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Coimbatore-35
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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

23ECB101 – CIRCUIT ANALYSIS AND DEVICES

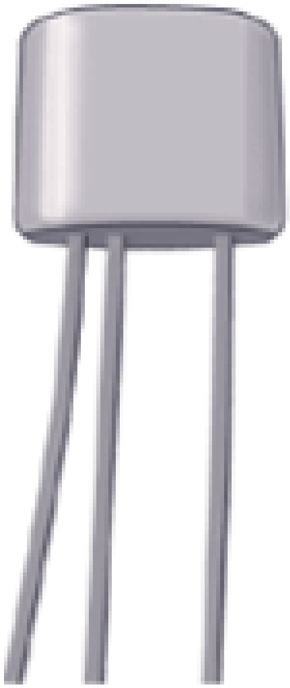
I YEAR/ II SEMESTER

UNIT 4 – TRANSISTORS AND THEIR APPLICATIONS

TOPIC - Bipolar Junction Transistor

What is a Transistor?

- Semiconductors: ability to change from conductor to insulator
- Can either allow current or prohibit current to flow
- Useful as a switch, but also as an amplifier
- Essential part of many technological advances



A Brief History

- Guglielmo Marconi invents radio in 1895
- Problem: For long distance travel, signal must be amplified
- Lee De Forest improves on Fleming's original vacuum tube to amplify signals
- Made use of third electrode
- Too bulky for most applications

The Transistor is Born

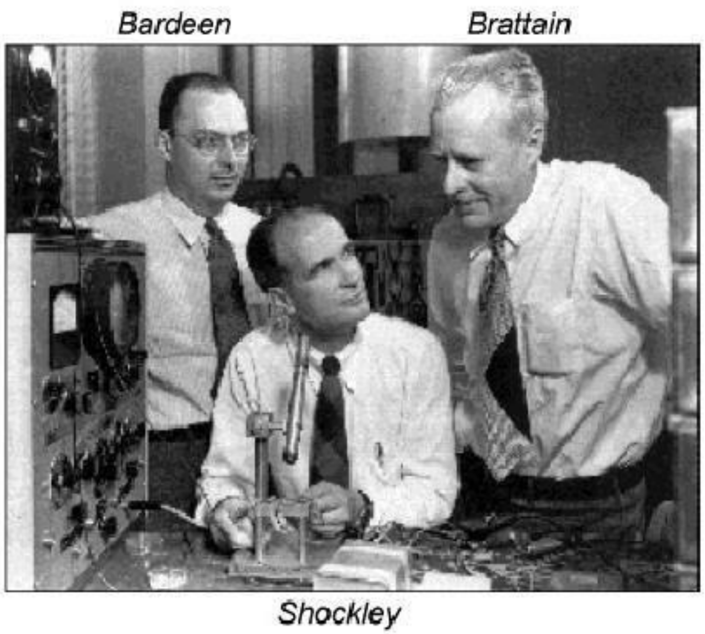
- Bell Labs (1947): Bardeen, Brattain, and Shockley
- Originally made of germanium
- Current transistors made of doped silicon

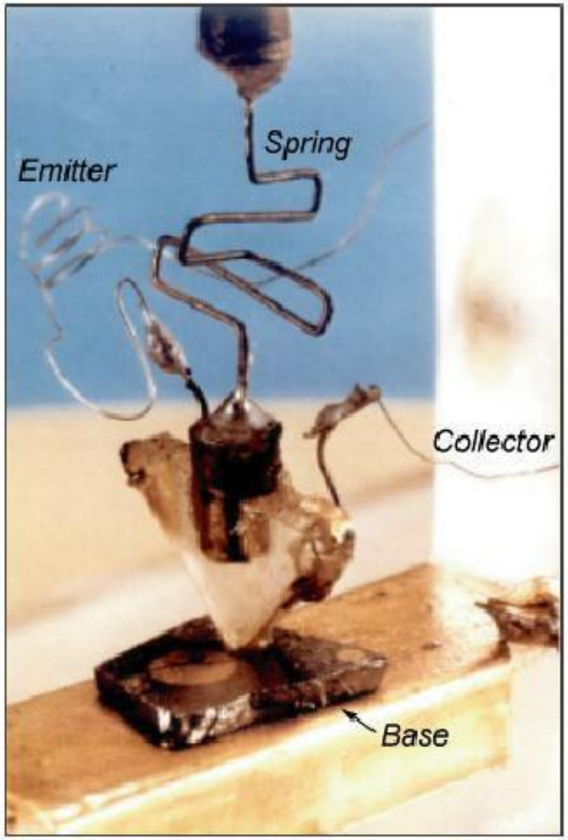
The first transistor was a point-contact transistor

The first point-contact transistor

John Bardeen, Walter Brattain, and William Shockley

Bell Laboratories, Murray Hill, New Jersey (1947)



