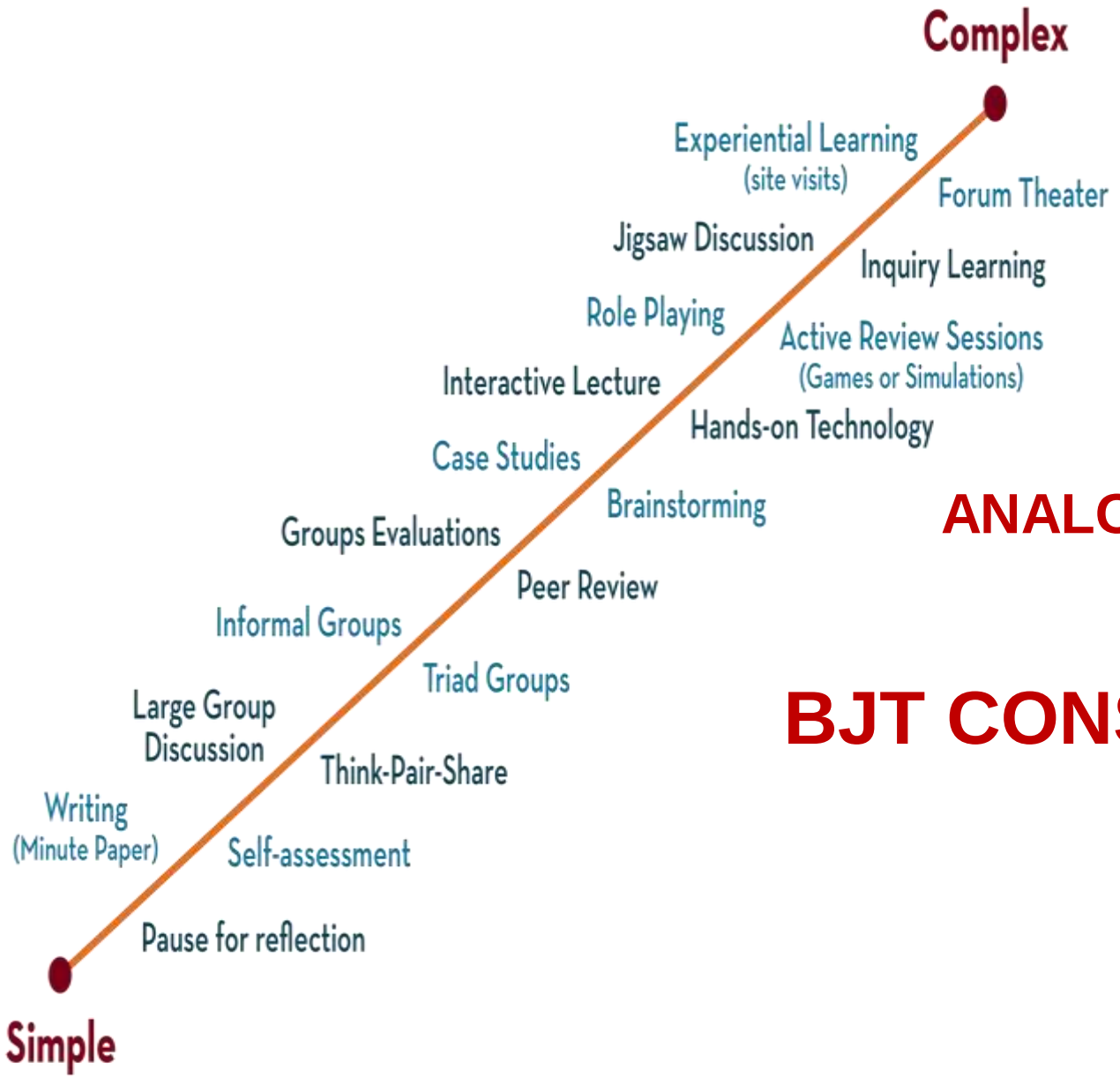


AY-2025-2026
ODD SEM

Department of ECE

ANALOG ELECTRONIC CIRCUIT DESIGN

23EC2104

Topic:

BJT CONSTRUCTION AND OPERATION

Session - 01

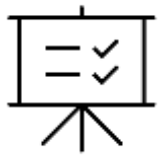
SESSION CONTENT

- Si vs Ge, npn vs pnp
- Unbiased BJT
- Biased BJT
- BJT Currents

AIM OF THE SESSION

To understand construction and operation of Bi-polar Junction Transistor

INSTRUCTIONAL OBJECTIVES



This Session is designed to:

1. Understand the physical structure and biasing of BJT
2. Understand current generation mechanism of BJT
3. Understand operating modes of BJT

LEARNING OUTCOMES

At the end of this session, you should be able to:

1. Demonstrate regions of n-p-n BJT
2. Formulate BJT current equation
3. Identify various modes of operation of BJT

WHY BJT?

