ELECTRONIC COMPONENTS

Semiconductors

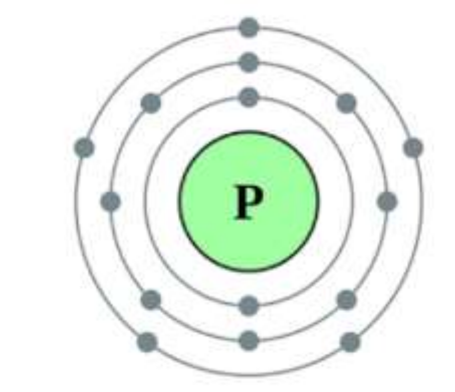
It is the field of science and engineering which deals with the study of electron devices and their utilization. An electron device is one in which movement of electrons takes place through vacuum or gas or a semiconductor.

Classification of Materials:

- Conductors: valence electrons<4
- Insulators: valence electrons>4
- Semiconductors: valence electrons=4

Valence electrons: Electrons in outermost orbit

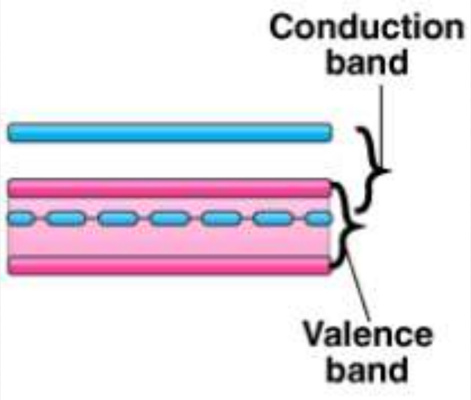
valence electrons for phosphorous is 5



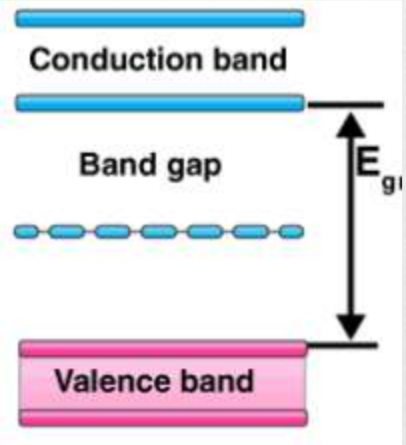
Electron configuration of phosphorous:

$$1S^2 2S^2 2P^6 3S^2 3P^3$$

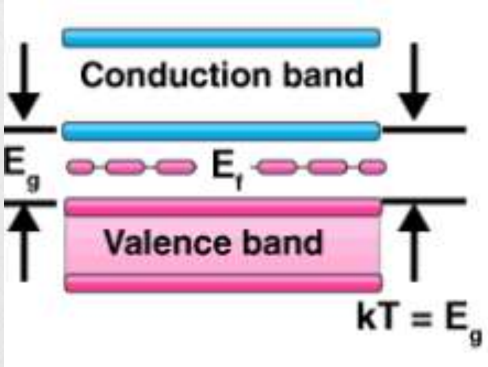
Conductors



Insulators



Semi Conductors



Classification of Semiconductors:

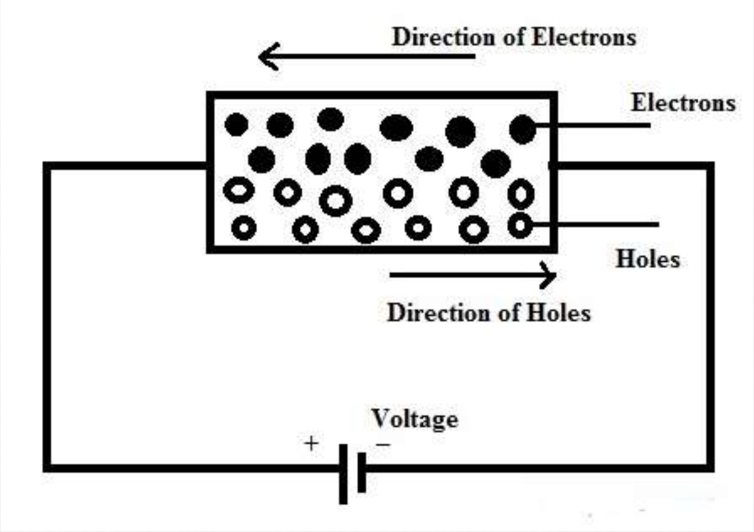
1. Intrinsic Semiconductors
2. Extrinsic Semiconductors

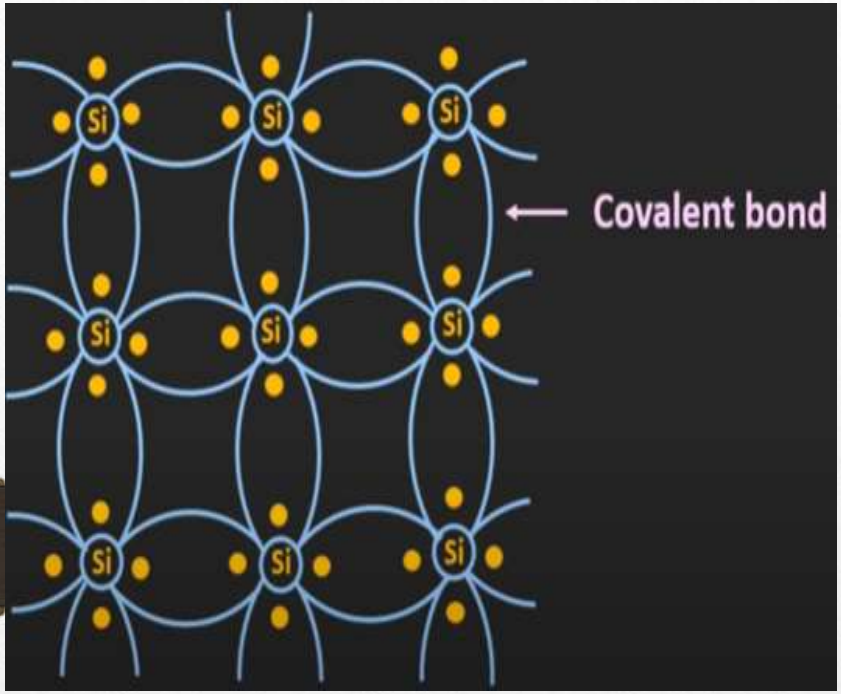
Properties of Intrinsic Semiconductor:

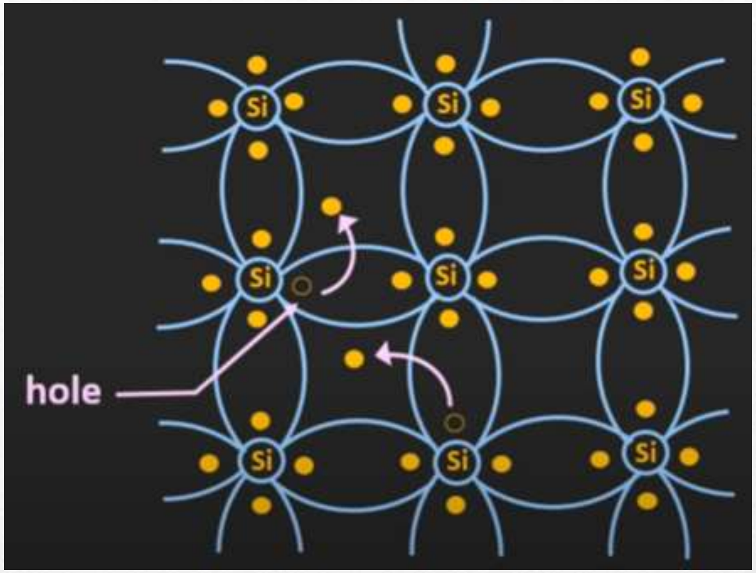
1. They have four Valence Electrons
2. Properties lies between conductor and insulator
3. Conduction property can be varied by varying the temperature
4. They have negative temperature coefficient of resistance
5. Properties can be varied by adding impurities to semiconductor
6. Resistivity is greater than conductor and less than an insulator
7. Current in a semiconductor consists of movement of electrons and holes

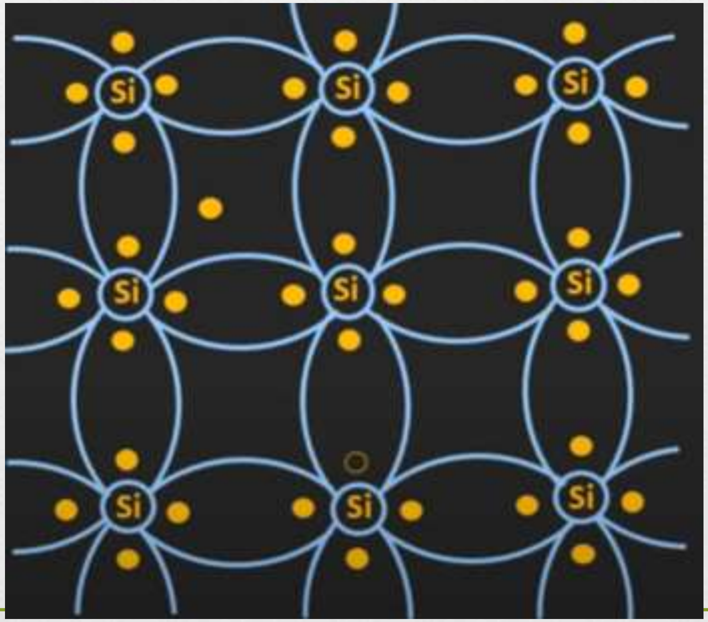
Hole formation in Intrinsic Semiconductor:

- At room temperature some electrons move from valence band to conduction band
- As the electron leaves in the valence band it creates a vacant space known as hole
- When electric field is applied both electrons and holes constitute current
- Total current is sum of electron and hole current




Si
Covalent bond


Si
hole


Si

Extrinsic Semiconductor: Conduction in semiconductors can improved by adding impurities to it.

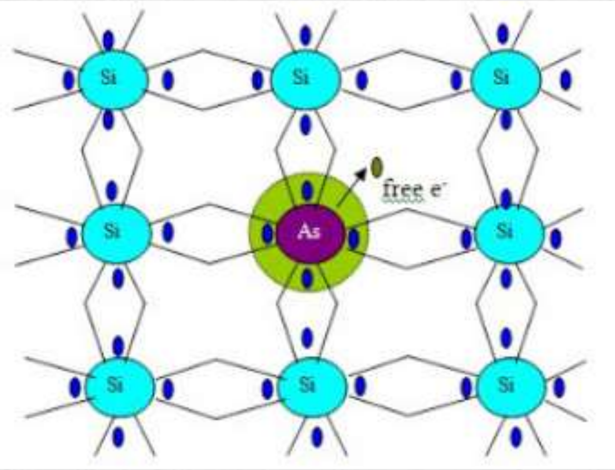
Doping: Process of adding impurities to a semiconductor is called doping.

Doping Agent or Dopant: Impurity added is called dopant or doping agent.

