Ministry of Higher Education
University of Al-Maarif
Medical Instruments Engineering Techniques Department

Power Electronic

For
Students of Third class

Lecture TWO
Power Transistor

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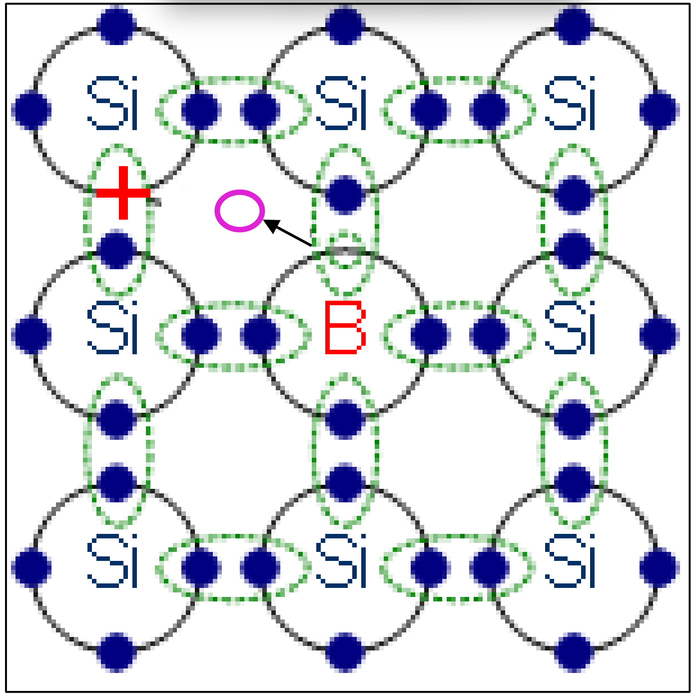
Department of Medical Instrumentation Engineering Techniques
2024-2025