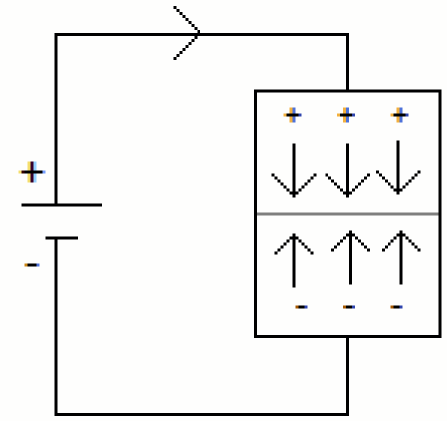


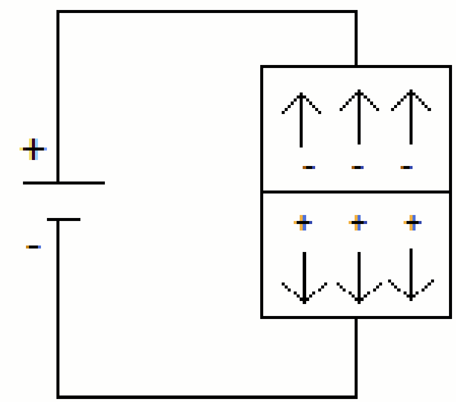
How Transistors Work

- Doping: adding small amounts of other elements to create additional protons or electrons
- P-Type: dopants lack a fourth valence electron (Boron, Aluminum)
- N-Type: dopants have an additional (5^{th}) valence electron (Phosphorus, Arsenic)
- Importance: Current only flows from P to N

Diodes and Bias

- Diode: simple P-N junction.
- Forward Bias: allows current to flow from P to N.
- Reverse Bias: no current allowed to flow from N to P.
- Breakdown Voltage: sufficient N to P voltage of a Zener Diode will allow for current to flow in this direction.





Bipolar Junction transistor

Bipolar Junction transistor

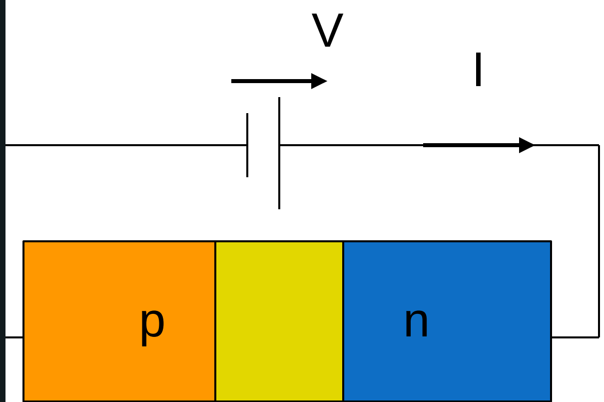
bles and electrons
etermine device characteristics

