UNIT-I

⇓

Semi Conductor physics

Energy Band :- The range of energies possessed by an electron in a solid is known as energy band.

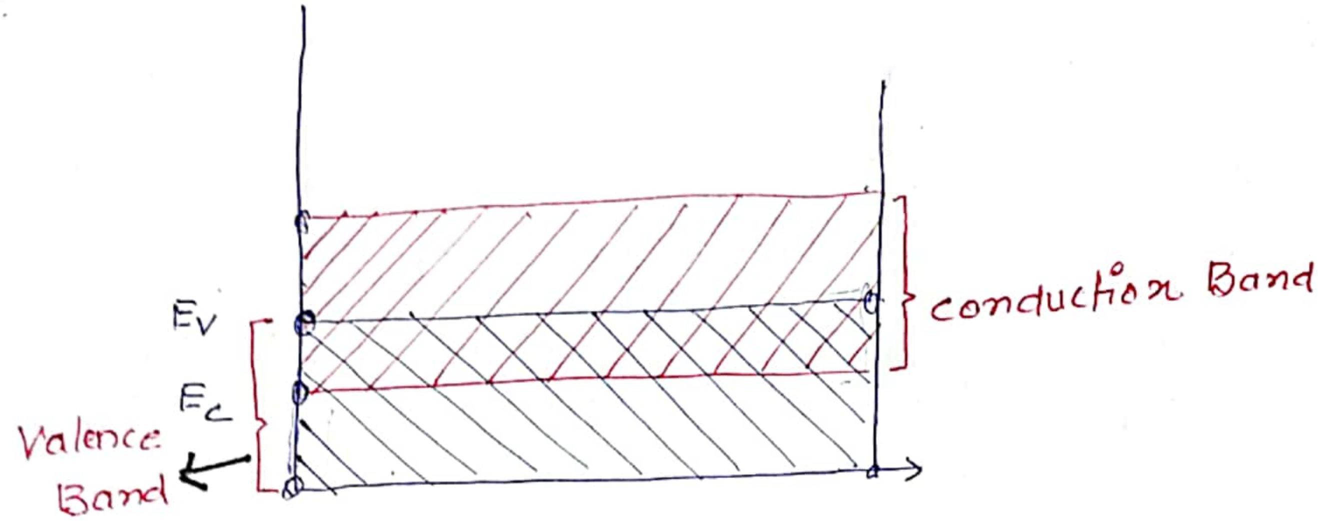
**

→ Electrons in any orbit posses definite energy.

→ Electron in any orbit of any atom Have a range of energies rather than a single energy, this is known as energy band.

Valence Band :- Range of energies possessed by Valence electrons is known as Valence band.

Conduction Band :- Range of energies possessed by conduction band (free electrons) is known as. C. Band.

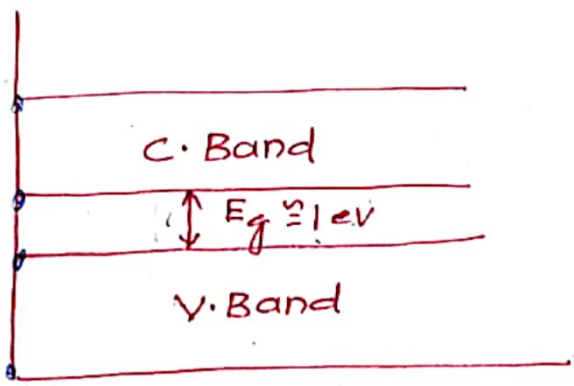


$E_V \rightarrow$ Highest energy level in V.Band.

$E_c \rightarrow$ Lowest energy level in conduction band.

Due to this overlapping, a small potential difference across a conductor causes the free electrons to constitute electric current.

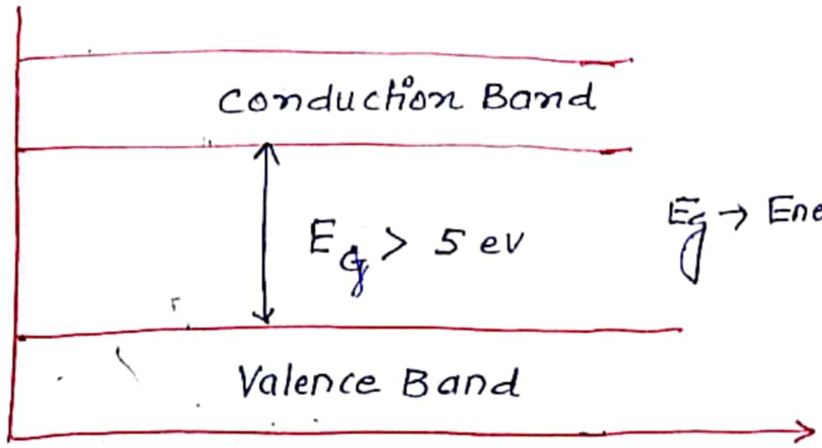
Semiconductors:- Here Valence band is almost full & conduction band is almost empty. Energy gap b/w these Two bands is very small of the order of 1.1eV for Si And 0.7 for Ge. Therefore small electric field is required to push the electrons from Valence band To the conduction band.



Forbidden Energy Gap :- separation b/w conduction band And Valence band in the energy level is known as forbidden Energy Gap. No electrons can stay in this band. Width of forbidden energy gap is a measure of the bondage of valence electrons to the atom. Greater the energy gap, tightly the valence electrons are bound to the nucleus.

Classification of solids :- Based on conductivity, solids are classified as :-

Insulators :- In Terms of energy band, valence band is full while the conduction band is empty.
eg:- Diamond, glass etc.



$E_g \rightarrow$ Energy gap.

Energy band diagram for insulators

* $1\ ev = 1.6 \times 10^{-19} J$

Conductors :- conductors easily allow the passage of electric current through them. bcoz there are large no. of free electrons available in a conductor.

Semi conductors:- conductivity lies b/w conductors And Insulators. Resistivity of semiconductors varies from 10^{-5} to 10^{4} ohm-meter whereas 10^{-8} to 10^{-6} ohm meter for conductors And from 10^{7} to 10^{8} ohm-meter for insulators. Si & Ge are mostly used semi-Conductors.

properties of semi-Conductors:- (i) They Have 4 valence electrons.

(ii) They Have (-ve) temp. of Coefficient ~~of~~ of Resistance ie R↓ T↑.

(iii) properties of semi-conductors can be varied by adding impurities to semiconductors

(iv) Current in semi-Conductors consists of movement of electrons And Holes.

Q:- Why silicon is Widely used than Germanium.

Ans) Valence electrons in Ge —— 4th shell
Valence electrons in Si —— 3rd shell

Means Ge Valence electrons are at higher energy levels than those in Si. Hence Ge Valence electrons will need smaller amount of additional energy to escape from Valence band to conduction band. Hence Ge produces more no. of electron hole pairs than Si, as a result leakage current is more in Ge based semiconductor than Si. This property makes Ge more unstable at high temperatures.

QNo. Why silicon is preferred as compared to Germanium.

Sol^n

Atomic No of Si (14) :- 2,8,4 {3 shells}

Atomic No of Ge (32) :- 2,8,18,4 {4 shells}

that means in Ge electrons in outermost shell —— loosely Bound than Si

b'coz $\boxed{F \propto \frac{1}{d^2}}$

ie if we give some energy to Ge atom, electrons in outermost shell jump to the conduction band & becomes free.

When electron jumps to the conduction band, a vacant site is left behind it, that is called holes.

ie if energy to the atom ↑↑↑, electrons and Holes ↑↑↑

ie Minority charge carriers ↑↑↑ ie Leakage current also ↑↑↑

that means leakage current is more in Ge than Si which is undesirable, that's why Si is preferred.

Diode Ratings :-

(Not to do)

(i) Forward voltage drop
(ii) Max. forward current | peak surge Current
(iii) Average forward current
(iv) Reverse saturation current
(v) Power Dissipation
(vi) Junction Temperature
(vii) Peak Inverse voltage

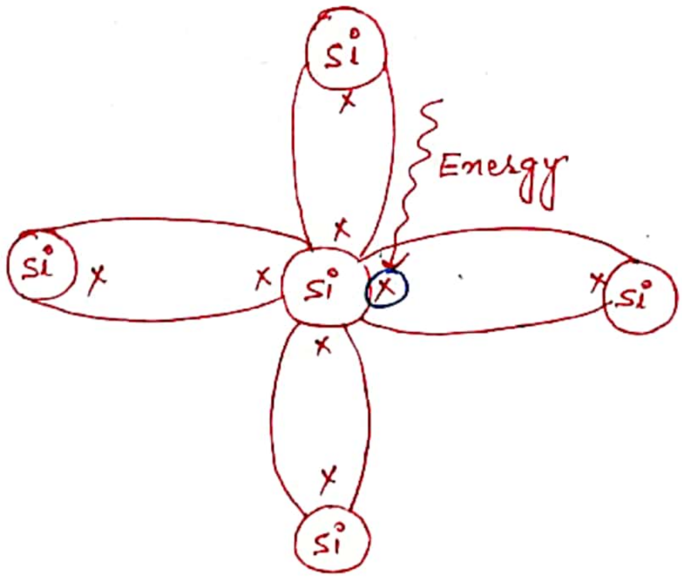
Definitions from Book.

Types of semi conductors :- These are two types of s. conductors.

- Semiconductors
  - Intrinsic or pure semiconductor
  - Extrinsic or Impure semiconductor
    - N-Type semiconductor
    - P-Type Semi-conductor

Intrinsic Semi conductors :- si & Ge are the most widely used intrinsic semi-conductors.

eg :- Si has total 14 electrons in its atomic structure. Each Atom in a silicon crystal contributes 4 valence electrons so that the atom is tetravalent. The atoms are bonded together by a force which results from sharing the Neighbouring atoms. This bonding Force is called a Covalent bond.



After giving energy, bonded electrons break the bond & becomes free. Behind a free electron, there is a vacant site known as HOLE.

This is known as Electron-Hole pair generation, where –

$$\boxed{\text{No. of Free electrons } n = \text{No of Holes } p}$$

Here $n = p = n_i \rightarrow$ Intrinsic concentration of charge carriers.

Disadvantage of Intrinsic semiconductor :- At room temp. pure or intrinsic semiconductors will not conduct enough value of current. Therefore some modifications has to be applied in order to increase the semiconductor's conductivity, which is known as 'DOPING.'

Q> Why semiconductor behaves as an insulator at 0°K.

Mean Life time :- Time duration for which a free electron And Hole exists before recombination.

Extrinsic Semiconductors :- In order to make the intrinsic semiconductors useful, their characteristics have to be altered by adding a certain Amount of desired impurity atoms. The resulting semiconductors are called impure or extrinsic semiconductors.

* The process of adding impurities to the intrinsic semiconductor material either to increase the no. of free electrons to or increase the no. of Holes, is known as DOPING.

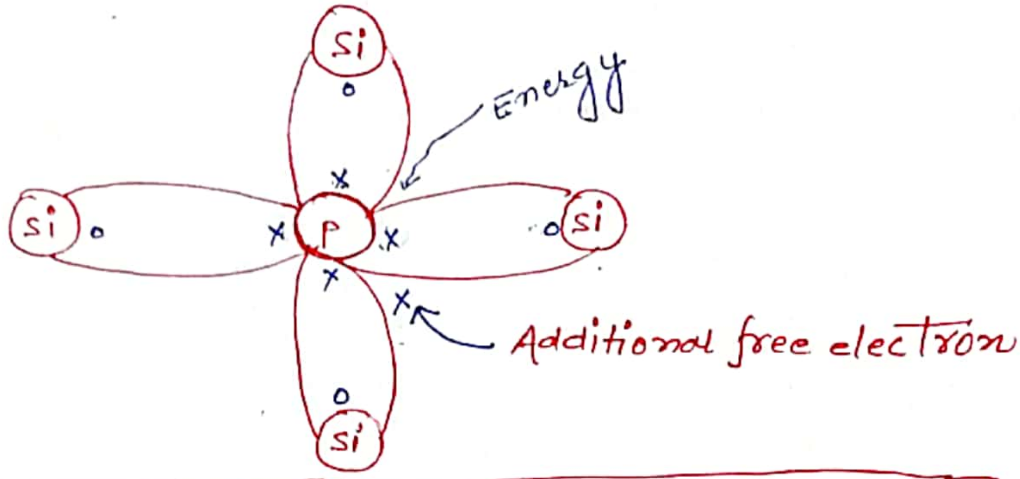
Types of Extrinsic semiconductors :- Generally two types of impurity atoms are added to the semiconductor. Normally the impurity atoms containing 5 valence electrons (called pentavalent atoms) And the impurity atoms containing 3 valence electrons called trivalent impurity atoms. Generally the resulting semiconductor may be of the following two types :-

N-type :- When a small Amount of pentavalent impurity (Group V) is added to a pure semiconductor, it is known as N-Type semiconductor.

eg :- Arsenic, Antimony, phosphorous etc.

Pentavalent means 5 electrons in outermost orbit. out of 5 electrons, 4 electrons Form covalent bond with $\bar{e}$ of neighbouring Ge or si atom. The 5^{th} $\bar{e}$ is loosely bonded with a Nucleus And finds no place in covalent bond thus it moves as free or valence electrons. Hence a very small is sufficient to excite this electron to move from valence band to conduction band. Therefore for each impurity atom one free electron will be available in Ge or si atom.

Though ~~for~~ each Arsenic Atoms provides one free electron yet an extremely small amount of impurity provides enough atoms to supply Millions of free electrons. These type of impurities are called Donar impurities b'coz it donates electrons to Ge or si crystal.



Hence

$\boxed{\text{No. of dopant Atoms = No. of Free electrons}}$ as minority carriers

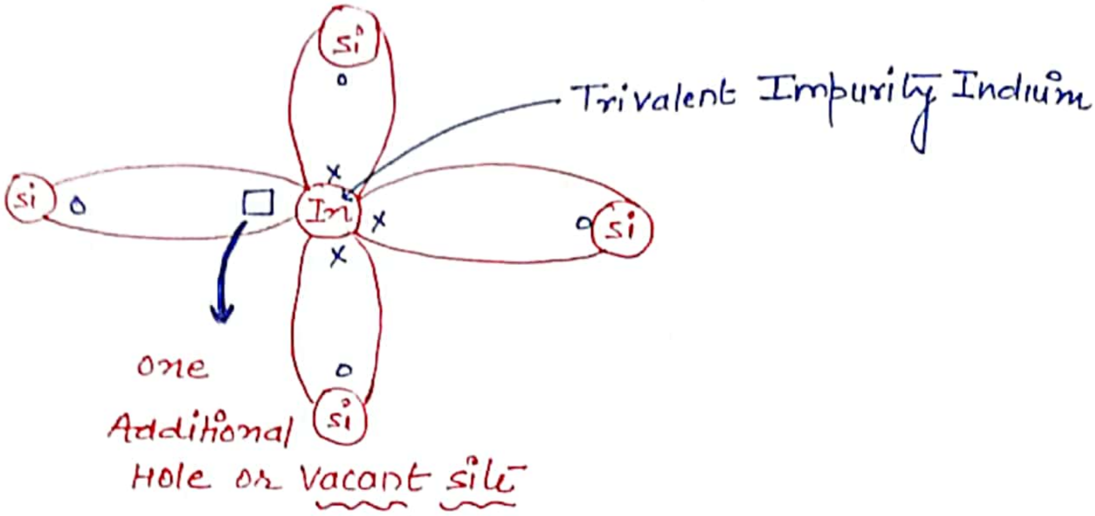
$\boxed{n > p \text{ — No. of Holes}}$

Electrons as majority carriers

P-type Semiconductor :- When a small Amount of trivalent impurity is added to pure semiconductor, it is called as P-type semiconductor.

Trivalent Impurities :. Gallium, Indium, Boron

A small Amount of trivalent impurity is added to a pure semi-conductor to get p-type semiconductor. Trivalent impurity means, it Has 3 valence electrons in the outermost orbit. Three electrons form a covalent bond with 4 surrounding electrons of Ge or Si atoms. one bond is incomplete which leads to formation of hole as shown below. Thus the addition of trivalent impurity provides a large no. of Holes in the semi-conductor.