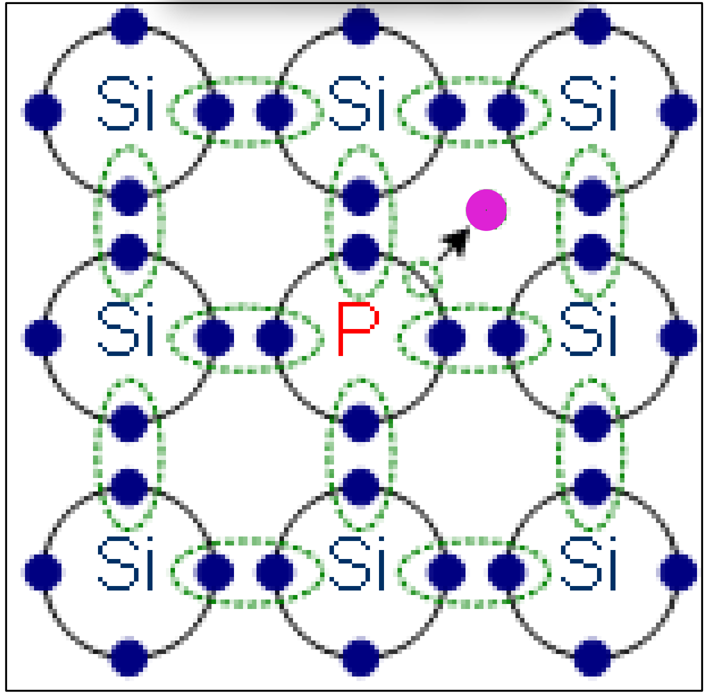
Diode Principle

p-doping



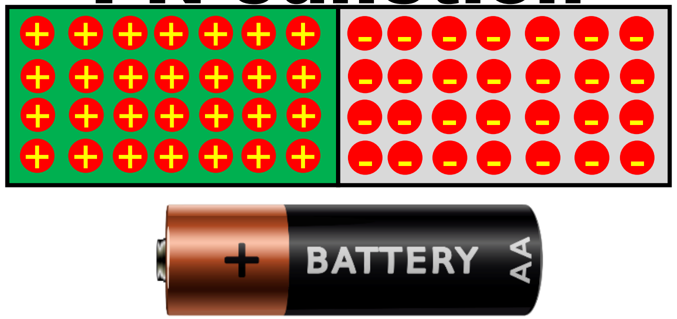
Free hole

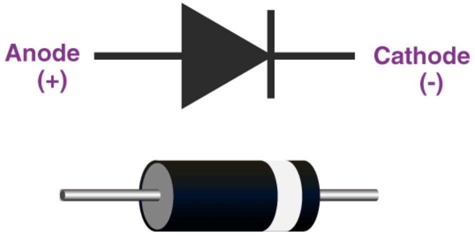
n-doping



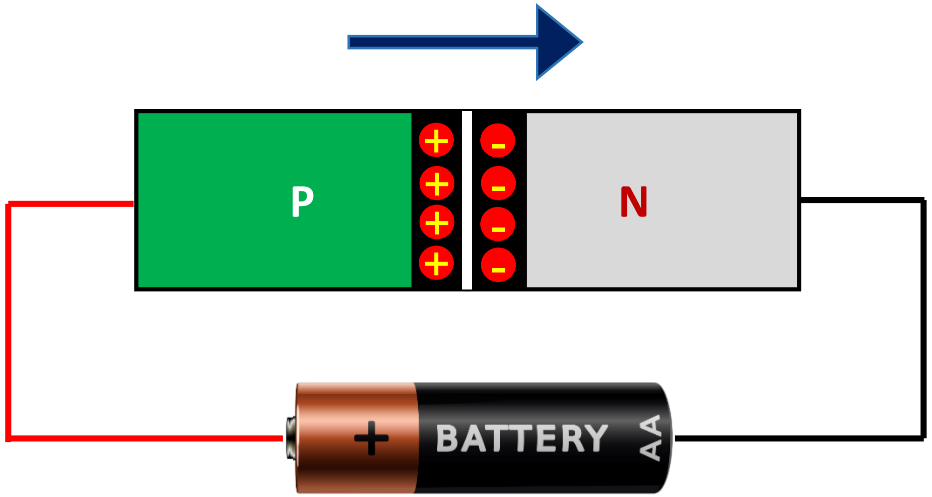
Free electron

PN-Junction