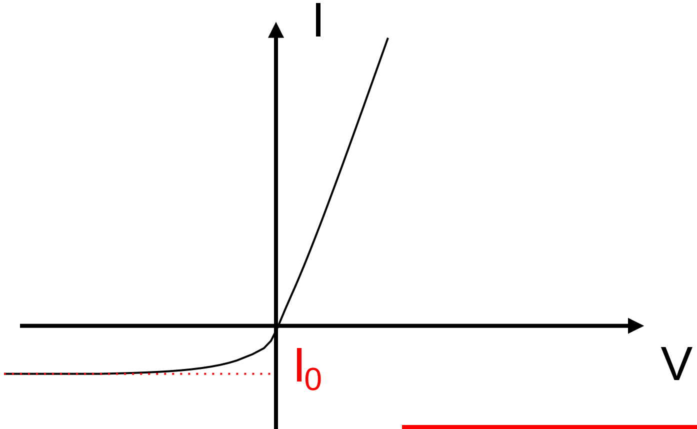
Three terminal device

Control of two terminal currents

Amplification and switching through 3rd contact

How can we make a BJT from a pn diode

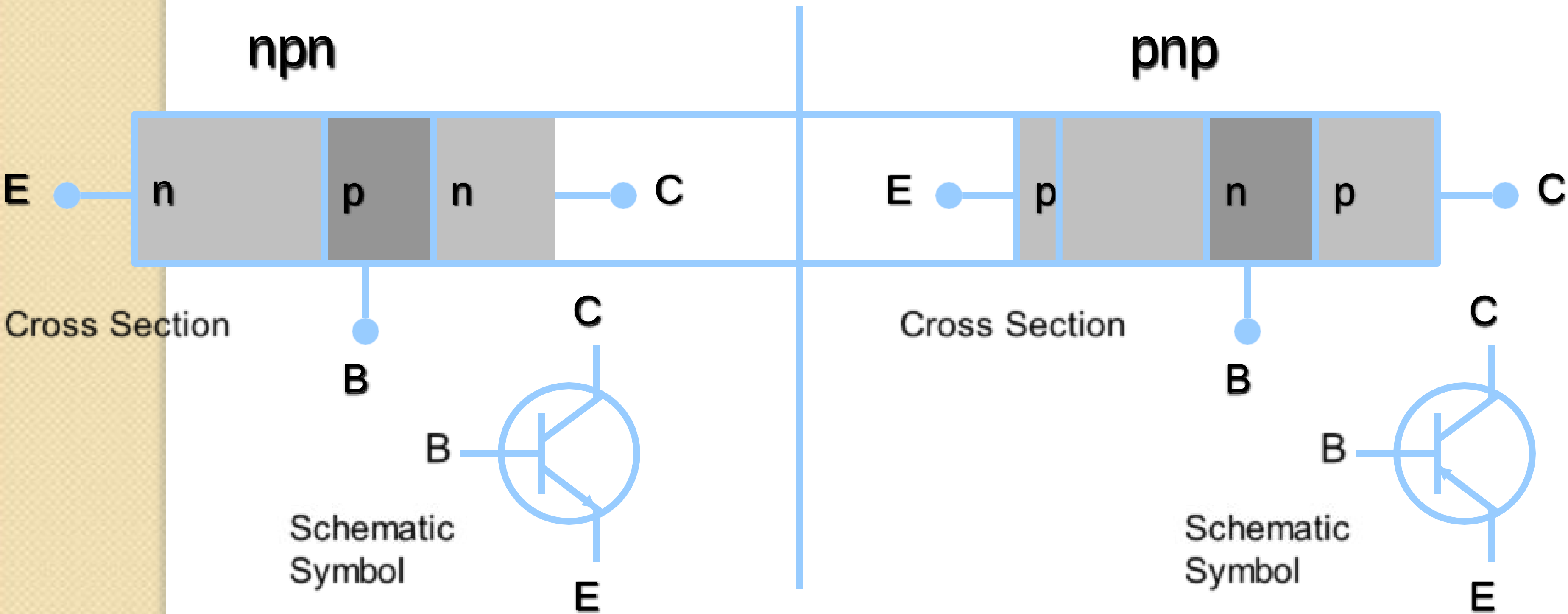




- Take pn diode
  - Remember reverse bias characteristics
  - Reverse saturation current: I_0

The BJT – Bipolar Junction Transistor

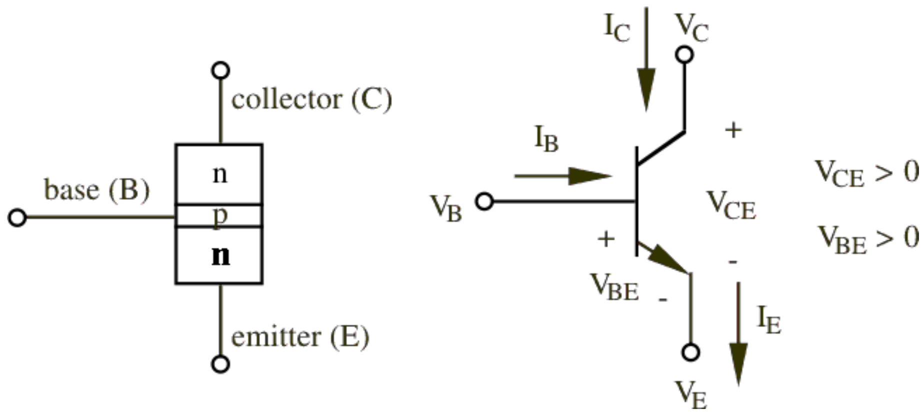
The Two Types of BJT Transistors:



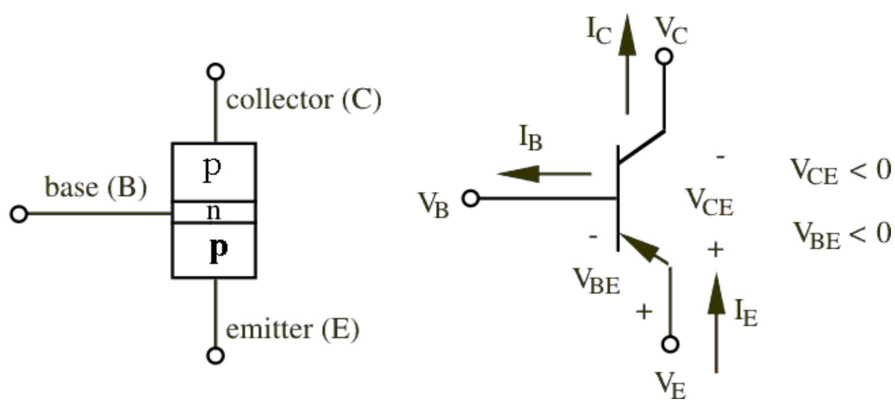
- Collector doping is usually ~ 10^6
- Base doping is slightly higher ~ $10^7 – 10^8$
- Emitter doping is much higher ~ 10^{15}