Hence

$$\boxed{\text{No. OF Holes} = \text{No. OF Dopants}}$$

or

No. OF Holes As Majority Carriers → $\boxed{p > n}$ → No. OF Free electrons As Minority carriers

Effect OF temperature :-

(i) CONDUCTOR :- As $\boxed{T \uparrow\uparrow, \ R \uparrow}$ → +ve temp. coefficient

(ii) Semi Conductors (Intrinsic) :- As $\boxed{T \uparrow\uparrow, \ R \downarrow\downarrow}$ → -ve temp coefficient

(iii) Extrinsic Semiconductors {Both P And N Type} :- As $\boxed{T \uparrow\uparrow, \ R \downarrow\downarrow}$ → -ve Temp cefficient

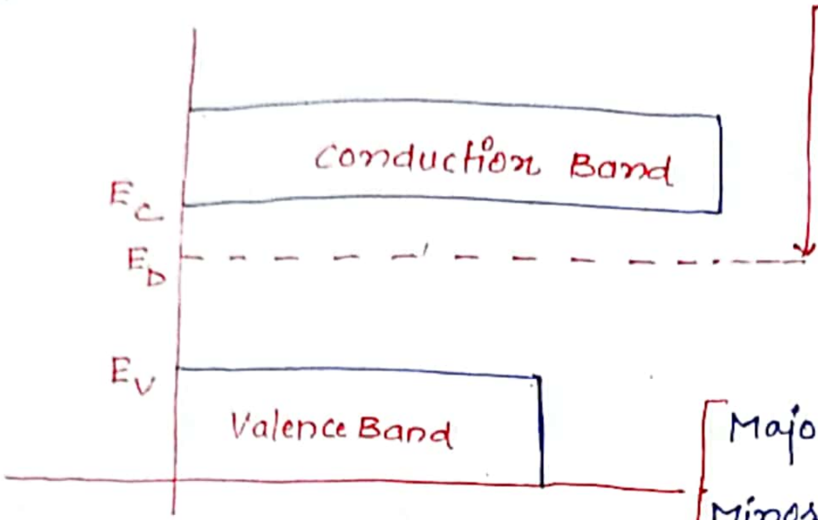
When T ↑ ↑ ↑ ↑ ↑, it becomes Intrinsic Semiconductor

(iv) Insulator :- T ↑↑↑↑↑↑, only few electrons will jump to conduction Band, Hence R ↓ ↓ (-ve temp. coefficient).

* As T ↑↑↑↑↑, Insulator will breakdown.

Donar Energy Level :-

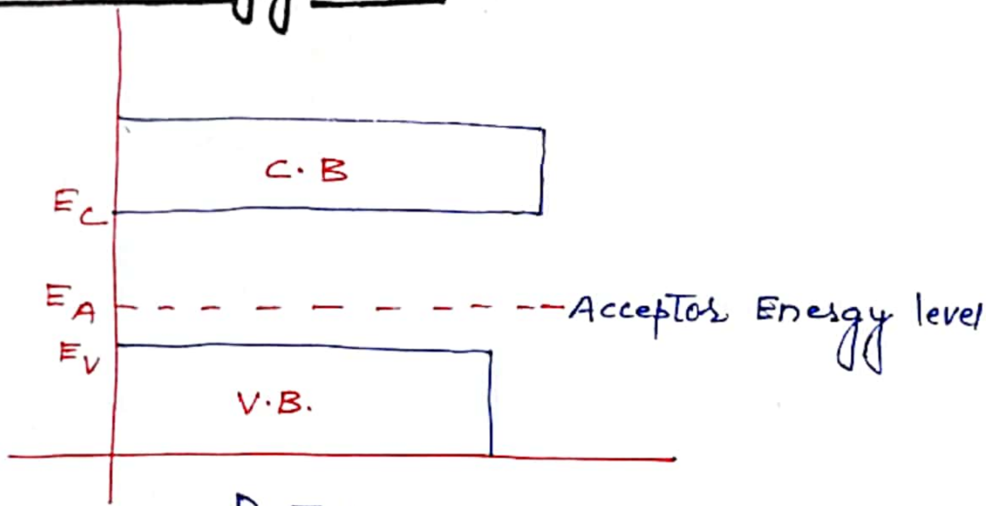
E_D → Donar Energy level



N-Type

- Majority charge carriers → e^-
- Minority charge carriers → h^+

Acceptor Energy Level :-



P-Type

- Majority charge carriers → holes h^+
- Minority charge carriers → e^-

SEMICONDUCTOR DIODE

⇒

P-N Junction :- If a piece of p-type semiconductor is joined to a N-type semiconductor in such a manner that the crystal structure remains continous at the boundary, then a new structure called P-N junction is formed. Such a P-N junction makes a versatile device called as semiconductor diode, P-N junction diode or crystal diode.

⇒ There are two basic processes which are responsible for the movement of electrons and holes in a semiconductor are –

(i) **Drift :-** The drift current which flows inside a semiconductor under the influence of externally applied electric field.

(ii) **Diffusion :-** The transport of charges takes place in a semiconductor which can be explained by a mechanism called, 'DIFFUSION'.

Diffusion can be encountered only in semi-conductors. It is absent in metals.

The P-N Junction can not be made simply by Joining two pieces, special fabrication techniques are required to form a P-N Junction.

A semiconductor P-N junction is formed when a wafer of the semiconductor material such as silicon is doped so that one region is N-type & the other is p-type. PN junction is an important device b'coz all other semiconductor devices contain at least one P-N junction.

→ Working of p-n junction diode :-

→ Part (a) Unbiased Diode :-

(i) No external voltage is applied between the Terminals of the p-n junction, Hence p-n junction is said to be unbiased.

(ii) The free electrons from n side will diffuse into p-side And recombine with the holes present there.

(iii) Each electron diffusing into p side will leave behind a (+ve) immobile ion on the n-side.

(iv) When an electron combines with a hole on the p-side, an atom which accepts this electron, loses its electrical neutral status And becomes a (-ve) immobile ion.

(v) Due to this recombination process, a large no. of (+ve) ions accumulate near the junction on the n-side & a large no. of negative immobile ions will accumulate on the p-side near the junction as shown below –

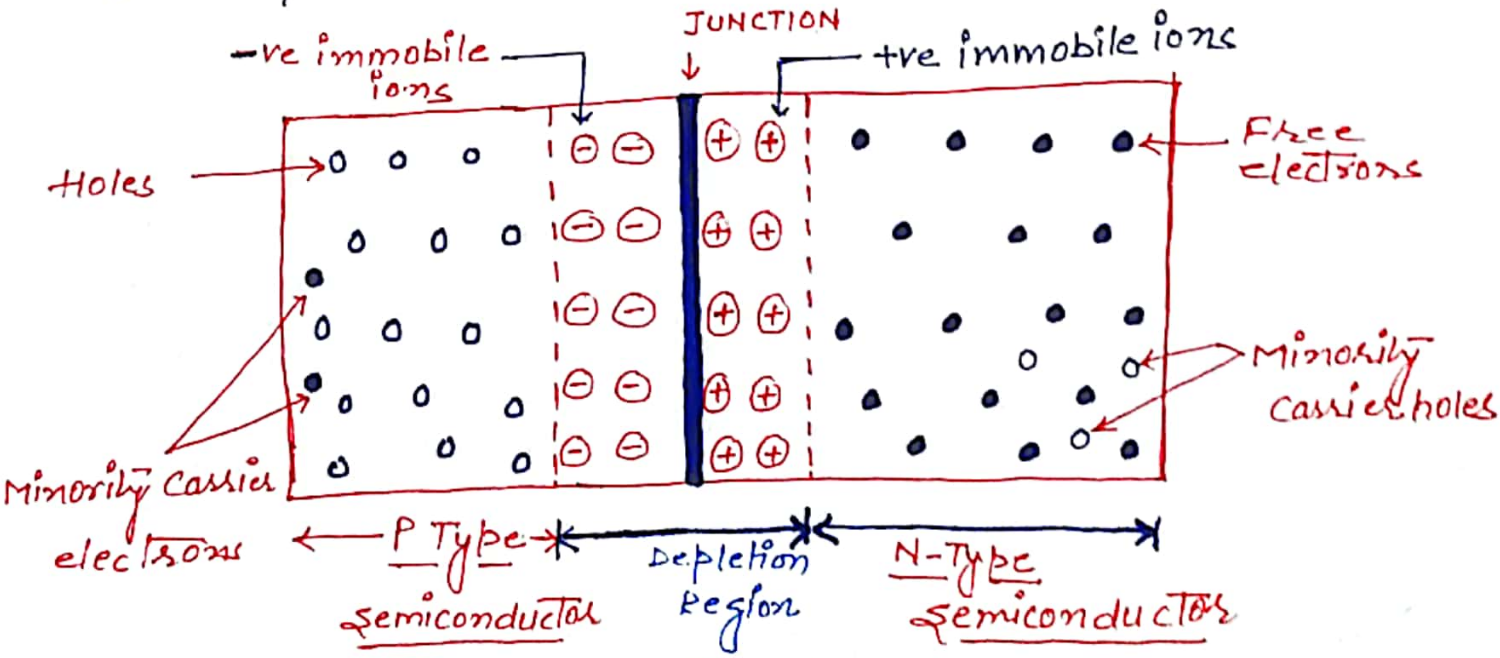


Fig-A

The Negatively charged ions on the p-side will start repelling the electrons which attempt to diffuse into the 'p' side and after some time, the diffusion will ~~start~~ stop completely. At this point, the junction is said to have attained an equilibrium.

Depletion Region :- The shaded region on both sides of the junction in Fig (A) contains only immobile ions and no free charge carriers such as electrons or holes. In other words, this region is "depleted" of the free charge carriers. Therefore this region is called as the 'depletion Region.' or 'space charge Region'.

In this state of equilibrium, the depletion region gets widened to such an extent that electrons can't cross the junction anymore.

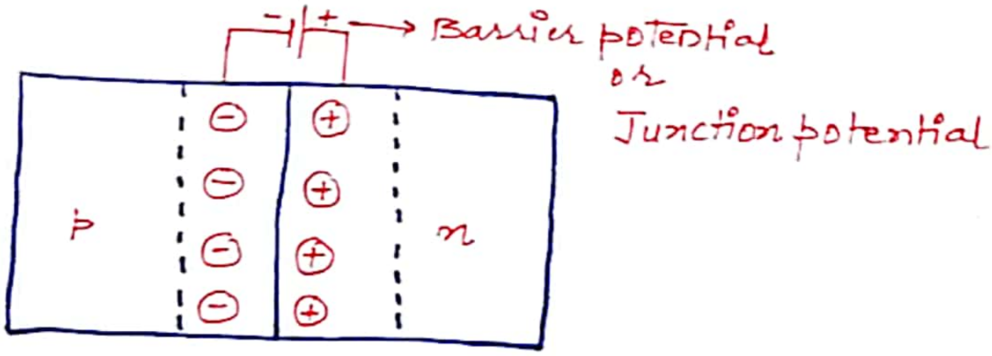
Width of depletion Region:- Due to presence of depletion region the electrons or holes cannot diffuse to the other side, Hence it is said that the depletion region acts as a BARRIER.

* Practically Width of Depletion Region is of the order of 0.5 to 1 micron where 1 micron = 1×10^{-6} meter.

BARRIER POTENTIAL OR JUNCTION POTENTIAL :-

Due to the presence of immobile (+ve) & (-ve) ions on opposite side of the junction, an electric field is created across the junction. This electric field is known as "Barrier Potential" or junction potential or cut in voltage. This is called as barrier potential b'coz it acts as barrier to oppose the flow of electrons & holes across the junction.

→ Barrier potential represents the height of the barrier that is to be overcome for commencement of flow of electron & holes. It is measured in volts. For Silicon Barrier potential = .6V
For Germanium = 0.2 V



If we want to cross the electrons And Holes across the junction then an external voltage of appropriate polarity Has to be applied in order to overcome the opposition of barrier potential.

* Depletion region always penetrate more on the side which is lightly doped as compared to the other.

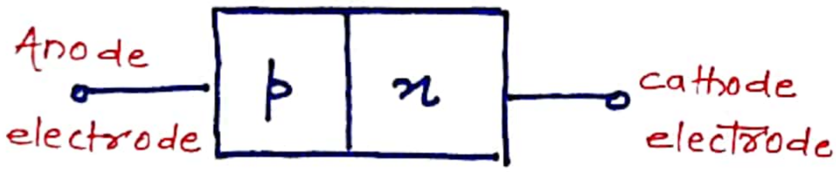
Factors deciding the barrier potential value :- (i) semiconductor material used {si or Ge}

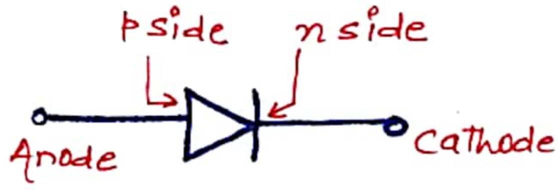
(ii) Intrinsic concentration of si or Ge before doping.

(iii) Level of doping on p & n sides.

(iv) Temperature.

⇒ **Terminals of P-N Junction Diode** :- P-N Junction itself forms the most basic semiconductor device called semiconductor diode. The meaning of the term diode is the device having "two electrodes" (di-ode).





symbol

* The current will flow through diode if & only if an external voltage source is connected to it with appropriate polarities.

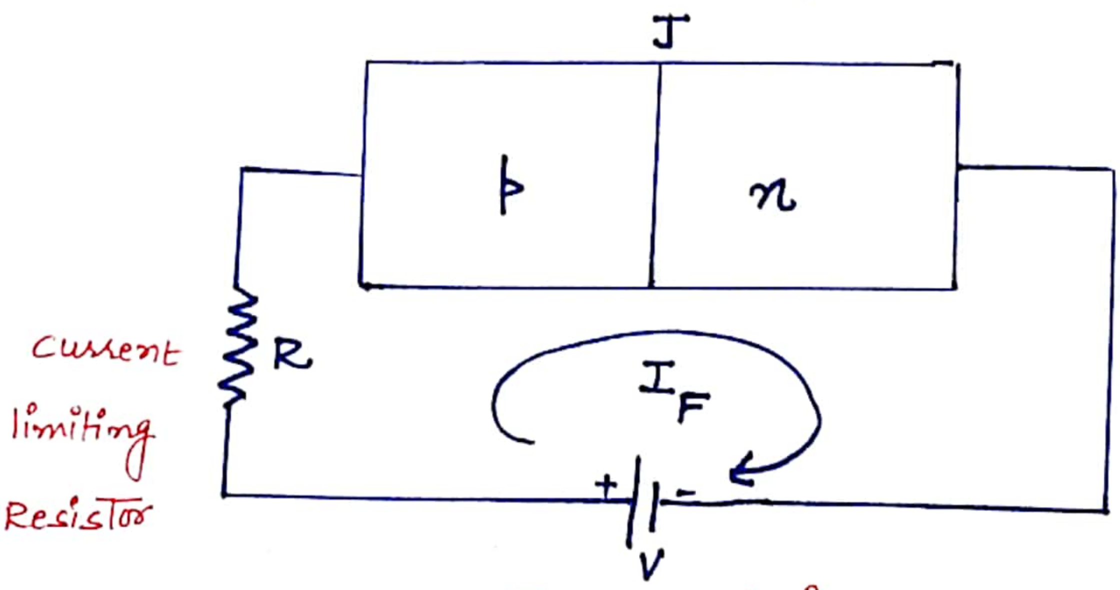
⇒ Part (b) :-

⇒ **Biasing of a p-n junction diode :-** When the p-n junction is formed, the depletion region gets created and the movement of electrons and holes stop. Thus the current flowing through an unbiased p-n junction is zero. To make the current to flow, we have to bias the p-n junction diode.

Biasing is the process of applying external d.c. voltage to the semiconductor diode. There are two types of biasing -

(i) **Forward Biasing :-** If p-region (Anode) is connected to the (+ve) terminal of the external d.c. source and n-side (cathod) is connected to the negative terminal then the biasing is said to "forward biasing"

* Generally a resistance is connected in series with the diode to limit the current flowing through it.