N-type semiconductor: It is obtained by adding a pentavalent impurity to a semiconductor

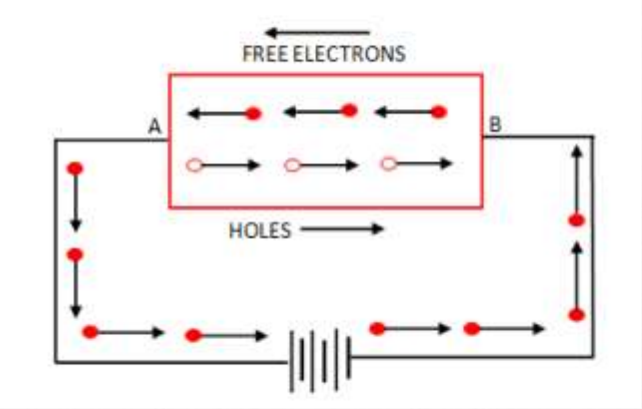
Elements are such as arsenic, bismuth, phosphorous and antimony

Donor: A pentavalent impurity when doped with a semiconductor donates one electron to the conduction band. Such doping agent is called donor



Conduction in N-type semiconductor

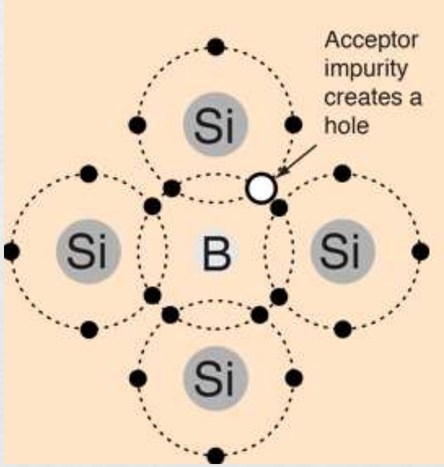
- Due to more free electrons electron current is dominant over the hole current.
- Majority carriers are electrons and minority carriers are holes



P-type semiconductor: It is obtained by adding a trivalent impurity to a semiconductor

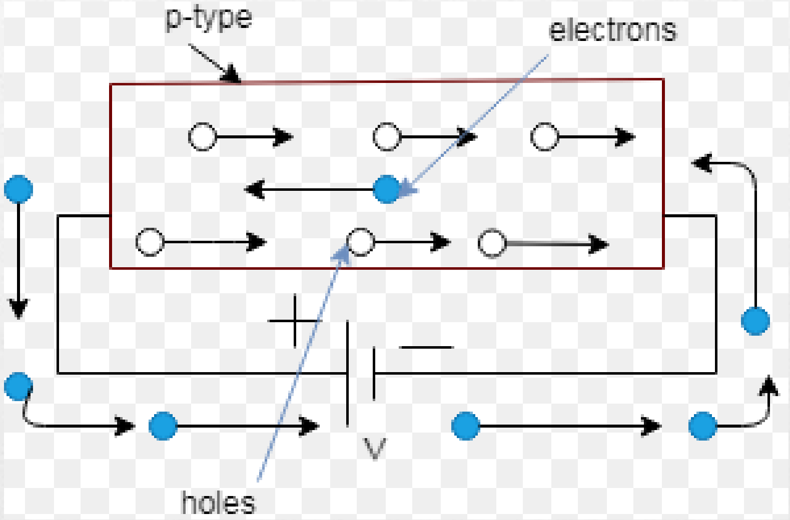
Elements are such as Gallium, boron and Indium

<ins>Acceptor:</ins> A trivalent impurity when doped with a semiconductor accepts one electron to achieve stable state. Such doping agent is called acceptor



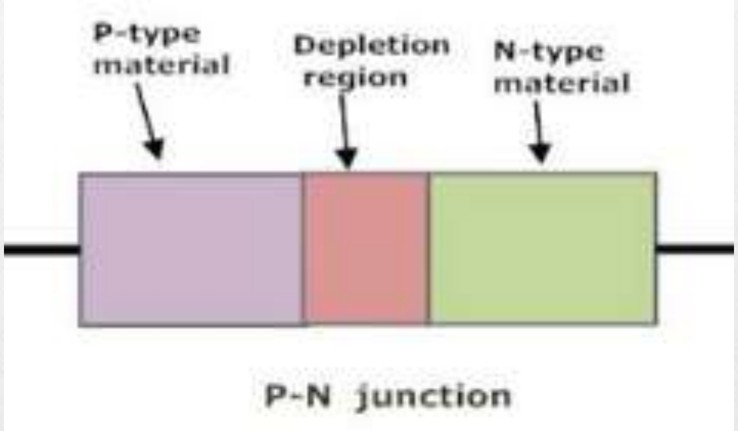
Conduction in P-type semiconductor

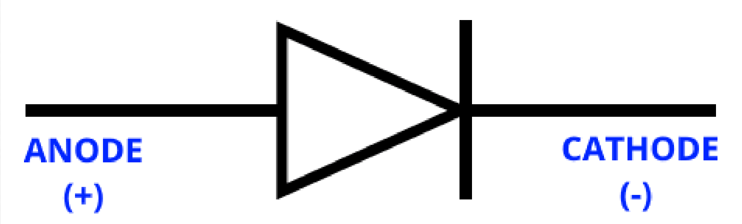
- Due to more holes, hole current is dominant over the electron current.
- Majority carriers are holes and minority carriers are electrons



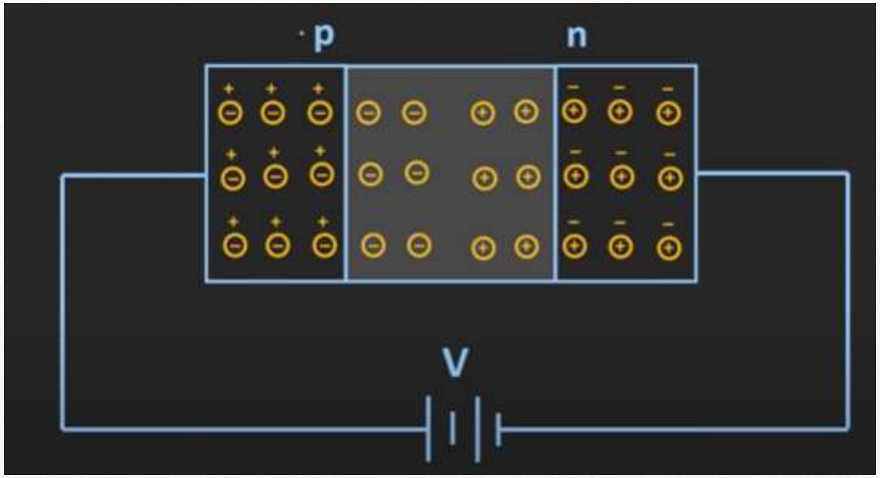
P-N Diode

The materials p-type and n-type are chemically combined with a fabrication technique to form a p-n junction. The p-n junction forms a popular semiconductor device called diode.