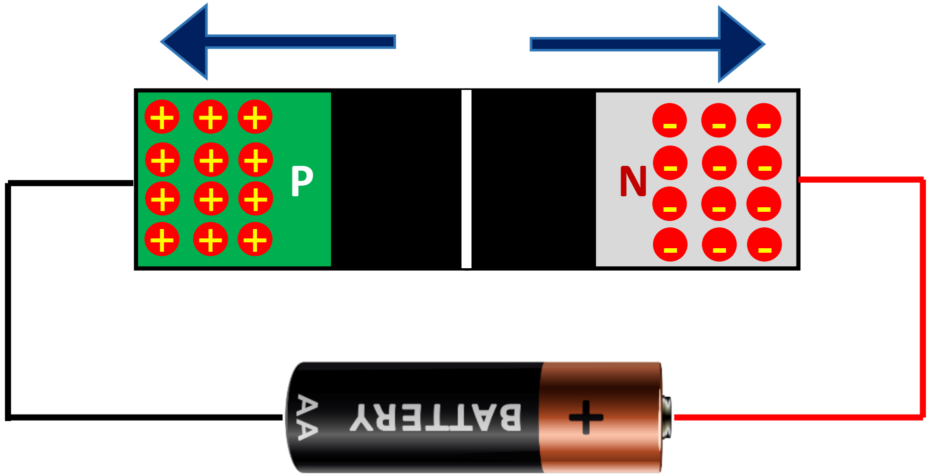




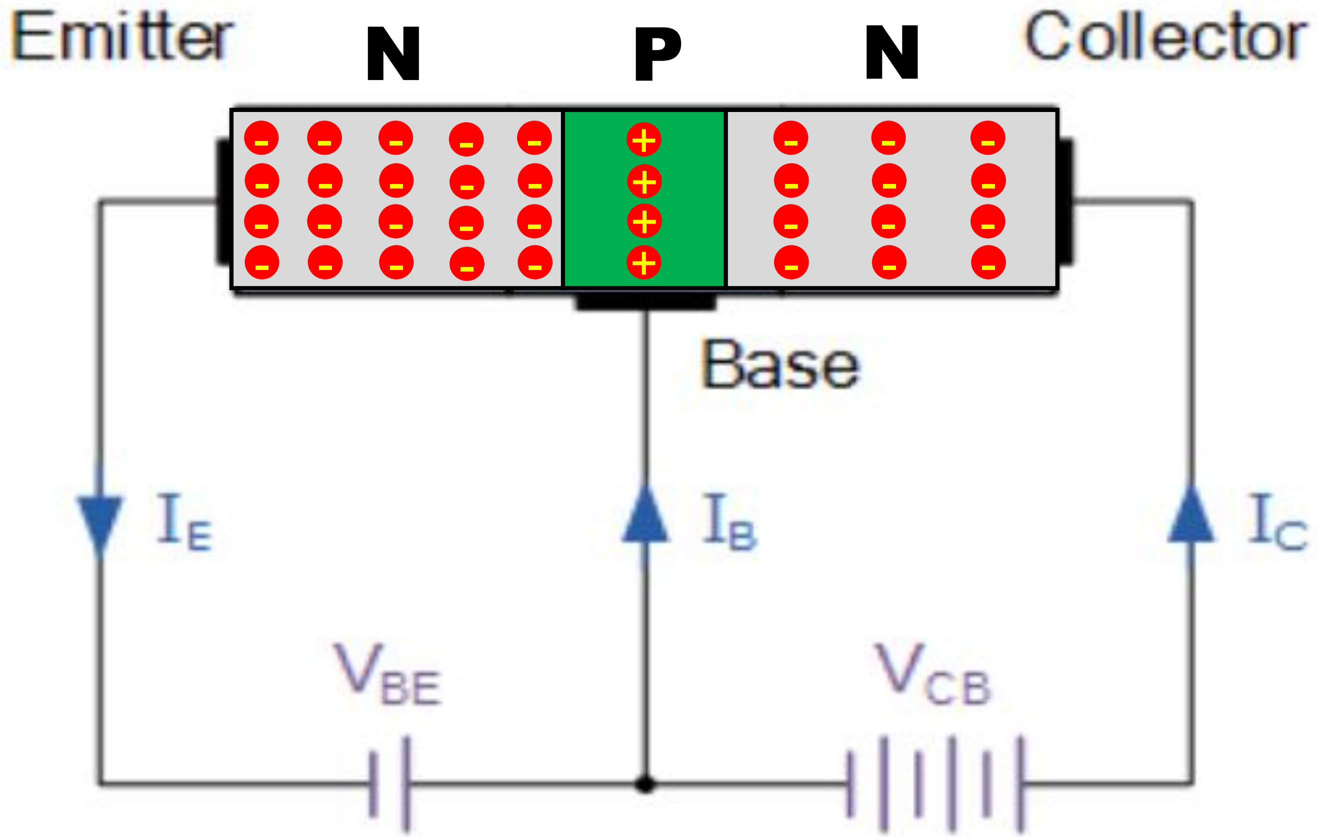
Forward Biasing

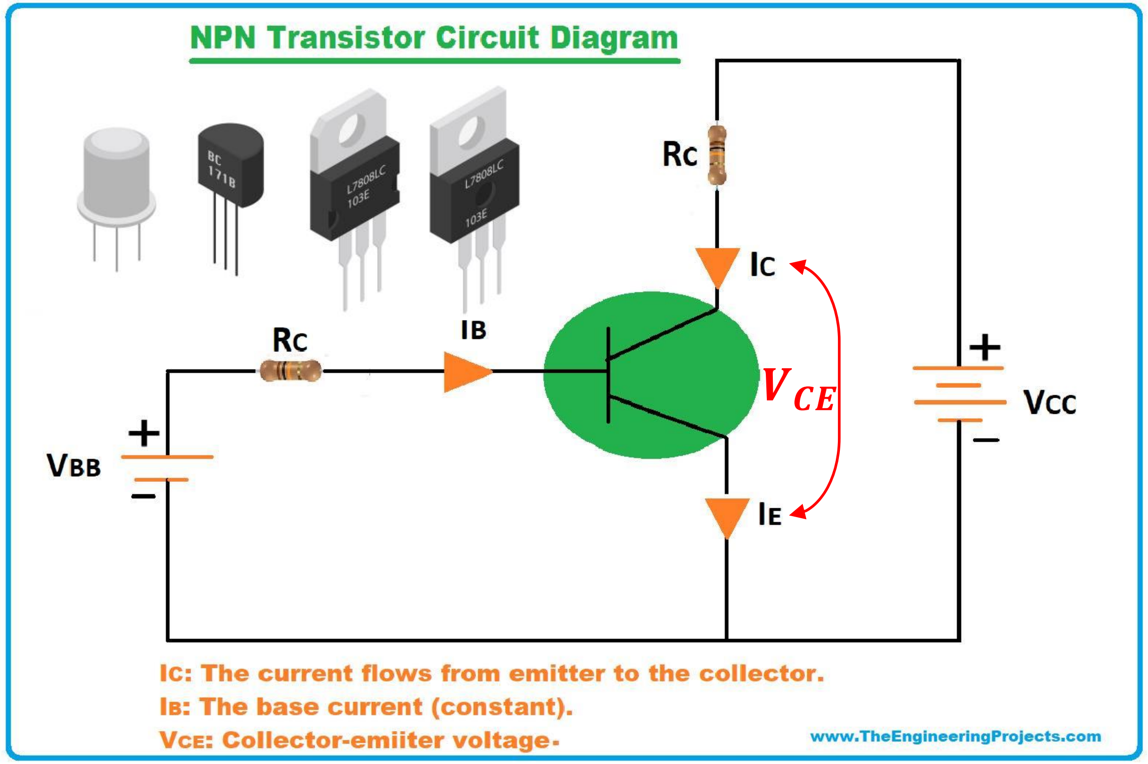


Reverse Biasing



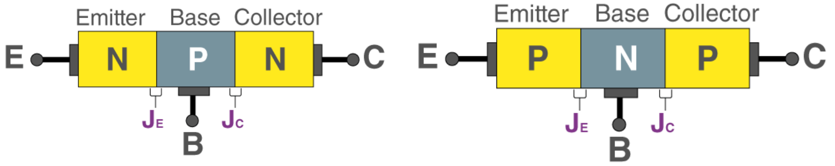
Power Bipolar Junction Transistor (BJT) Principle





