# Regions of Operation/Biasing

## Active Region (Amplification)

**Condition # 1: B-E junction is FB**

$$V_{be} = 0.7V, i_c = \beta i_b = I_s e^{\frac{V_{BE}}{V_T}}$$

**Condition # 2: B-C junction is RB**

$V_{bc} < 0$ OR $V_{ce} > 0.7V$
$V_{ce} = V_{cb} + V_{be} > 0.7V$
$\rightarrow V_{cb} + 0.7 > 0.7V$
$\rightarrow V_{cb} > 0V$
$\rightarrow V_{bc} < 0V$

Therefore, if $V_{ce}$ is FB, $V_{bc}$ will be RB

**Summary**
$V_{be} = 0.7V, i_c = \beta i_b$
$V_{bc} < 0$ OR $V_{ce} > 0.7V$

## Saturation Region – (Switch ON)

**Condition # 1: B-E junction is FB**

$$V_{be} = 0.7V, i_c = I_s e^{\frac{V_{BE}}{V_T}} \left( 1 - \frac{e^{-\frac{V_{CE}}{V_T}}}{\alpha_{sat}} \right)$$

**Condition # 2: B-C junction is FB**

$V_{bc} > 0$ OR $V_{ce} < 0.7V$
$V_{ce} = V_{cb} + V_{be} < 0.7V$
$\rightarrow V_{cb} + 0.7 < 0.7V$
$\rightarrow V_{cb} < 0V$
$\rightarrow V_{bc} > 0V$

**Summary**
$V_{be} = 0.7V$
$V_{ce} < 0.7V$
$V_{ce} \cong V_{ce-sat} = 0.2V$
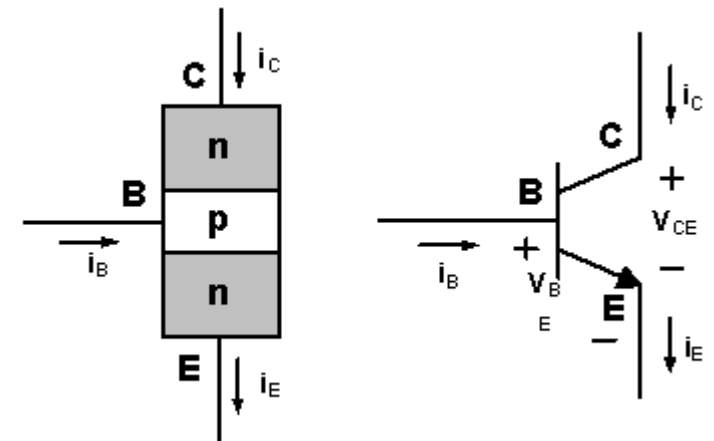$i_c < \beta i_b$

## Cut-off Region – (Switch OFF)

**Condition # 1: B-E junction is RB**
$V_{be} < 0$
$i_b = i_c = i_e = 0$

**Condition # 2: B-C junction is RB**
$V_{bc} < 0$

# DC Circuit Analysis

1.  Assume an operating mode i.e. active, saturation or cut-off. Remember amplification happens in active region.

    Typically it is recommended to begin by active region unless you can observe otherwise.

2.  Enforce the **equality conditions** relevant to region of operation.

3.  Analyse the circuit with enforced conditions to calculate unknown currents/voltages.

4.  Check the inequality conditions and compare results with assumptions. If they are consistent, you are done.

5.  Otherwise, repeat the process by assuming different region of operation.

**Active Region**

Equality Conditions
$V_{be} = 0.7V, i_c = \beta i_b$

Inequality Conditions
$V_{bc} < 0$ OR $V_{ce} > 0.7V$

**Saturation Region**

Equality Conditions
$V_{be} = 0.7V, V_{ce} \cong V_{ce-sat} = 0.2V$

Inequality Conditions
$V_{ce} < 0.7V$
$i_c < \beta i_b$

**Cutoff Region**

Equality Conditions
$i_b = i_c = i_e = 0$

Inequality Conditions
$V_{be} < 0, V_{bc} < 0$