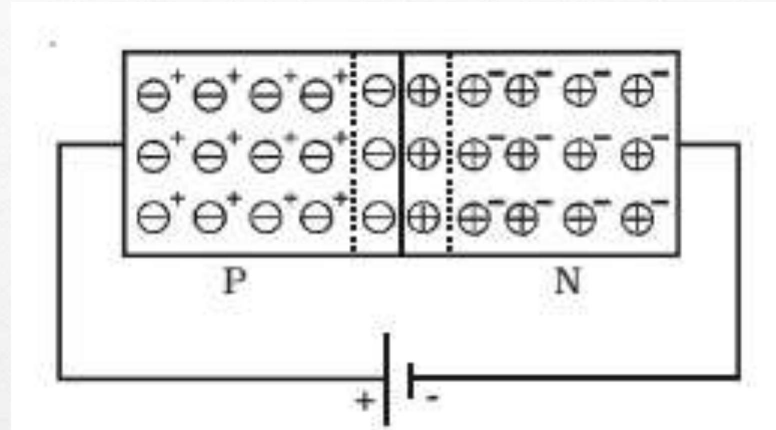




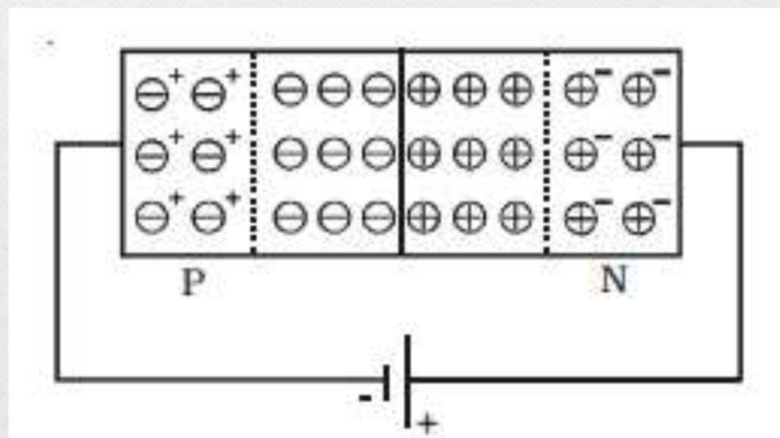
Symbol



Forward bias



Reverse bias



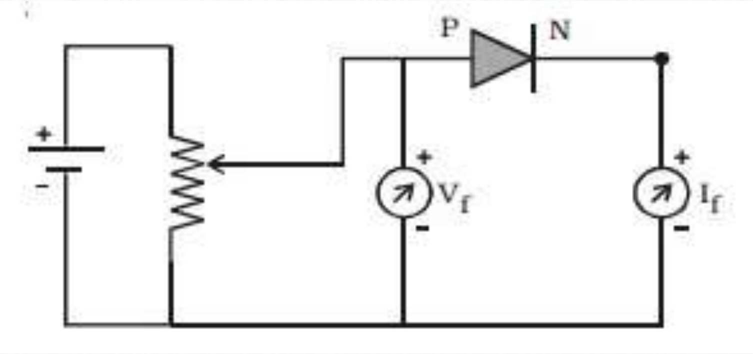
$\oplus$: *Acceptor Ions*

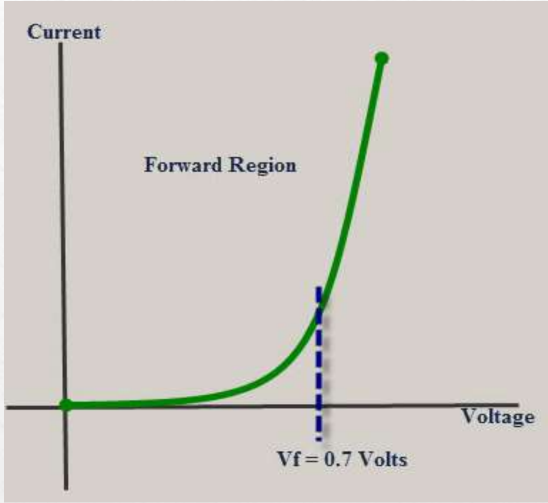
$\ominus$: *Donor Ions*

+: Holes

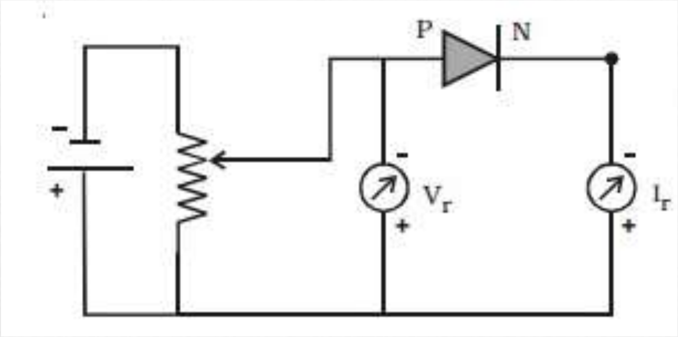
– : Electrons

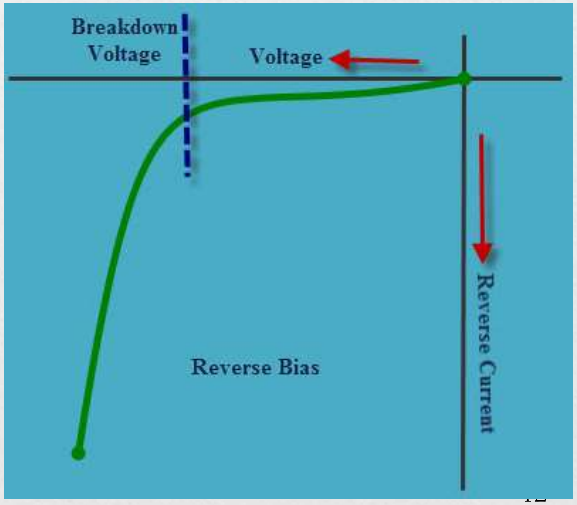
Forward bias characteristics



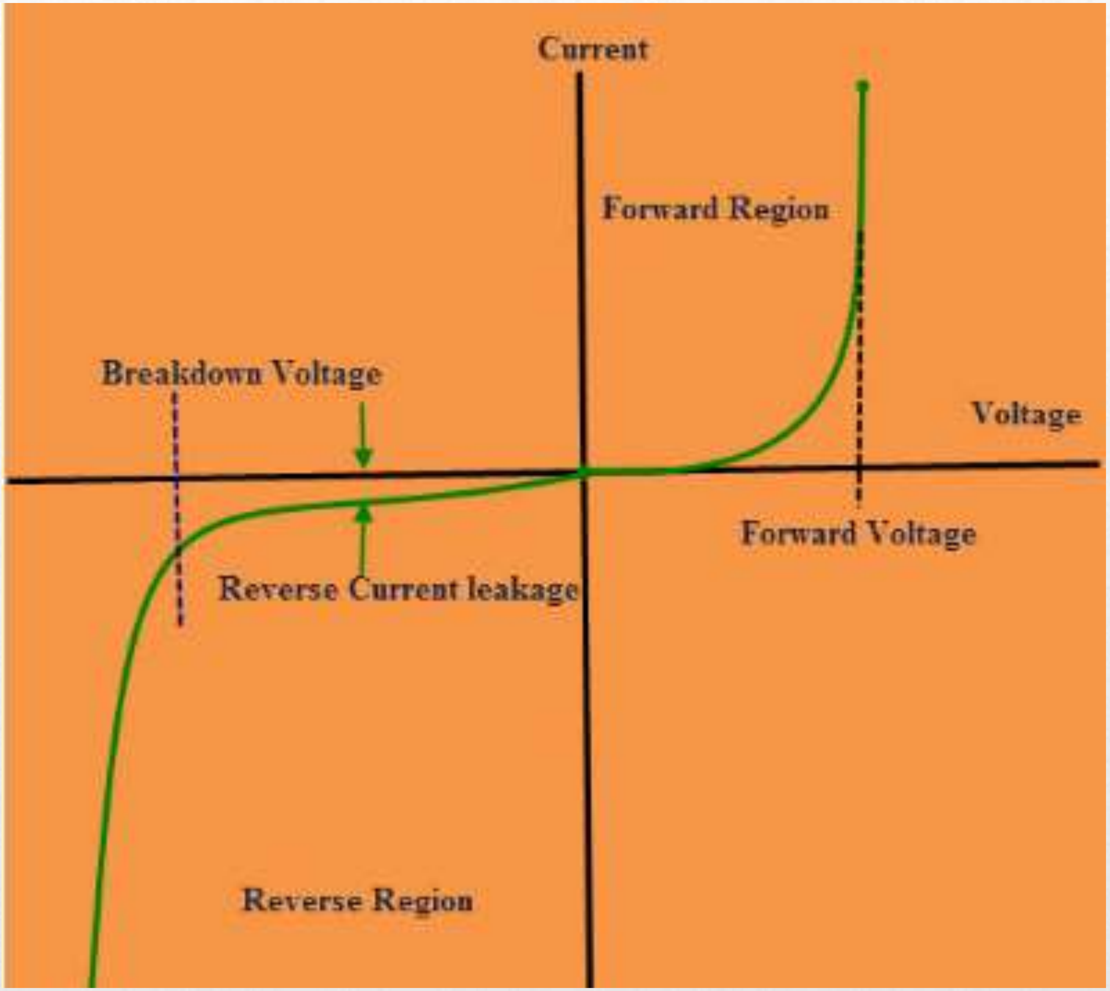


Reverse bias characteristics



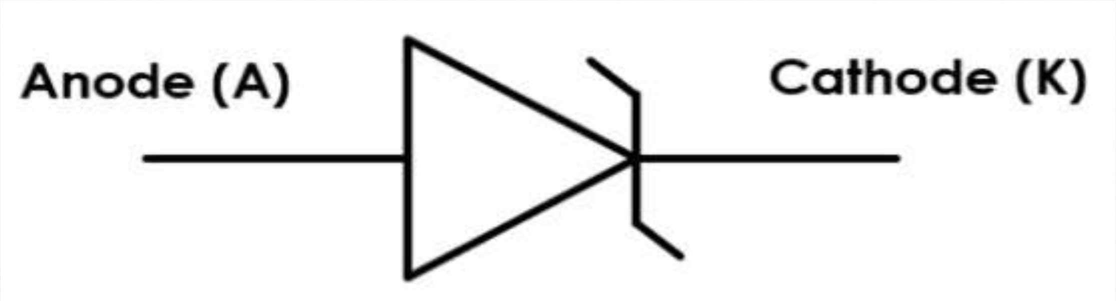


V-I characteristics of P-N Diode

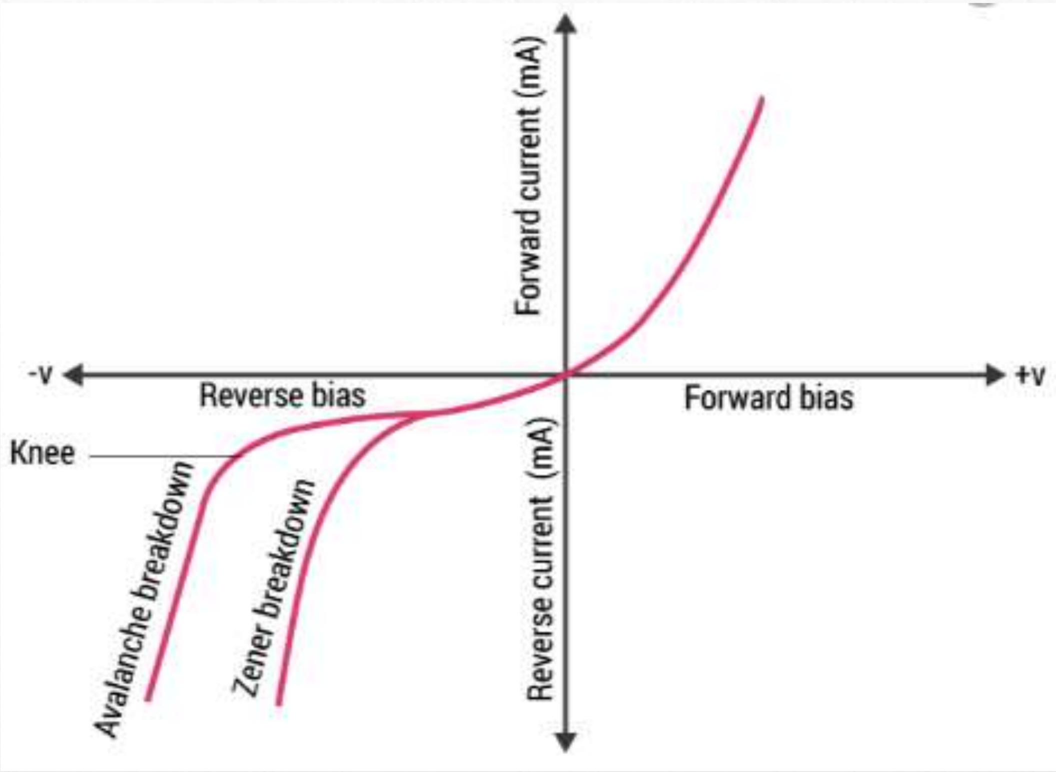


Zener diode

A property doped with adequate power dissipation capabilities to operate in breakdown region is known as zener diode.

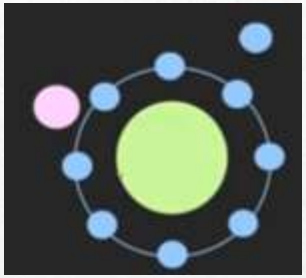


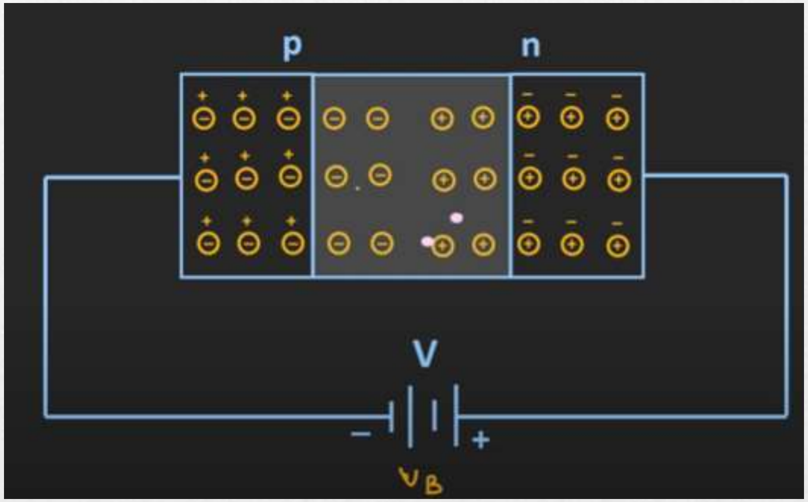
V-I characteristics of zener diode

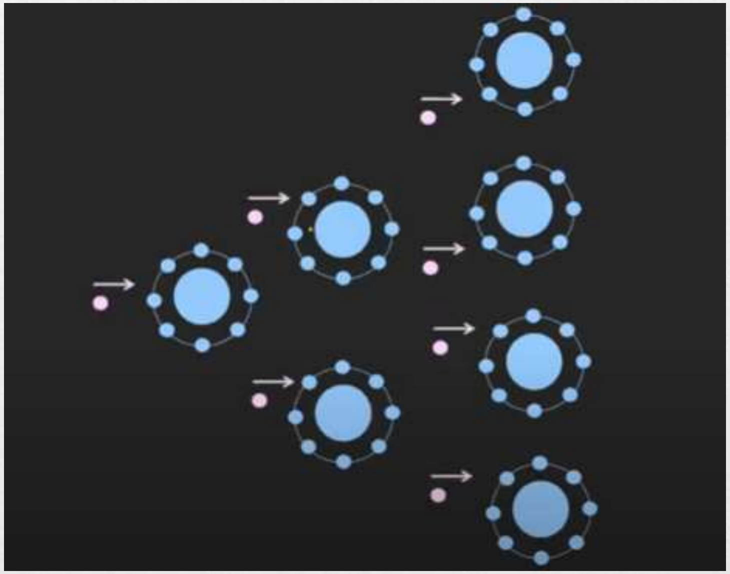


Zener Breakdown: Due to heavily doped, the depletion layer is narrow and Higher electric field is generated. So in reverse biased minority carrier moves and large amount of current is produced.

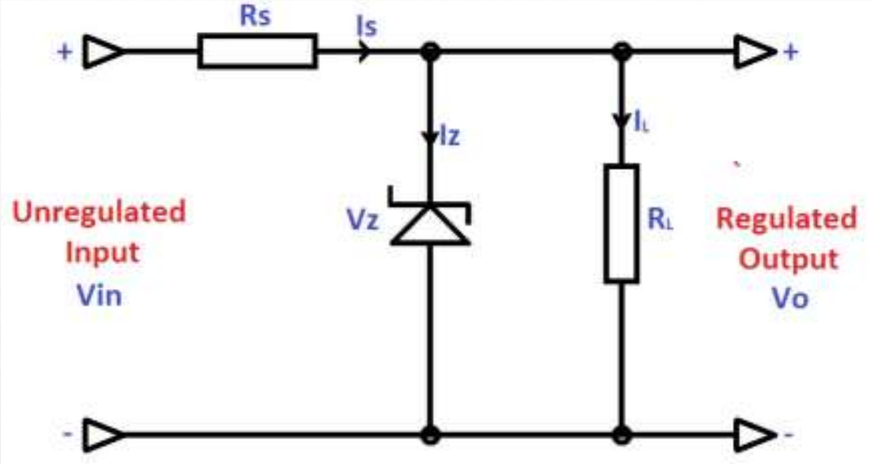
<u>Avalanche Breakdown effect:</u> When an external voltage is applied it accelerates the minority carriers in the depletion region.
When these carriers attain sufficient kinetic energy they disrupt the covalent bond and create new electrons by Collision.