- Completely Controlled Device
- Current Source
- Amplifier

Si vs Ge

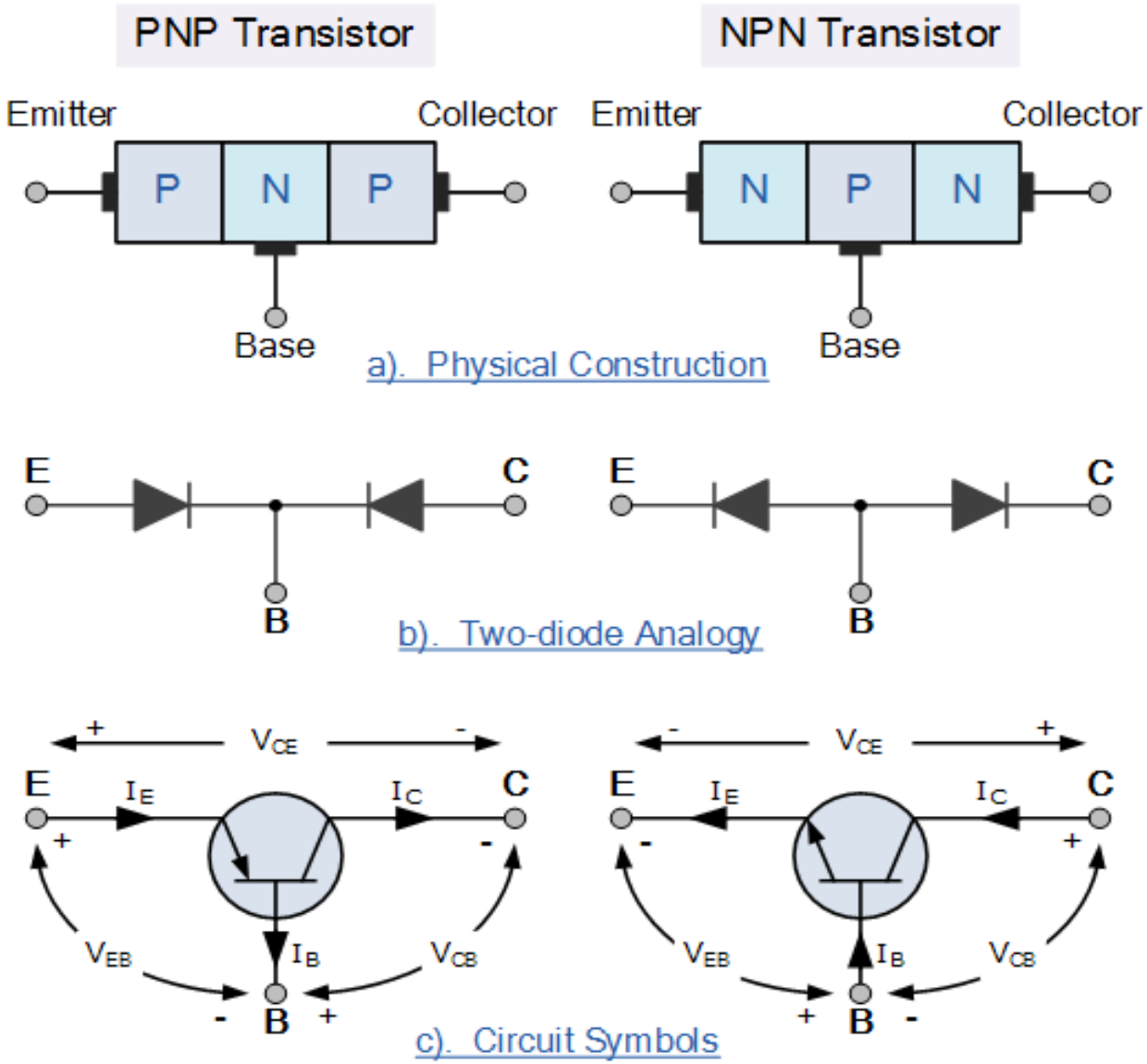
- Give your thoughts on energy band gaps and ease of availability for Silicon and Germanium

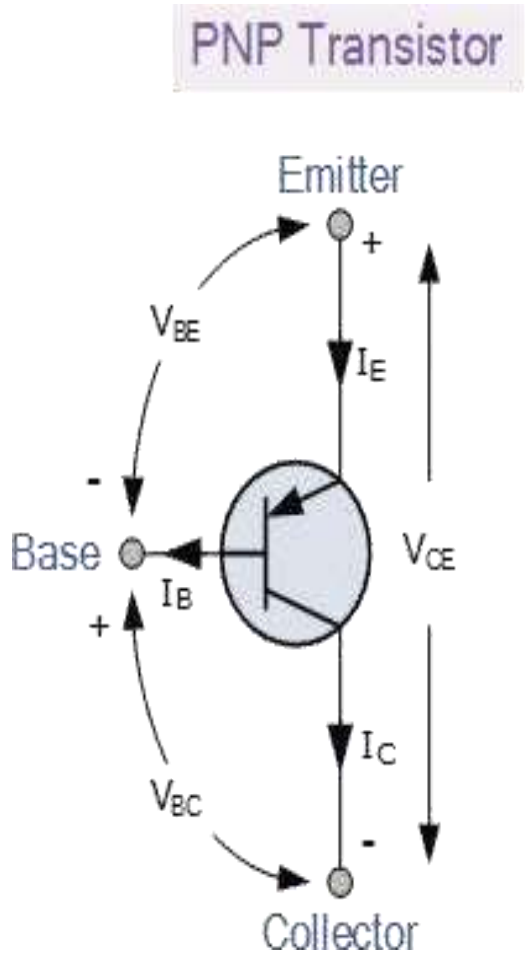
npn vs pnp

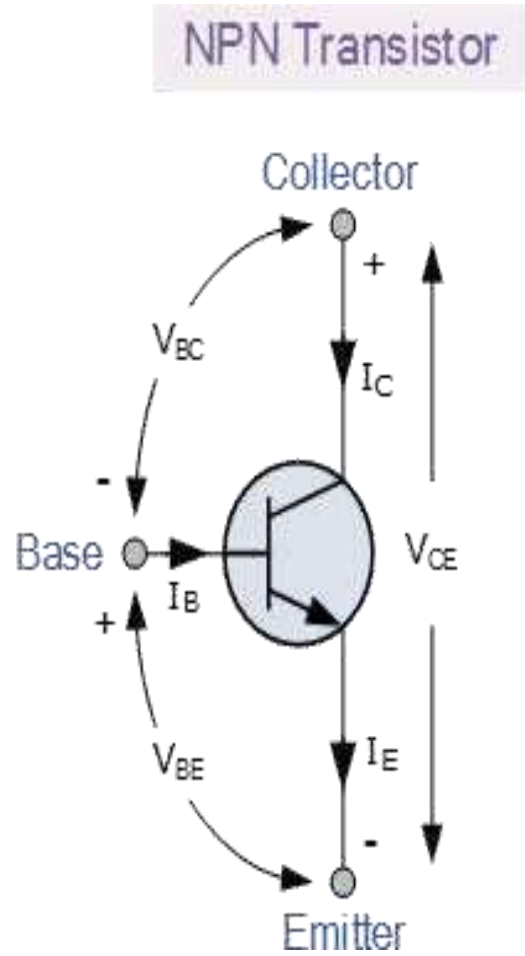
- Electrons are lighter
- Holes are heavier

