Unit-2 Diodes & their Applications

❖ **Syllabus :**

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– II Diodes and Their Applications	2a. Explain with sketches working of the given diode using V-I characteristics. 2b. Measure zener voltage on the given V-I characteristics of the zener diode. 2c. Describe with sketches the working principle of given type of filter. 2d. Compare the salient features of the given type of rectifiers.	2.1 Symbol, construction and working principle of P-N junction diode 2.2 Rectifiers:Half wave, Full wave and Bridge Rectifier,working principle , circuit diagram, performance parameters PIV, ripple factor,efficiency, Need for filters: circuit diagram and working of 'L', 'C' and 'π" filter. 2.3 Zener diode working principle, symbole, as voltage regulator 2.4 Symbol, construction and working principle of light emitting diode(LED) 2.5 Working principle and block diagram of regulated power supply.

❖ **<u>Introduction :</u>**

Semiconductors: are the devices which act as an insulator at room temperature but show conductivity when the temperature increases. Eg: silicon, germanium.
Two types of semiconductors :

- **Intrinsic (pure form)**
- **Extrinsic (with impurities : doping)**

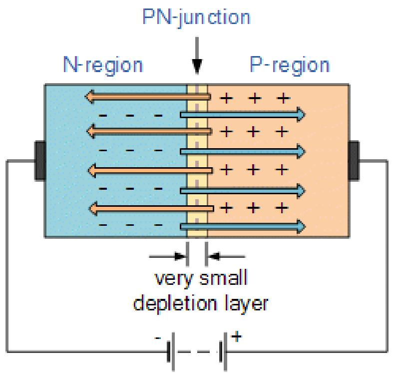
***doping: the process of adding impurities is called doping.**
Impurities: trivalent (3) & pentavalent (5)
Extrinsic semiconductors are of two types :

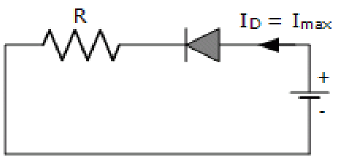
- **P-type (trivalent impurities)**
- **N-type (pentavalent impurities)**

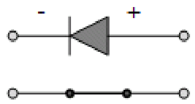
N-type : can be formed by the addition of pentavalent impurities, electrons (e-) are the majority charge carriers in N-type semiconductors. [holes (+) are the minority charge carriers]
P-type : can be formed by the addition of trivalent impurities, holes (+) are the majority charge carriers in P-type semiconductors. [electrons (e-) are the minority charge carriers.

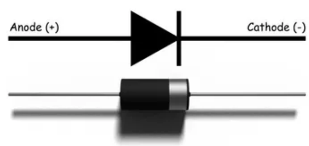
❖ **<u>P-N Junction Diode</u>**

- **Diode : is an electrical component that allows the flow of current in only one direction.**
- **The P-N junction forms most basic semiconductor device hence it is also called *semiconductor diode* or *rectifier diode.***
- **It is a unidirectional device.**
- **Definition : *When a P-type semiconductor is suitably joined to an N-type semiconductor under suitable condition by using special technique to form a junction, the contact surface is known as a P-N Junction Diode.***
- **Construction :**
  - ➔ **A P-N junction diode is formed by connecting P and N type semiconductors under suitable conditions using a special technique.**
  - ➔ **P-N junc. Diode consists of a P-N junc. Formed either of Germanium or Silicon.**
  - ➔ **It has two terminals anode (A) – P-region & cathode (K) – N-region.**









Working Principle.

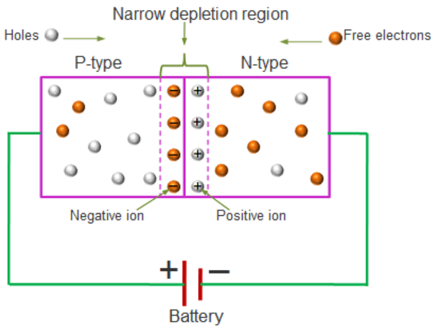
- **As soon as the P-N junction is formed, some of the holes which are near the junction from P-region diffuse to the N-region and combine with the free electrons.**
- **Similarly some of the free electrons near the junction, from the N-region diffuse to the P-region and combine with the holes.**
- **The diffusion takes place because the holes and the electrons move randomly due to thermal energy and also because difference in concentration's in the two regions, thus some holes and electrons diffuse towards each other across the junction and recombine.**
- **The additional holes which try to diffuse into the N-region are repelled by the positive charge of donor ions and the additional electrons which try to diffuse to the P-region are repelled by the negative charge of acceptor ions.**
- **The total recombination of holes and electrons does not occur and further diffusion of holes and electrons across the junction is stopped.**
- **The depletion layer formed contains positive charge on N-side and negative charge on P-side.**
- **As the depletion layer builds up, the space-charge across P-N junction increases and the potential difference builds up across P-N junction.**

❖ Barrier Potential

- **The electric field between the positive and the negative ions is called the barrier.**
- **The physical distance from one to the another is called the width of barrier.**
- ***The difference in potential from one side of the barrier to the other side is referred to as height barrier i.e barrier potential***

❖ Biasing of P-N Junction diode.

- **The external dc voltage applied to the semiconductor device is called a bias.**
- **A P-N junction connected to an external voltage source is known as biased P-N junction.**

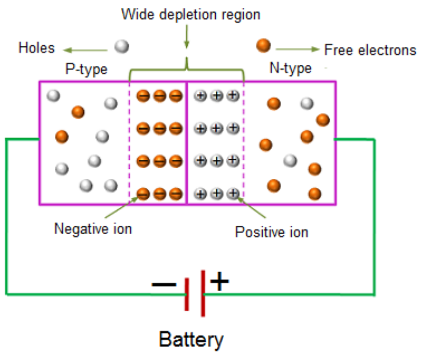


Forward bias

Forward Bias

(.) If we connect a battery to the P-N junction in such a way that the positive terminal of the battery is connected to the P-region and the negative terminal of the battery is connected to the N-region, then the biasing is called forward biasing.

(.) Majority charge carriers diffuse across the junction hence, large amount of current flows though the P-N junction when connected in forward-bias, this current is called forward current (I_F).



Reverse bias

Reverse Bias

(.) If we connect bettery to the P-N junction in such a way that the negative terminal of the battery is connected to the P-region and the positive terminal of the battery is connected to the N-region, then the biasing is called reverse biasing.

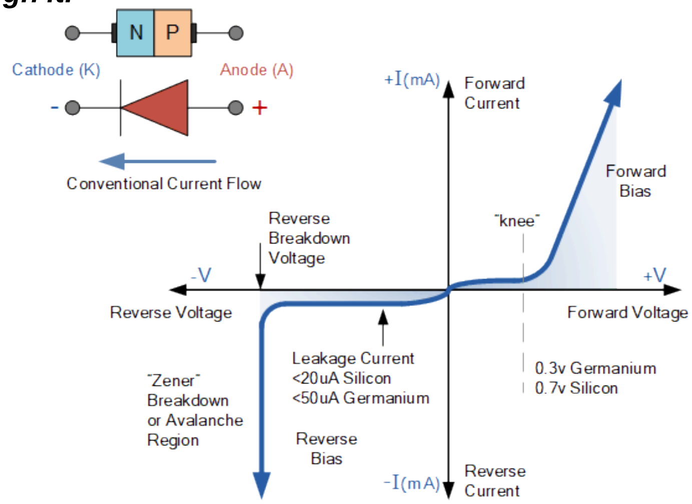
(.) There is no current due to majority charge carriers in reversed P-N junction.

(.) The current due to minority charge carriers remains constant, whether applied voltage is increased or decreased, this current is called reverse saturation current (I_o).

Specifications	Applications
➔ Maximum reverse voltage ➔ Maximum forward current. ➔ Reverse saturation current ➔ Forward voltage ➔ Power dissipation ➔ Cut in Voltage (knee voltage)	➔ Used as rectifier in DC supply ➔ Used as switch in logic circuits ➔ Used as voltage doubler, 3x, 4x in multiplier circuits ➔ Used for wave shaping in clamping circuits ➔ Used as detector in demodulation circuits of communication server.

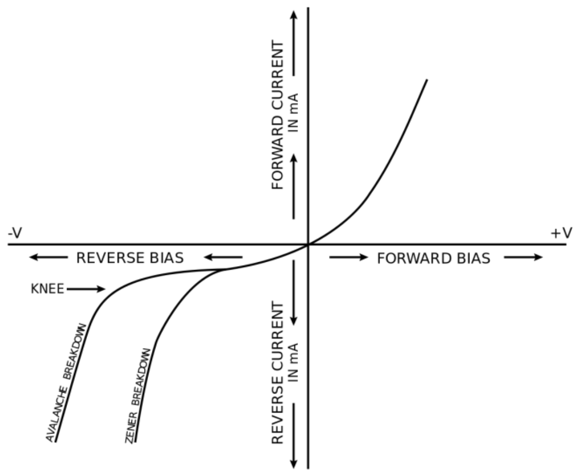
❖ V-I Characteristics of P-N Junction Diode

- ***The V-I characteristic is a graph between the voltage applied across the terminals of an semiconductor diode and the resulting current that flows through it.***



- **Forward characteristics**
  Observation : p-n junction conducts the current only after the cut-in (knee) voltage.
- **Reverse characteristics**
  Observation : in p-n junction flow of reverse current is very small till the break-down voltage V_{BR} is reached.

❖ Types of Breakdown



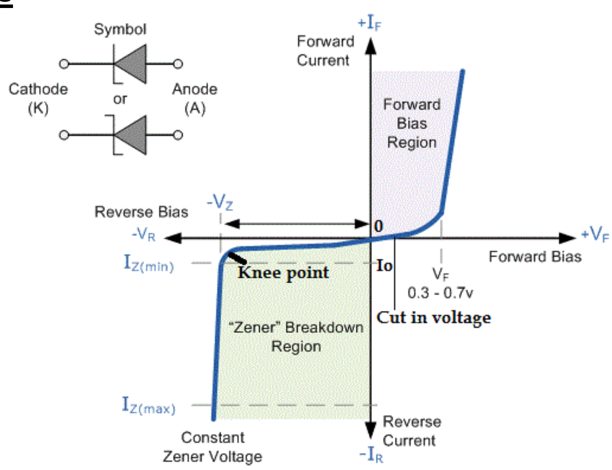
Zener Breakdown	Avalanche Breakdown
➔ It occurs in in the p-n junctions which are heavily doped. ➔ It occurs due to rupture of covalent bonds by strong electric field setup in depletion region by the reverse voltage.	➔ It occurs in junctions which are lightly doped and have wide depletion widths ➔ It occurs at higher reverse voltages when thermally generated electrons get enough energy to produce more electrons by collision.

❖ <u>Zener Diode</u>

- **Zener diodes are designed to operate in the breakdown region of a p-n junction without any damage.**
- ***A properly doped p-n junction diode, which has a sharp reverse breakdown, is known as Zener diode. It is also called a voltage reference, voltage regulator or breakdown diode.***
- ***Construction : similar to p-n junction; just doping concentration is high**

- **Working principle**
  - ➔ **When Zener diode is reverse biased, it conducts the reverse current due to minority charge carriers and this reverse current will be very small so long as the reverse voltage is less than the breakdown voltage**
  - ➔ **As the reverse voltage is increased to breakdown voltage, a large number of electron-hole pairs are produced and the reverse current sharply increases.**
  - ➔ **This reverse current is known as Zener current and the breakdown voltage is called Zener voltage.**
  - ➔ **If the voltage is increased beyond Zener voltage, then the Zener current increases but the voltage across Zener diode remains constant.**
  - ➔ **This it provides a constant voltage and can be used as a constant voltage source, eg: voltage regulator, pulse amplifier.**

❖ <u>V-I Characteristics</u>



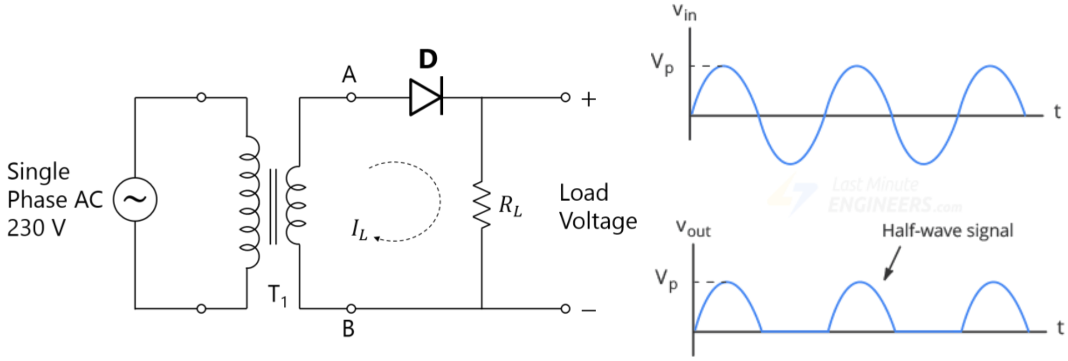
- **Forward characteristic**
  It indicates that the forward current is very small for voltages below knee voltage and large for voltages above knee (i.e cut-in voltage) [similar to p-n junc. diode]
- **Reverse characteristic**
  It indicates that negligible reverse saturation current flows until we've reached the breakdown voltage and if the voltage is further increased, then Zener current increases but the voltage remains constant.

❖ Rectifiers

- ***a rectifier is an electronic circuit, used for converting alternating voltage or current (A.C) into unidirectional (D.C) voltage or current.***
- **The process that converts alternating current (AC) or voltage into unidirectional (i.e direct) current (DC) is called *rectification*.**
- **Types of rectifiers:**
  - ➔ **Half wave rectifier**
  - ➔ **Full wave rectifier:**
    Centre-tapped full wave rectifier
    Full-wave bridge rectifier

❖ Half-Wave Rectifier

- ***A half-wave rectifier is an electronic circuit which allows the unidirectional (dc) current to flow through the load during only one-helf period of the input ac cycle.***
- **The rectifier conducts only during positive half cycles of input ac supply, the negative half-cycles are suppressed, and there is no flow of current and no voltage drops across the load.**



- **During the positive half cycle of the ac input voltage the polarity is such that the p-n junction is in forward biased, hence the diode conducts and the current flows through the load resistor for all instantaneous voltages greater than knee voltage.**
- **During negative half cycle of the ac input voltage the polarity is such that the p-n junction is in reverse biased, hence the diode does not conduct and there is partial/no flow of current through the load resistor**

Performance Parameters

Peak Inverse Voltage (PIV) : it is defined as the maximum voltage at which the p-n junction diode must withstand without it's damage during the negative half cycle of the input ac signal.

PIV of half wave rectifier = peak voltage of input ac signal [PIV = V_m]

Ripple : The AC component present in the rectifier output of a rectifier diode is called ripple

Ripple factor (r) : the measure of how successful a rectifier circuit is doing the rectification is called ripple factor, denoted by (r)

Ripple factor = RMS value of AC component / DC value of output voltage

It is expressed in %

The ripple factor of half wave rectifier is 1.21 or 121%

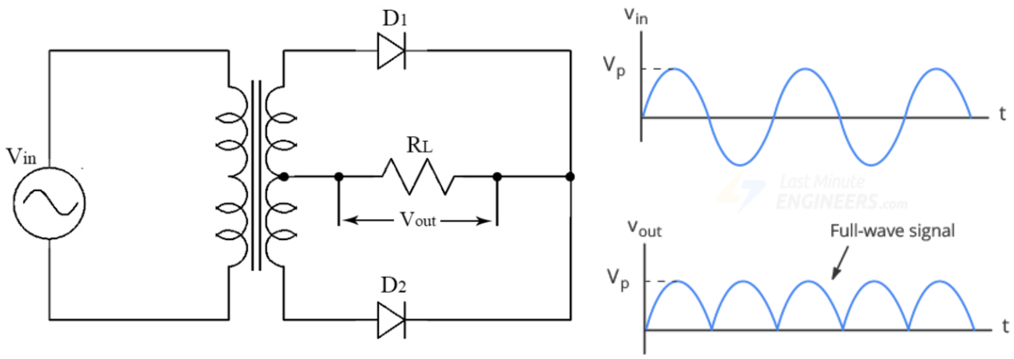
Rectifier efficiency : the ratio of output dc power delivered to the load to the applied input ac power is called rectifier efficiency. denoted by (ɳ)

ɳ = output dc power / input dc power

The maximum value of (ɳ) for half-wave rectifier is 40.6%

❖ Full-Wave Rectifier – Centre tapped

- ***a full-wave rectifier is an electronic circuit which utilizes a centre-tap transformer and allows the unidirectional (d.c) current to flow through the load during the entire period of input ac signal.***
- **In full-wave rectifier, both half cycles of input AC signal are utilized.**



- **During the positive half cycle of the ac input voltage the polarity is such that the p-n junction is in forward biased, hence the diode D1 conducts (D2 is in reversed biased) and the current flows through the load resistor for all instantaneous voltages greater than knee voltage.**
- **During negative half cycle of the ac input voltage the polarity is such that the p-n junction is in forward biased, hence the diode D2 conducts (D1 is in reversed biased) and the current flows through the load resistor for all instantaneous voltages greater than knee voltage.**

Performance Parameters

Peak Inverse Voltage (PIV) : it is defined as the maximum voltage at which the non-conducting p-n junction diode must withstand without it's damage during the negative half cycle of the input ac signal.