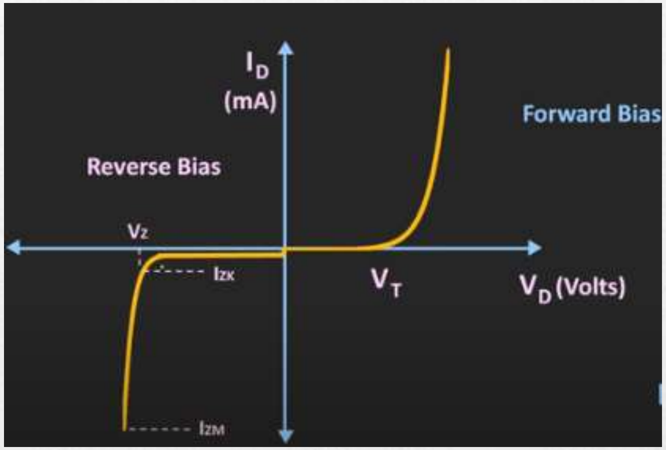






Zener Diode as a stabilizer: Zener diode can be used as constant voltage Source particularly when there is a change in load voltage or load current





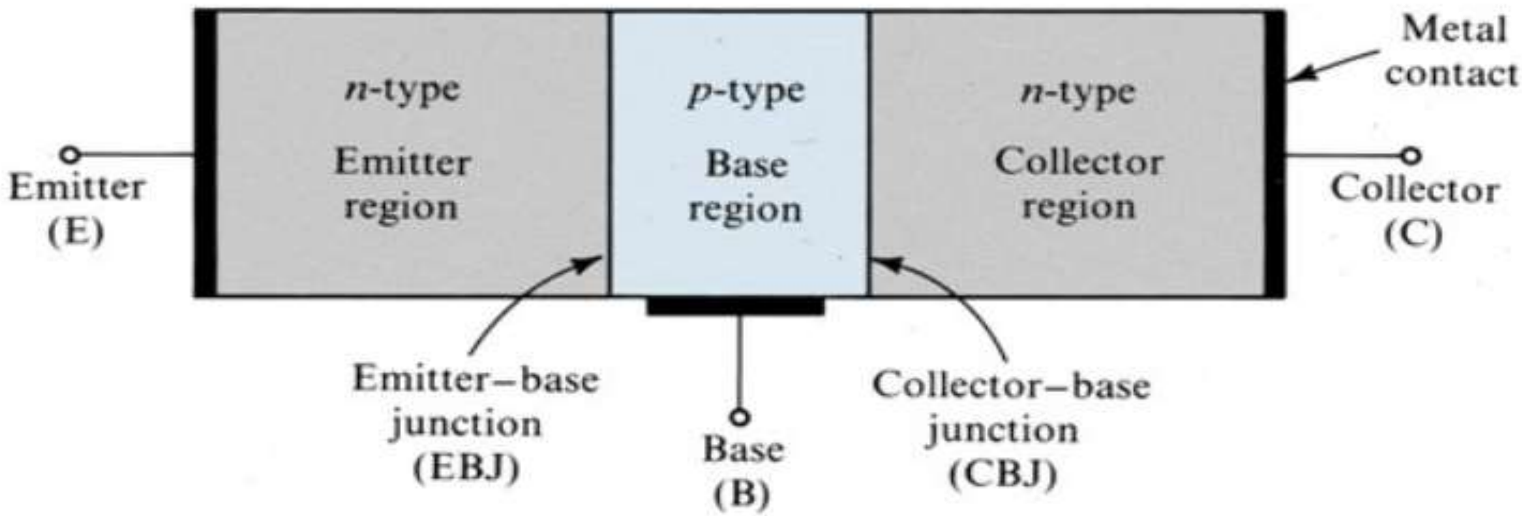
Applications of zener diode:

1. As a voltage regulating element in voltage regulator
2. In zener limiters
3. Clipping circuits: which are used to clip off the unwanted portion of the voltage waveform
4. Various protection circuits

Transistors

A ***transistor*** *is a semiconductor device used to amplify and* switch electronic *signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals changes the current flowing through another pair of terminals., a transistor can amplify a signal. found embedded in integrated circuits.*

The Bipolar Junction Transistor (BJT)



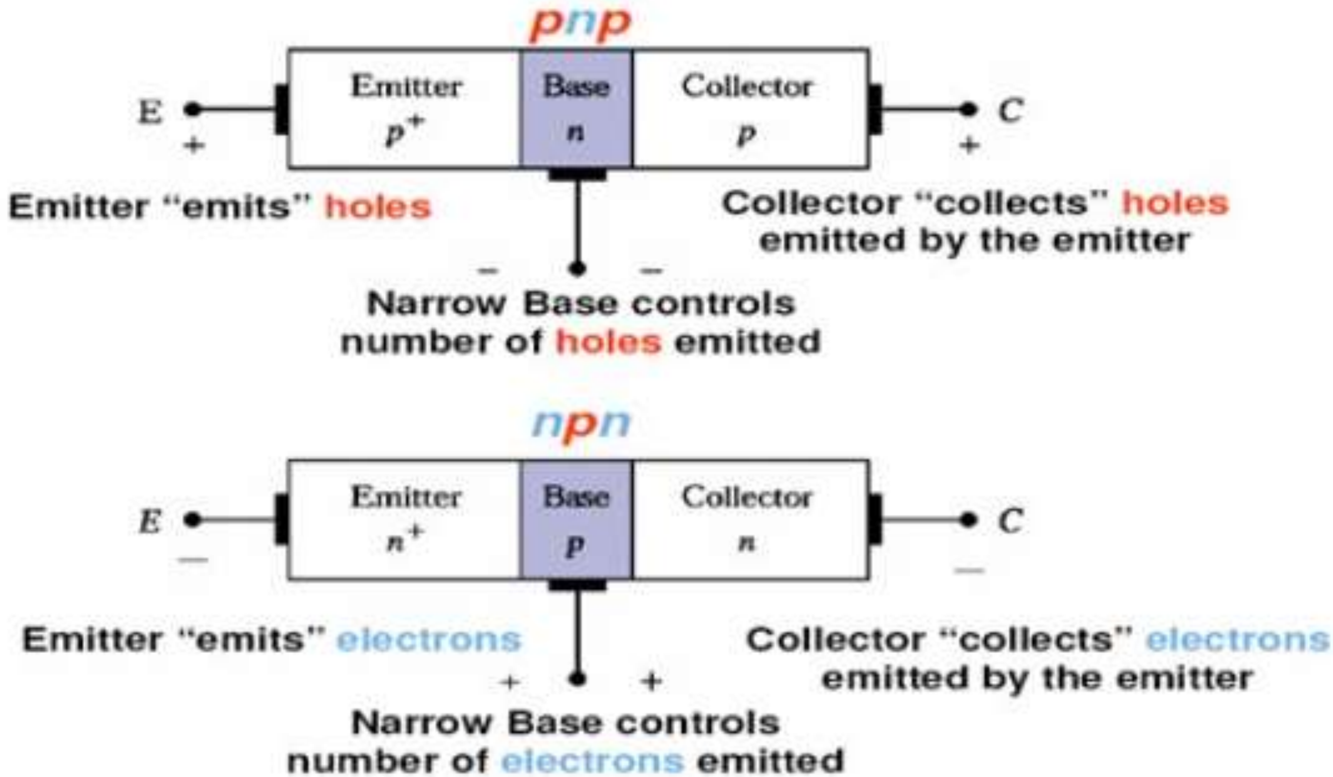
- **Bipolar** : both electrons and holes are involved in current flow.
- **Junction** : has two *p-n* junctions.
- **Transistor** : Transfer + Resistor.
- It can be either ***n-p-n*** type or ***p-n-p*** type.
- Has three regions with three terminals labeled as

i. Emitter (E)

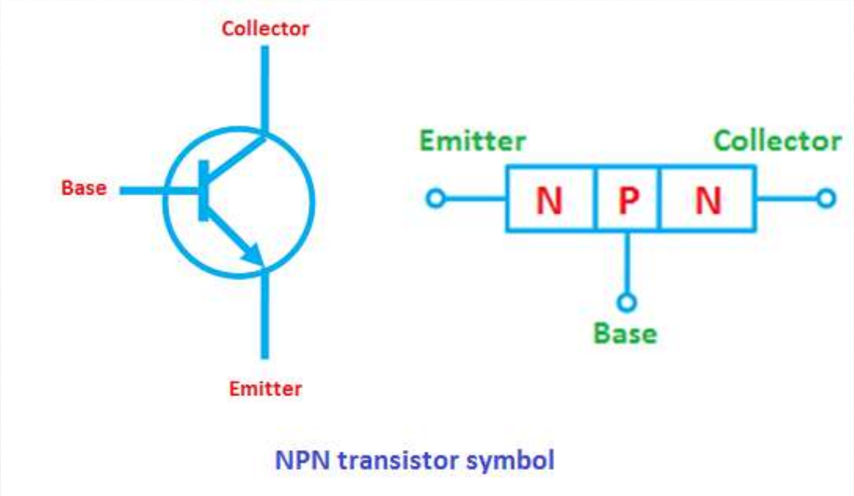
ii. Base (B) and

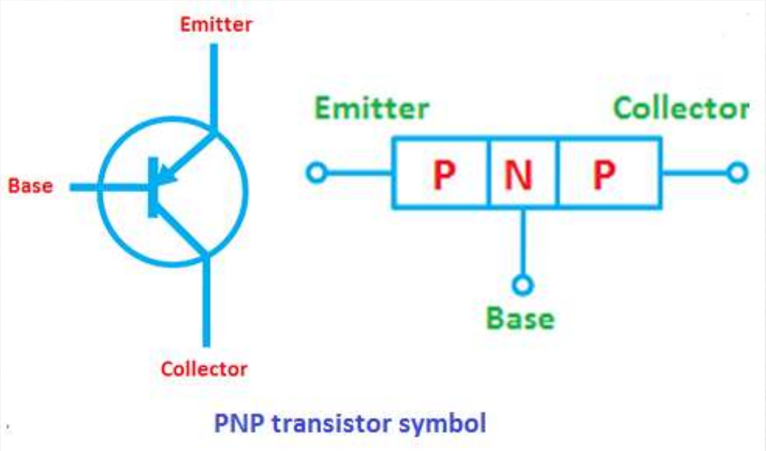
iii. Collector (C)

- **Base** is made much narrow.
- **Emitter** is heavily doped (p^+, n^+).
- **Base** is lightly doped (p^-, n^-).
- **Collector** is lightly doped (p, n).