Give your thoughts on which devices can be faster

BJT


PNP Transistor
NPN Transistor
Emitter
Collector
P
N
P
N
P
N
Base
a). Physical Construction
E
C
B
b). Two-diode Analogy
+
V_{CE}
-
I_E
I_C
V_{EB}
I_B
V_{CB}
c). Circuit Symbols


PNP Transistor
Emitter
V_{BE}
I_E
Base
I_B
V_{CE}
I_C
V_{BC}
Collector

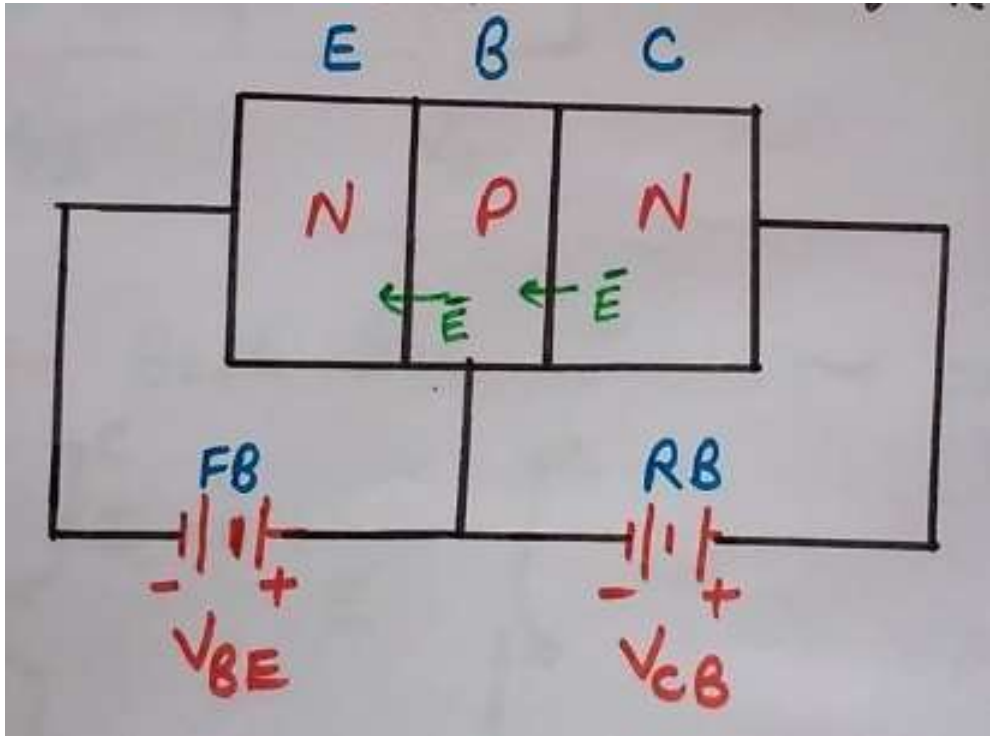

NPN Transistor
Collector
V_{BC}
I_C
Base
I_B
V_{CE}
V_{BE}
I_E
Emitter

BJT

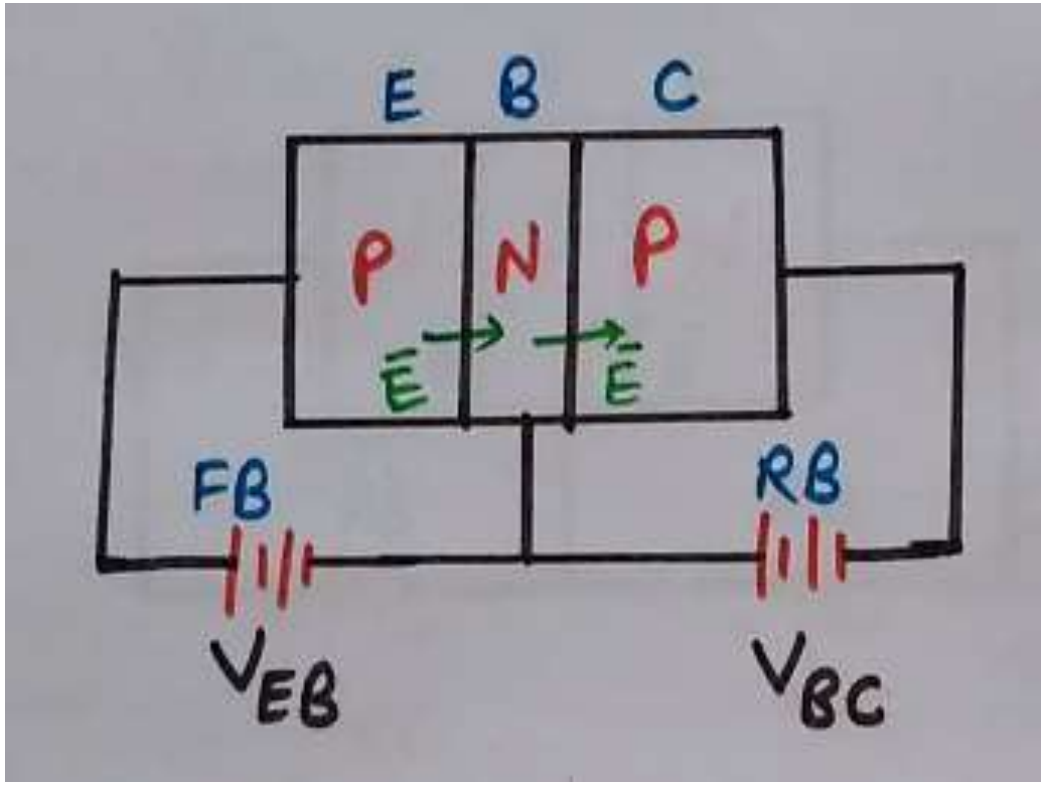
Operation Modes of BJT

*Active mode
*Saturation mode
*Cutoff mode

Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward



Active Mode Operation of BJT Transistor(NPN BJT)