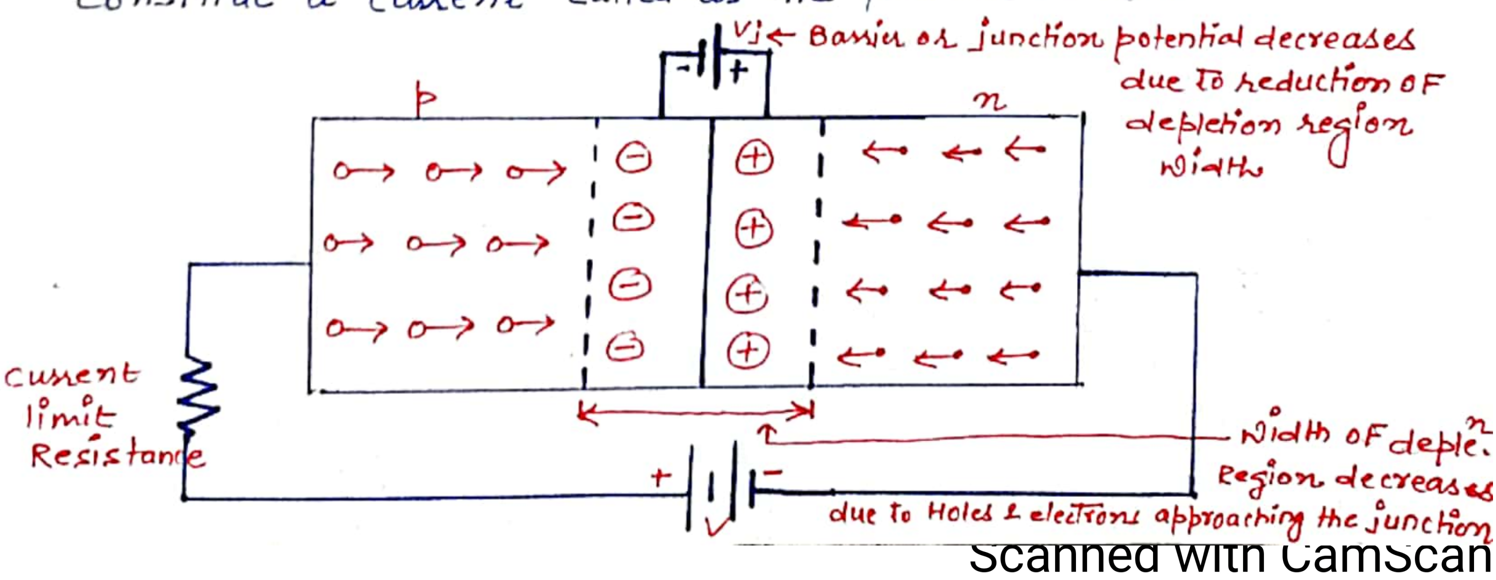
Forward Biasing

Operation of Forward Biasing:- Due to Negative terminal of external source connected to n-region free electrons from n-side are pushed towards the p-side. Similarly the positive end of the supply will push holes from p-side toward the n-side.

With increase in the external supply voltage V, more & more no. of holes & electrons (n-side) start travelling towards the junction. The holes will start converting the (-ve) ions into neutral atoms & the electrons will convert the (+ve) ions into neutral atoms, As a result of this, the width of depletion region will reduce.

Due to reduction in the depletion region width, the barrier potential will also reduce. Eventually at a particular value of V, the depletion region will collapse. Hence a large no. of Holes & electrons (majority carriers) can cross the junction under the influence of externally connected d.c. voltage.

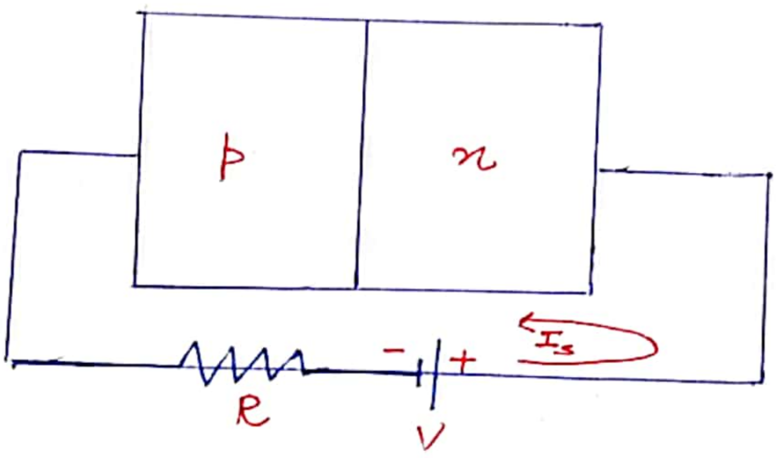
The large no. of majority carriers crossing the junction constitue a current called as the forward current.



* Here the current is the electron current which is in opposite direction to that of conventional current. xxx

* The forward current through a p-n junction diode flows due to majority carriers and its direction of flow is always from Anode to Cathode.

Reverse Biasing a Diode :-

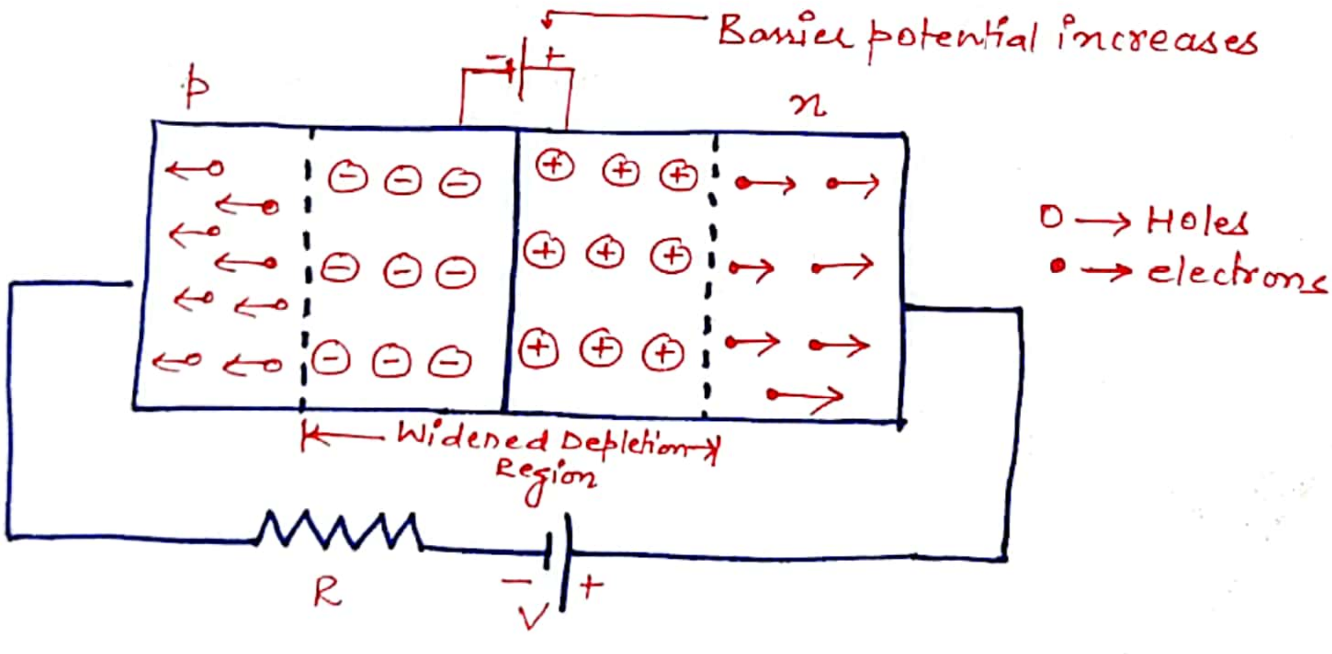


Reverse biasing a semiconductor diode

If p region of a diode is connected to the (-ve) terminal of the external D.C supply & n-region is connected to the (+ve) terminal of the D.C. supply, then a diode is said to be

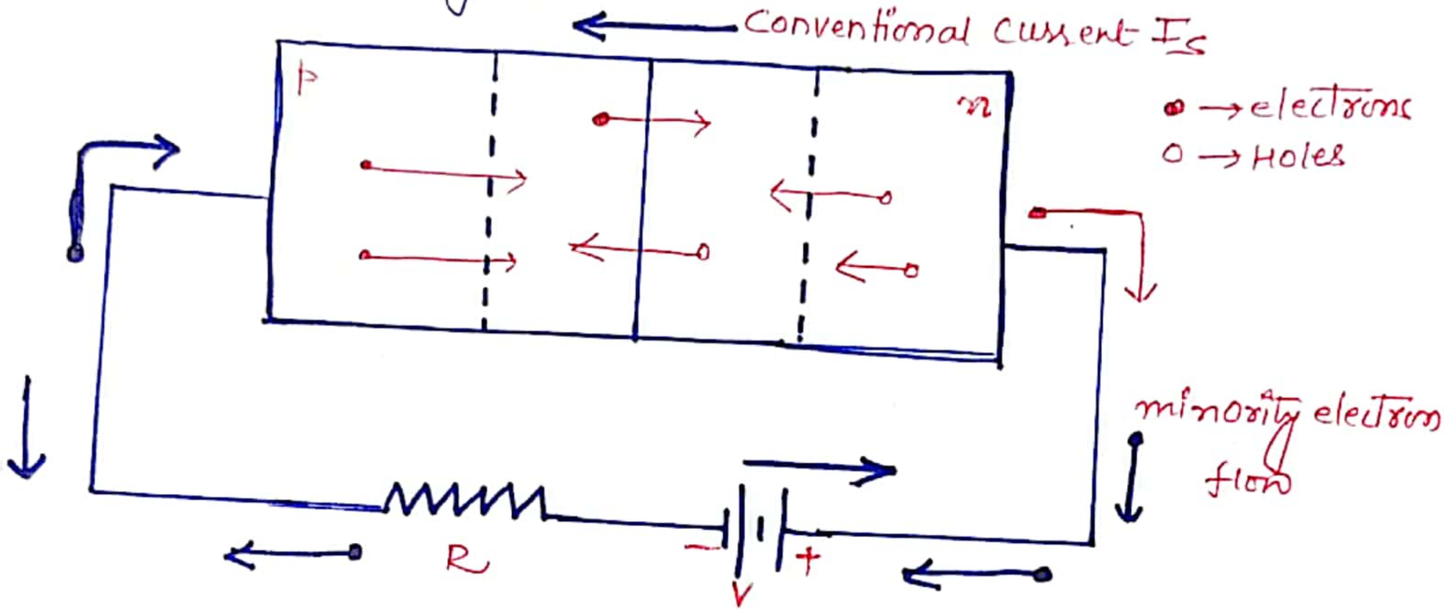
'Reverse biased'. Reverse current is denoted by I_S & flows from cathode to Anode of the diode or in the opposite direction to that of the forward current.

Operation :- When a diode is reversed biased, holes in the p-region are attracted towards the (-ve) terminal of the supply & electrons on n-side are attracted towards the (+ve) terminal of the supply. Due to movement of electrons & holes away from the junction, width of depletion region increases, this happens due to creation of more no. of (+ve) & (-ve) immobile ions. Hence barrier potential or junction potential also increases.



Current flow in reverse biased diode :- ① We know that p-region consists of a small no. of electrons & n-region contains a small no. of holes. These are minority carriers which are generated thermally.

→ The minority electrons in the p-region are attracted by the (+ve) end of D.C supply, Hence these electrons will cross the junction & constitute the reverse current I_s of the diode. This is shown in Fig (A).

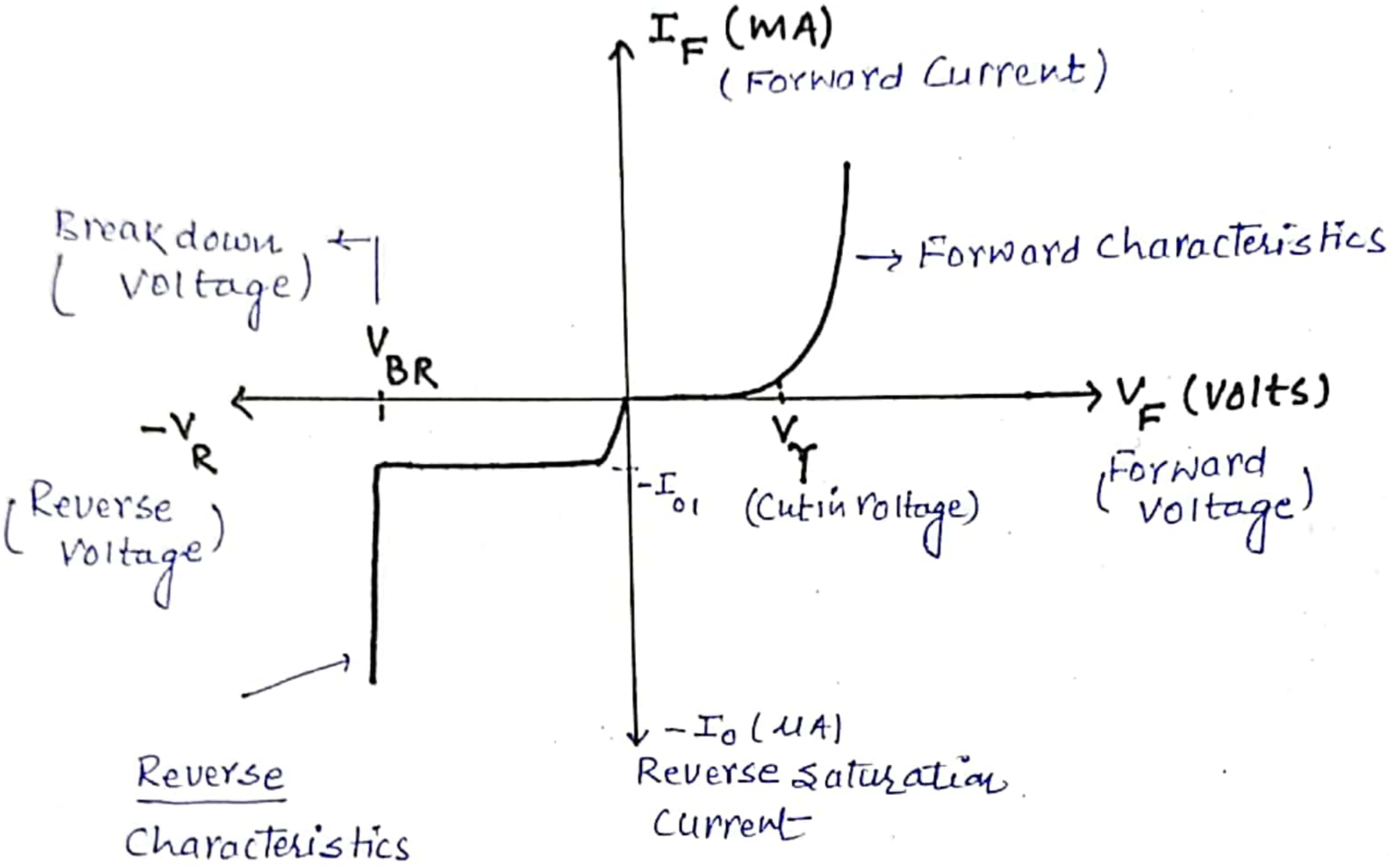


current flow in reverse biased diode Fig(A)

Reverse current is also called as 'Reverse saturation' current. As this current is due to the minority carriers, it is small in amplitude, typically of the order of few μA for Ge diodes & few nanoamperes for Si diode.

Reverse saturation current flows due to minority carriers which exist due to elevated temp., Hence reverse saturation current is dependent on temp. At a constant temp., the reverse saturation current remains constant independent of reverse voltage.

V-I characteristics of p-n junction diode :-



① When $\boxed{V_F = 0}$, process of diffusion takes place & the $\boxed{\text{net-diffusion current} = 0}$ {Case of unbiased}

② When $\boxed{V_F = +ve}$ means diode is Forward biased ;

I_F increases slowly because charge carriers haven't gained sufficient momentum to puncture depletion layer.

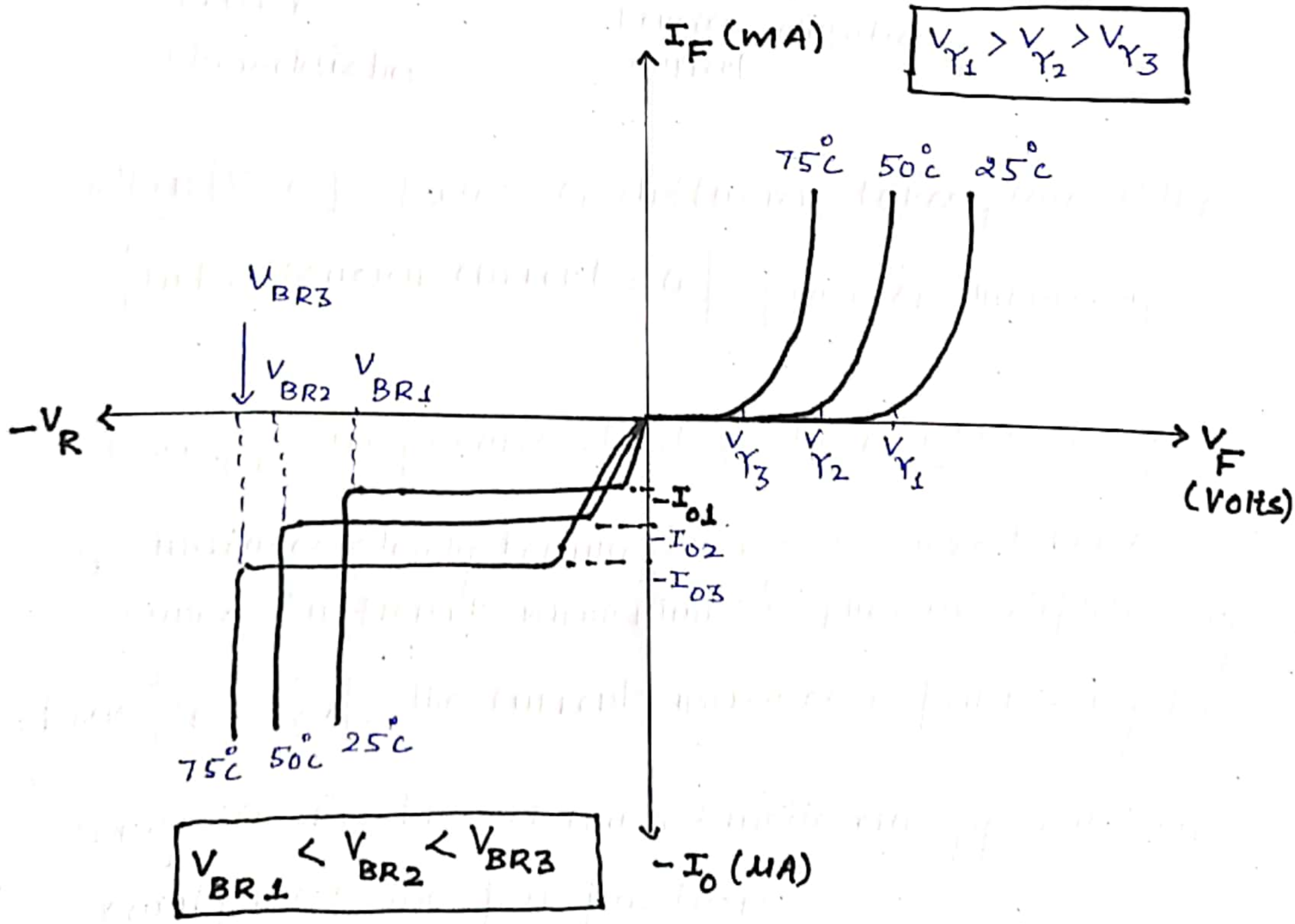
⇒ When $\boxed{V_F \geq V_\gamma,}$, the current increases exponentially b'coz charge carriers has so much kinetic energy that they easily cross the p-n junction.