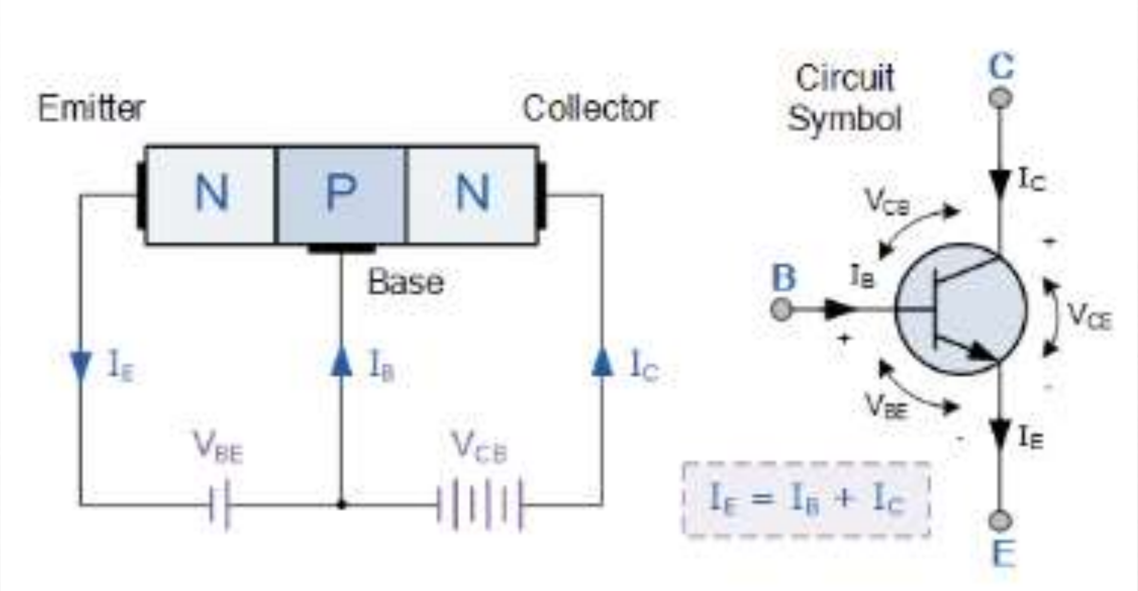


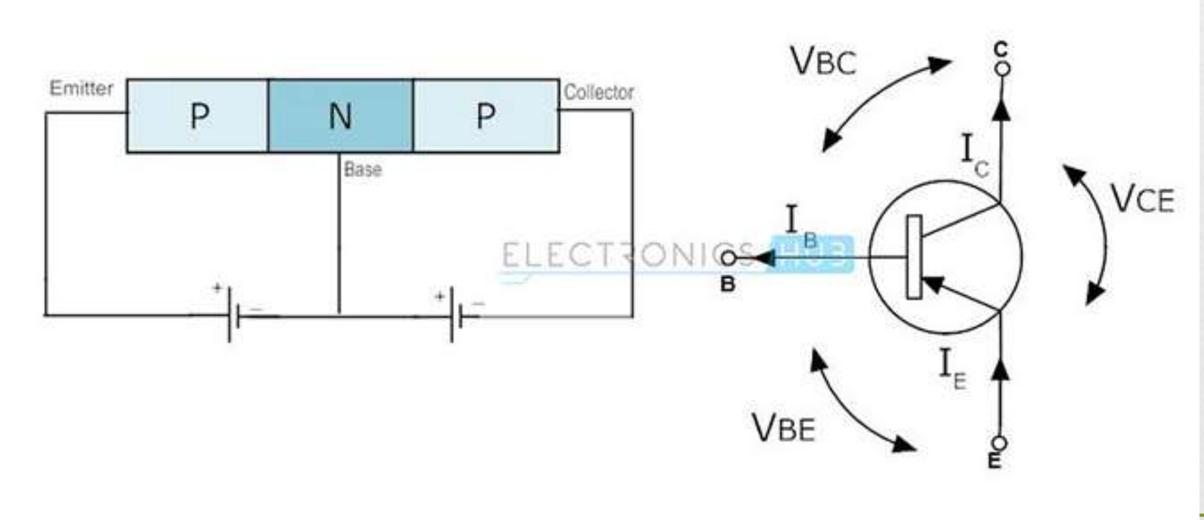
BIPOLAR JUNCTION TRANSISTOR





Operation of Transistor

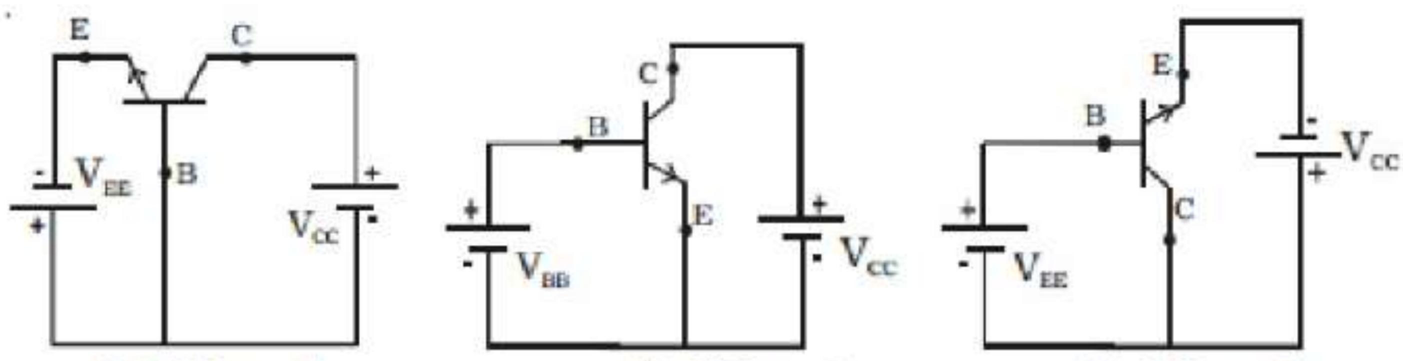




Configurations

Depending on the terminal connected common to both input and output, the Transistor configuration can be classified into three types

i. Common Emitter Configuration
ii. Common Base Configuration
iii. Common Collector Configuration



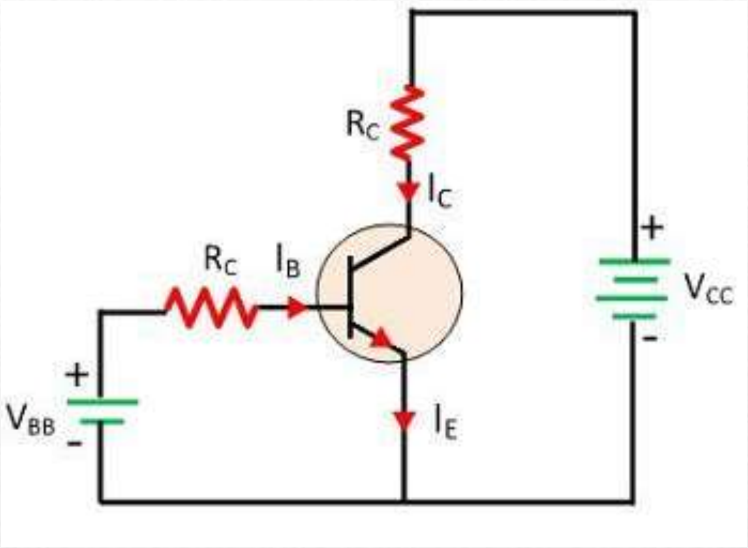
(a) CB mode (b) CE mode (c) CC mode

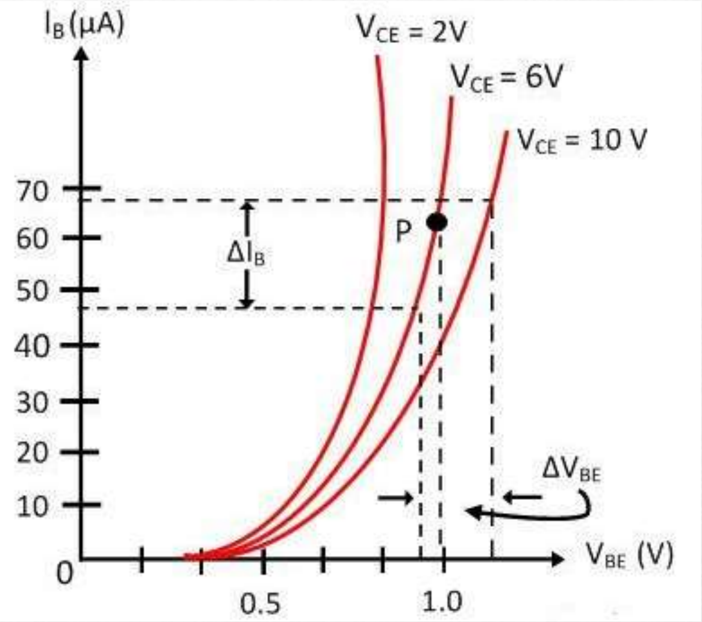
Modes of Operation

- Based on the bias voltages applied at the two p-n junctions, transistors can operate in three modes:
  1. **Cut-off** (both EB and CB junctions are reversed biased)
  2. **Saturation** (both EB and CB junctions are forward biased)
  3. **Active mode** (EBJ is forward biased and CBJ is reversed biased)
- Cut-off and Saturation modes are used in switching operation.
- Active mode is used in amplification purposes.

Transistor Characteristics

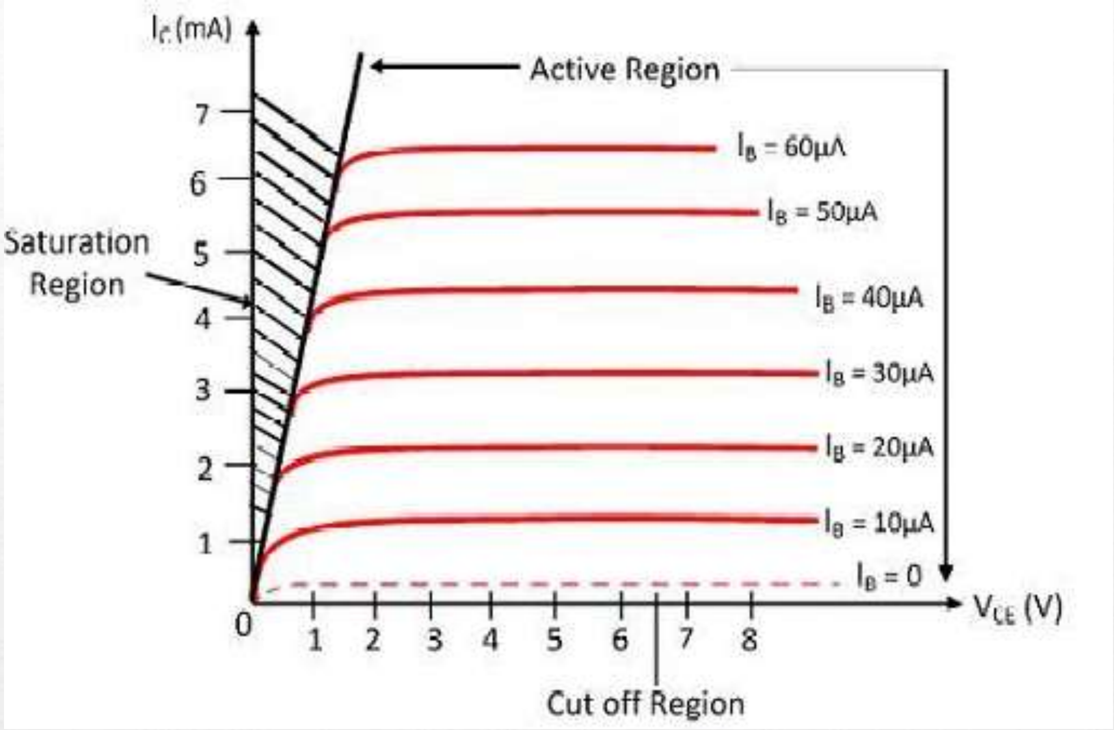
Input Characteristics





$$V_{CE} = V_{CB} + V_{BE}$$
$$V_{CE} \uparrow \; V_{CB} \uparrow$$
$$V_{CB} : Reverse\ biased\ so\ depletion\ region\ \uparrow I_B \downarrow$$

Output Characteristics



Active Region: i/p Forward biased and o/p Reverse biased
Saturation Region: Both are forward biased
Cut off region: Both are reverse biased

Parameters of transistor

1. Input resistance (r_i)

In CE configuration, after the cut in voltage base current increases rapidly with small increase in base emitter voltage. It is the ratio of change in base emitter voltage to the resulting change in base current at constant collector emitter voltage .

$$r_i = \Delta V_{BE} \; / \; \Delta I_B$$

2. Output resistance (r_o)

In CE configuration, from the output characteristics we can see that change in collector – emitter voltage causes the little change in collector current for constant base current.

$$r_o = \Delta V_{CE} \;/\; \Delta I_C$$

3. Current amplification factor (α)

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

$$I_C = \alpha I_E$$

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

Current amplification factor (β)

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

$$I_E = I_C + I_B$$

$$I_C = \alpha(I_C + I_B) + I_{CBO}$$

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$$

$$I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$$

Assume $\beta = \dfrac{\alpha}{1-\alpha}$ $1+\beta = \dfrac{1}{1-\alpha}$

$$I_C=\beta\, I_B+(1+\beta)\, I_{CBO}$$

The term $(1+\beta)\, I_{CBO}$ is the reverse leakage current in CE configuration. It is designated as I_{CEO}

$$I_B \ll I_C$$

$$I_{CEO} = (1+\beta)\, I_{CBO}$$

$$I_C = \beta I_B + I_{CEO}$$

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

Relation between ‘α’ and ‘β’

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

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

$$I_E = I_C + I_B$$

$$I_B = I_E - I_C$$

$$\beta = \frac{I_C}{I_E - I_C}$$

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

Divide RHS and LHS by 1+β

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

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

Substitute β in RHS we get

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

Advantages of Transistor:
1. Longer life
2. Low power consumption
3. Higher efficiency
4. Smaller in size
5. Light in weight

Applications:
1. Used as switches
2. Used in amplifiers to enhance weak signals
3. Used in oscillator circuits

Field Effect Transistor (FET)

- FET is a three terminal semiconductor device.