Bipolar Junction Transistor (BJT)

- 3 adjacent regions of doped Si (each connected to a lead):
  - Base. (thin layer, less doped).
  - Collector.
  - Emitter.
- 2 types of BJT:
  - npn
  - pnp
- Most common: npn



npn bipolar junction transistor

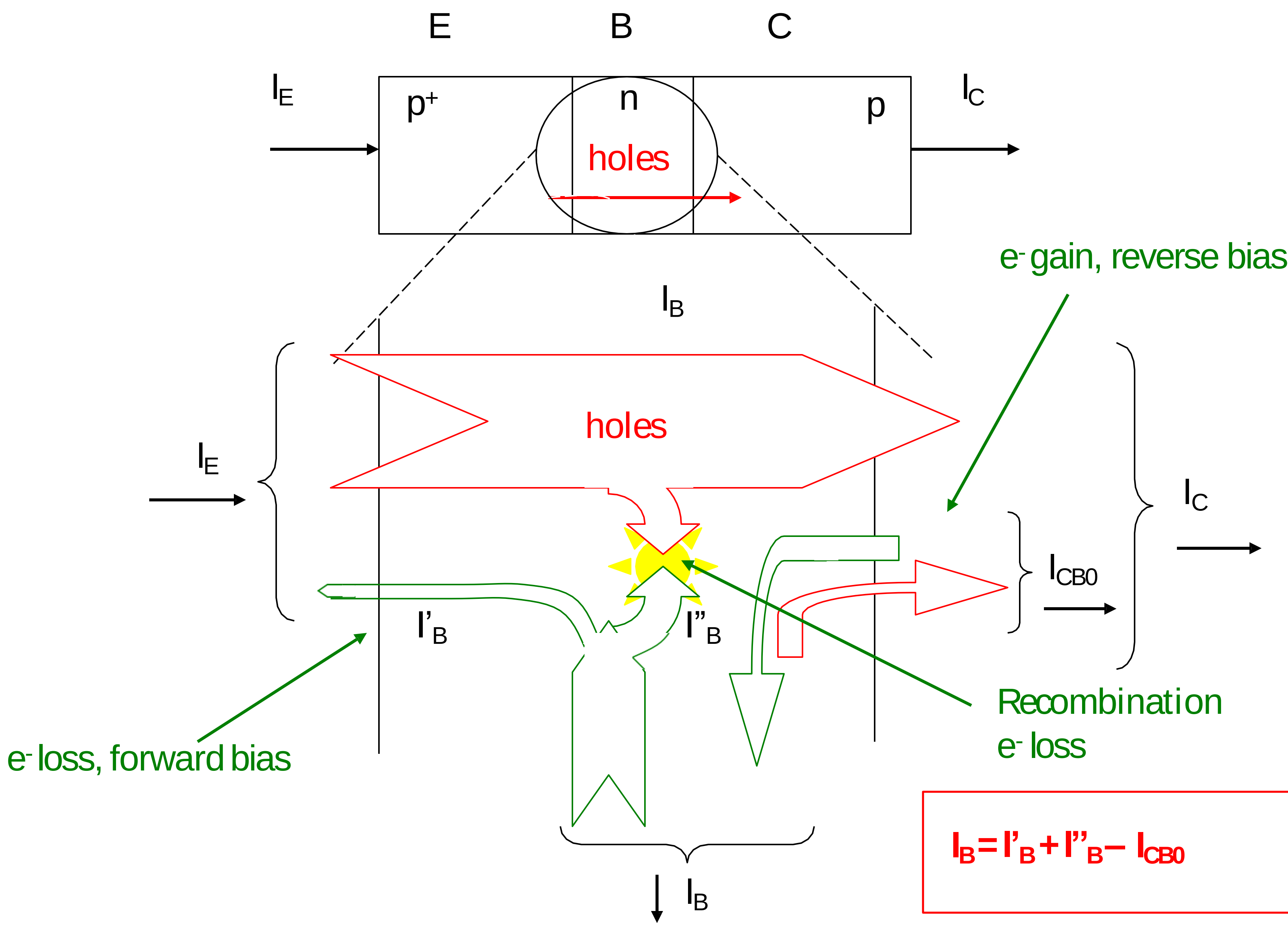


pnp bipolar junction transistor

Developed by Shockley (1949)