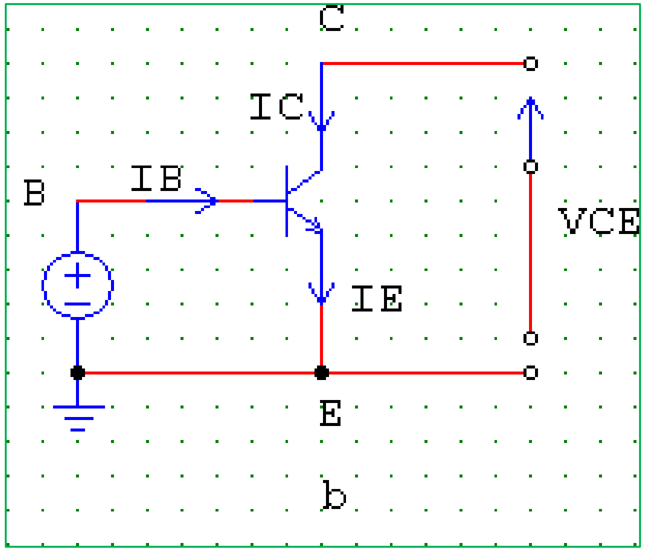
$$I_C + I_B = I_E$$

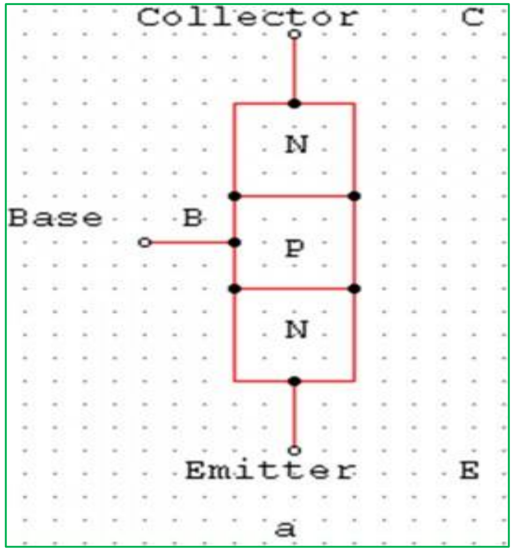
$$\beta = \frac{I_C}{I_B}$$

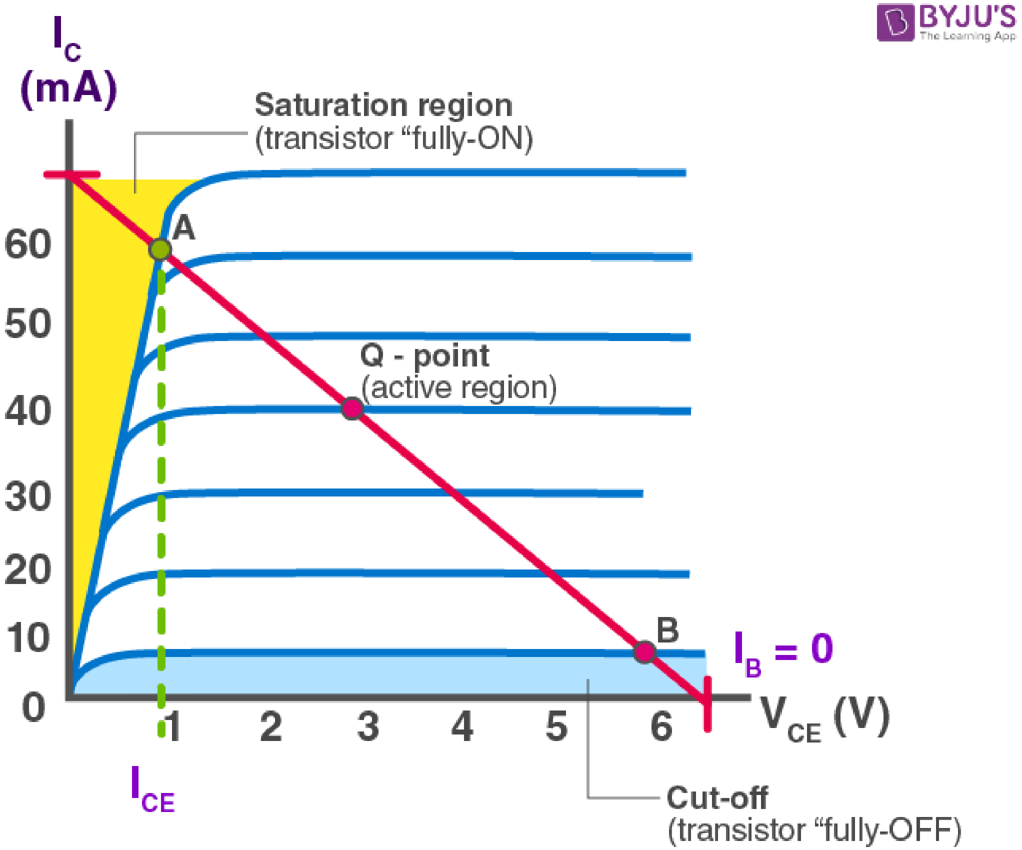


- The transistor consists of three layers: NPN or PNP.
- The collector current (I_C) is **dependent** on the base current (I_B).
- A change in base current I_B results in an **amplified** change in collector current I_C.
- The **ratio** of these currents ranges from 15 to 100 and called beta β.

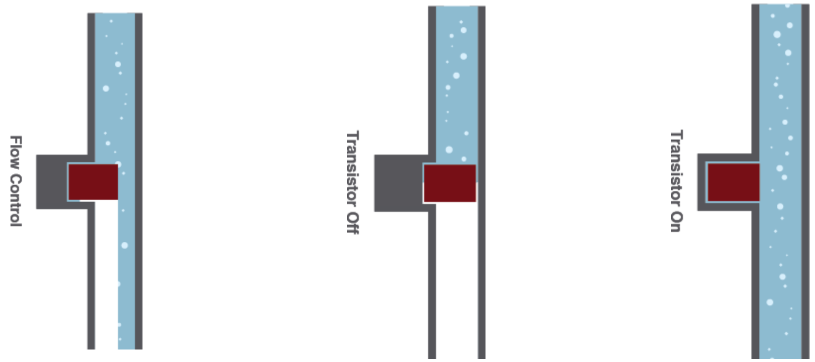
Characteristics of (BJTs)







- The transistor is used as **a switch** (Saturation + cut-off region) and as **amplifier** (active region) in **power applications**
- It has **controlled** turn-on and turn-off characteristics.
- Operates in the saturation region to **reduce on-state voltage drop**.
- **Switching speed** is **higher** than that of **thyristors.**
- **Voltage** and **current** ratings are **lower** than those of thyristors.