- It is unipolar transistor i.e. depends only on one type of charge carrier, either electron or hole.

- The current is controlled by the applied electric field hence, it is a voltage controlled device

- FET is simple to fabricate and occupies less space on a chip than a BJT. About 100000 FETs can be fabricated in a single chip. This makes them useful in VLSI (very large scale integrate) system.

Types of FET

1. JFET – (i) N – channel JFET

   (ii) P – channel JFET

2. MOSFET – (i) Enhancement MOSFET

   (ii) Depletion MOSFET

•FET consists of three terminals:

Source (S) : Majority carriers enter the bar

Drain (D) : Majority carriers leave the bar.

Gate (G) :Heavily doped controlling terminal

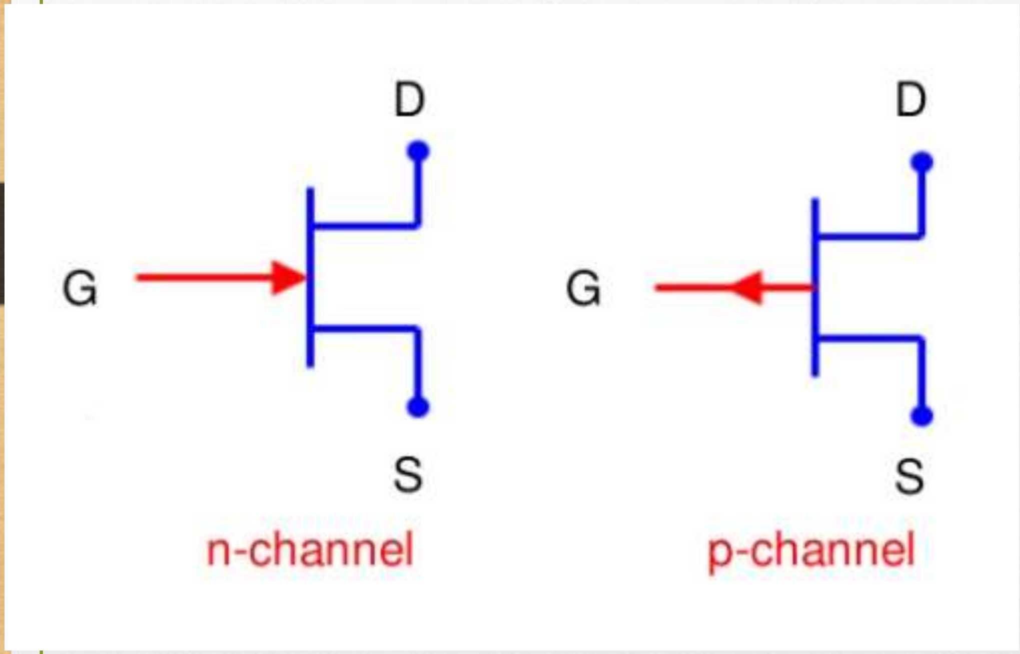
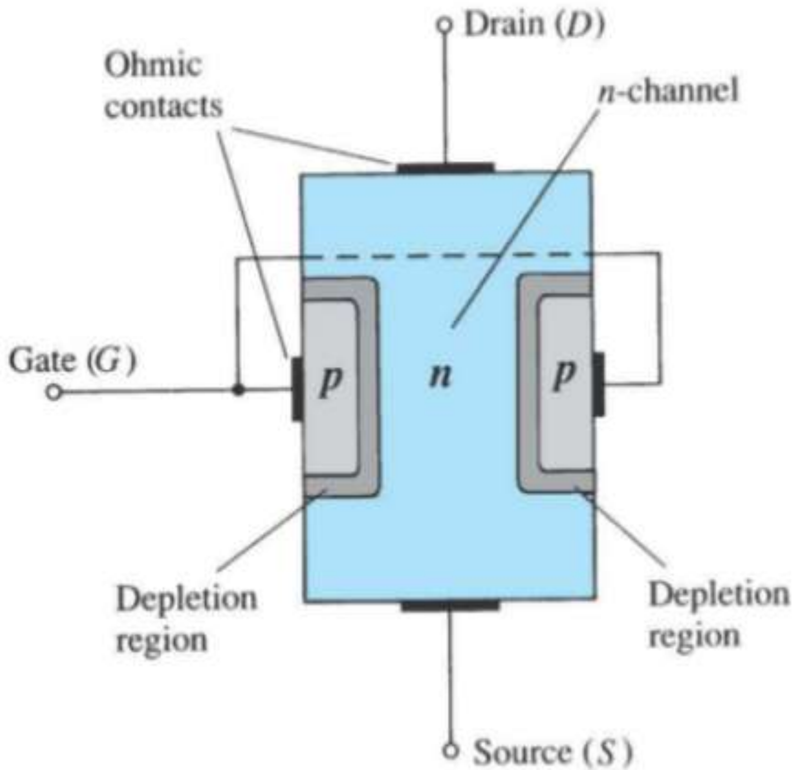
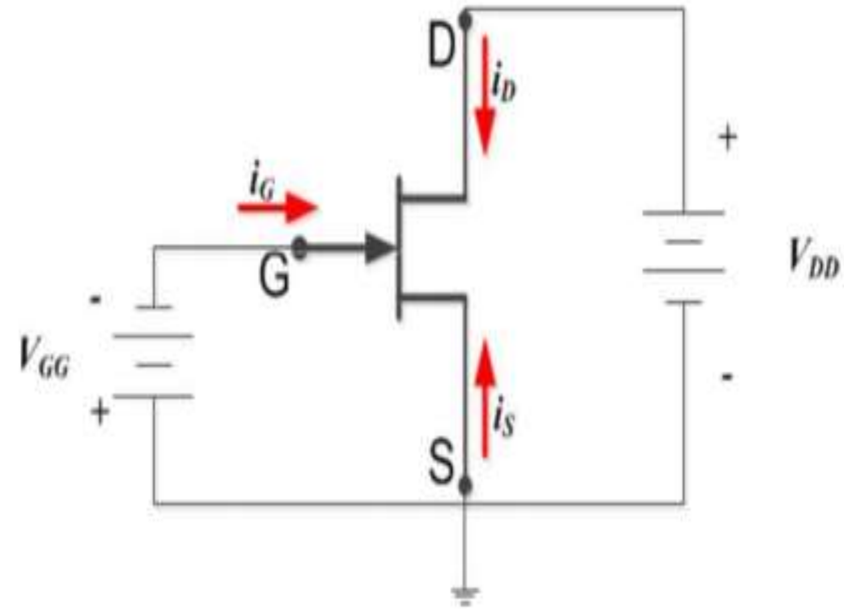


Fig.1.Symbols of N channel and P channel JFET

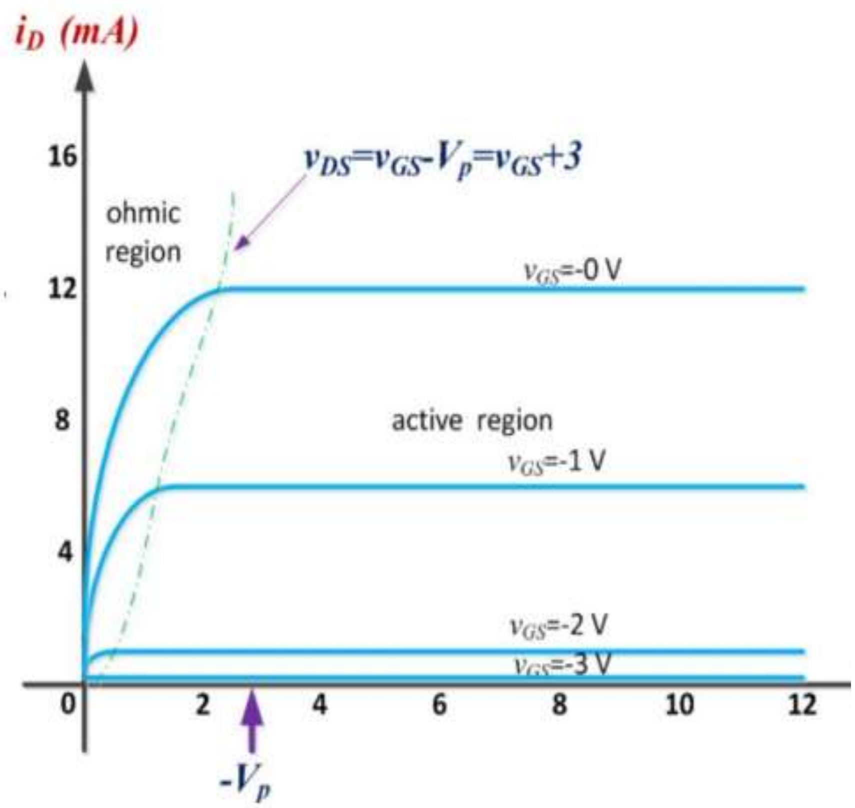
Fig.2.Operation of FET

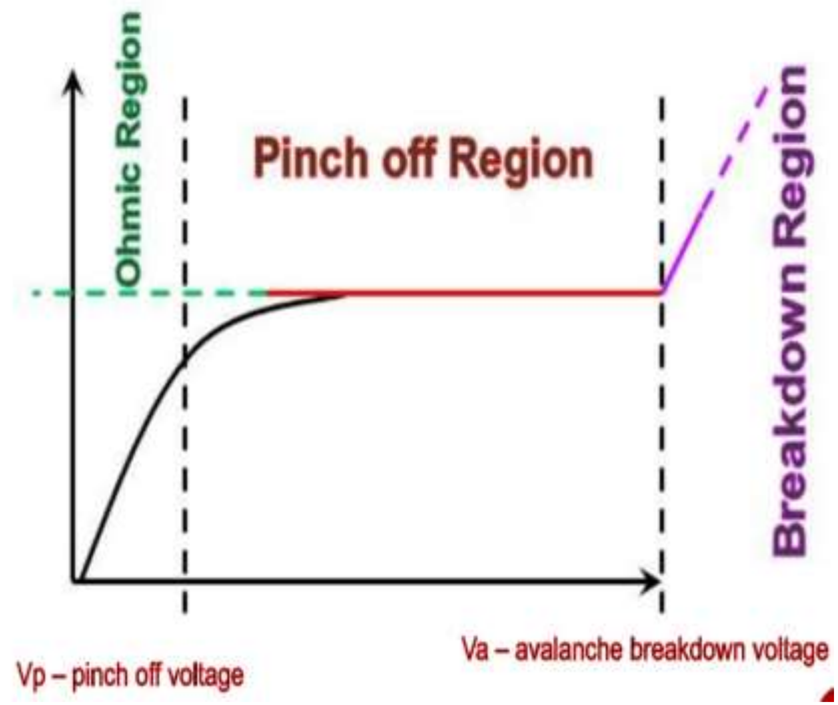
Working Principle of N – channel JFET





Drain Characteristics of JFET

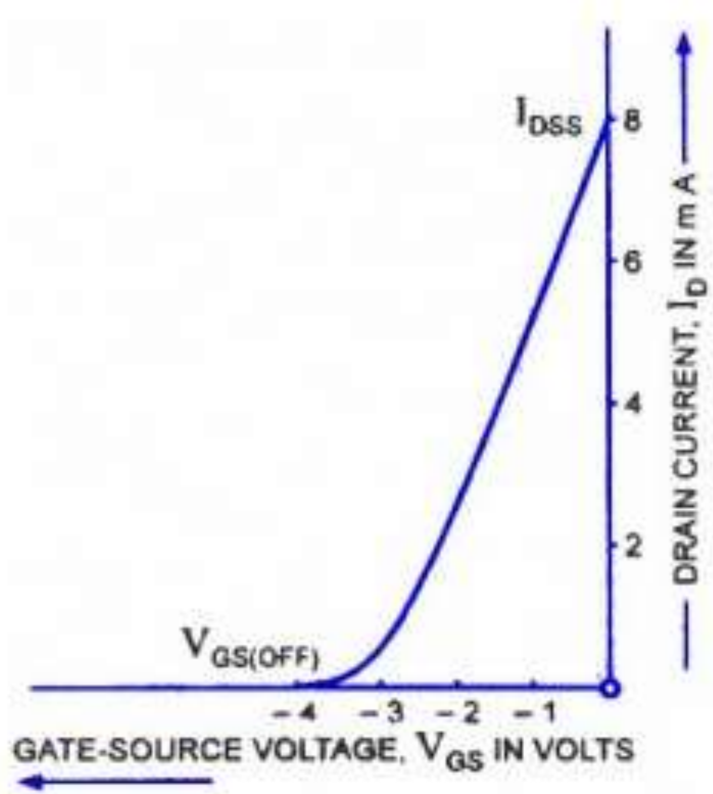




Regions of JFET action

1. Ohmic Region – linear region
   - JFET behaves like an ordinary resistor
2. Pinch Off Region
   - Saturation or Amplifier Region
   - JFET operates as a constant current device because Id is relatively independent of Vds
   - Idss – drain current with gate shorted to source.
3. Breakdown Region
   - If Vds is increased beyond its value corresponding to Va – avalanche breakdown voltage.
   - JFET enters the breakdown region where Id increases to an excessive value.