(3) When $\boxed{V_F = -ve}$ means diode is Reverse biased;

A reverse saturation Current flows due to minority charge carriers.

⇒ It is also observed that when reverse voltage is increased to a very high value, Reverse current increases exponentially & the diode may breakdown. This reverse voltage is known as <u>Breakdown voltage</u>

<u>Effect of temp on V-I characteristics :-</u>



⇒ As Temp increases, the Cut in voltage of diode is reduced.

⇒ As T is increased, the reverse saturation current is also increased and the breakdown voltage also increases.

———————— x ———————— x ————————

Diode Equation :-

$$\boxed{I_D = I_0\left[e^{V/\eta V_T} - 1\right]}$$

Where

$I_D \rightarrow$ Diode Current (mA)

$I_0 \rightarrow$ Reverse saturation Current (μA)

$V \rightarrow$ Applied voltage

$\eta \rightarrow$ constant ; $\left.\begin{aligned}\eta &= 1 - Ge\\ &= 2 - Si\end{aligned}\right\}$ below V_γ &

& $\left.\begin{aligned}\eta &= 1 - Ge\\ &= 1 - Si\end{aligned}\right\}$ Above V_γ

$V_\gamma \rightarrow$ Cut in voltage

$V_T \rightarrow$ Voltage Equivalent of temp.

$$\boxed{V_T = \frac{T^\circ k}{11,600}}$$

Boltzman's Constant

$$\left\{ V_T = \frac{KT}{q} = \frac{1.38\times10^{-23}\times T}{1.6\times10^{-19}} \right\}$$

charge of $\bar{e}$

⇒ Cut in voltage / Thereshold voltage / Barrier voltage :- It is the min. voltage at which diode starts conduction.

For Ge, $V_\gamma = .3\,V$
For Si, $V_\gamma = .7\,V$

⇒ **Diode Current Equation Approximation :-**

I

I^{st} case :- When diode is unbiased.

ie $\boxed{V = 0}$

$$I_D = I_0\left[e^{V/\eta V_T} - 1\right]$$

$$I_D = I_0\left[e^0 - 1\right]$$

$$\boxed{I_D = 0}$$

Case II :- When diode is Forward Biased ie $\boxed{V = +ve}$

$$I_D = I_0\left[e^{V/\eta V_T} - 1\right]$$

Due to forward biased; $e^{V/\eta V_T} >> 1$

so $\quad I_D = I_0 e^{V/\eta V_T}$

But $\quad I_D >> I_0$, Neglecting I_0

$$\boxed{I_D = e^{V/\eta V_T}}$$

Case III :- When diode is Reverse Biased ie $\boxed{V = -ve}$

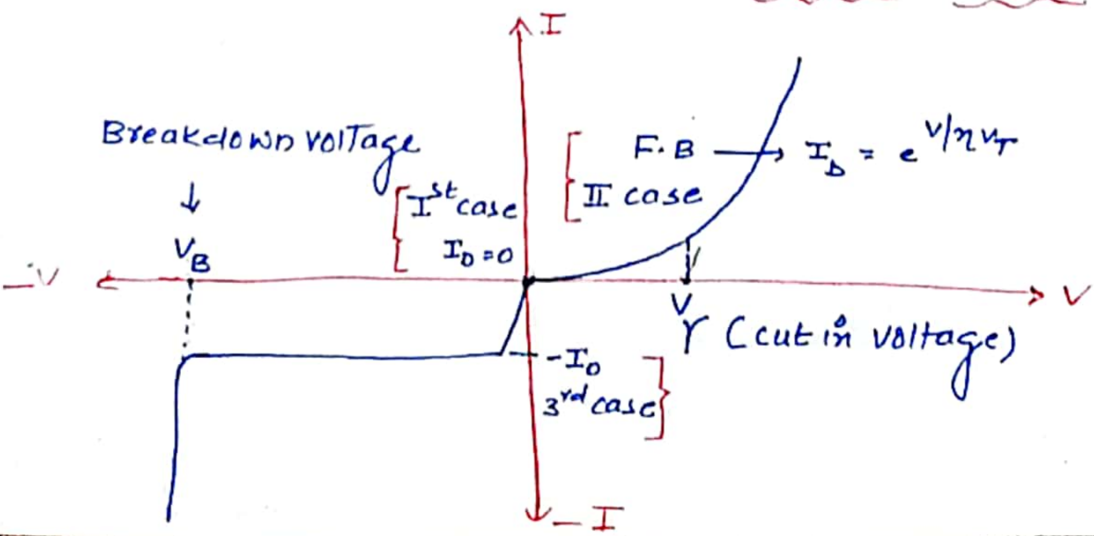
$$I_D = I_0\left[e^{V/\eta V_T} - 1\right]$$

$e^{V/\eta V_T} << 1$ {due to -ve voltage}

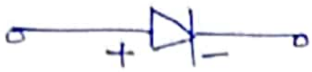
Neglecting $e^{V/\eta V_T}$

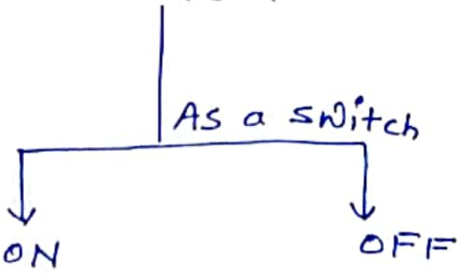
$$\boxed{I_D = -I_0}$$

V-I characteristics on the basis of above 3 cases :-

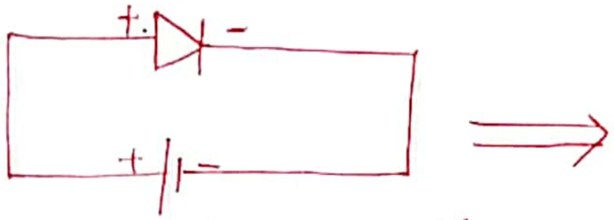


Ideal Diode :- Ideally diode acts as a switch.

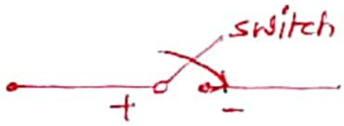




* As a switch diode will be ON when it is forward biased. that means max. current flows through diode.



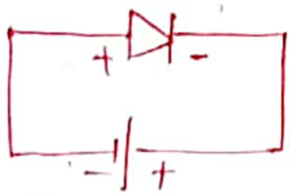
Diode in F.B. condition



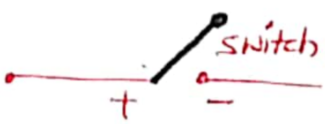
diode as a closed switch.

(a)

* Diode will be OFF, when it is Reverse biased. ie No current will flow through it.



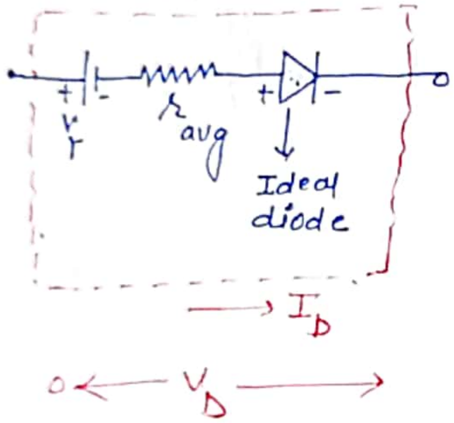
Diode in R.B. condition



Diode as a open switch

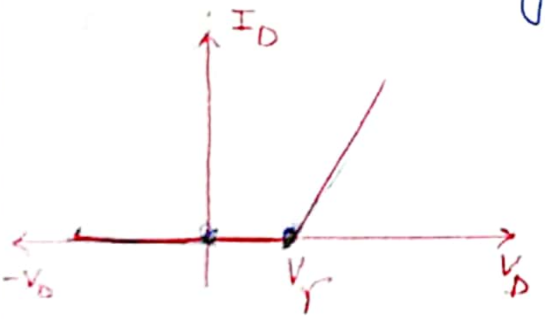
Diode Equivalent circuit :- It is defined only when the diode is forward Biased.

Piecewise Linear



V_γ For Ge = ·3 V
For Si = 0·7 V

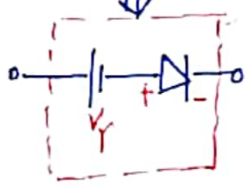
this acts as a Applied voltage

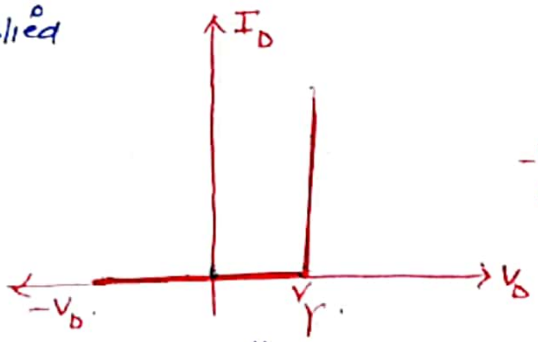


V_γ is that minimum threshold voltage which is required to ON the diode so upto V_γ diode is OFF ie No current flows. But at V_γ is reached current start increases exponentially b'coz diode is ON

Simplified

Here r_{avg} is sufficiently small to be Neglected

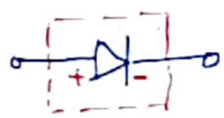




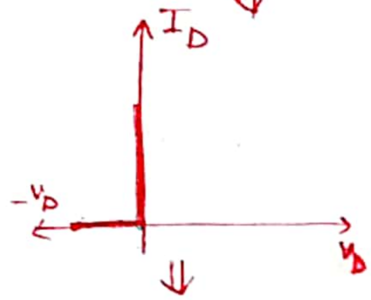
Here diode is OFF when voltage is < V_γ
As V_γ is reached diode is ON & Current shoots up b'coz resistance r_{avg} is Neglected

Ideal

Here r_{avg} & V_γ is removed



this acts as a switch



As voltage is Reverse Biased diode is OFF & No current Flows. As soon as voltage becomes zero ie we change the polarity of the battery Current shoots up.

Rectifier :- converts A-C into pulsating D-C eg:- Mobile charger

Note :- For DC, the Necessity condition :-

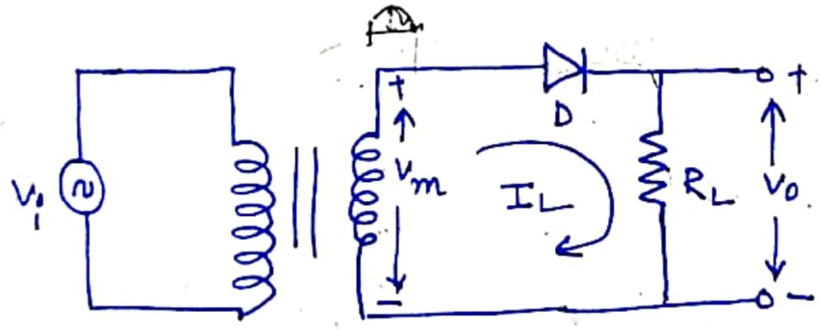
(i) It should be uni-polar.

(ii) It should constant with time.

RECTIFIER

- Half Wave {use only one diode}
  - +ve
  - −ve
- Full Wave {uses two or more diode}
  - Centre tapped
  - Bridge

+ve Half Wave Rectifier :- uses only one half of input A-C waveform.



⇒ During (+ve) Half cycle (0 to T/2)

D → F.B ⇒ closed switch

so $\boxed{V_o = I_L \times R_L = V_m}$ → Ideally

But practically :-

$R_F \rightarrow$ Forward Resistance of diode

$R_L \rightarrow$ Load Resistance

$R_S \rightarrow$ Resistance of secondry Winding

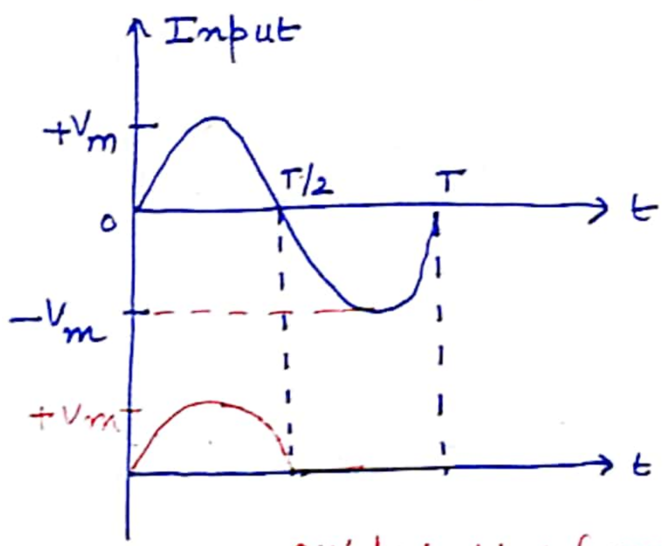
So
$$\boxed{I_L = \frac{V_m}{R_F + R_L + R_S}}$$

But $R_L \rightarrow k\Omega$

& R_F & R_S are in ohms $\Rightarrow$ $R_L >>> R_F$ & R_S

So
$$\boxed{I_m = \frac{V_m}{R_L}}$$

During (-ve) Half cycle :- $D \rightarrow R.B \Rightarrow$ open switch $\Rightarrow$ No current through R_L $\Rightarrow$ $\boxed{V_0 = 0}$



output Waveform

Note :- (-ve) Half Wave Rectifier, Do it by own.

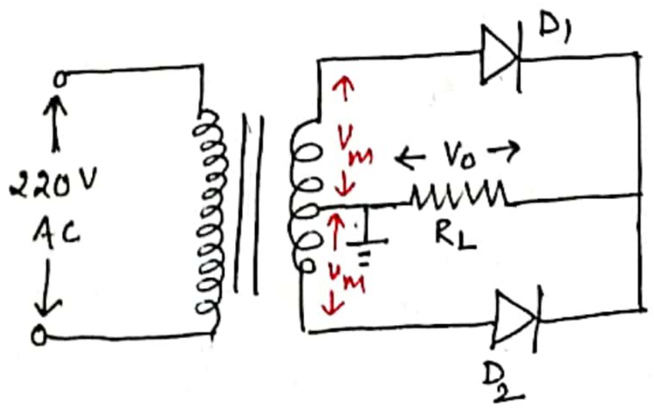
Q1) What do we need full wave Rectifier. or What are the limitations or disadvantages of Half wave Rectifier (HWR)

Sol^n:- At the output of rectifier, we get unipolar signal, but this is varying with time; it is not constant that means a.c components are present in the o/p of the rectifier, these a.c components are called as '<u>Ripples</u>' or '<u>pulsating DC</u>', which are not desired at the o/p. So in order to remove these ripples, we use filters.