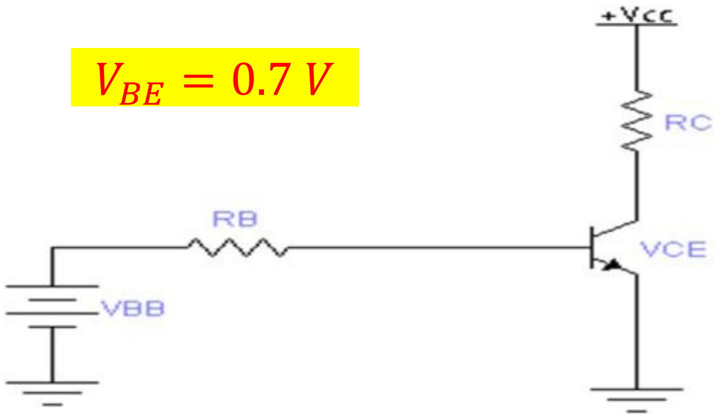


Input Circuit

$$V_{BB} = I_B R_B + V_{BE} \Rightarrow V_{BB} - V_{BE} = I_B R_B \quad \div I_B$$

$$\therefore R_B = \frac{V_{BB} - V_{BE}}{I_B} \quad (1)$$

$$V_{BE} = 0.7\ V$$



Output Circuit

$$V_{CC} = I_C R_C + V_{CE} \Rightarrow V_{CC} - V_{CE} = I_C R_C \quad \div I_C$$

$$\therefore R_C = \frac{V_{CC} - V_{CE}}{I_C} \quad (2)$$

The equation above can be used to draw the dc load line by choosing two points as follows:

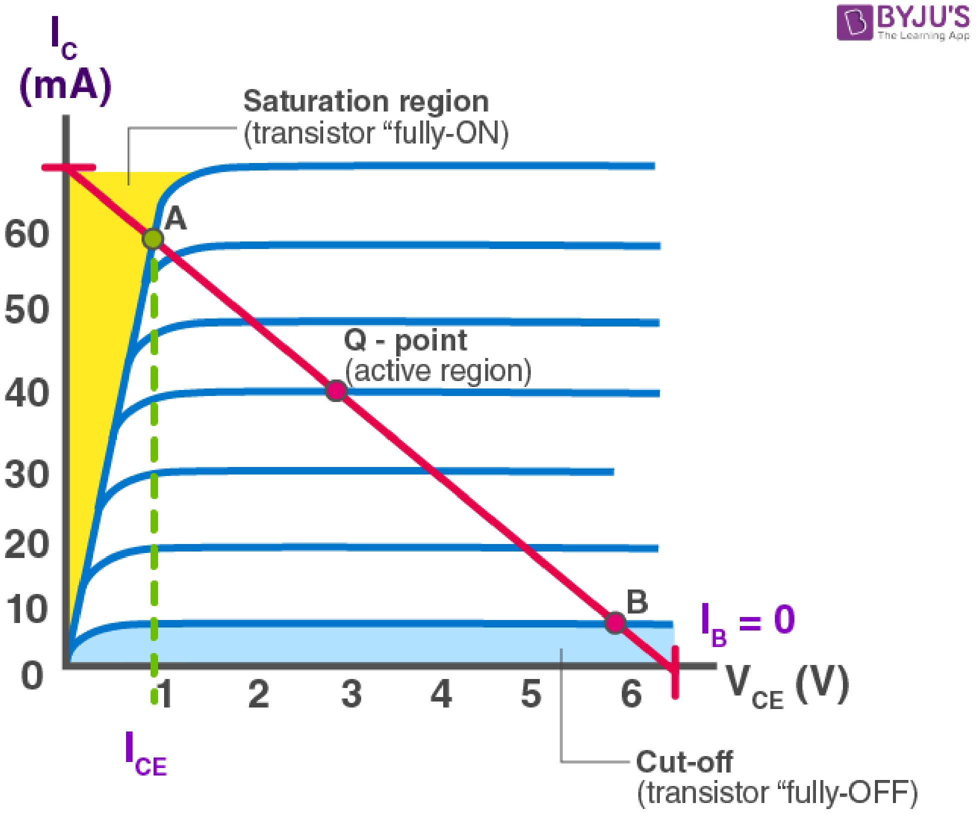
At cut off region:
I_C (cut off) = 0
V_{CE} (cut off) = V_{CC}