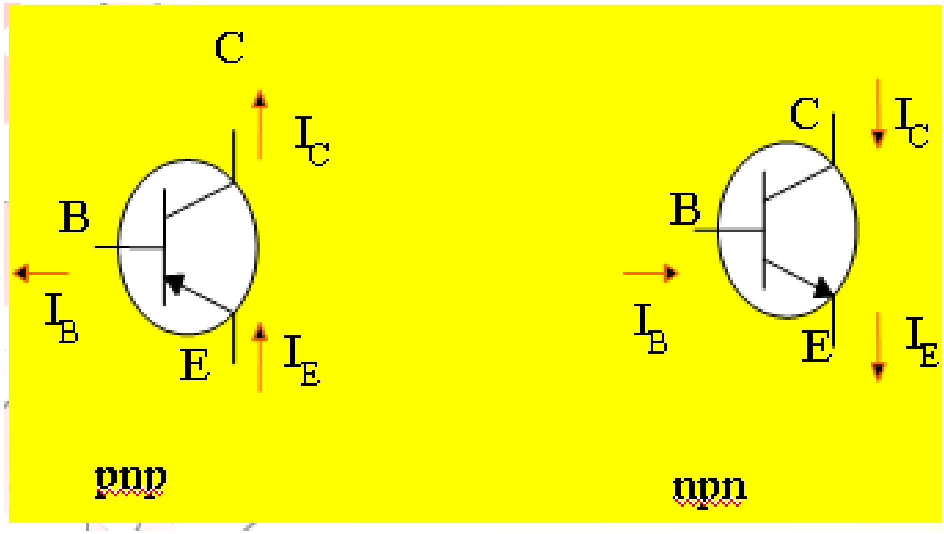
Carrier flow in BJTs

Carrier flow in BJTs



$$I_B = I'_B + I''_B - I_{CB0}$$

Transistor currents



-The arrow is always drawn on the emitter

-The arrow always point toward the n-type

-The arrow indicates the direction of the emitter current:

pnp:E□ B

npn: B□ E

I_C=the collector current
I_B= the base current
I_E= the emitter current

- By imaging the analogy of diode, transistor can be construct like two diodes that connected together.
- It can be conclude that the work of transistor is base on work of diode.

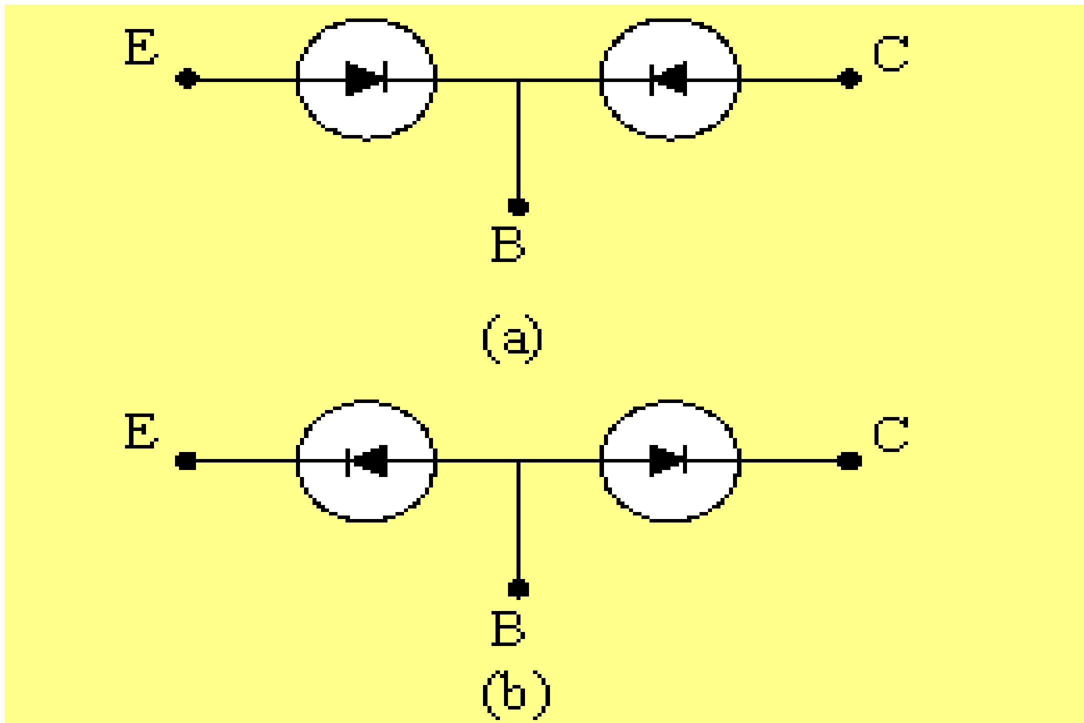


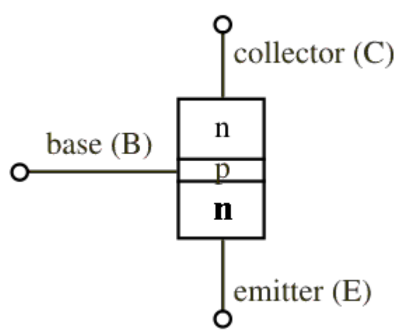
Fig. 4.2: (a) pnp transistor (b) npn transistor