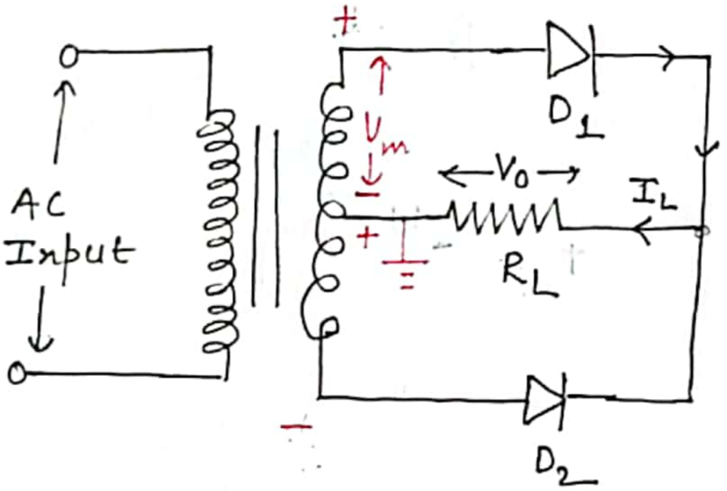
Moreover in H.W.R, only one Half of cycle (either +ve or -ve) is used ie we get o/p in either (+ve) Half cycle or in (-ve) Half cycle that means one half cycle is wasted, so in order to overcome this problem '<u>FULL WAVE RECTIFIER</u>' is used. Rectification efficiency of HWR is low.

<u>Full Wave Rectifier</u>:-

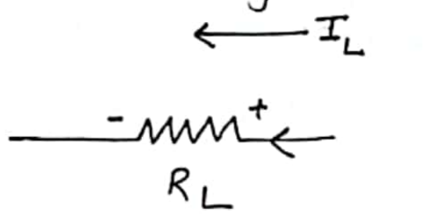
(i) <u>Centre tapped</u>:-



During (+ve) Half cycle :-

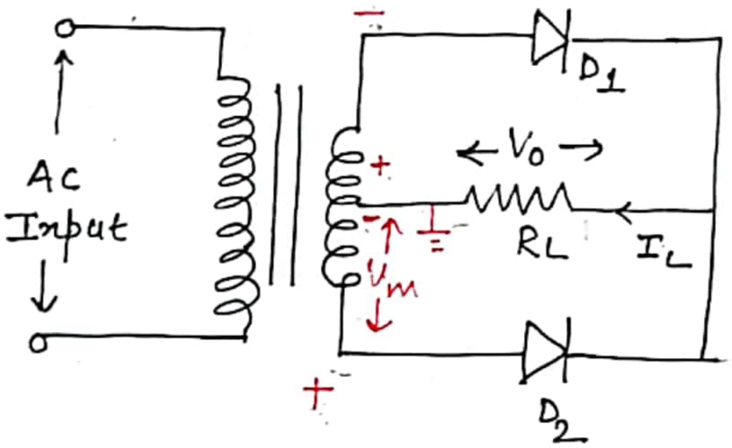


During (+ve) H.C

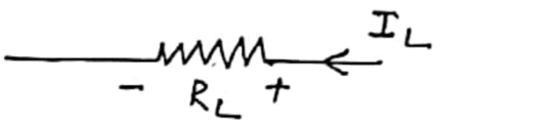


$\Rightarrow \left.\begin{array}{l} D_1 \longrightarrow F.B \\ D_2 \longrightarrow R.B \end{array}\right\} \Rightarrow \boxed{V_0 = I_L R_L = V_m}$

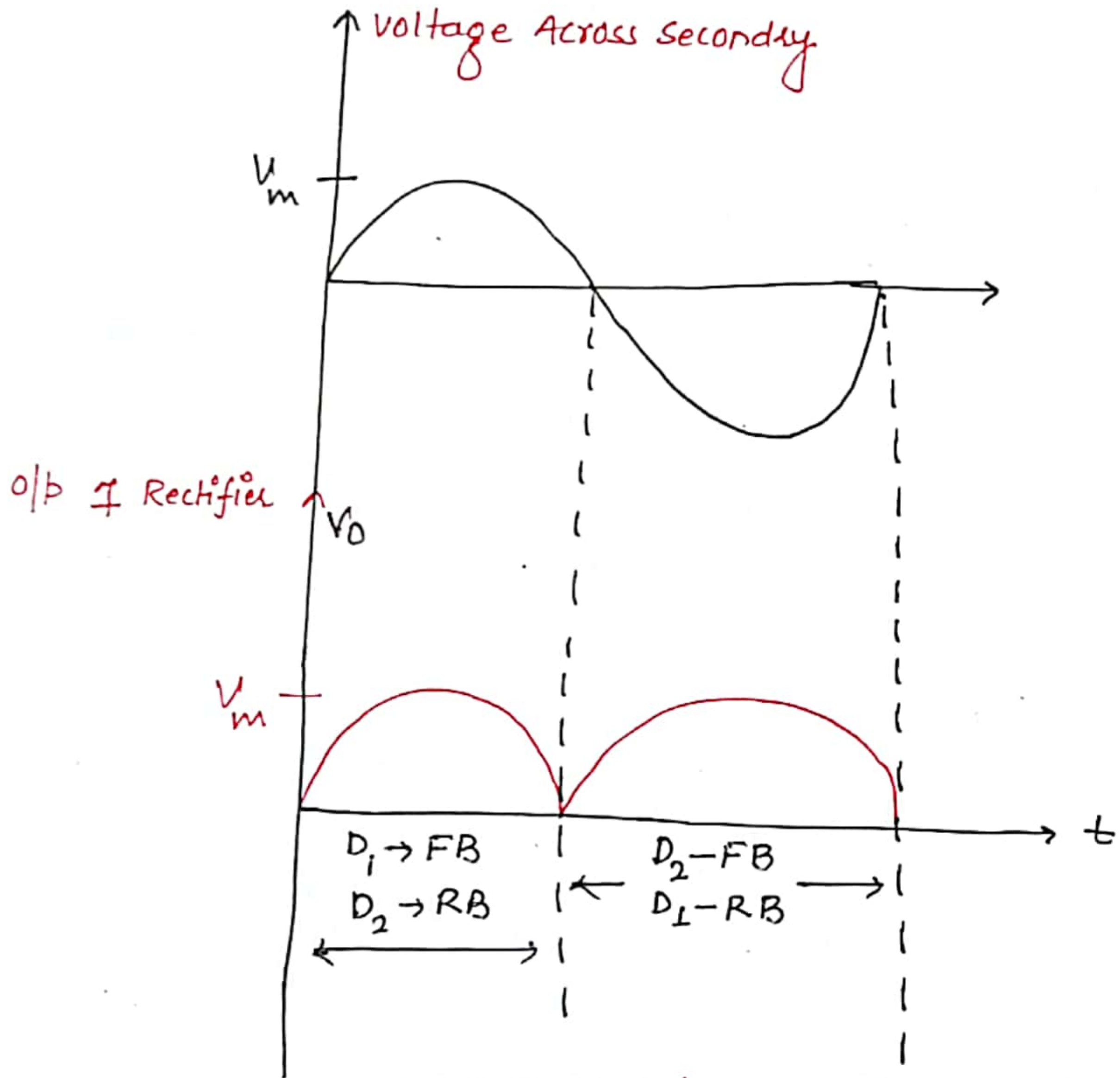
During (-ve) Half cycle :-



During (-ve) Halfcycle

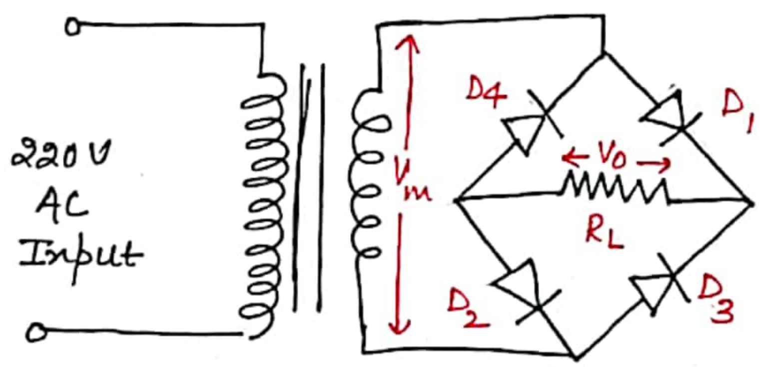


$\Rightarrow \left.\begin{array}{l} D_1 \rightarrow RB \\ D_2 \rightarrow FB \end{array}\right\} \Rightarrow \boxed{V_0 = I_L R_L = V_m}$

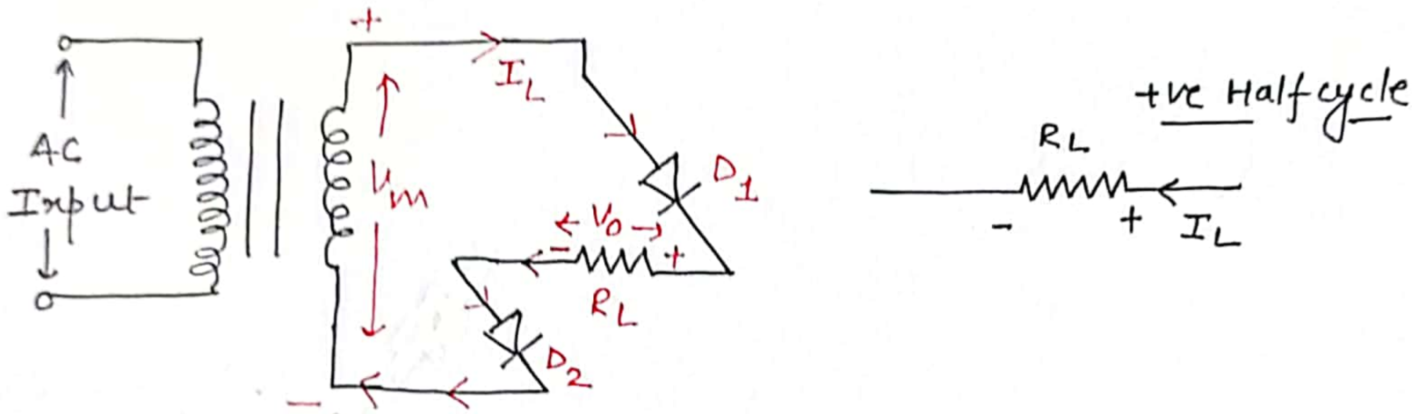


Output Waveform of Full Wave Centre tapped Rectifier

(2) Bridge Rectifier :-



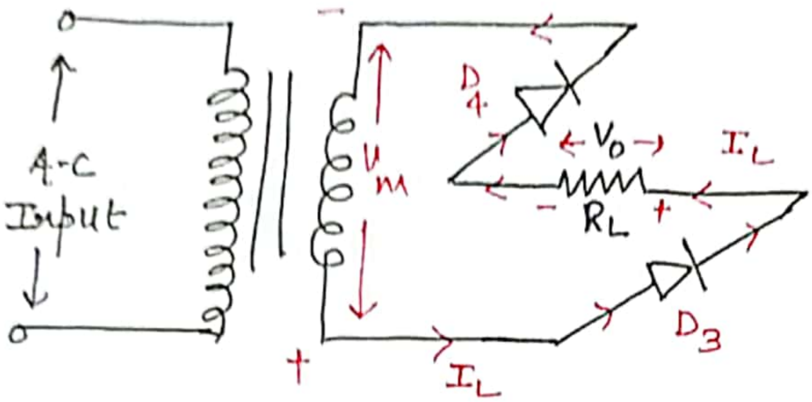
During (+ve) Half cycle :-



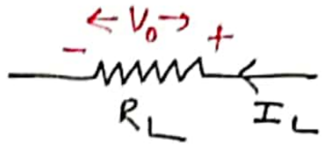
$\Rightarrow$ $D_1, D_2 \rightarrow FB$
$D_3, D_4 \rightarrow RB$ $\Rightarrow$ $\boxed{\text{output voltage } V_0 = I_L R_L = V_m}$

Scanned with CamScanner

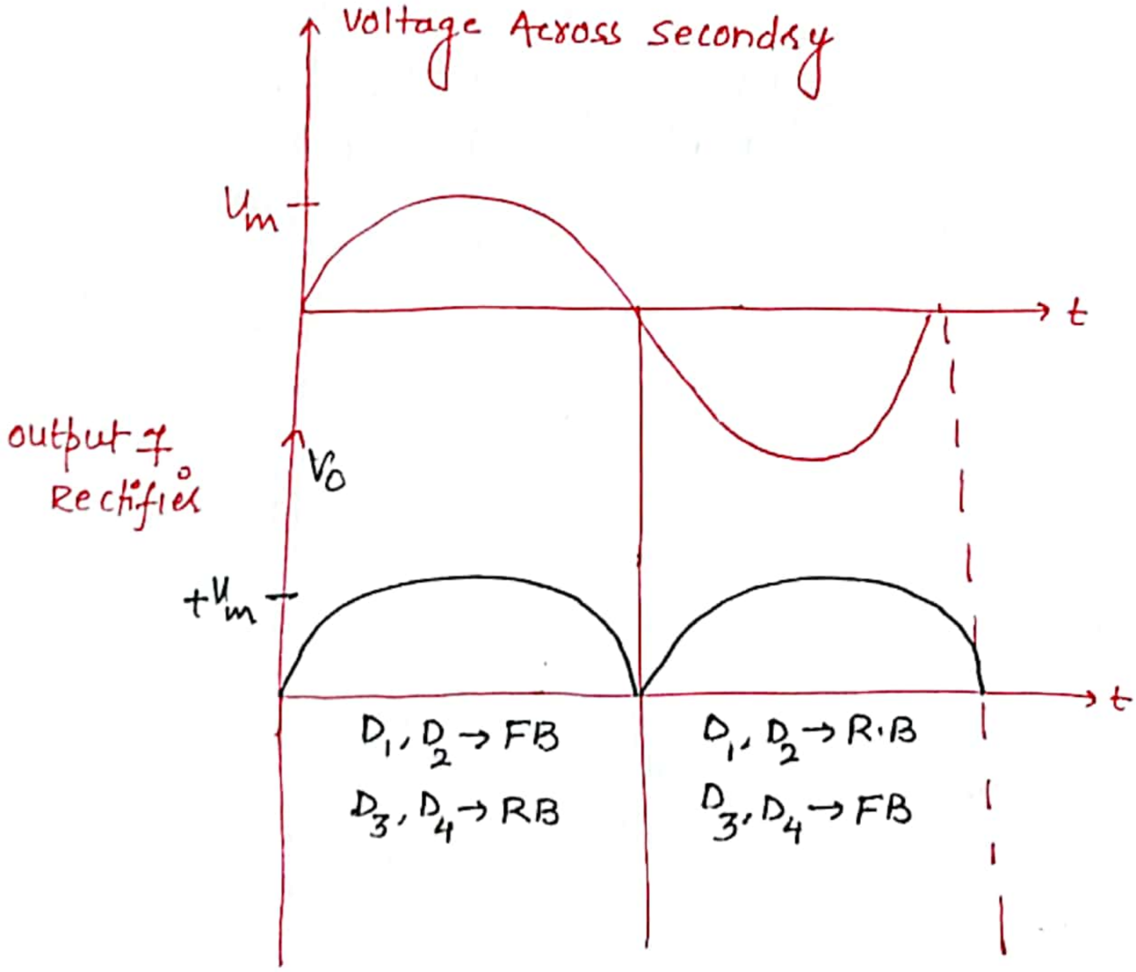
During (-ve) Half cycle :-



During (-ve) Half cycle



$\Rightarrow$ $\left.\begin{array}{l} D_3, D_4 \rightarrow FB \\ D_1, D_2 \rightarrow RB \end{array}\right\}$ $\Rightarrow$ $\boxed{V_0 = I_L R_L = V_m}$



Derivations of Rectifier

Electronics Engineering

Prepared by :- Mudit Saxena & Arpita Johri

PARAMETERS	HALF WAVE RECTIFIER	FULL WAVE RECTIFIER

(1) Average or Dc values of output voltage & Load current

HALF WAVE RECTIFIER

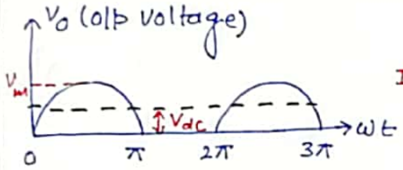


Fig.(a) o/p voltage waveform For Half wave Rectifier

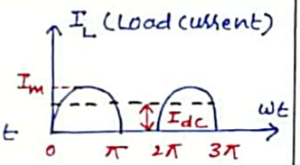


Fig.(b) Load current waveform For Half wave rectifier

⇒ Mathematically o/p voltage may be given as :-

$$\left.\begin{aligned} V_0 &= V_m \sin\omega t, && \text{For } 0 \le \omega t \le \pi \\ &= 0, && \text{For } \pi \le \omega t \le 2\pi \end{aligned}\right\} \longrightarrow (1)$$

We know

$$V_{avg} \text{ or } V_{dc} = \frac{\text{Area under the Curve over Full cycle}}{\text{Base}} \longrightarrow (A)$$

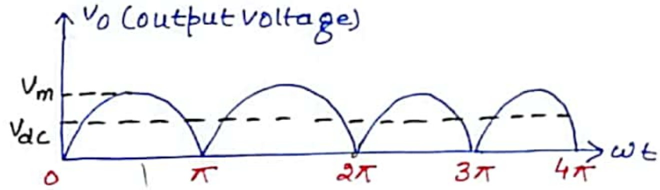
but

$$\text{Area} = \int_0^{2\pi} V_0\, d(\omega t) = \int_0^{\pi} V_0\, d(\omega t) + \int_{\pi}^{2\pi} V_0\, d(\omega t) \longrightarrow (2)$$

From eqn (1), put the value of V_0 in eqn (2):-

$$\text{Area} = \int_0^{\pi} V_m \sin\omega t\, d(\omega t) + \int_{\pi}^{2\pi} 0\, d(\omega t)$$

FULL WAVE RECTIFIER



Average or dc value of o/p voltage

⇒ Mathematically o/p voltage may be given as :-

$$\left.\begin{aligned} \Rightarrow V_0 &= V_m \sin\omega t, && \text{For } 0 \le \omega t \le \pi \\ &= -V_m \sin\omega t, && \text{For } \pi \le \omega t \le 2\pi \end{aligned}\right\}$$

⇒ (-) sign indicates that during second half cycle, the sine wave is inverted

⇒ We know:-

$$V_{dc} = V_{avg} = \frac{\text{Area under the Curve over Full cycle}}{\text{Base}}$$

But

$$\text{Area} = \int_0^{2\pi} V_0\, d(\omega t) = \int_0^{\pi} V_0\, d(\omega t) + \int_{\pi}^{2\pi} V_0\, d(\omega t)$$

HWR

$$\text{Area} = V_m\left[-\cos\omega t\right]_0^{\pi} + 0$$

$$= V_m\left[-\cos\pi - (-\cos 0)\right]$$

$$= V_m[1+1]$$

$$\boxed{\text{Area} = 2V_m}$$

From eq^n Ⓐ, we get :-

$$\boxed{V_{dc} \text{ or } V_{avg} = \frac{2V_m}{2\pi} = \frac{V_m}{\pi} = 0.318V_m}$$

⇒ Thus dc value of o/p voltage is 31.8% of the maximum A.C I/p voltage.

⇒ Similarly average or dc value of load current may be calculated as follows :-

⇒ $I_{avg} = I_{dc} = \frac{V_{dc}}{R_L}$

but $V_{dc} = \frac{V_m}{\pi}$ (above calculated)

⇒ so $I_{dc} = \frac{V_m}{\pi R_L}$ but $\frac{V_m}{R_L} = I_m$

FWR

⇒ $\text{Area} = \int_0^{\pi} V_m \sin\omega t\, d(\omega t) + \int_{\pi}^{2\pi} -V_m \sin\omega t\, d(\omega t)$

$$= \left[-V_m\cos\omega t\right]_0^{\pi} + \left[V_m\cos\omega t\right]_{\pi}^{2\pi}$$

$$= V_m\left[-\cos\pi + \cos 0\right] + V_m\left[\cos 2\pi - \cos\pi\right]$$

$$= V_m[1+1+1+1]$$

$$\boxed{\text{Area} = 4V_m}$$

so $V_{dc} = V_{avg} = \frac{\text{Area}}{\text{Base}} = \frac{4V_m}{2\pi} = \frac{2V_m}{\pi}$

$$\boxed{V_{dc} = V_{Avg} = 0.636V_m}$$

⇒ Thus dc value of o/p voltage is 63.6% of max. A.C Input voltage.

⇒ Similarly avg or dc value of load current may be calculated as follows:-

$I_{avg} = I_{dc} = \frac{V_{dc}}{R_L}$ ⇒ but $V_{dc} = \frac{2V_m}{\pi}$ (above)

HWR

$\Rightarrow I_{dc} = I_{avg} = \frac{I_m}{\pi}$

$$\boxed{I_{dc} = I_{avg} = 0.318\, I_m}$$

$\Rightarrow$ d.c value of Load current is 31.8% of max. value of load current

FWR

$I_{dc} = \frac{2V_m}{\pi R_L}$ but $\frac{V_m}{R_L} = I_m$

so $I_{avg} = I_{dc} = \frac{2I_m}{\pi}$

$$\boxed{I_{avg} = I_{dc} = 0.636\, I_m}$$

$\Rightarrow$ DC value of Load current is 63.6% of max. value of load current

---

2 Ripple Factor

HWR

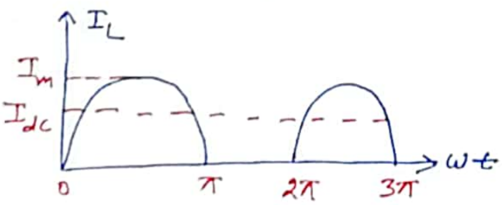
We know

Ripple factor $\boxed{r = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}} \rightarrow (1)$

$\Rightarrow$ For Half wave rectifier, we know

$\Rightarrow \boxed{I_{dc} = \frac{I_m}{\pi}}$ (calculated above)

but $I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} I_L^2\, d(\omega t)}$



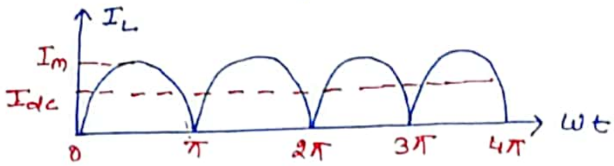
FWR

We know $\boxed{r = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}} \rightarrow (1)$

$\Rightarrow$ For Full wave rectifier, we know.

$\boxed{I_{dc} = \frac{2I_m}{\pi}}$ (above)

but $I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} I_L^2\, d(\omega t)}$



HWR

but $I_L = I_m \sin\omega t$, For $0 \le \omega t \le \pi$
$= 0$, For $\pi \le \omega t \le 2\pi$

$$I_{rms} = \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} I_m^2 \sin^2\omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0 \, d(\omega t)\right]}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2\omega t \, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi}\left(\frac{1-\cos 2\omega t}{2}\right) d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi \times 2}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[(\pi-0)-(0-0)\right]}$$

$$= \sqrt{\frac{I_m^2}{4}}$$

$$\boxed{I_{rms} = \frac{I_m}{2}}$$

FWR

but $I_L = I_m \sin\omega t$, For $0 \le \omega t \le \pi$

Therefore

$$I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2\omega t \, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{\pi}\int_0^{\pi} \frac{(1-\cos 2\omega t)}{2} d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{\pi}\left[\frac{\omega t}{2} - \frac{\sin 2\omega t}{4}\right]_0^{\pi}}$$

$$= \sqrt{\frac{I_m^2}{\pi} \times \frac{\pi}{2}}$$

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}}$$

put the value of I_{rms} & I_{dc} in eqn (1):-

HWR	FWR

HWR

⇒ put the value of I_{dc} & I_{rms} in eqn ①

ripple factor $r = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$

$$r = \sqrt{\left[\frac{(I_m/2)}{(I_m/\pi)}\right]^2 - 1}$$

$$\boxed{r = 1.21}$$

FWR

$$r = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1}$$

$$= \sqrt{\frac{\pi^2}{8} - 1}$$

$\boxed{r = 0.482}$ which is much smaller than Half wave rectifier, Due to this reason, Full wave rectifier is widely used.

Note:- 1) Ripple factor should be as low as possible

2) Ripple factor indicates that how close the rectified o/p is to the pure ideal dc voltage waveform.

③ Efficiency of Rectifier

We know

$$\boxed{\text{Rectifier Efficiency } (\eta) = \frac{\text{dc Power Delivered}}{\text{A.C Input power}}}$$

$$\eta = \frac{P_{dc}}{P_{ac}}$$

⇒ but

$$P_{dc} = I_{dc}^2 \times R_L$$

$$P_{ac} = I_{rms}^2 (R_L + R_F)$$

Where $R_L \rightarrow$ Load Resistance

$R_F \rightarrow$ Forward Resistance of diode

HWR	FWR

$$\boxed{\eta = \frac{I_{dc}^2 \times R_L}{I_{rms}^2 \times (R_L + R_F)}} \longrightarrow (A)$$

For Half Wave Rectifier

We know
$$\left.\begin{aligned} I_{dc} &= \frac{I_m}{\pi} \\ I_{rms} &= \frac{I_m}{2} \end{aligned}\right\}$$

⇒ put the values in eq^n (A)

$$\eta = \frac{\left(\frac{I_m}{\pi}\right)^2 \times R_L}{\left(\frac{I_m}{2}\right)^2 \times (R_L + R_F)}$$

$$= \frac{4}{\pi^2} \times \frac{R_L}{(R_L + R_F)}$$

$$\boxed{\eta = \frac{0.406}{1 + \frac{R_F}{R_L}}}$$, Efficiency will be max, when $\boxed{R_L >> R_F}$

⇒ $\boxed{\eta_{max} = 0.406 = 40.6\%}$

For Full Wave Rectifier

We know
$$\left.\begin{aligned} I_{dc} &= \frac{2I_m}{\pi} \\ I_{rms} &= \frac{I_m}{\sqrt{2}} \end{aligned}\right\}$$

⇒ put the values in eq^n (A):-

$$\eta = \frac{\left(\frac{2I_m}{\pi}\right)^2 \times R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 \times (R_L + R_F)} = \frac{8}{\pi^2} \times \frac{R_L}{R_L + R_F}$$

$$\boxed{\eta = \frac{0.812}{1 + \frac{R_F}{R_L}}}$$

⇒ Efficiency will be max, when $R_L >>> R_F$

$\boxed{\eta_{max} = 0.812 = 81.2\%}$ which is twice as that of HWR. Hence a FWR is twice as effective as a HWR.

	HWR	FWR
4. Peak Inverse Voltage (PIV)	PIV is the maximum Amount of voltage that a diode has to withstand when it is operated in reverse Bias. $\boxed{PIV = V_m}$ → For Half wave	For Full wave < centre tapped, Bridge Rectifier. ⇒ For centre tapped :- $\boxed{PIV = 2V_m}$ ⇒ For Bridge :- $\boxed{PIV = V_m}$
5. Transformer Utilization Factor (TUF)	$TUF = \frac{\text{DC Power Delivered to the Load}}{\text{AC power rating of transformer secondary}}$ $\boxed{TUF = \frac{V_{dc} I_{dc}}{V_{rms} I_{rms}}}$ For Half wave Rectifier :- $TUF = \frac{V_{dc} I_{dc}}{V_{rms} I_{rms}}$	⇒ For Full wave Rectifier :- $TUF = \frac{TUF(\text{Primary}) + TUF(\text{secondry})}{2}$ $TUF = \frac{0.574 + 0.812}{2}$ $\boxed{TUF = 0.693 = 69.3\%}$

⇒ but
$$\left.\begin{aligned} V_{dc} &= V_m/\pi \\ I_{dc} &= I_m/\pi \\ V_{rms} &= V_m/\sqrt{2} \\ I_{rms} &= I_m/2 \end{aligned}\right\} \text{For Half Wave Rectifier}$$

⇒ put these values, we get :-

$$TUF = \frac{[V_m/\pi]\,[I_m/\pi]}{(V_m/\sqrt{2})\,[I_m/2]} = \frac{2\sqrt{2}}{\pi^2}$$

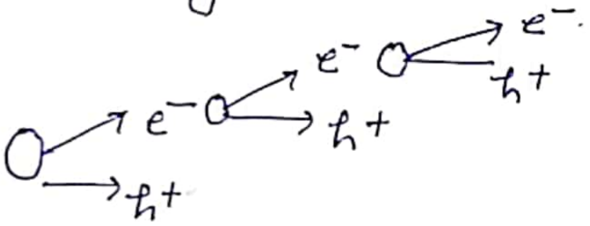
$$\boxed{TUF = 0.287 = 28.7\%}$$

⇒ TUF should be as high as possible.

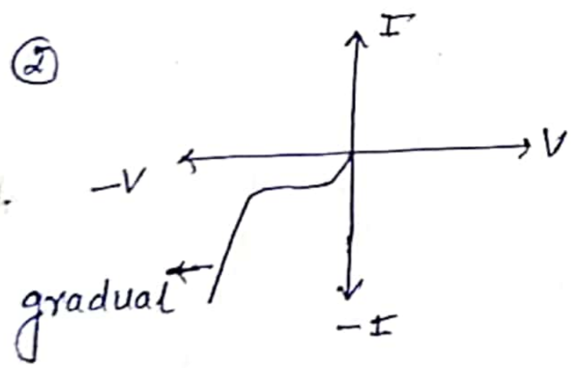
⇒ TUF for Half wave Rectifier = 28.7 % indicates that the transformer is being utilized to only 28.7 % of its full capacity

Breakdown Mechanism :-

1. **Avalanche Breakdown :-** (1) When the diode is Reverse biased, minority charge carriers gain momentum and collide with bonds. Due to this elastic collision, Electron hole pair is released. These released charge carriers will again collide with other bonds thus due to this cumulative multiplication of charge carriers, the reverse current increases exponentially and leads to breakdown of diode



(2)



(2) **Zener Breakdown :-** It is usually observed in heavily doped diode where the depletion layer is very narrow.

P.T.O

$\Rightarrow \quad E = \dfrac{V}{d}$

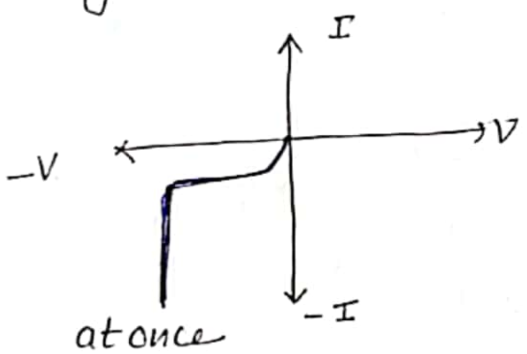
d — width of depletion layer which is in μm.

$\Rightarrow \quad E = \dfrac{\text{volts}}{\mu m} = \dfrac{\text{volts}}{10^{-6}\, m}$

$\Rightarrow \quad \boxed{E = 10^{6}\ \dfrac{V}{m}}$

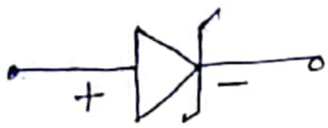
⇒ Due to narrow depletion layer, an electric field of the order of 10^6 V/m exist and the bonds are broken at once. Hence reverse current increases exponentially in reverse direction.

2.)

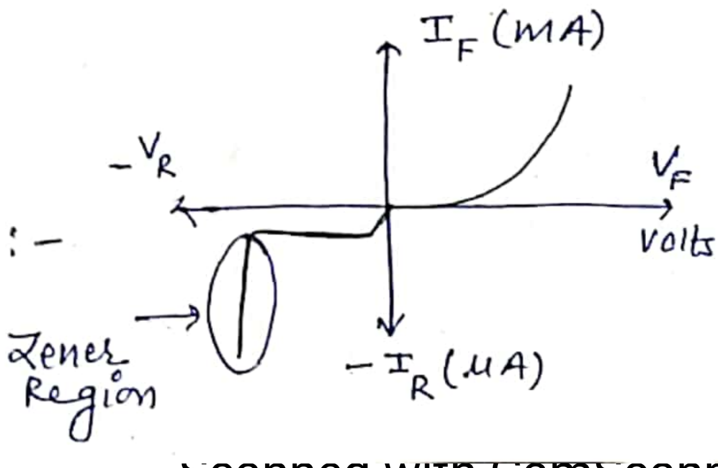


Zener Diode:- Zener diode is a special purpose diode because it conducts as conventional diode in Forward ~~diode~~ biased and also conducts when it is reverse biased.

Symbol:

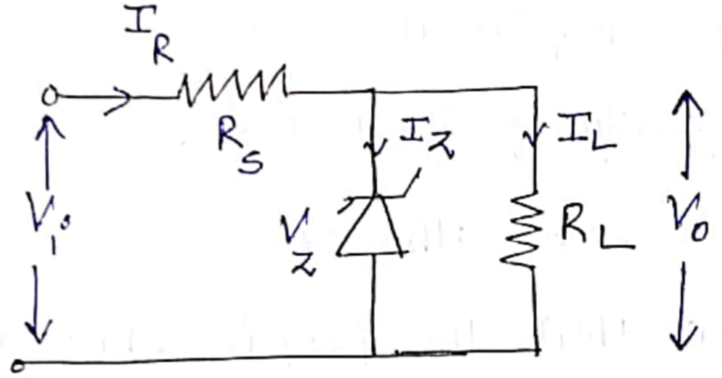


V-I characteristics of Zener:-

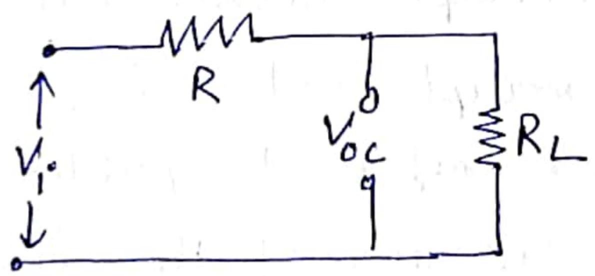


Zener Diode As Voltage Regulator or Shunt Regulator :-

⇒ Zener diode is used as Voltage Regulator where o/p voltage is Constant irrespective of changes in input voltage.



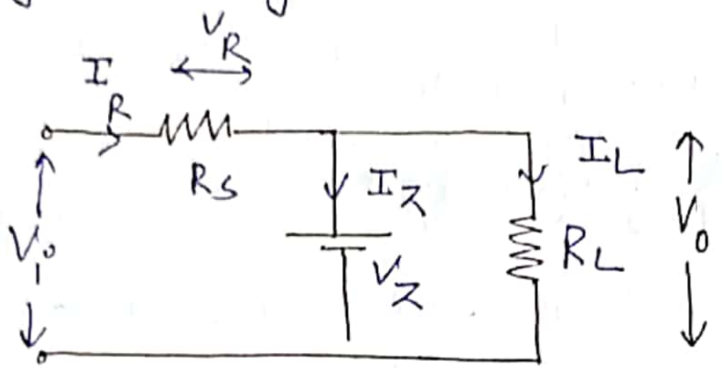
Step1:- First check whether Zener diode is 'ON' or 'OFF' by removing it from the ckt and Calculating open ckt Voltage V_{oc}.



$$\boxed{V_{oc} = \frac{R_L}{R+R_L} V_i}$$

Step2:- if $\boxed{V_{oc} \geq V_z}$, Zener is 'ON' otherwise 'OFF'

Step 3 Once Zener Diode is 'ON', replace Zener diode by a battery of V_Z.



Calculations:- Case 1:- When R_L & V_i both Fixed

1) $\boxed{V_0 = V_Z}$

2) $\boxed{I_L = \frac{V_0}{R_L} = \frac{V_Z}{R_L}}$

3) $\boxed{V_R = I_R R}$ or $\boxed{V_R = V_i - V_Z}$

4) $\boxed{I_R = \frac{V_R}{R_S}}$ or $\boxed{I_R = \frac{V_i - V_Z}{R_S}}$

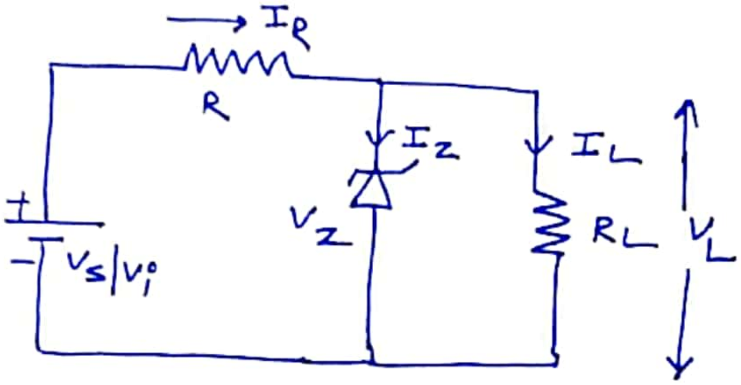
5) $\boxed{I_Z = I_R - I_L}$

6) $\boxed{P_Z = V_Z I_Z}$

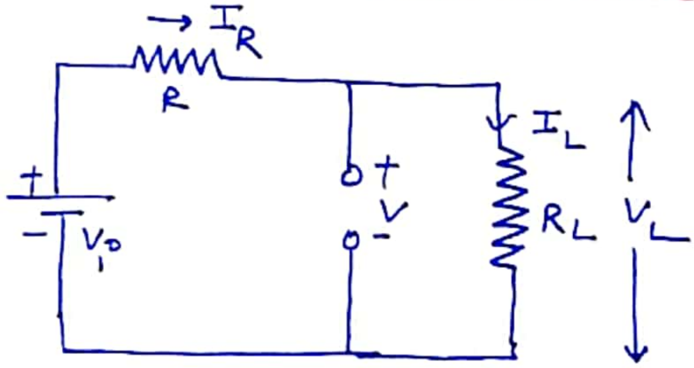
Here we can see from formula 1 that we get constant o/p equal to V_Z irrespective of changes in I/P voltage.

For Numericals :-

Case I :- V_i & R_L Fixed :-



→ To check the status of diode whether it is ON or OFF, circuit is modified as



$$\boxed{V = \frac{V_i R_L}{R + R_L}}$$

if
$V > V_Z \longrightarrow$ Diode is ON
$V < V_Z \longrightarrow$ Diode is OFF

When zener diode is ON :- $\boxed{V_L = V_Z}$ → see from the previous topic

$$\boxed{I_R = \frac{V_S - V_Z}{R}}$$

$$\boxed{I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L}} \quad \boxed{\because V_L = V_Z}$$

$$I_R = I_Z + I_L$$

$$\boxed{I_Z = I_R - I_L}$$

$\boxed{\text{Power Dissipation } P_Z = V_Z I_Z}$

When Diode is OFF :-

$$\boxed{V_L = V = \frac{V_S R_L}{R + R_L}}$$

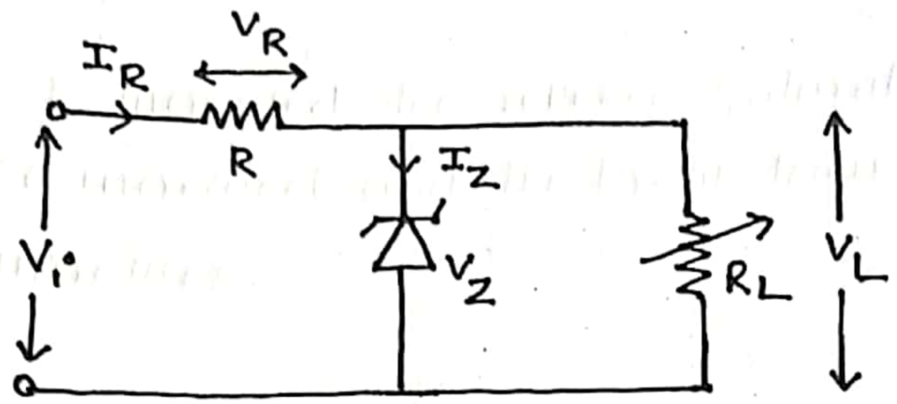
$$\boxed{I_Z = 0}$$

$$\boxed{I_R = \frac{V_S - V_L}{R}}$$

$$\boxed{P_Z = 0}$$

$$\boxed{I_L = \frac{V_L}{R_L}}$$

Case 2 :- When V_i is fixed & R_L is Variable



⇒ Let $R_{L(min)}$ be the minimum value of R_L that will make the Zener diode 'ON'.

⇒ The minimum condition to make Zener diode 'ON' is –

$$\boxed{V = V_Z}$$

⇒ but $V = \frac{R_{L(min)}}{R + R_{L(min)}} V_i$

Hence $V_Z = \frac{R_{L(min)}}{R + R_{L(min)}} V_i$

① ∴ $\boxed{R_{L(min)} = \frac{V_Z R}{V_i - V_Z}}$

② $\boxed{I_{L(max)} = \frac{V_L}{R_{L(min)}}}$

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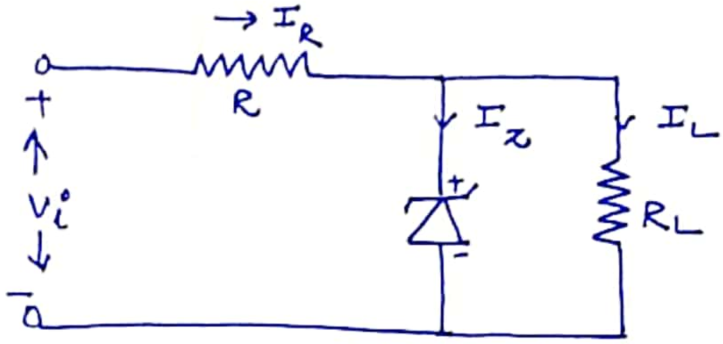
③ We know $I_R = I_Z + I_L$

but $I_R = \dfrac{V_i - V_Z}{R}$

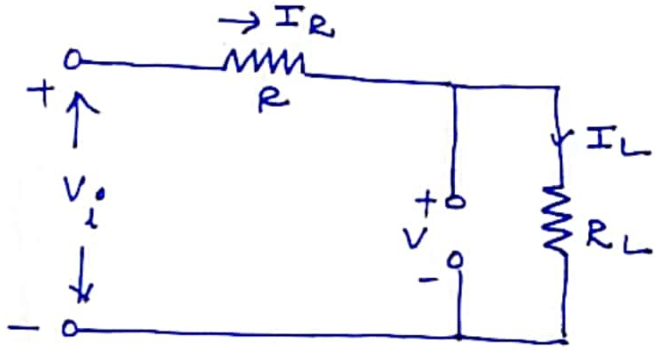
$$\therefore \boxed{I_{L(min)} = \underbrace{I_R}_{\text{fixed}} - I_{ZM}} \rightarrow \text{max. zener Current}$$

④ $$\boxed{R_{L(max)} = \frac{V_L}{I_{L(min)}} = \frac{V_Z}{I_{L(min)}}}$$

CASE (3) Fixed R_L, Variable V_i :-



In order to make the diode ON, we modify the ckt as given below:-



To make the diode ON

$$\boxed{V \geq V_z}$$

Where

$$\boxed{V = \frac{V_i \times R_L}{R + R_L}}$$

⇒ So minimum voltage required to make the Diode 'ON'

$$V_{min} = V_z$$

$$\downarrow$$

$$\frac{V_{i\,min} \times R_L}{R + R_L} = V_z$$

(i) $$\boxed{V_{i\,min} = \frac{V_z (R + R_L)}{R_L}}$$

② $\boxed{V_{i(max)} = V_{R(max)} + \underbrace{V_Z}_{\text{Fixed}}} \Rightarrow \left\{ \begin{array}{l} V_R = V_i - V_Z \\ \boxed{V_i = V_R + V_Z} \end{array} \right\}$

$\Rightarrow \boxed{V_{R(max)} = I_{R(max)} \times R}$

but $\boxed{I_{R(max)} = \underbrace{I_L}_{\text{fixed}} + I_{ZM}} \rightarrow$ Max. Zener Current

---

Varactor Diode | Varicap diode :-

→ Varactor diode is a specially designed p-n junction diode which can be used as voltage dependent variable capacitor.

→ It is also called as tuning diode or voltage variable capacitance (VVC).

Symbol :- It is a two terminal device. The terminals are Anode and Cathode.

Principle of operation :- The varactor diode is a p-n junction diode which is operated in the reverse biased condition.

* The p-region and n-region act like the plates of capacitor while the depletion region acts like dielectric. Thus there exists a capacitance at the p-n junction called transition capacitance.

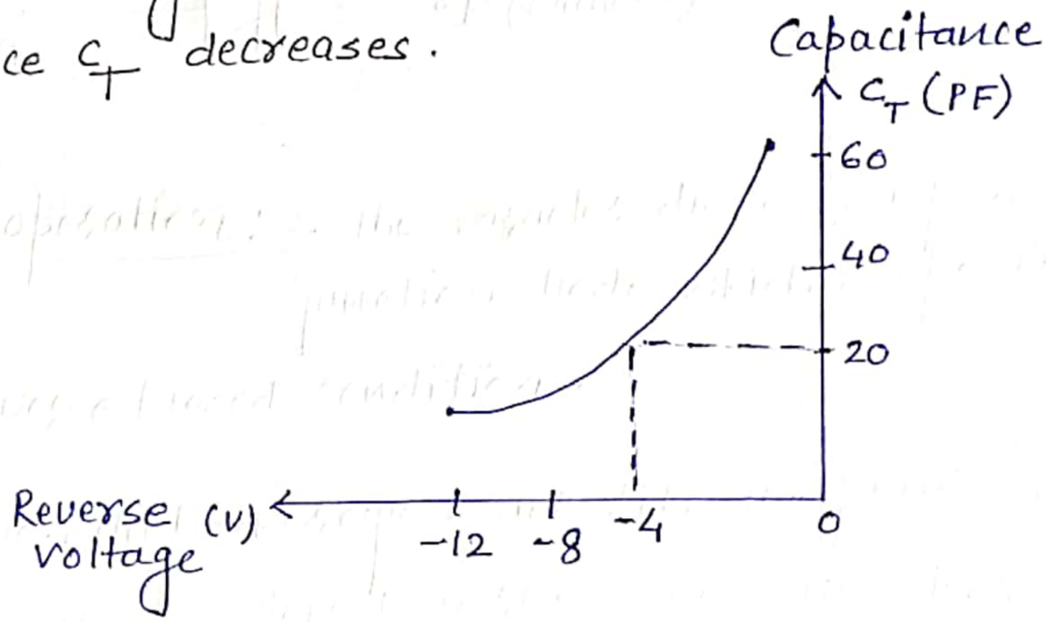
* The transition Capacitance C_T of a p-n junction diode is given by :-

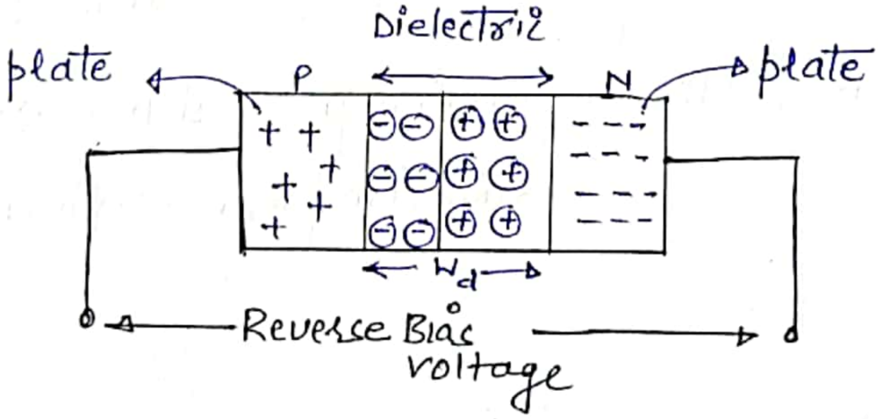
$$\boxed{C_T = \frac{\epsilon A}{W_d}}$$

Where $W_d \longrightarrow$ is the Width of depletion region which is dependent on the applied reverse voltage.

$A \rightarrow$ Area of Cross section.

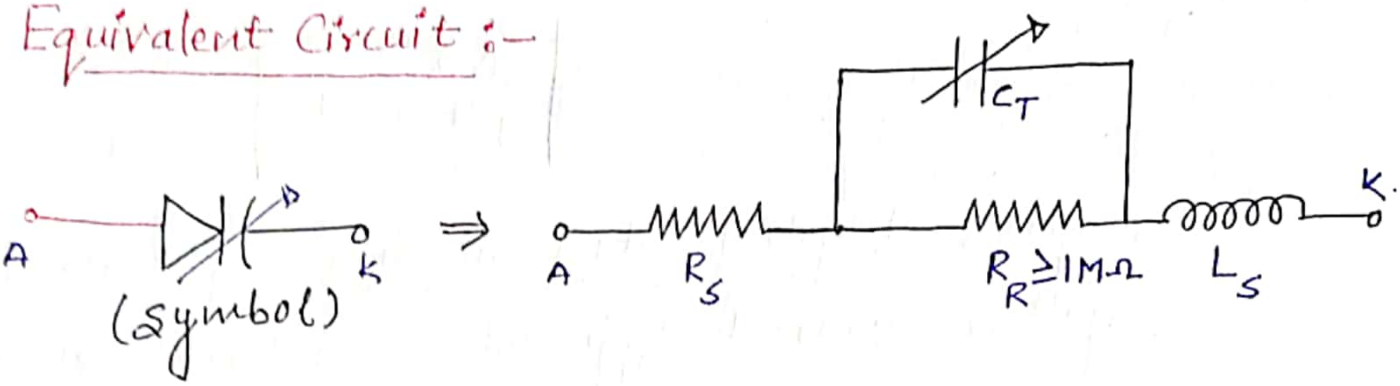
* As the applied reverse Voltage increases, the width of depletion region increases, therefore transition capacitance C_T decreases.





→ In short, Capacitance C_T can be Controlled by varying the reverse applied voltage.

Equivalent Circuit :-



* Since Varactor is reverse biased, the reverse resistance R_R in the equivalent ckt is very large, of the order of $1M\Omega$.
* While R_S is the geometric resistance of diode which is very small of the order of $.1\Omega$ to 12Ω.
* L_S is the effective inductance which is of the order of 10 nH.
* C_T is variable because it depends on the applied reverse voltage.

Effect of Temp:- Varactor diode have positive temp. Coefficient ie C_T Value increases by small amount as temp. increases.

Applications :- ① Main application of Varactor diode is LC tuned ckts.

② In TV receivers

③ FM Modulator.

④ Automobile radios.

Tunnel Diode :- The operation of tunnel diode is based on a special characteristic, known as the 'Negative Resistance'.

* The semiconductor materials used for constructing the tunnel diodes are Germanium or Gallium Arsenide.

* Construction of a tunnel diode is similar to that of p-n junction diode but both p and n sides are very heavily doped than the conventional rectifier diodes.

* The heavy doping of both the sides of junction results in extremely narrow depletion region when the tunnel diode is reverse biased.

Tunneling Phenomenon :- The width of depletion region is inversally proportional to the level of doping.

→ So as the doping increases, the width of depletion region decreases.

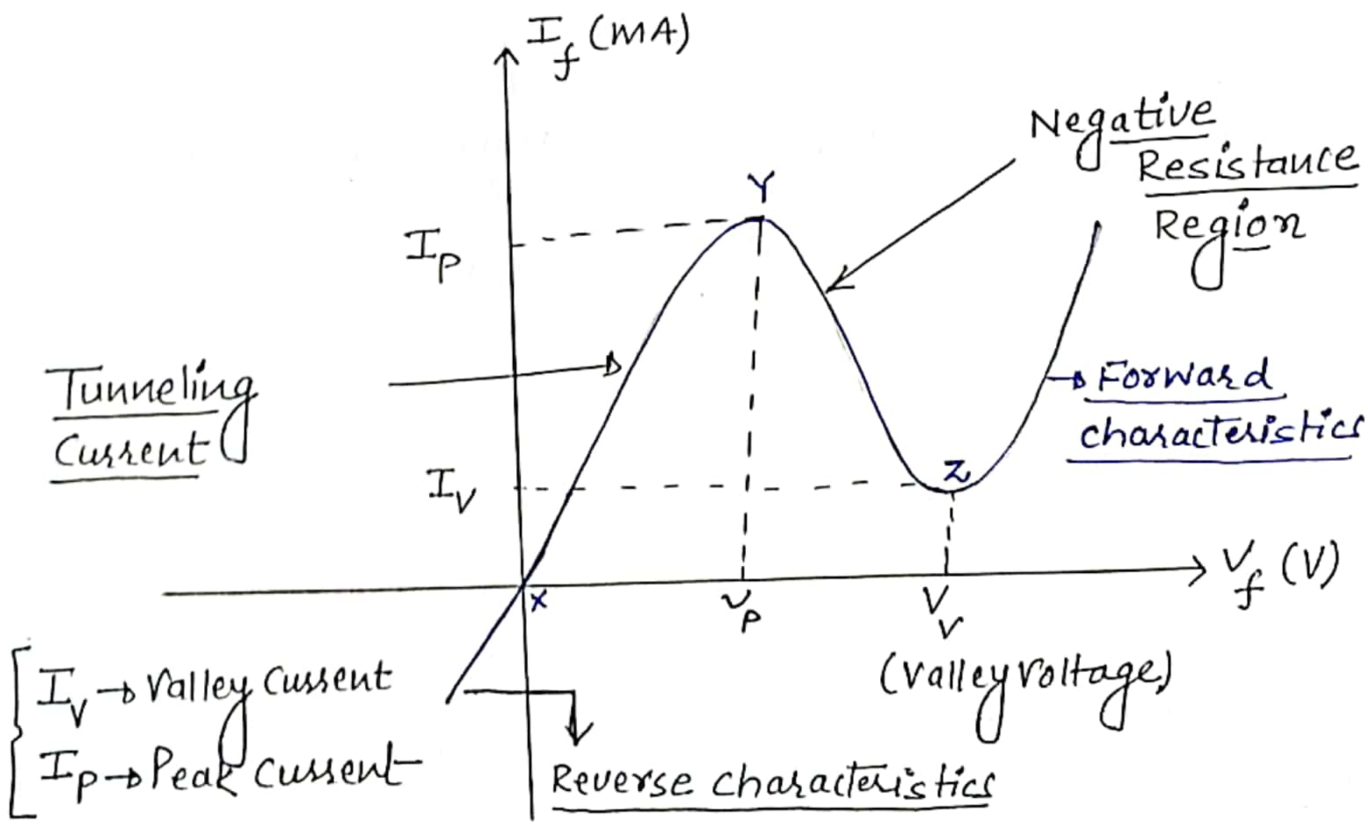
→ Due to the thin depletion region, an electron penetrates through the barrier. This is called 'Tunneling'.

and such high doping density p-n junction devices are called Tunnel diodes. Also known as Esaki diode.

Tunnel diode characteristics :-

① Reverse characteristics :- Due to heavy doping of p and n sides, the depletion region is extremely narrow when the tunnel diode is reverse biased. Therefore the reverse current starts flowing as soon as a very small reverse voltage is applied.

→ Thus the tunnel diode allows the conduction to take place for all reverse voltages. There is no breakdown effect as observed in conventional diode.



Forward characteristics :- Forward characteristics is divided into 3 regions.

① **Region X to Y :-** In the region, the forward voltage V_F is extremely small but heavy conduction will take place in this region because electrons 'tunnel' through the p-n junction. Tunneling occurs due to heavy doping. Impurity concentration (doping) is 1 part in 10^3 atoms.

② **Region Y to Z :-** In this region, at point Y, the forward voltage begins to develop a barrier and forward current starts decreasing inspite of continued increase in V_F. This region is called as '**Negative Resistance Region**'.

→ The diode resistance in region Y to Z is mathematically expressed as :-

$$\boxed{R_F = \frac{\Delta V_F}{\Delta I_F}}$$

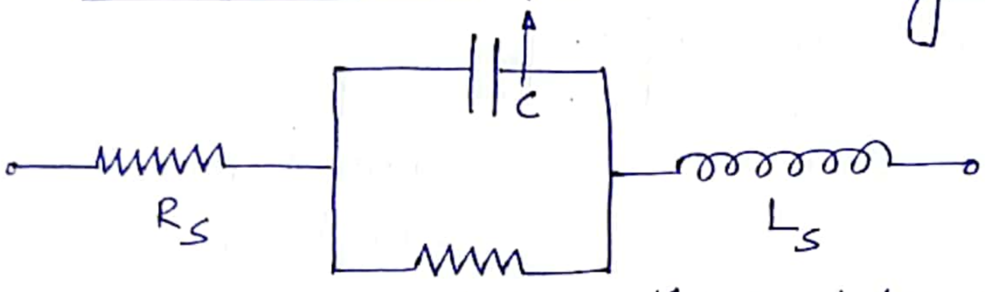
* ΔV_F is positive but ΔI_F is negative, Hence R_F is called as '**Negative Resistance**'

→ The negative resistance characteristics is utilised in the applications of tunnel diode such as Oscillator and microwave amplifier. (4)

Symbol And Equivalent ckt :-

symbol

junction Diffusion Capacitance



Applications :- ① As a high speed switch
② As a high Frequency oscillator.
③ In pulse and digital circuits.

Advantages :- ① Low cost
② Low Noise.
③ Construction is simple.
④ It consumes low power.

Disadvantages :- ① No isolation between input & output.
② Low output voltage swing so amplification is required.

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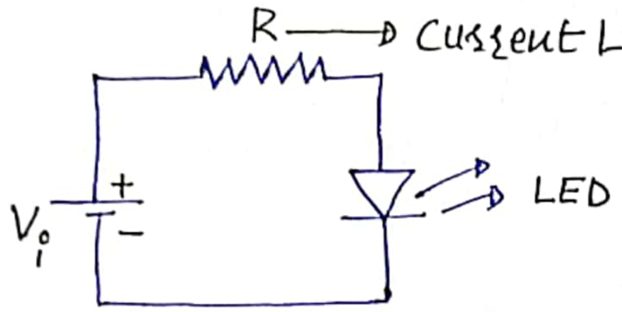
LED :- (Light Emitting diode) :- An LED emits light when electrical energy is applied to it.

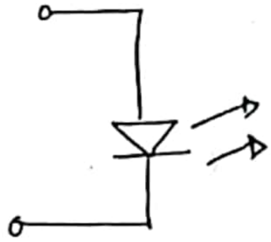
* LED is a two terminal device, the terminals are Anode (A) and Cathode (K).

* A PN junction is formed between anode and cathode, so LED is basically a PN junction diode.

* For proper operation, LED is always forward biased.



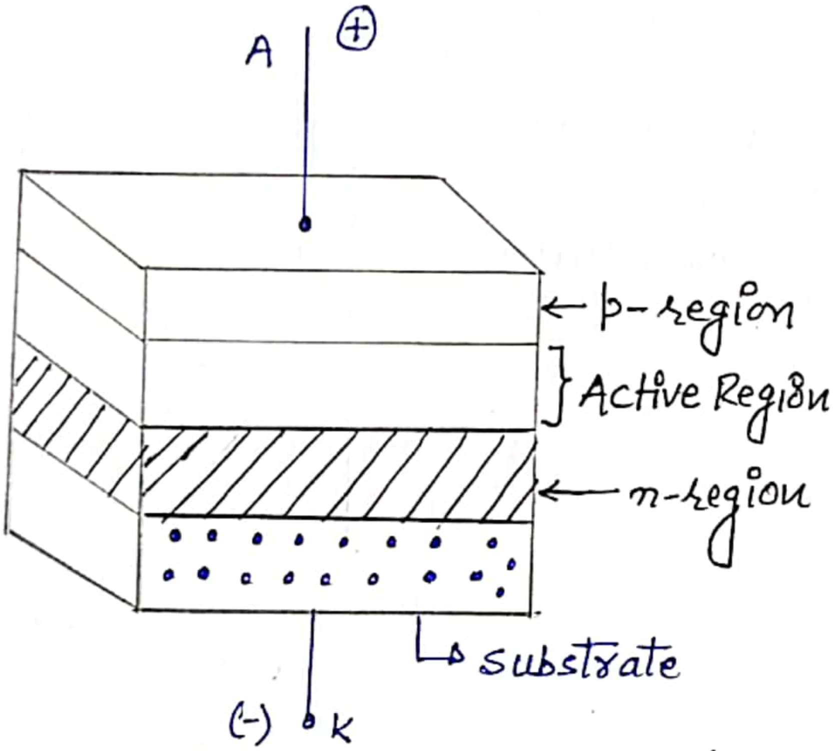
LED BIASING

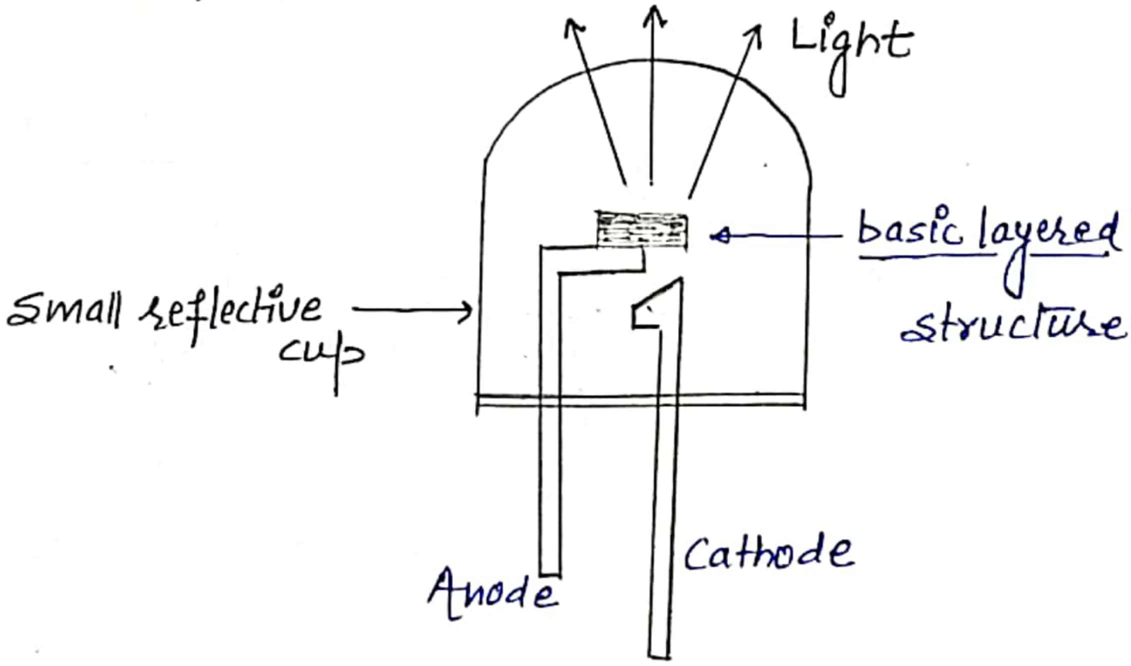


(symbol)

Construction :- In LED, 3 semi conductors layers are deposited on the substrate. The Active region exists between p and n regions. The light emerges from the active side in all the directions when electron hole pairs recombine.

* The disadvantage of this structure is that the LED emits light in all directions. The problem can be solved by placing the structure inside a small reflective cup so as to focus the light in the desired direction.





Semiconductor Material used :- LEDs are made of Gallium Arsenide (GaAs), Gallium Arsenide Phosphide (GaAsP) and Gallium Phosphide (GaP).

Principle of operation :- When LED is forward biased, the electrons in the n-region will cross the junction and recombine with the holes in the p-type material.

* These free electrons reside in the conduction band and holes in the valence band.

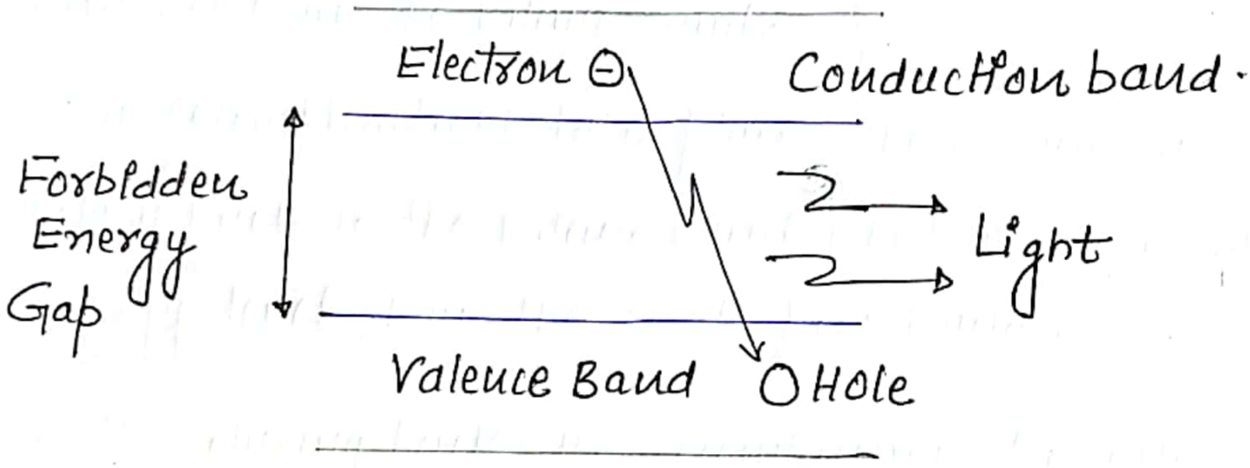
* When recombination takes place, these electrons return back to the valence band which is at a lower energy level than the conduction band.

* While returning back, the recombining electrons give away (release) the excess energy in the form of light. This process is called as '<u>Electro Luminescence</u>'. In this way LED emits light.

Colours of Emitted Light :- The colour of emitted light is decided by its wavelength which depends on the

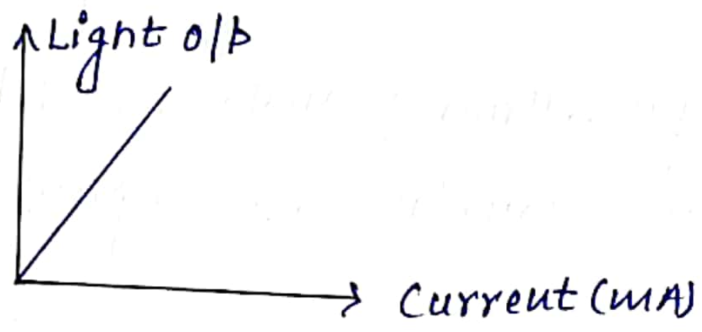
· Value of forbidden Energy gap. Forbidden gap depends on materials used. