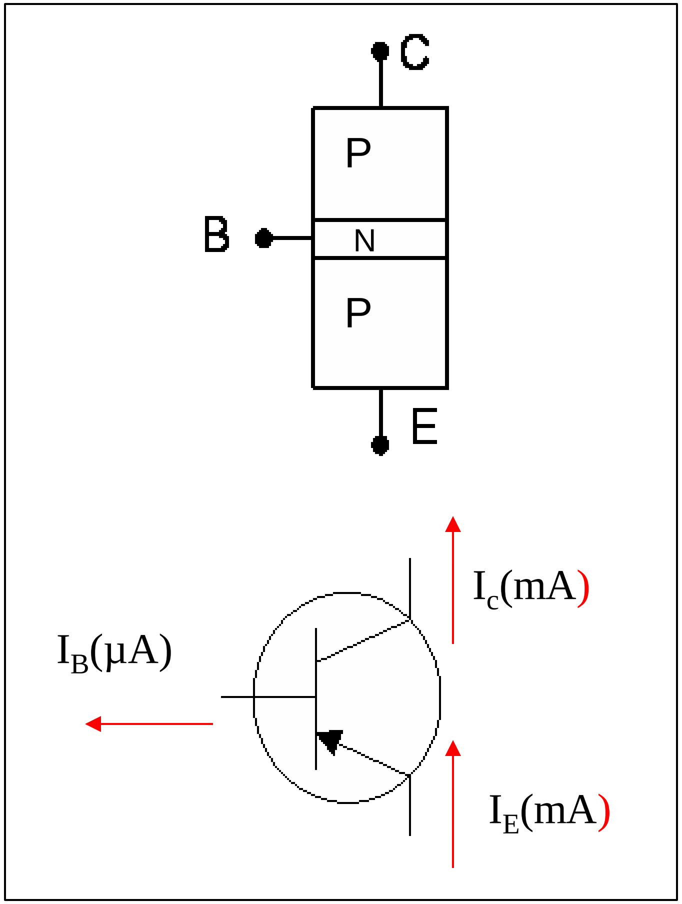
(a) (b) (c) (d)

Introduction

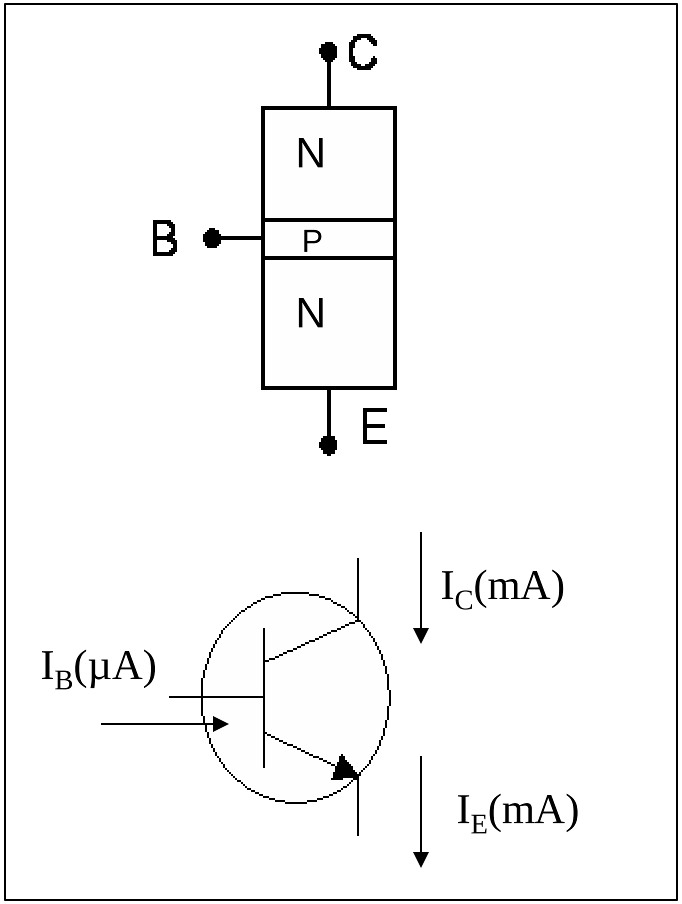
- BJT is bipolar because both holes (+) and electrons (-) will take part in the current flow through the device
  - N-type regions contains free electrons (negative carriers)
  - P-type regions contains free holes (positive carriers)
- 2 types of BJT
  - NPN transistor
  - PNP transistor
- The transistor regions are:
  - Emitter (E) – send the carriers into the base region and then on to the collector
  - Base (B) – acts as control region. It can allow none, some or many carriers to flow
  - Collector (C) – collects the carriers

Structure and Symbol of BJT

PNP



NPN



Arrow shows the current flows

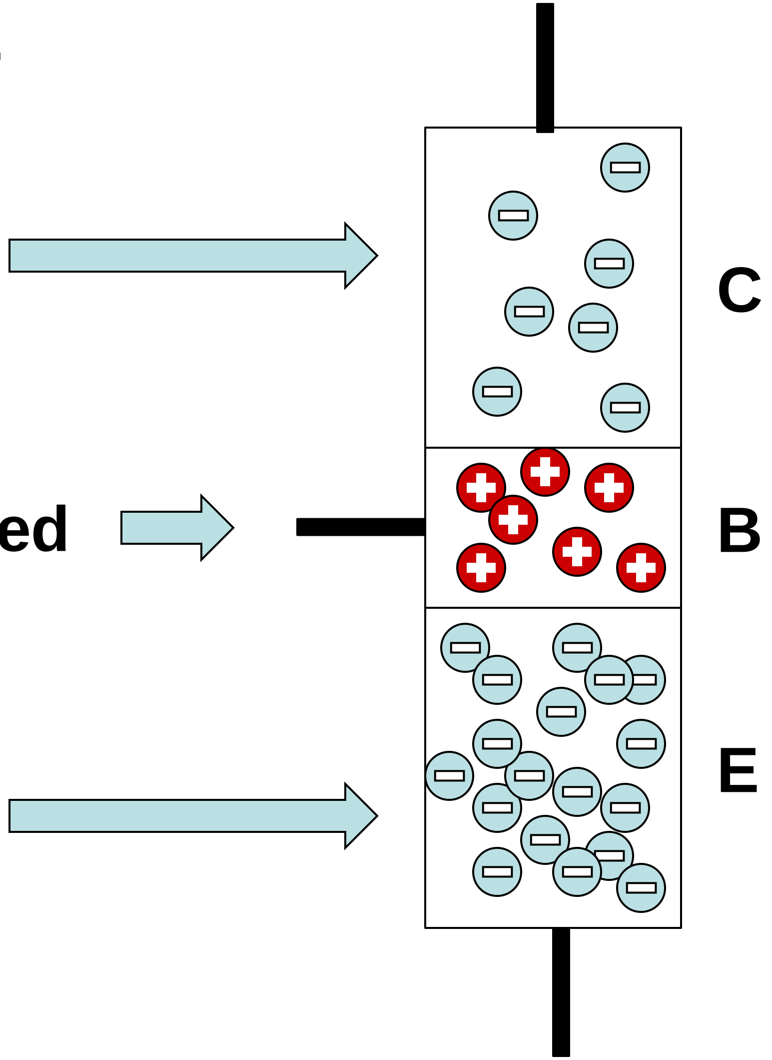
Structure of Transistor

NPN Transistor

Collector is lightly doped

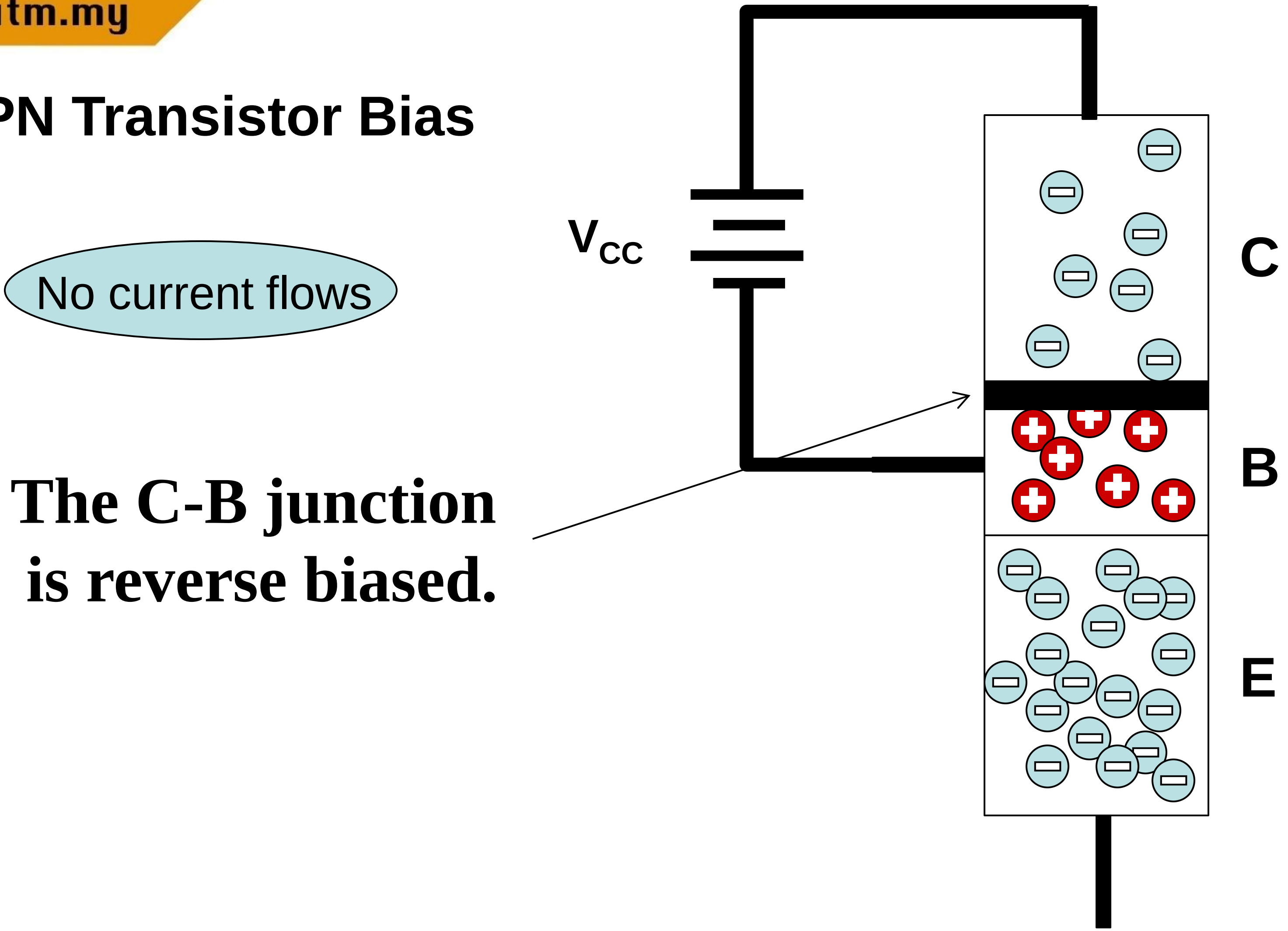
Base is thin and lightly doped

Emitter is heavily doped



Transistor Operation

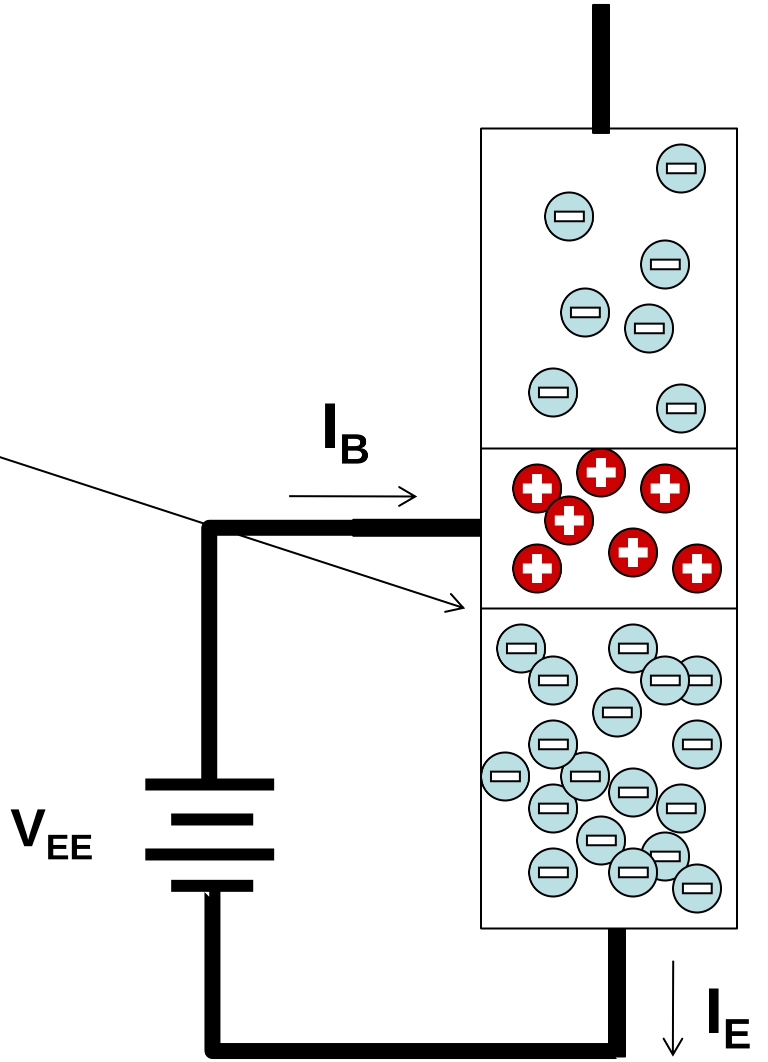
NPN Transistor Bias



Transistor Operation

NPN Transistor Bias

The B-E junction is forward biased.



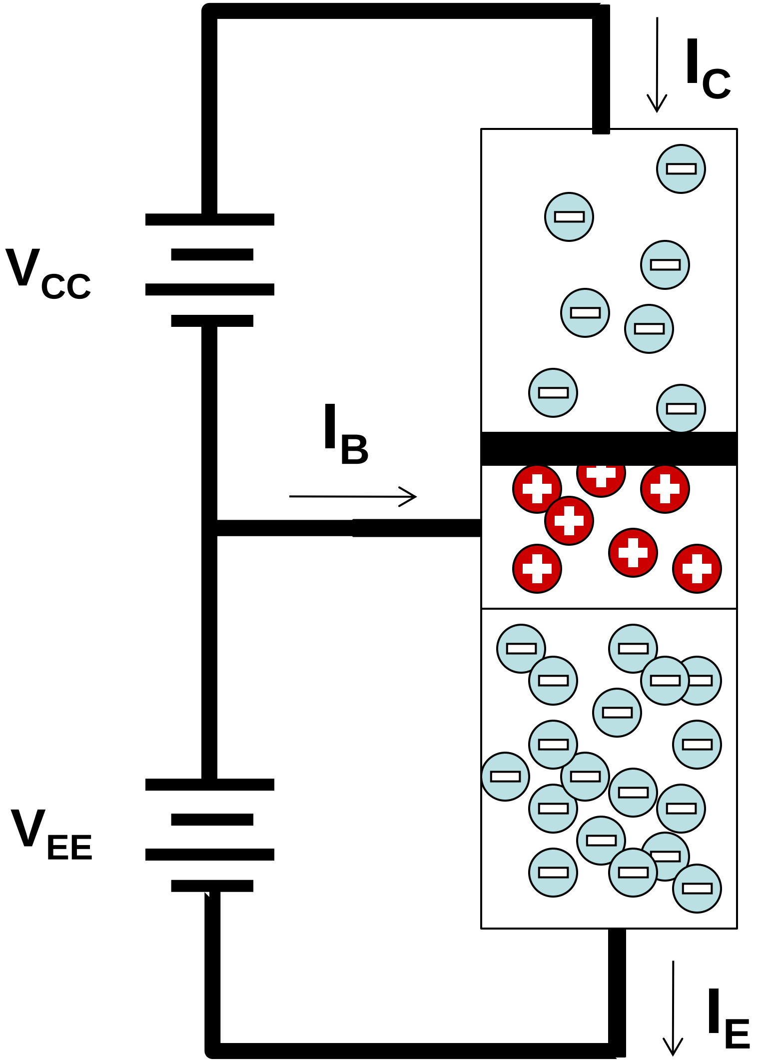
Current flows from B to E

Transistor Operation

NPN Transistor Bias

When both junctions are bias, current flows everywhere

Applying Kirchhoff's current law, we obtain $I_E = I_C + I_B$ and also $I_C = I_{Cmajority} + I_{COminority}$



Alpha (α)

- Also known as DC short current gain, h_{FB}
- Level of I_C and I_E due to majority carriers

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

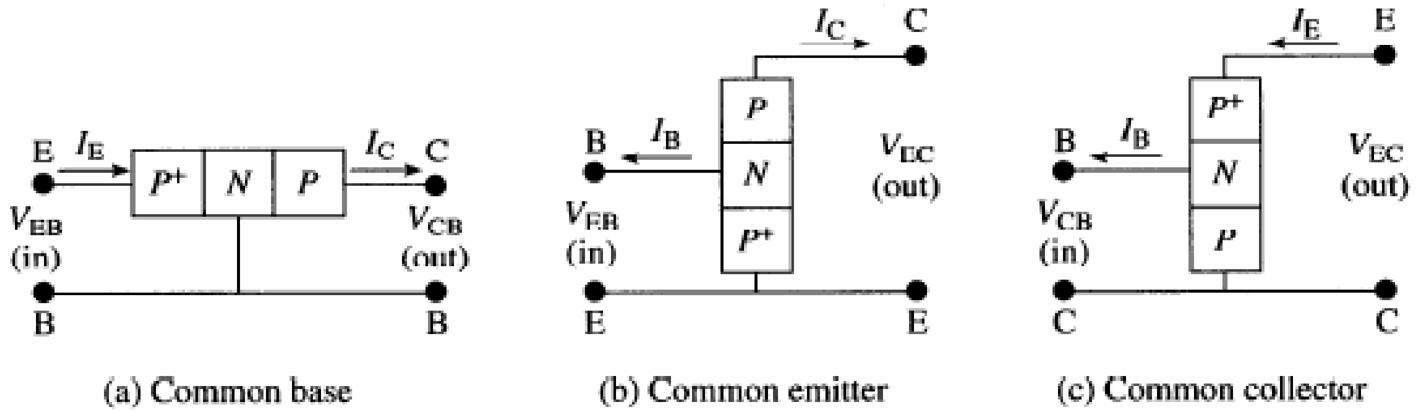
so that

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

*Note that $I_{CBO} = I_{CO}$

Transistor Configuration

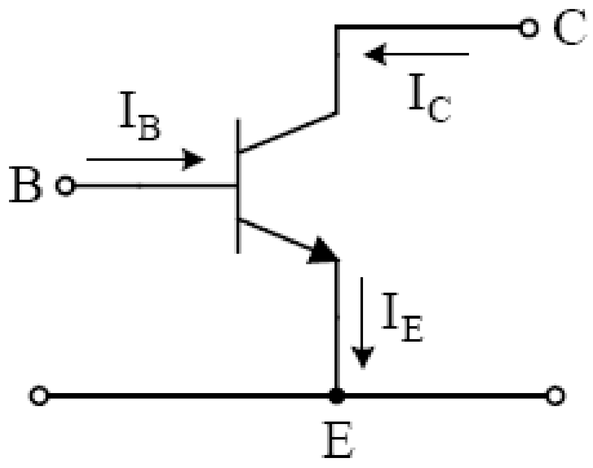
- Transistor configuration – is a connection of transistor to get variety operation.
- 3 types of configuration:
  - *Common Collector*.
  - *Common Base*.
  - *Common Emitter*



Transistor Configuration

Common Emitter Configuration

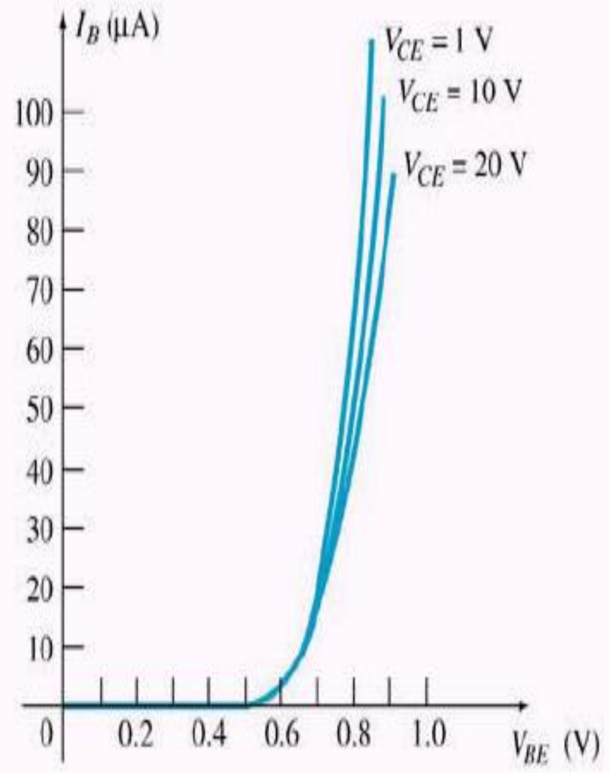
- Emitter terminal is common for input and output circuit
- Input – BE
- Output – CE
- Mostly applied in practical amplifier circuits, since it provides good voltage, current and power gain



I-V Characteristic

Input Characteristic

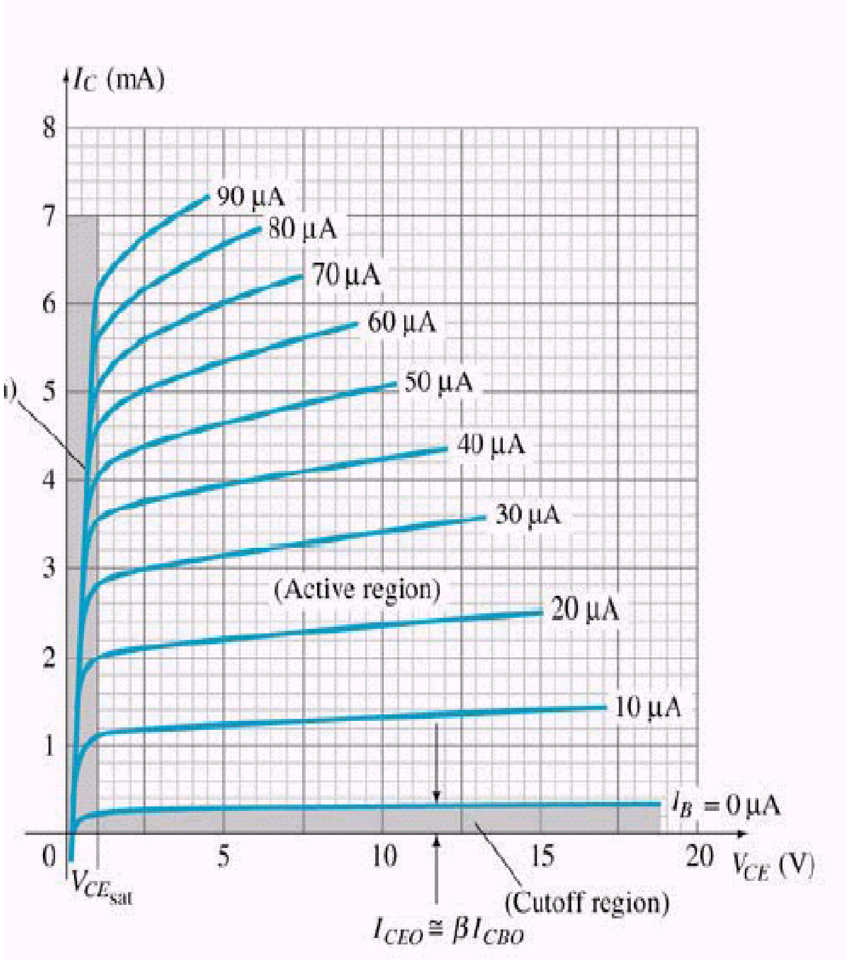
- Input characteristic: input current (I_B) against input voltage (V_{BE}) for several output voltage (V_{CE})
- From the graph
  - $I_B = 0$ A $V_{BE} < 0.7$V (Si)
  - $I_B =$ value $V_{BE} > 0.7$V (Si)
- The transistor turned on when $V_{BE} = 0.7$V



I-V Characteristic

Output Characteristic

- Output characteristic: output current (I_C) against output voltage (V_{CE}) for several input current (I_B)
- 3 operating regions:
  - Saturation region
  - Cut-off region
  - Active region



I-V Characteristic

- Saturation region – in which both junctions are forward-biased and I_C increase linearly with V_{CE}
- Cut-off region – where both junctions are reverse-biased, the I_B is very small, and essentially no I_C flows, I_C is essentially zero with increasing V_{CE}
- Active region – in which the transistor can act as a linear amplifier, where the BE junction is forward-biased and BC junction is reverse-biased. I_C increases drastically although only small changes of $I_{B.}$
- Saturation and cut-off regions – areas where the transistor can operate as a switch
- Active region – area where transistor operates as an amplifier

Beta (β)

- Also known as DC short current gain, h_{FE}
- Relation between I_C and I_B

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

Alpha (α) and Beta (β)

$$\alpha = \frac{I_C}{I_E} \quad , \; \beta = \frac{I_C}{I_B}$$

From $I_E = I_C + I_B$

We have $$\frac{I_C}{\alpha} = I_C + \frac{I_C}{\beta}$$

and dividing both side of equation by I_C results in

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

or

$$\beta = \alpha\beta + \alpha = (\beta + 1)\alpha$$

so that

$$\alpha = \frac{\beta}{\beta + 1} \qquad \text{or} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

Let’s have a break…