PIV of half wave rectifier = peak voltage of input ac signal [PIV = $2V_m$]

Ripple : The AC component present in the rectifier output of a rectifier diode is called ripple

Ripple factor (r) : the measure of how successful a rectifier circuit is doing the rectification is called ripple factor, denoted by (r)

Ripple factor = RMS value of AC component / DC value of output voltage

It is expressed in %

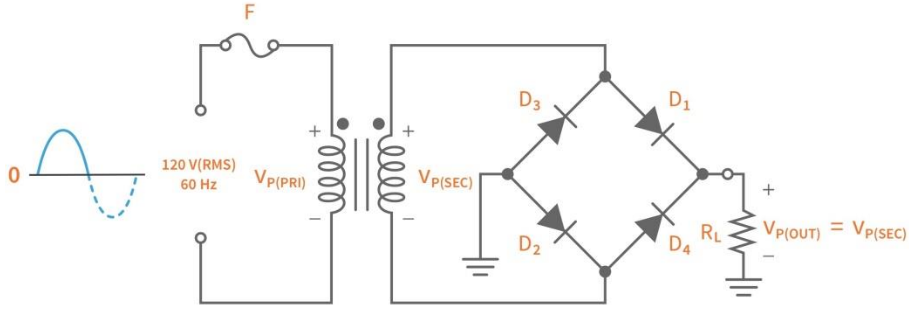
The ripple factor of half wave rectifier is 0.482 or 48.2%

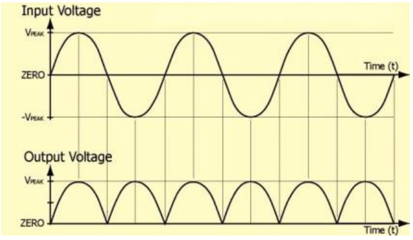
Rectifier efficiency : the ratio of output dc power delivered to the load to the applied input ac power is called rectifier efficiency. denoted by (ɳ)

ɳ = output dc power / input dc power

The maximum value of (ɳ) for half-wave rectifier is 81.2%

❖ **Full-Wave Rectifier – Bridge**





- **During the positive half cycle of the ac input voltage the polarity is such that the p-n junction is in forward biased, hence the diode D1 & D2 conducts (D3 & D4 are in reversed biased) and the current flows through the load resistor for all instantaneous voltages greater than knee voltage.**
- **During negative half cycle of the ac input voltage the polarity is such that the p-n junction is in forward biased, hence the diode D3 & D4 conducts (D1 & D2 are in reversed biased) and the current flows through the load resistor for all instantaneous voltages greater than knee voltage.**

Performance Parameters

Peak Inverse Voltage (PIV) : it is defined as the maximum voltage at which the non-conducting p-n junction diode must withstand without it's damage during the negative half cycle of the input ac signal.

PIV of half wave rectifier = peak voltage of input ac signal [PIV = V_m]

Ripple : The AC component present in the rectifier output of a rectifier diode is called ripple

Ripple factor (r) : the measure of how successful a rectifier circuit is doing the rectification is called ripple factor, denoted by (r)

Ripple factor = RMS value of AC component / DC value of output voltage

It is expressed in %

The ripple factor of half wave rectifier is 0.482 or 48.2%

Rectifier efficiency : the ratio of output dc power delivered to the load to the applied input ac power is called rectifier efficiency. denoted by (ɳ)

ɳ = output dc power / input dc power

The maximum value of (ɳ) for half-wave rectifier is 81.2%

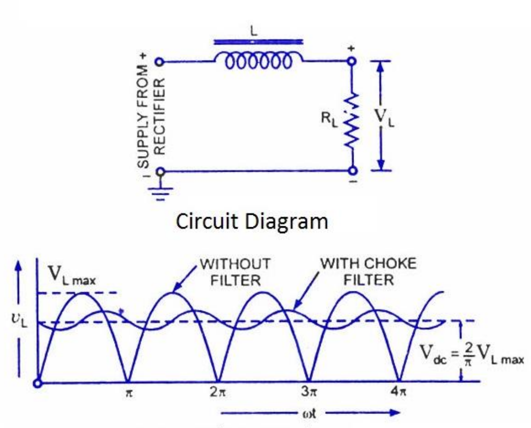
- **Why bridge rectifier?**
  - ➔ **It does not require centre-tap secondary winding transformer.**
  - ➔ **If stepping up or stepping down of voltage is not required, then we may achieve rectification without the use of transformer.**