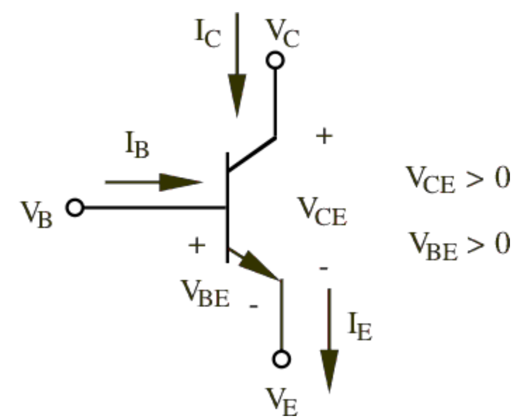
BJT npn Transistor

- 1 thin layer of p-type, sandwiched between 2 layers of n-type.
- N-type of emitter: more heavily doped than collector.
- With $V_C > V_B > V_E$:
  - Base-Emitter junction forward biased, Base-Collector reverse biased.
  - Electrons diffuse from Emitter to Base (from n to p).
  - There's a depletion layer on the Base-Collector junction □no flow of e^- allowed.
  - **BUT** the Base is thin and Emitter region is n^+ (heavily doped) □ electrons have enough momentum to cross the Base into the Collector.
  - The small base current I_B controls a large current I_C

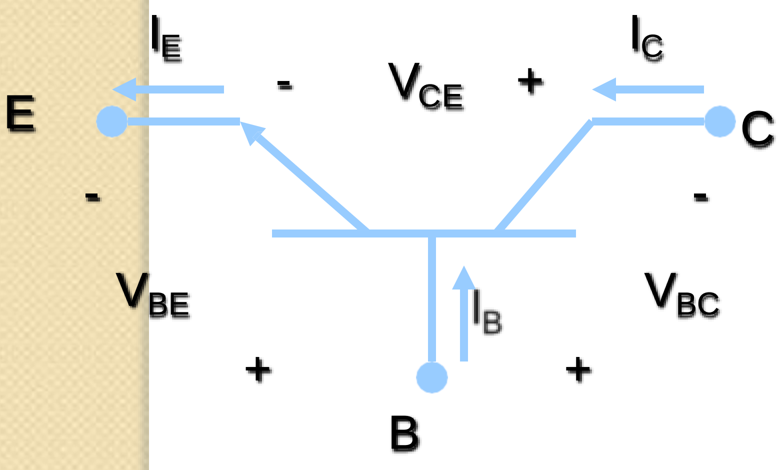
$$V_C > V_B > V_E$$

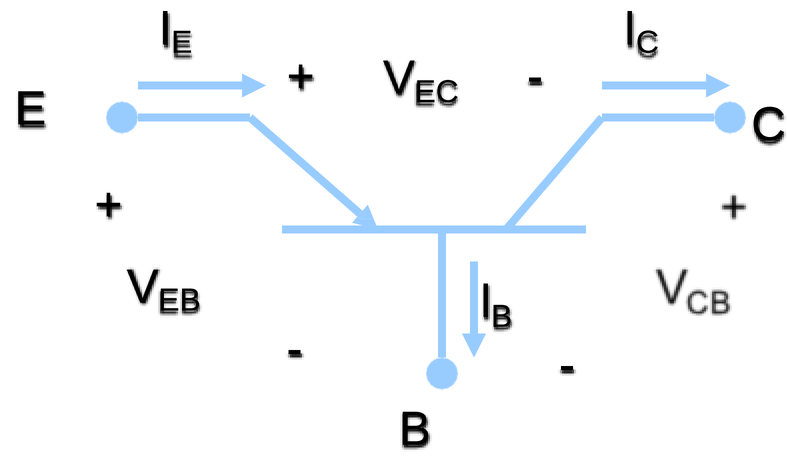
$$I_E = I_C + I_B$$
$$V_{BE} = V_B - V_E$$
$$V_{CE} = V_C - V_E$$
$$I_C = \beta I_B$$