Transfer Characteristics of JFET



$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$V_{GS} = V_P\left[1 - \sqrt{\frac{I_D}{I_{DSS}}}\,\right]$$

Important Parameters of JFET

Transconductance (gm) :

It is the ratio of change in drain current to the change in gate source voltage at constant drain source voltage.

$$g_m = (\Delta I_D / \Delta V_{GS}) \quad V_{DS} \text{ constant}$$

Output resistance (rd):

It is the ratio of change in AC drain source voltage to the change in AC drain current at constant gate source voltage

$$r_d = (\Delta V_{DS} / \Delta I_D) \quad V_{GS} \text{ constant}$$

Amplification factor(μ):

It is the change in the AC drain-voltage

$$\mu = (\Delta V_{DS} / \Delta V_{GS}) \quad I_D \text{ constant}$$

2.3 Comparison Between FET and BJT

FET	BJT
i) Carriers of only one type i.e either electron or hole (majority carrier) are responsible for the conduction.	i) Carriers- electron and hole (majority and minority carrier)-involved in current conduction
ii) It is the drift mechanism that helps the movement of carriers	ii) The carriers are transported by the process of diffusion.
iii) More stable than BJT.	iii) Less stable than FET
iv) The FET is voltage controlled device or voltage amplifier.	iv) It is current controlled device or current amplifier
v) Input impedance offered much higher than BJT	v) Input impedance offered is Less
vi) Easy to fabricate and required less space and hence all the ICs use as their basic technology and preferred VLSI design.	vi) Not easy as compared to FET.
vii) Less noisy compared to BJT thats way extensively used in communication devices.	vii) Required more space than FET.
viii) Offers high power gain compared to BJT	vii) More noisy than FET.

Advantages of FET

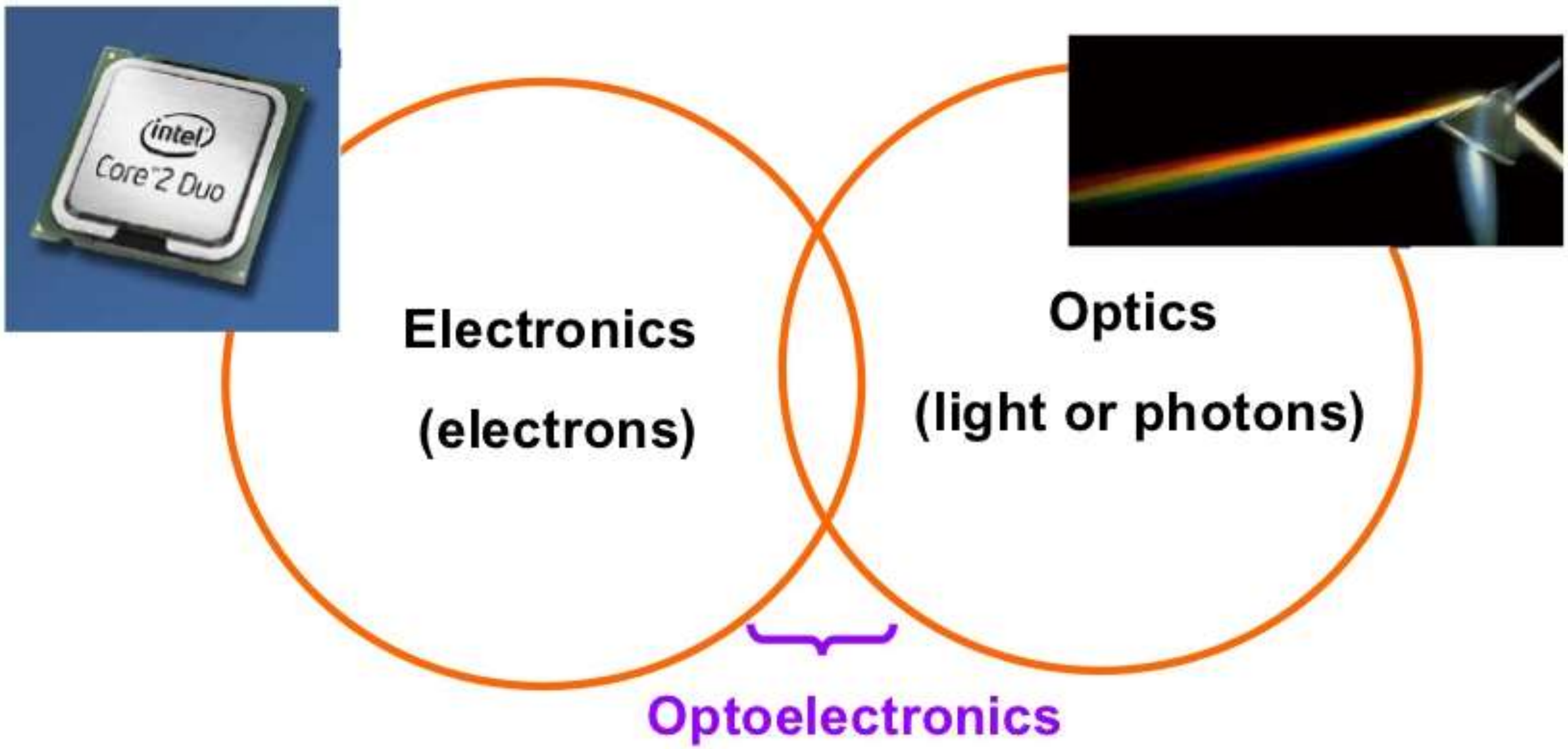
- It has very high input impedance
- The operation is noiseless
- There is no risk due to thermal runaway
- Longer life
- High power gain
- Small size
- High efficiency

Applications of FET

- Buffer amplifiers
- Phase shift oscillators

Optoelectronic devices

Optoelectronics is the study and application of electronic devices that interact with light



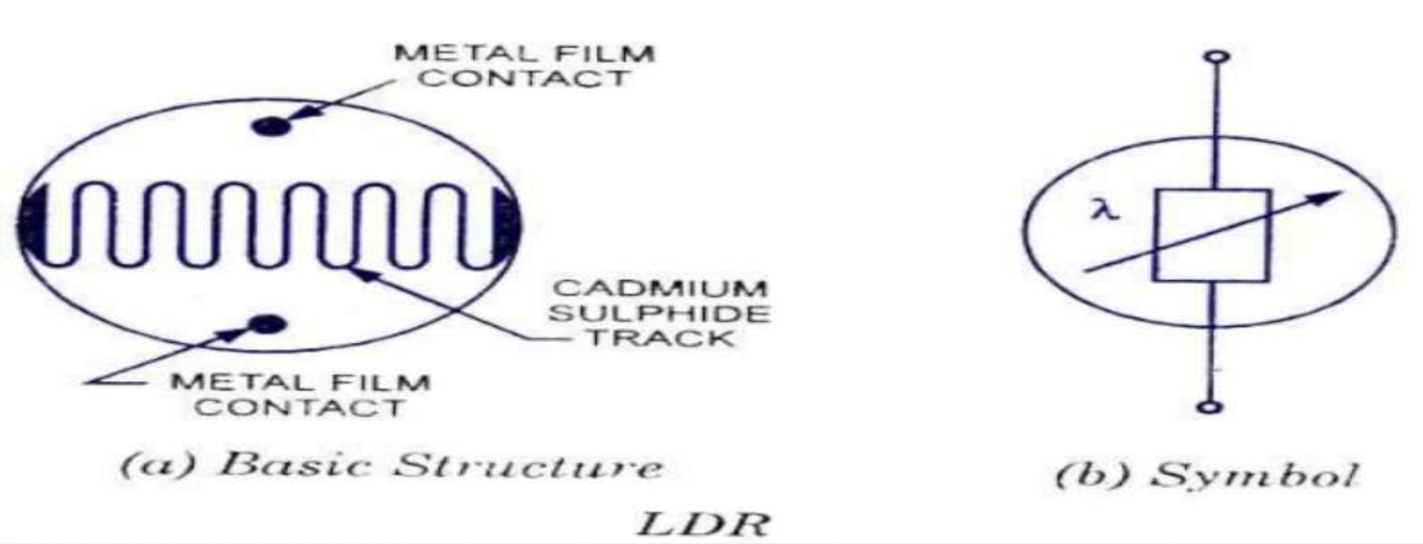
Major optoelectronic devices

- LDR (Light Dependent Resistor)
- Photo diode
- Photo transistor
- solar cell
- Photo couplers

LDR (Light Dependent Resistor)

- A light dependent resistor (LDR) or a photo resistor or photocell is a light controlled variable resistor . Its resistance changes with Light intensity that falls on it.

- The resistance of a photo resistor decreases with increasing Incident light intensity . In other words , it exhibits photoconductivity.



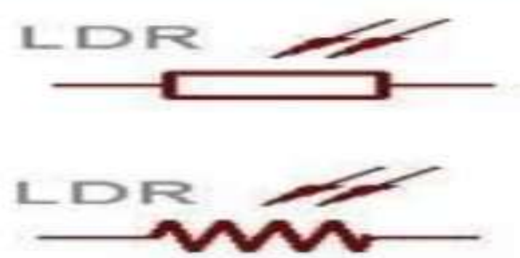
WORKING OF LDR

- A LDR works on the principle of photoconductivity.

- Photo conductivity is an optical phenomenon in which the materials Conductivity reduces when light is absorbed by the materials.

- When light falls i.e, when the photons fall on the devices , the electrons in the valence band of the semiconductor material are excited to the conduction band.

- These photons in the incident light should have energy greater than the band gap of the semiconductor material to make the electron jump from the valence band to the conduction band.



ADVANTAGES:

- LDRs are cheap are readily available in many sizes and shapes.
- Practical LDRs are available in a variety of sizes and packages styles , the most popular size having a face diameter of roughly 10 mm.
- They needs very small power and voltage for its operation.

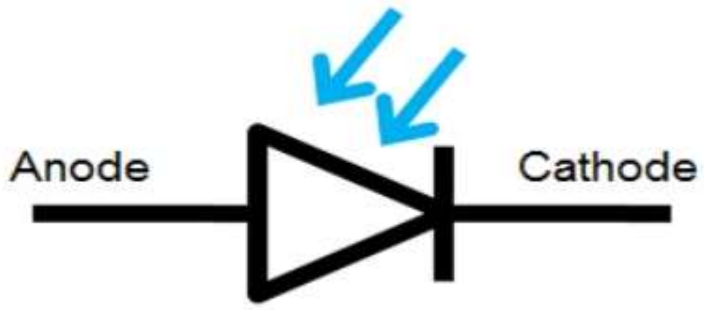
DISADVANTAGES:

- Highly inaccurate with a response time of about tens or hundreds of milliseconds.

Photo Diode

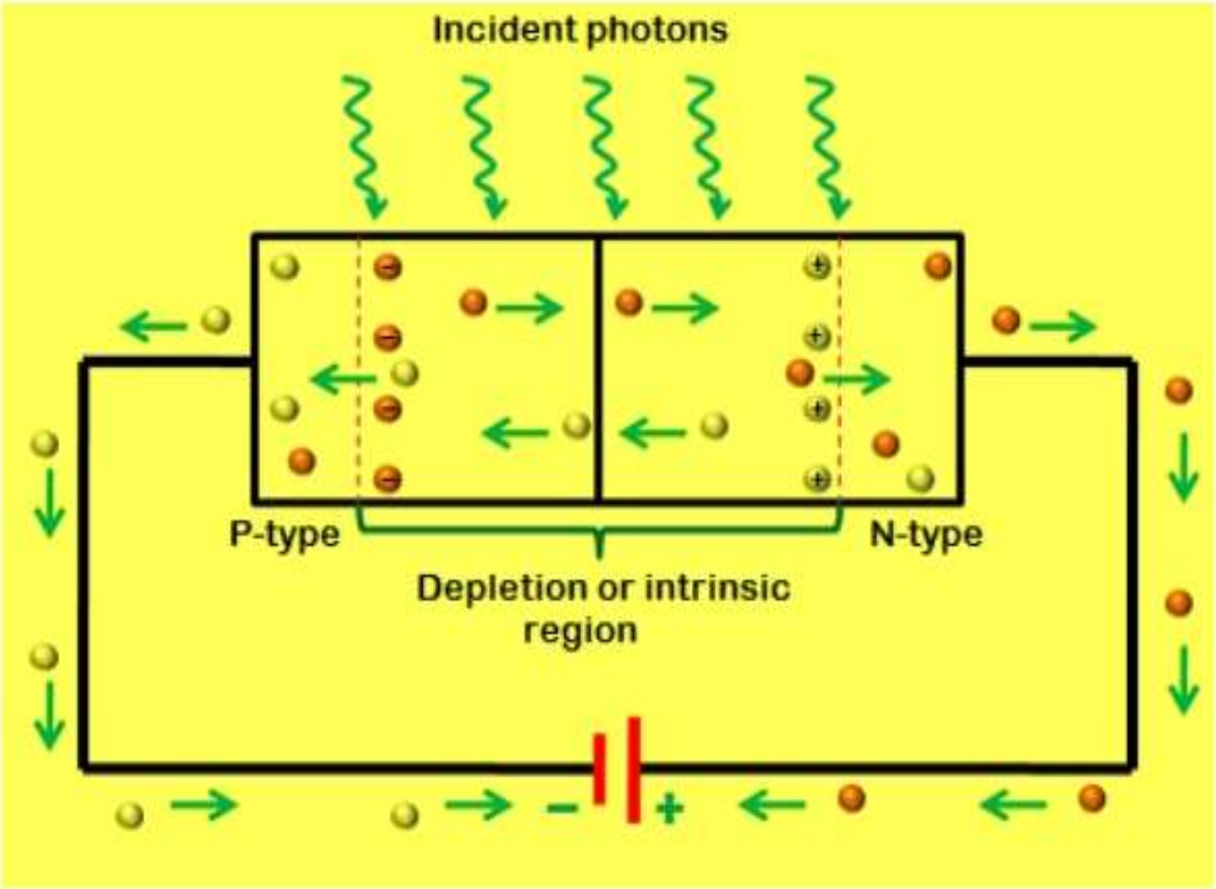
- A photodiode is a PN-junction diode that consumes light energy to produce electric current. Sometimes it is also called as photo-detector, a light detector, and photo-sensor. These diodes are particularly designed to work in reverse bias condition, it means that the P-side of the photodiode is associated with the negative terminal of the battery and n-side is connected to the positive terminal of the battery.

- A photodiode is one type of light detector, used to convert the light into current or voltage based on the mode of operation of the device.



Photodiode symbol

Working of Photodiode



Modes of operation

The operating modes of photodiode include three modes, namely

- Photovoltaic mode
- Photoconductive mode
- Avalanche diode mode

Applications of Photodiode

- The applications of photodiodes involve in similar applications of photodetectors like charge-coupled devices, photoconductors, and photomultiplier tubes.

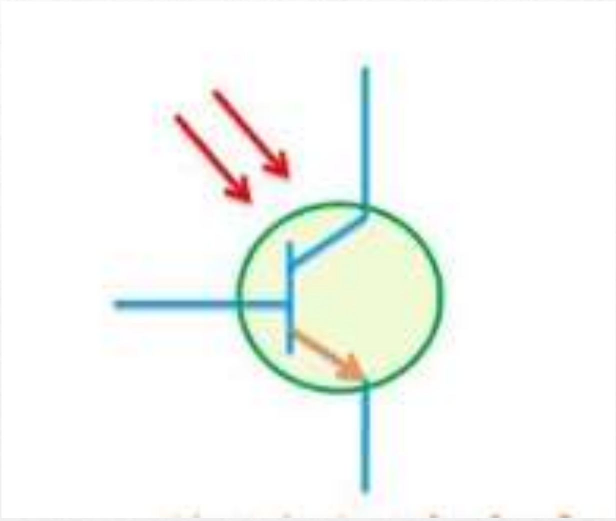
- These diodes are used in consumer electronics devices like smoke detectors, compact disc players, televisions and remote controls in VCRs.

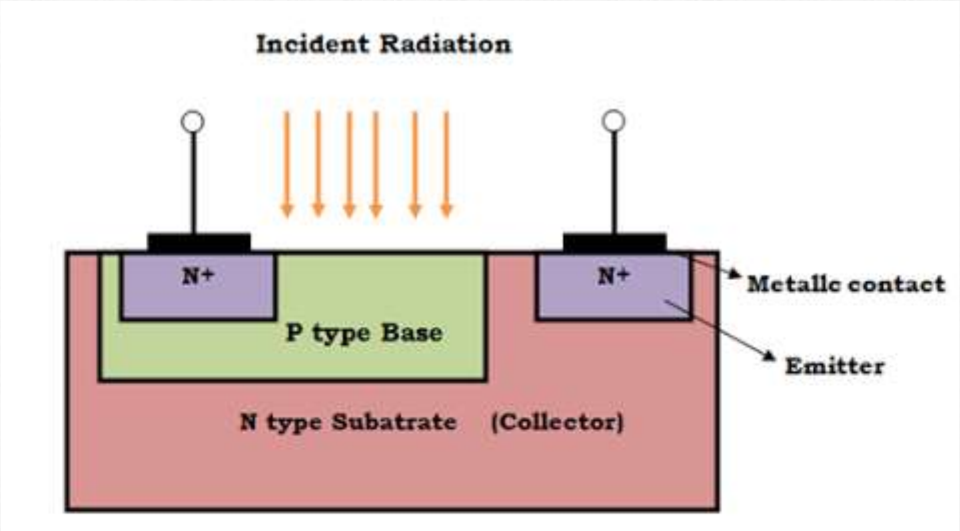
- It uses in consumer devices like clock radios, camera light meters, and street lights.

Photo Transistor

- The phototransistor is a transistor in which base current is produced when light strikes the photosensitive semiconductor base region.
- The collector-base P-N junction is exposed to incident light through a lens opening in the transistor package.
- When there is no incident light, there is only a small thermally generated collector-to-emitter leakage current i.e. $I_{(CEO)}$, this is called the dark current and is typically in the nA range.

Symbol of Phototransistor





$$\mathbf{I_C = (1 + \beta)I_{CO} + (1 + \beta)I_L}$$

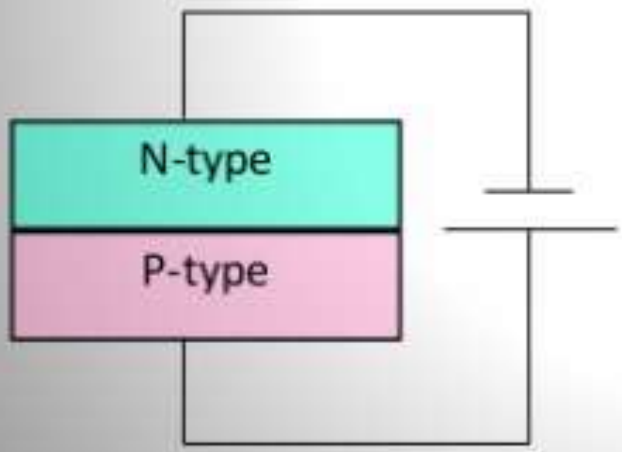
Solar cell

- Solar cell is the photovoltaic device that convert the light energy (which come from sun) into electrical energy .
- this device work on the principle of photovoltaic effect.
- ***Photovoltaic Device:-*** The generation of voltage across the PN junction in a semiconductor due to the absorption of light radiation is called photovoltaic effect. The Devices based on this effect is called photovoltaic device.

Principle of Solar Cell

The solar cells are based on the principles of photovoltaic effect. The ***Photovoltaic Effect*** is the photogeneration of charge carriers in a light absorbing materials as a result of absorption of light radiation.

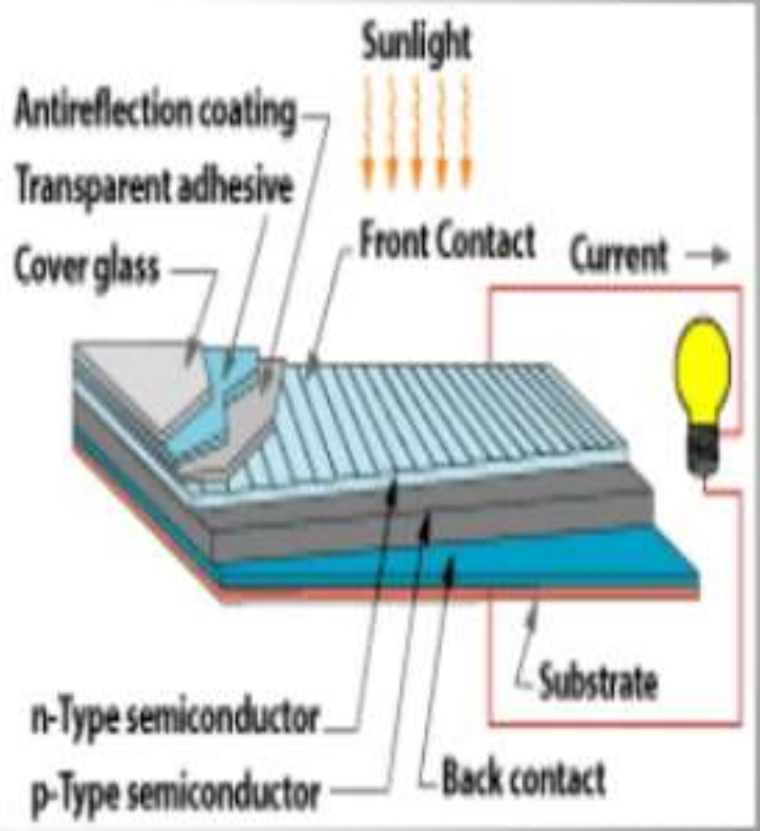
Single Solar cell



Working of solar cell

Working

- When a solar panel exposed to sunlight , the light energies are absorbed by a semiconductor materials.
- Due to this absorbed energy, the electrons are liberated and produce the external DC current.
- The DC current is converted into 240-volt AC current using an inverter for different applications.



Applications of solar energy

- Domestic power supply.
- Electric power generation in space.
- Drying Agricultural Products.
- Solar pumps are used for water supply.
- Water Heating.
- Generating Electrical Power.
- To providing electrical power to satellites.

photo couplers

- An opto-coupler also called as opto-isolator or photolaser is a passive component that can split or combine transmission data (optical power) feom optical fiber.
- It is an electronic device which is designed to transfer electrical signals by using light waves in order to provide coupling with electrical isolations between the input and output.