❖ **Filters**

- ***A filter is an electrical network which minimizes the undesirable AC component (ripple) from the rectifier output and allows the DC component to reach the load.***
- **Need of filters:**
  - ➔ **to provide ripple free dc voltage**
  - ➔ **the presence of ripple in an electronic circuit may affect it's operation.**
  - ➔ **Hence ripple must be kept away from load, and should be removed and rectified.**
  - ➔ **The work of the filter is to allow ripple free dc voltage to reach the load.**

❖ **Series Inductor Filter / Choke Input filter (L/LC)**

Full Wave Rectifier with Series Inductor Filter

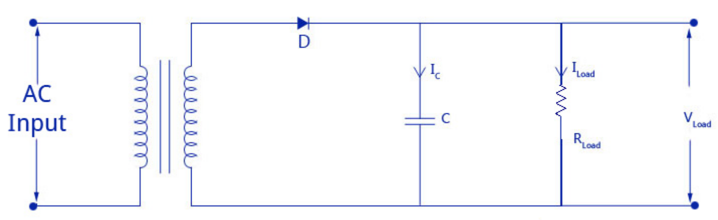


Output Voltage Waveforms

The pulsating output of the rectifier is applied across terminals of the filter circuit. The choke offers high opposition to the passage of a.c. component but negligible opposition to the d.c. component. The result is that most of the a.c. component appears across the choke while whole of d.c. component passes through the choke on its way to load.

❖ **Shunt Capacitor Filter (C) / Capacitor Output filter (π)**

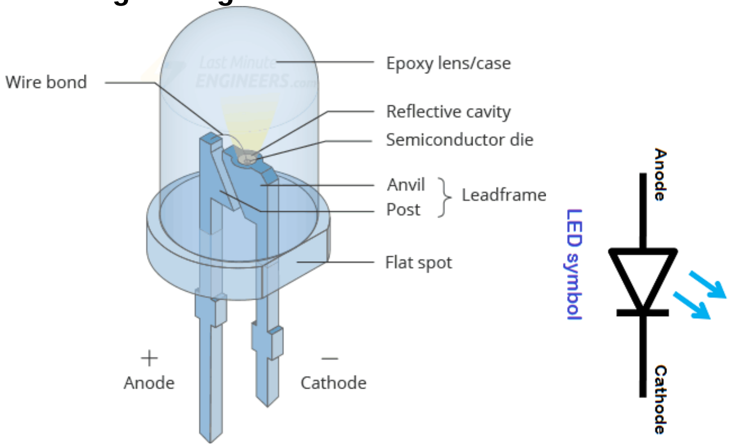
Half wave Rectifier with Capacitor Filter



The Shunt capacitor filters comprise of capacitor along with the load resistor. In this, the capacitor is connected in parallel with respect to the output of rectifier circuit and also in parallel with the load resistor. During conduction, the capacitor starts charging and stores energy in the form of the electrostatic field. The capacitor will charge to its peak value because the charging time constant is almost zero.

❖ LED

- **A p-n junction diode which emits light when in forward biased is known as light emitting diode.**
- **It works on the principle of electroluminescence.**
- **LED's are fabricated by using vapour phase or liquid phase epitaxy.**
- **Direct band gap red led's are fabricated on GaAs substrate and indirect band gap led's are an GaP substrate. Indirect band gap led's emit orange, yellow or green light.**



- **The N-type layer is grown on a P-type substrate by diffusion, then a thin P-type layer is grown on a N-type layer.**
- ***Germanium and Silicon are not used for manufacturing LEDs because these are heat producing materials; they are very poor in emitting light radiations.***
- ***The semiconductor materials used for manufacturing LED are Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP) & Gallium Nitride (GaN).***
- **Working Principle**
  - ➔ **The supply of higher energy electrons is provided by the forward-bias voltage of the P-N junction diode, the injected electrons into the N-region recombine near the junction.**
  - ➔ **The recombination of injected electrons with the holes, emits radiations which may be visible light or infrared.**
  - ➔ **The recombination radiation is emitted in all directions, with most of the light observed at the top surface.**
- **Applications**
  - ➔ **Used in 7-segment and 16-segement display.**
  - ➔ **Used in opto copulers.**
  - ➔ **Used in optical communication systems.**
  - ➔ **Used in infrared remote controls**
  - ➔ **Used in burglar alarm systems.**

❖ Regulated Power Supply