BJT Relationships - Equations





npn

$I_E = I_B + I_C$

$V_{CE} = -V_{BC} + V_{BE}$

pnp

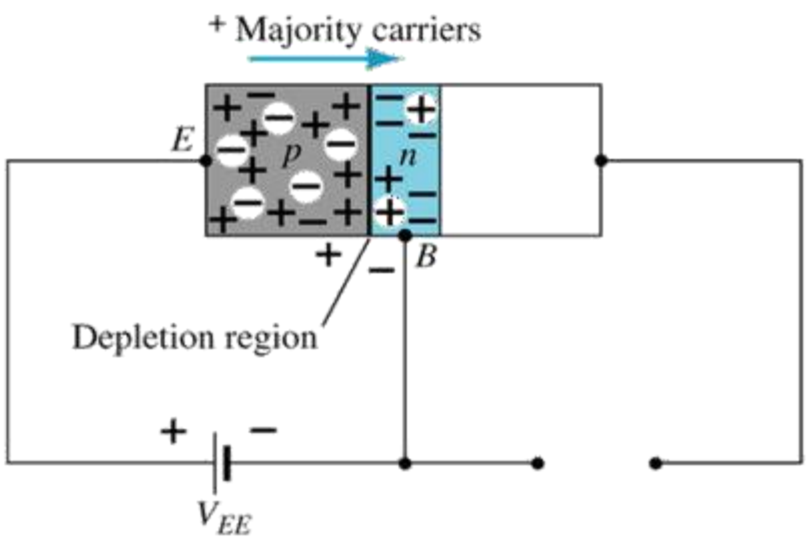
$I_E = I_B + I_C$

$V_{EC} = V_{EB} - V_{CB}$

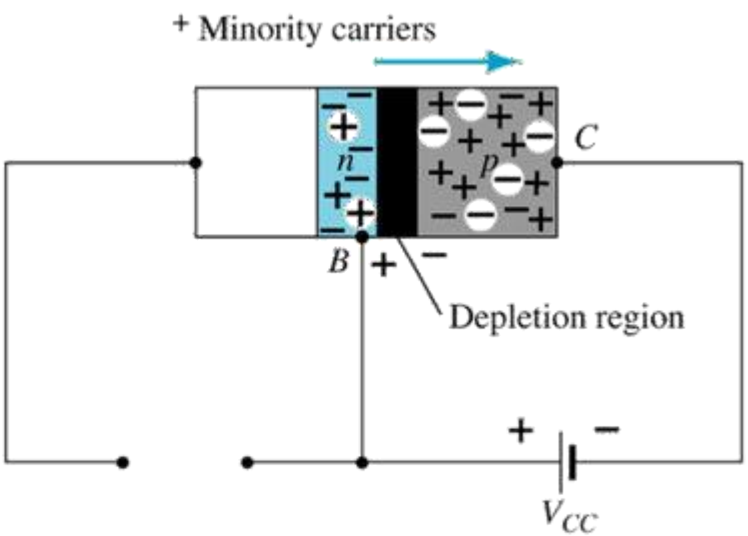
Note: The equations seen above are for the transistor, not the circuit.

Transistor Operation

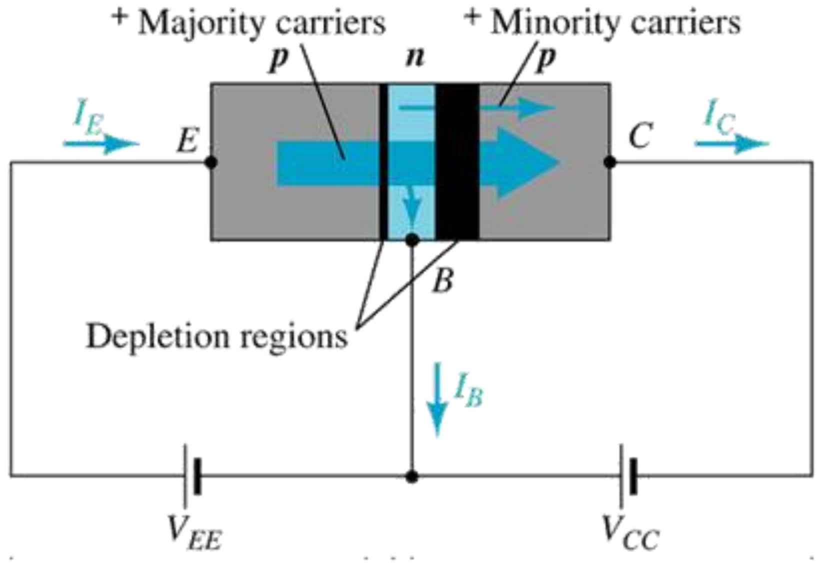
- The basic operation will be described using the pnp transistor. The operation of the pnp transistor is exactly the same if the roles played by the electron and hole are interchanged.
- One p-n junction of a transistor is reverse-biased, whereas the other is forward-biased.



Forward-biased junction of a pnp transistor



Reverse-biased junction of a pnp transistor



- Both biasing potentials have been applied to a pnp transistor and resulting majority and minority carrier flows indicated.
- Majority carriers (+) will diffuse across the forward-biased p-n junction into the n-type material.
- A very small number of carriers (+) will through n-type material to the base terminal. Resulting IB is typically in order of microamperes.
- The large number of majority carriers will diffuse across the reverse-biased junction into the p-type material connected to the collector terminal.

- Majority carriers can cross the reverse-biased junction because the injected majority carriers will appear as minority carriers in the n-type material.
- Applying KCL to the transistor:

$$I_E = I_C + I_B$$

- The comprises of two components – the majority and minority carriers

$$I_C = I_{Cmajority} + I_{COminority}$$

- I_{CO} – I_C current with emitter terminal open and is called leakage current.