At saturation region:
$V_{CE}(sat) = 0$ $\quad I_{C(sat)} = \frac{V_{CC}}{R_C}$

$\beta = \frac{I_{C(sat)}}{I_{B(sat)}}$ where β represents the DC current gain

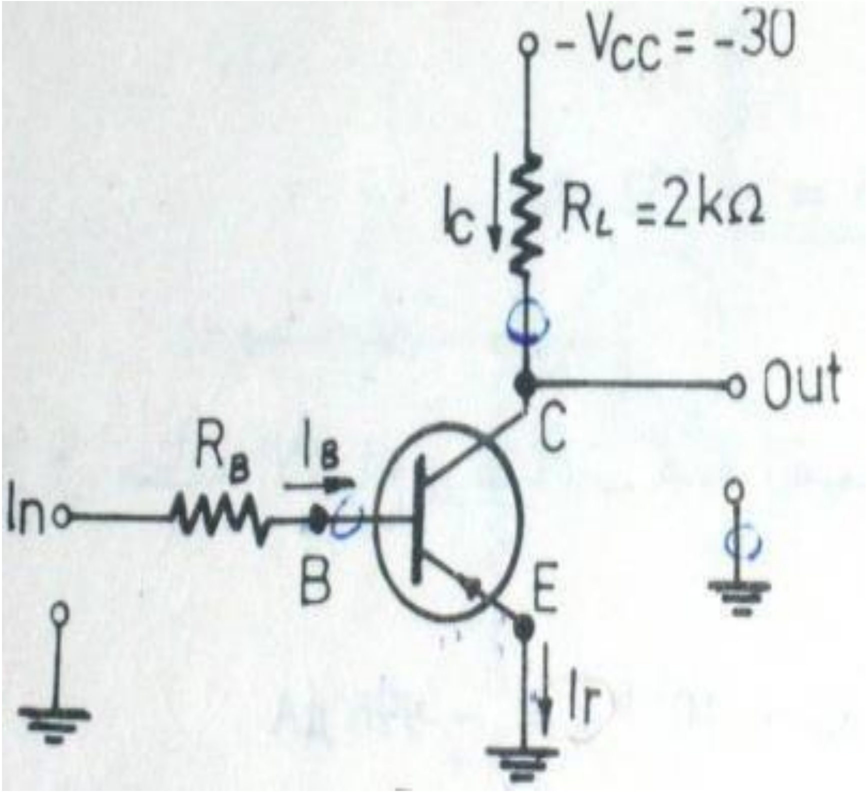
The perfect switch condition is: $I_{B(per)} > 3\times I_{B(sat)}$

$I_1 = 2\times I_{B(sat)}$ resistor current if connect parallel with base



EX:1/For transistor as a switch if the transistor has the following specification ($V_{CE\ (sat)}$ =1.5; $V_{BE\ (sat)}$ = 0.65; β = 45; V_{in} = 1.5 V) calculate the value of **R_B** which make the transistor works in saturation region.

Sol:



$$I_{C(sat)} = \frac{V_{CC} - V_{CE}}{R_C} = \frac{30-1.5}{2\ k} = 14mA$$

$$I_{B(sat)} = \frac{I_{C(sat)}}{\beta} = \frac{14\text{mA}}{45} = 0.3\ mA.$$

$$I_{B(per)} = 3\times I_{B(sat)}$$

$$I_{B(per)} = 3\times 0.3\text{mA} = 0.9\ \text{mA}$$

$$R_B = \frac{V_{BB} - V_{BE}}{I_B} = \frac{1.5 - 0.65}{0.9mA}$$

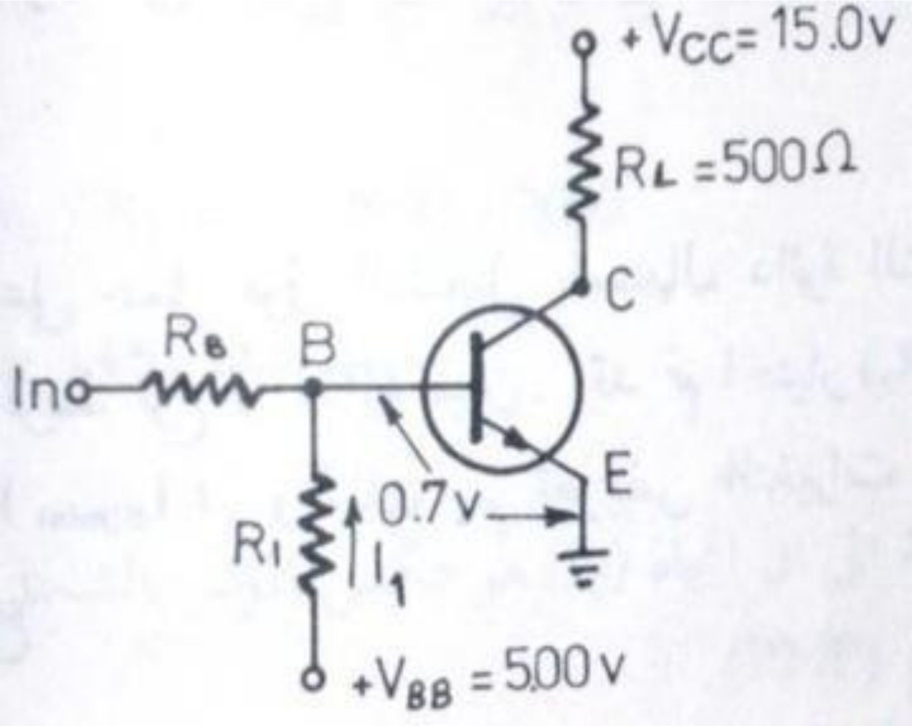
$$= 944\ \Omega \quad \cong 1\ \text{k}\Omega$$

EX: 2 For the circuit shown below (V_{BE}= 0.65 V, β= 50, and V_{in}=1V) Calculate the value of (R_1, R_B) which make the transistor works in saturation region.