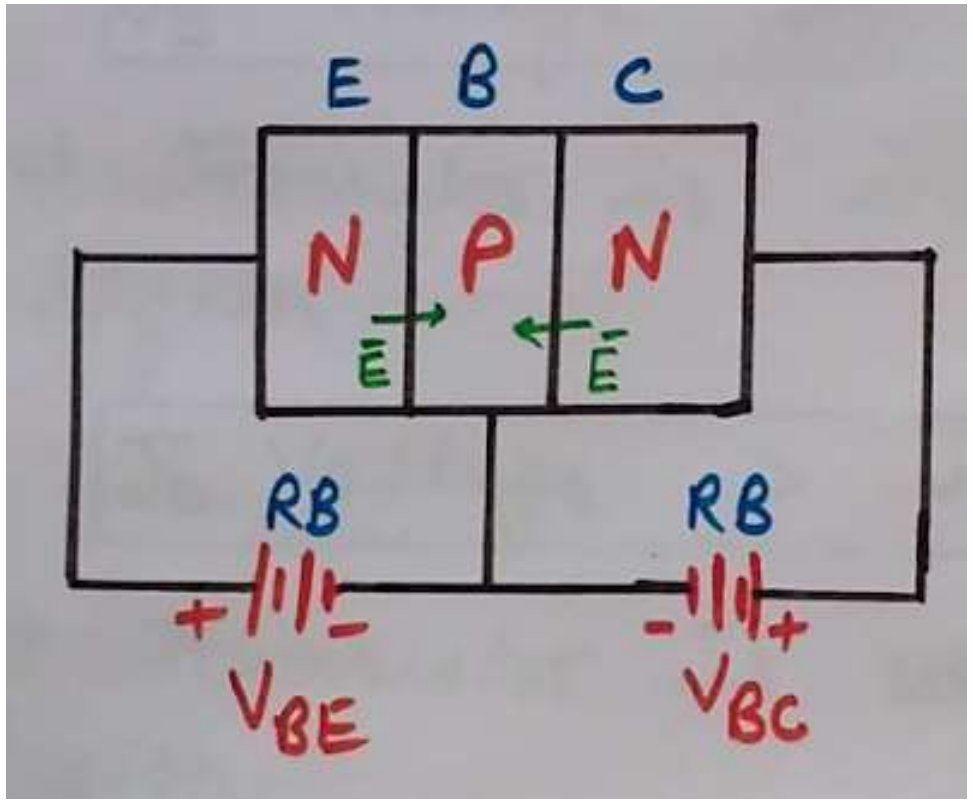
Active Mode Operation of PNP BJT

BJT

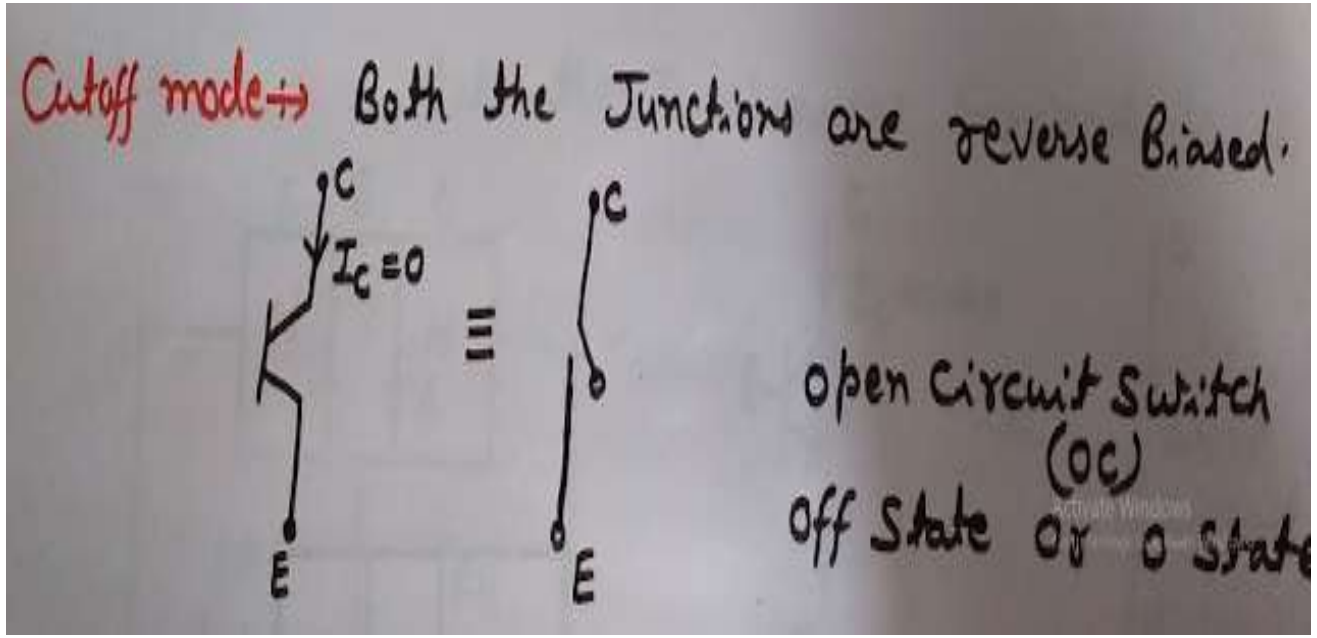
Operation Modes of BJT

*Active mode
*Saturation mode
*Cutoff mode

Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward



Cut off Mode Operation of BJT

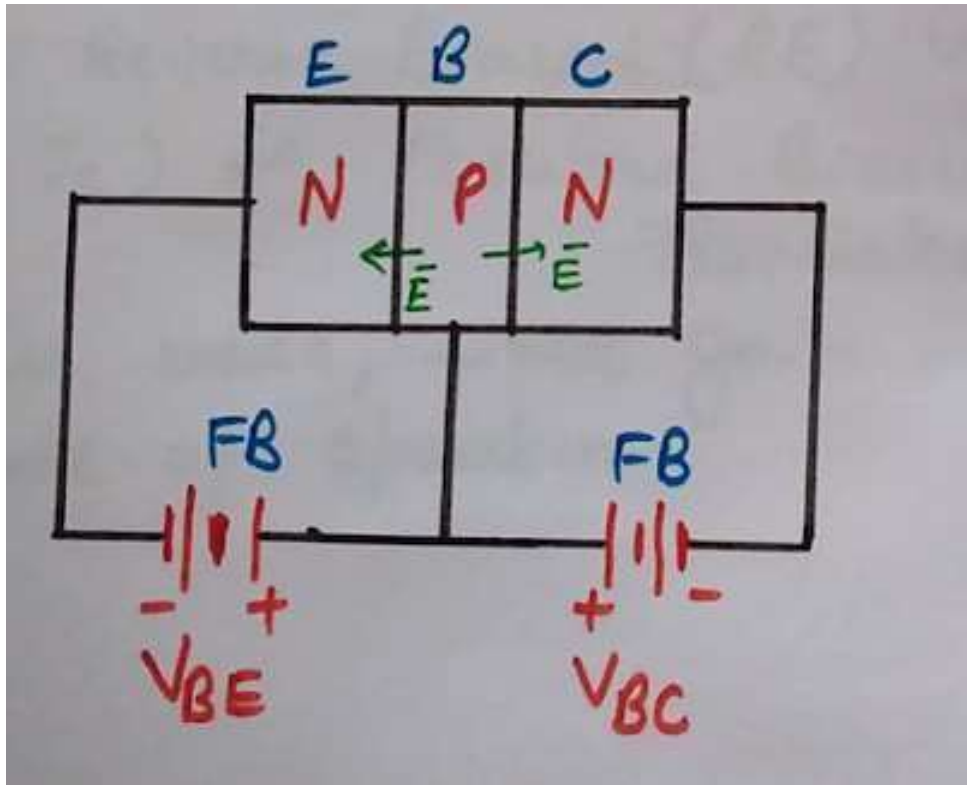


BJT

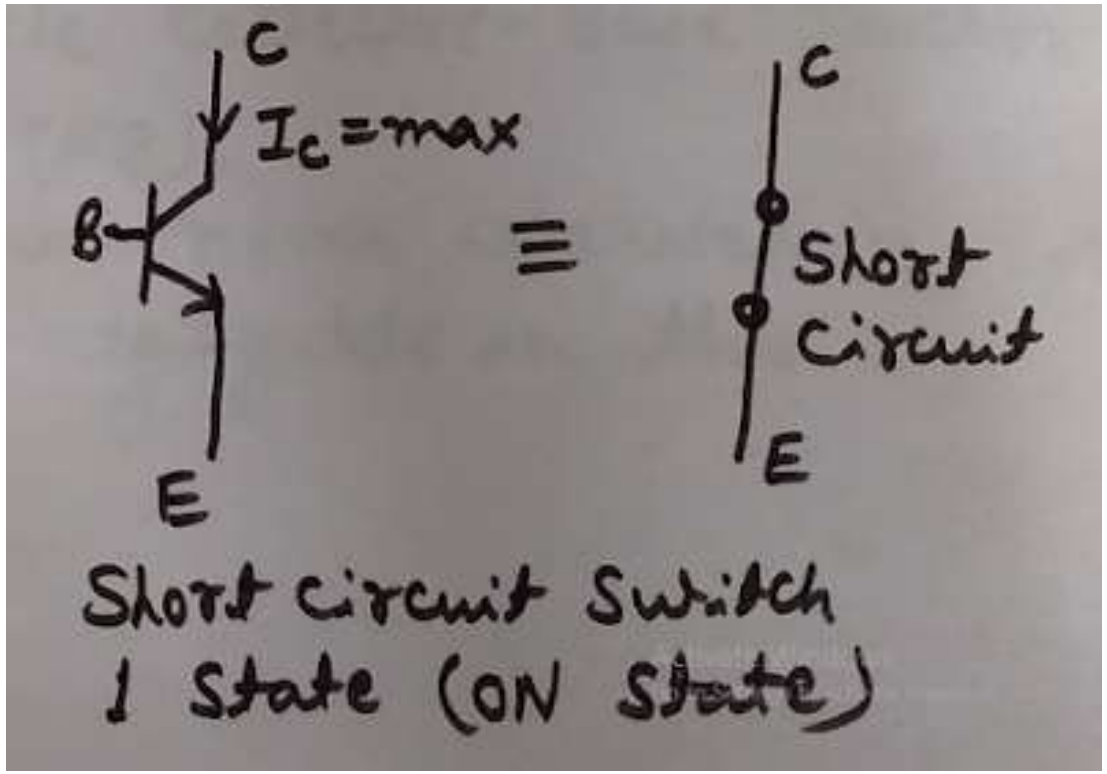
Operation Modes of BJT

*Active mode
*Saturation mode
*Cutoff mode

Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward



Saturation Mode Operation of BJT