Modes of Operation

Active:

- Most important mode of operation
- Central to amplifier operation
- The region where current curves are practically flat

Saturation:

- Barrier potential of the junctions cancel each other out causing a virtual short

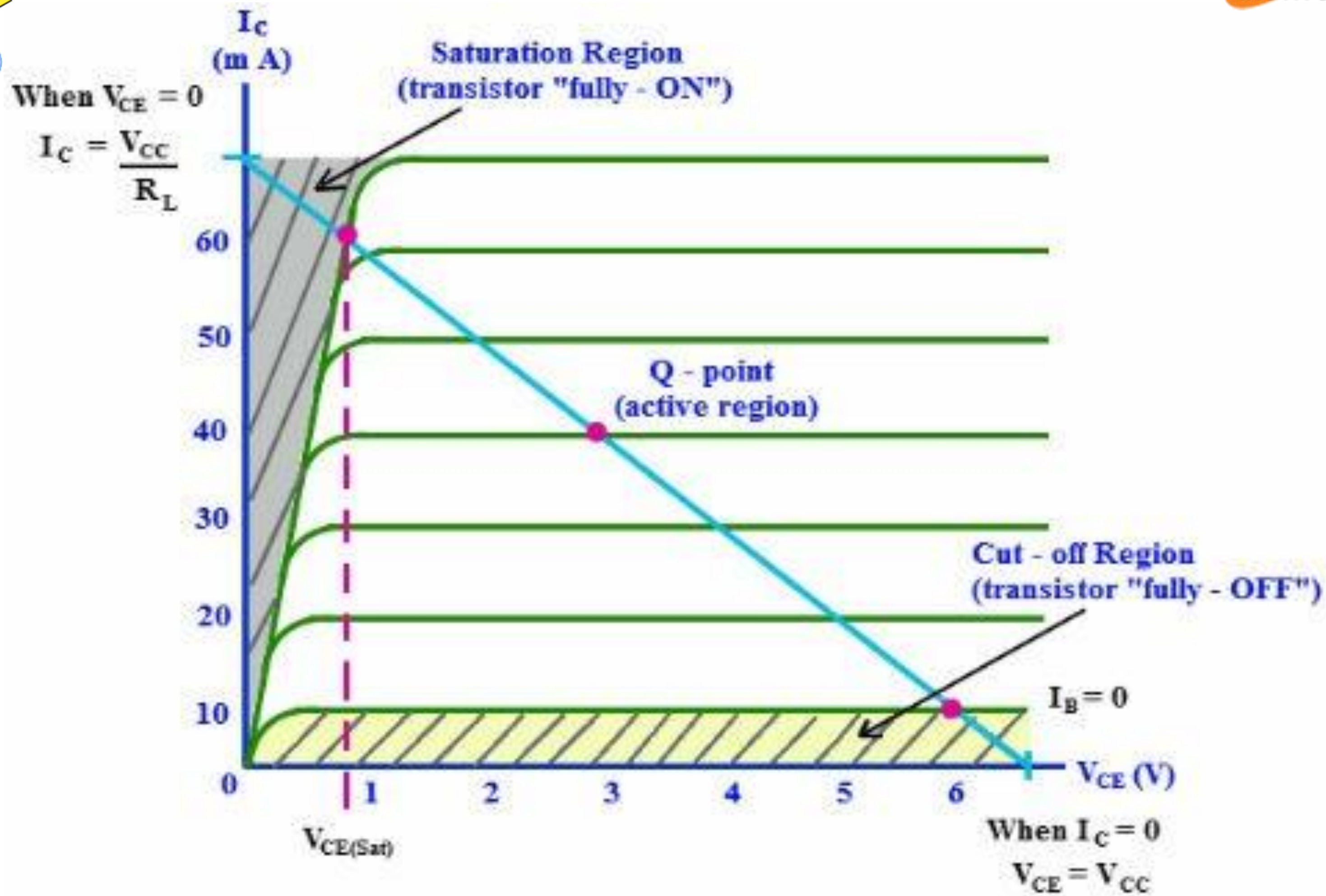
Cutoff:

- Current reduced to zero
- Ideal transistor behaves like an open switch

* Note: There is also a mode of operation called inverse active, but it is rarely used.

egions of Operation

T Regions of Operation



Operation region summary

Operation Region	I_B or V_{CE} Char.	BC and BE Junctions	Mode
Cutoff	I_B = Very small	Reverse & Reverse	Open Switch
Saturation	V_{CE} = Small	Forward & Forward	Closed Switch
Active Linear	V_{CE} = Moderate	Reverse & Forward	Linear Amplifier
Break-down	V_{CE} = Large	Beyond Limits	Overload


THANK YOU