$$I_{C(sat)} = \frac{V_{CC} - V_{CE}}{R_C} = \frac{15}{500} = 30\ mA$$

$$I_{B(sat)} = \frac{I_{C(sat)}}{\beta} = \frac{30mA}{50} = 0.6\ mA.$$

$I_{B(per)} = 3\times I_{B(sat)}$ ➡ $I_{B(per)} = 3\times 0.6mA = 1.8\ mA$



To certify the operation of the transistor in saturation region we may use

$I_1 = 2\times I_{B\ (sat)}$ ➡ $I_1 = 2\times 0.6 = 1.2\ mA$

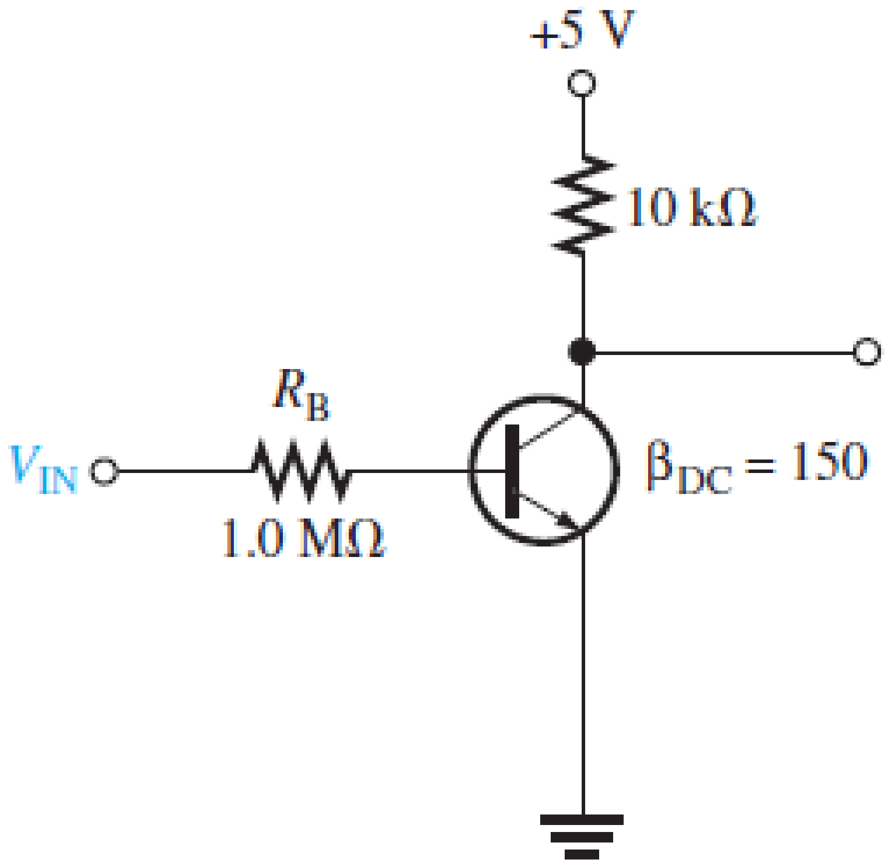
$$R_1 = \frac{V_{BB} - V_{BE}}{I_1} = \frac{5 - 0.65}{1.2\ mA} \Rightarrow \boxed{R_1 = 3.625\ k\Omega}$$

$$I_B = I_{B(per)} - I_1 = 1.8 - 1.2 = 0.6\ mA$$

$$R_B = \frac{V_{BB} - V_{BE}}{I_B} = \frac{1 - 0.65}{0.6\ mA} \Rightarrow \boxed{R_B = 0.583\ k\Omega}$$

H.W

Determine $I_{C(sat)}$ for the transistor in Figure 4–58. What is the value of I_B necessary to produce saturation? What minimum value of V_{IN} is necessary for saturation? Assume $V_{CE(sat)} = 0$ V.



Dynamic Switching Characteristics:

- **Time delay (t_d):**

Is the time taken for IC to reach 10 % of its final value $I_{C\ (sat)}$.

- **Rise time (t_r):**

Is the time taken for (Ic) to change from 10% to 90 % of Its final value $I_{C\ (sat)}$.

- **Conduction time (T_{ON}) = $t_d + t_r$**

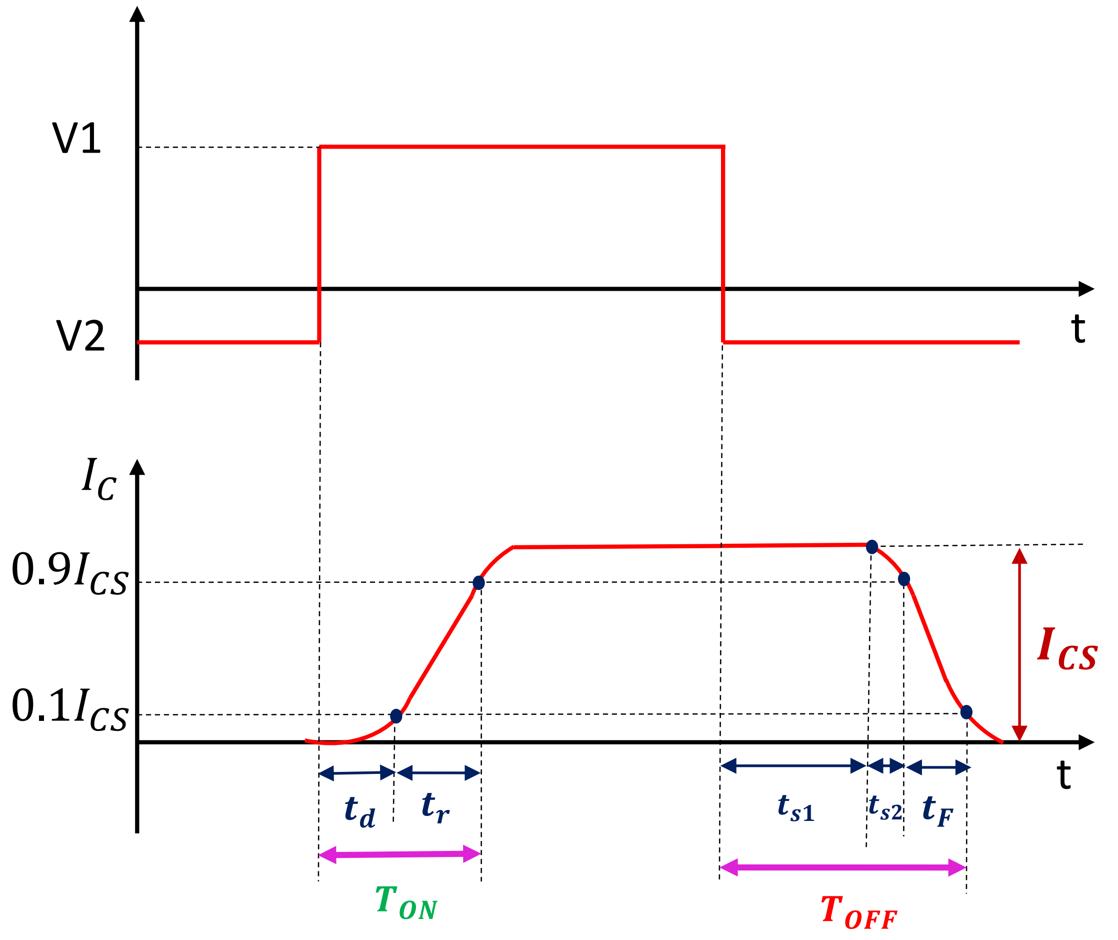
- **Storage time (ts):**

Is the time interval between the input and the point at which Ic reaches 90% of its final value IC (sat).

- **Fall time (t_F):**

Is the time taken for (Ic) to fall from 90% to 10% of its final value IC (sat) .

- **Cut off time (T_{OFF})= $t_s + t_F$**



It is important to Reduce Cut off time in switching Mode transistor . HOW?

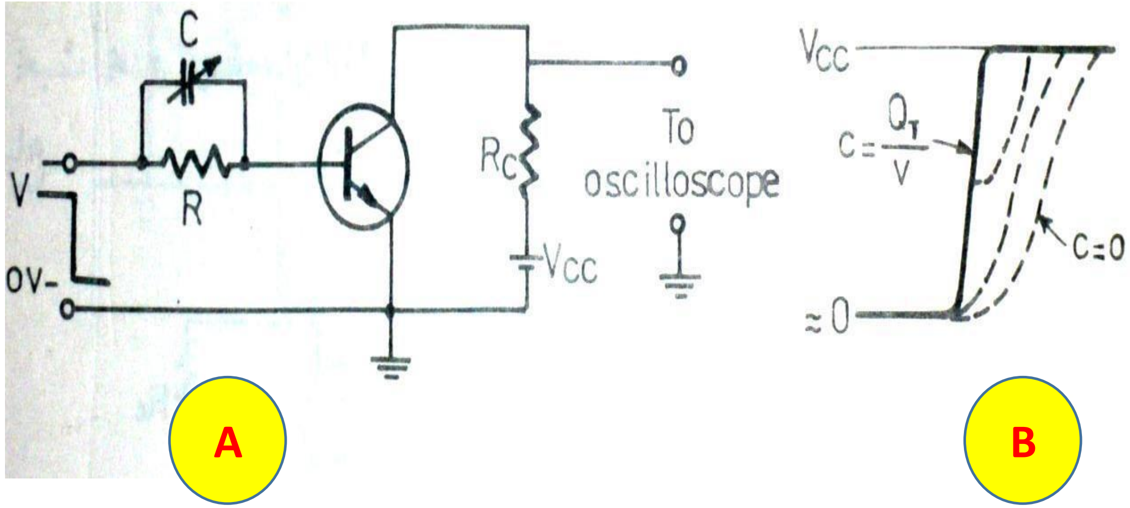
Improvement of Switching Time:

- Cut-off Time T_{OFF} can be improved by connecting a capacitor in parallel with the base resistor R_B.

- The capacitor helps to attract and remove the base charge more quickly.

- This reduces the storage time (t_S) , which in turn shortens the cut-off time.

- Faster removal of base charge leads to faster switching from ON to OFF states.



BJT applications in Medical Field

- **Pacemakers** and Implants for regulating and amplifying electrical impulses.
- Medical Imaging (**MRI, Ultrasound**) to process and amplify signals for accurate diagnostics.
- Wearable Devices like **glucose monitors** and **fitness trackers** to process health data.
- **ECG/EEG** systems to amplify heart and brain signals for monitoring.