UNBIASED BJT

Open Circuited npn BJT

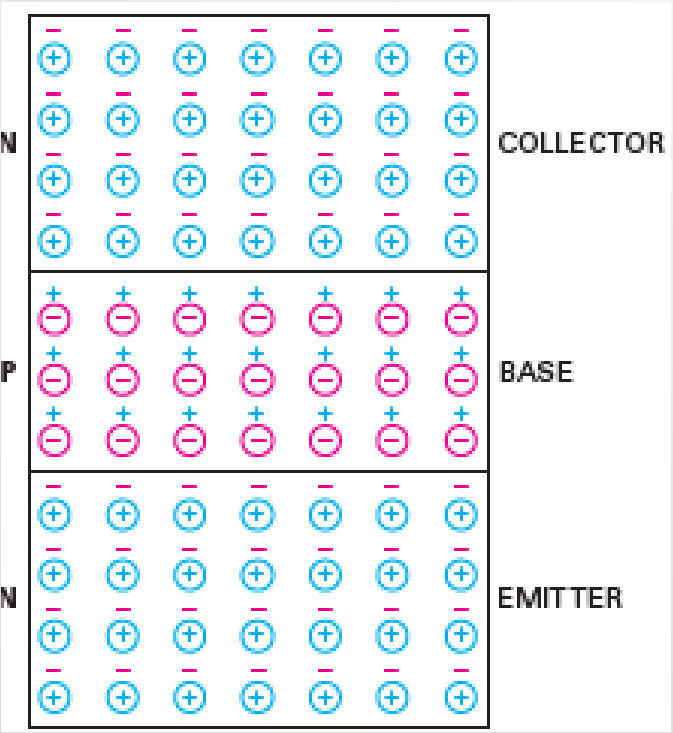


Fig. 1.1. Open circuited npn BJT

Depletion Regions

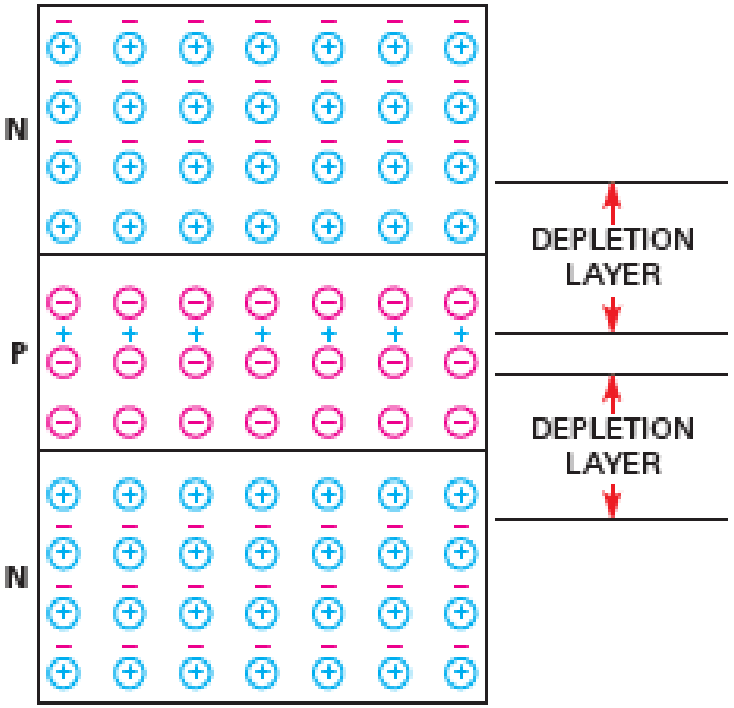


Fig. 1.2. Depletion regions at B-E and B-C junctions of open circuited npn BJT

Diode Equivalent Model

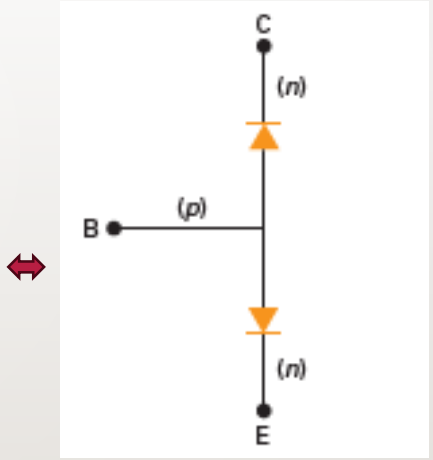


Fig. 1.3. Equivalent diode representation of BJT

- The BJT consists of three regions and two junctions
- Emitter, base, collector for the regions of BJT
- Volume wise C>E>>B
- Doping wise E>C>>B
- Two depletion regions as shown in Fig. 1.2 exists in open circuited BJT.
- The depletion voltages differ as doping concentration varies from emitter and collector
- The diode equivalent circuit notation is seen from Fig. 1.3 which depicts npn BJT as two diodes between Base-emitter and base-collector regions

BIASED BJT

Provide proper External voltages

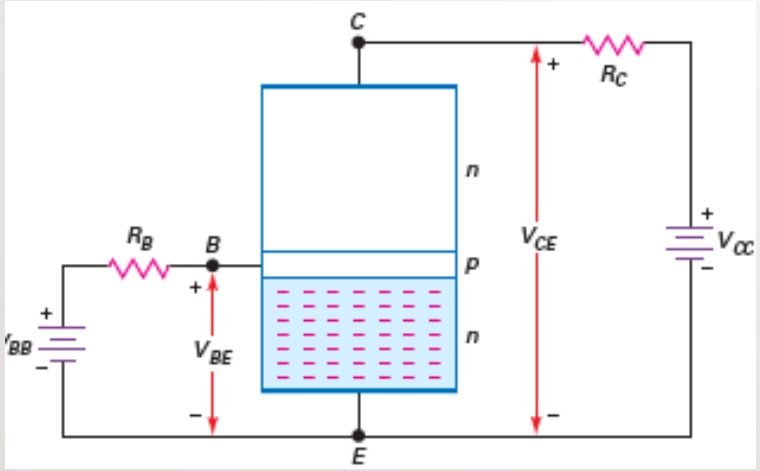


Fig. 1.4. Supplying external voltages to B-E and C-E terminals

- **External voltages are provided such that B-E is FB and B-C is reverse biased.**

Free electrons in Emitter injected into Base

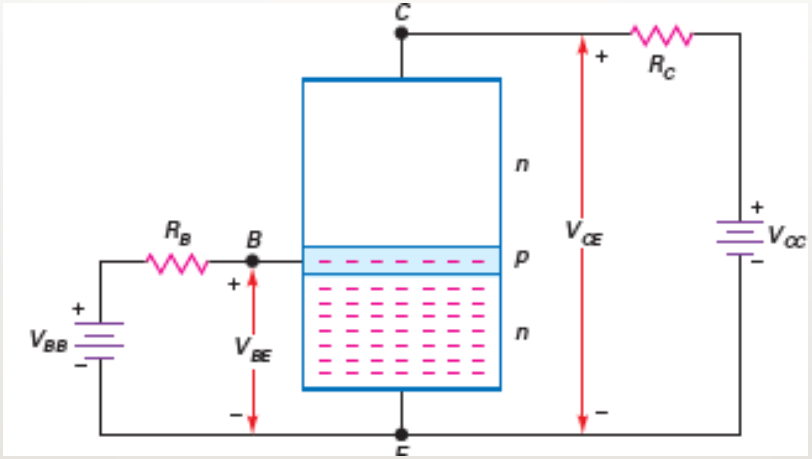


Fig. 1.5. Forward biased BE junctions injects electrons in to base region

- **The forward biased PN junction injects free electrons in to base region**

Electrons transported from Base to Collector

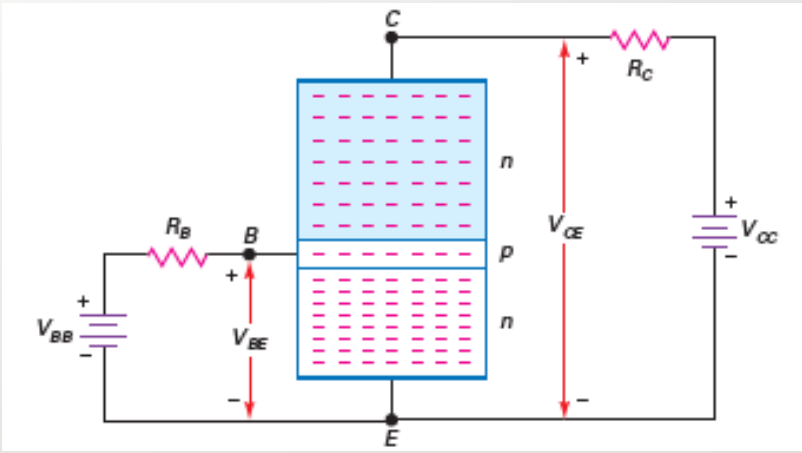
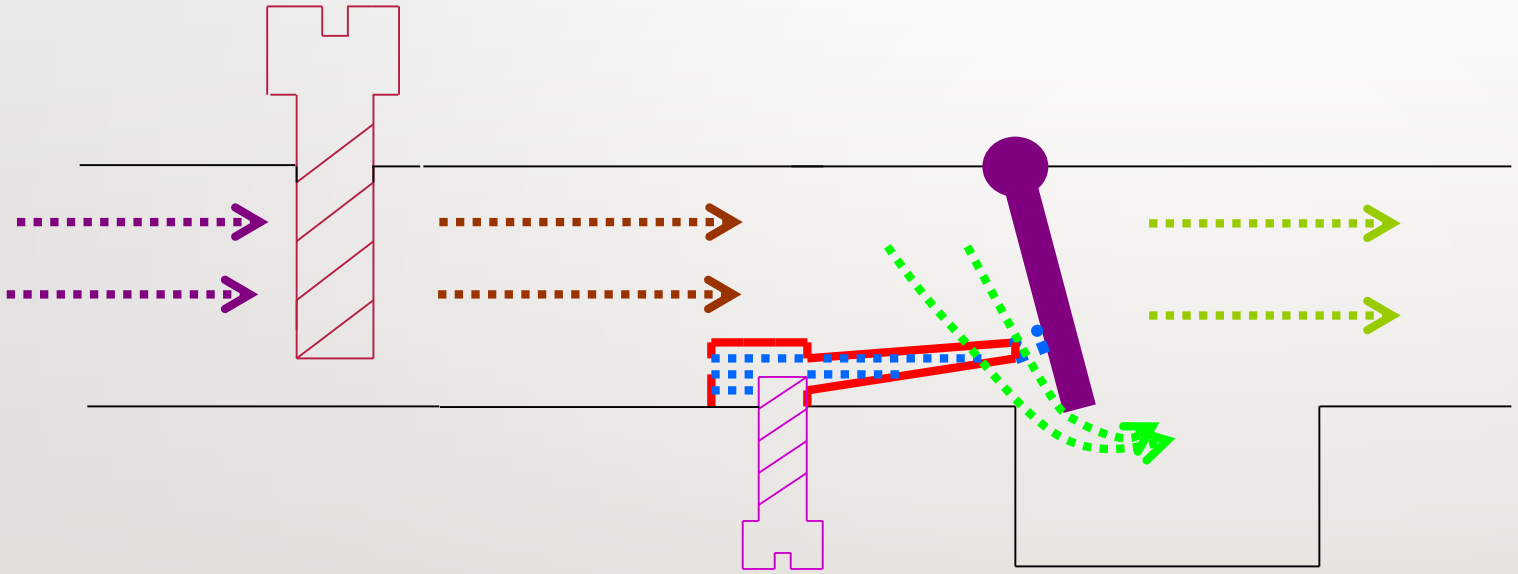


Fig. 1.6. Reverse biased BC junction transports electrons in to collector region

- **As the base region is very small electrons are transported in to collector region through the reversed biased B-C junction at**

Analogy with Transistor :Fluid-jet operated Valve



- The fluid jet operated valve is shown with two valves.
- First valve sets up the flow
- Second valve control the flow
- First valve position determine the volume of jet
- Second valve determine its rate
- This operation is analogous to BJT in the following manner
- V_{CE} sets up the drift for charge carriers from emitter to collector and V_{BE} sets up diffusion of charge carriers in to collector region

Fig. 1.6. Depicting BJT operation analogous to fluid-jet operated valve

Total CURRENT in BIASED BJT

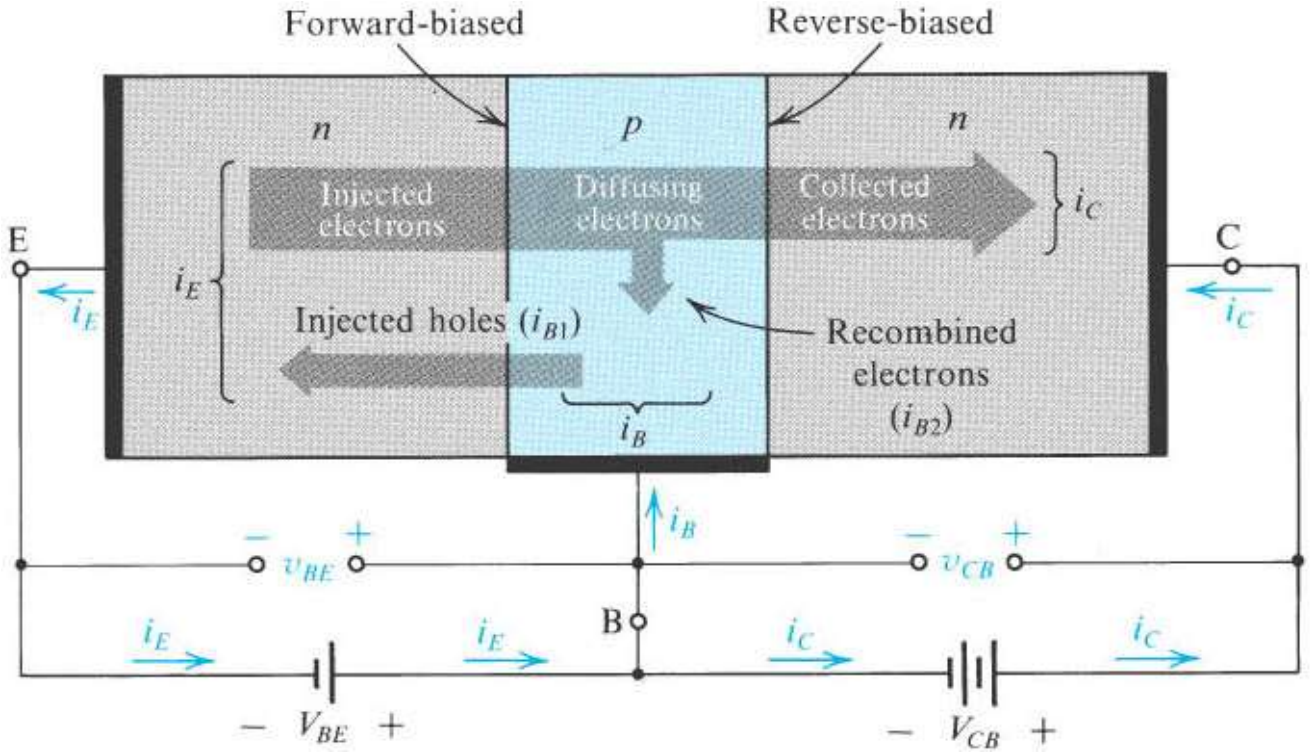


Fig. 1.6. Currents in Biased BJT

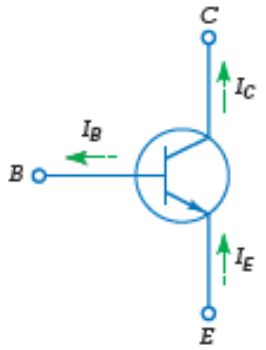


Fig. 1.7. Circuit symbol and flow of electrons in npn BJT

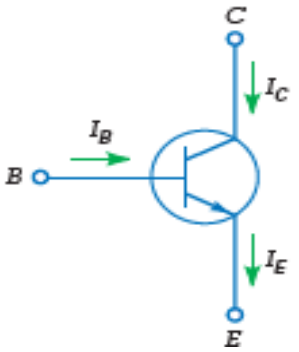


Fig. 1.8. Conventional current directions in npn BJT

BJT CURRENTS

- I_E – Largest emitter current
- Emitter electrons flow to the collector, $I_C \approx I_E$
- $I_B \leq 0.01\ I_C$
- KCL, $I_E = I_C + I_B$

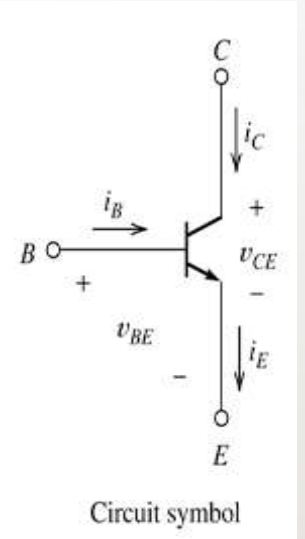


Fig. 1.9. Conventional currents and voltages directions in npn BJT

BJT α and β

- From Fig. 1. 9 $I_E = I_B + I_C$
- Define $\alpha_{dc} = I_C / I_E$
- DC alpha is slightly less than 1
- Low power transistor $\alpha_{dc} > 0.99$ and High power transistor $\alpha_{dc} > 0.95$
- Define $\beta_{dc} = I_C / I_B$ - known as a current gain

BJT α and β

- Then $\beta_{dc} = I_C / (I_E - I_C) = \alpha_{dc} / (1 - \alpha_{dc})$
- **Assignment – Derive $\alpha_{dc} = \beta_{dc} / (1 + \beta_{dc})$**
- Then $I_C = \alpha_{dc} I_E$ & $I_B = (1 - \alpha_{dc}) I_E$

Example Problems

1.1 A BJT has a collector current of 10 mA and base current of 40 μA. What is the current gain of the transistor

Solution: $\beta_{dc} = I_C / I_B$

$= 10\ mA/40\ \mu A$

$= 250$

1.2 A BJT has current gain of 175. If the base current is 0.1 mA, what is the collector current?

Solution: $\beta_{dc} = I_C / I_B$

Therefore, $I_C = \beta_{dc} I_B$

$= 175 * 0.1\ mA$

$= 17.5\ mA$

1. 3 A BJT has current gain of 175. If the base current is 0.1 mA, what is the emitter current?

Solution: From above problem, $I_C = 17.5$ mA

Now, $\alpha_{dc} = \beta_{dc} /(1+ \beta_{dc})$ implies $\alpha_{dc} = 0.004$

And $I_C = \alpha_{dc} I_E$ *implies* $I_E = I_C/\alpha_{dc}$ = 17.5 mA/0.994 = 17.6 mA

SELF-ASSESSMENT QUESTIONS

1. BJT is modelled as

(a) Voltage controlled voltage source
(b) Current controlled voltage source
(c) Current controlled current source
(d) Voltage controlled current source

2. What is the current in BJT in cut-off region

(a) βI_B
(b) $< \beta I_B$
(c) Zero

SELF-ASSESSMENT QUESTIONS

3. Which mode does BJT operate if B-E and B-C junctions are forward biased?

(a) Saturation
(b) Active
(c) Cut-off

4. Which parameter shall be constant to plot input characteristics?

(a) V_{CE}
(b) V_{BE}
(c) I_C
(d) I_B

ANSWERS

1. C
2. C
3. A
4. A

TERMINAL QUESTIONS

1. Describe the regions and p-n junctions of bi-polar junction transistor.
2. Discuss the current mechanisms in BJT.
3. Obtain the expression for total current in BJT.
4. Draw the symbol of npn BJT and identify conventional current directions.
5. Derive the analogy between electron flow in BJT and jet flow in valve operated tube.
6. Obtain the relations between various current gains in BJT

REFERENCES FOR FURTHER LEARNING OF THE SESSION

Reference Books:

1. Albert Malvino, David Bate, "Electronic Principles"
2. Robert L. Boylestad and Louis Nashelsky - "Electronic Devices and Circuit Theory"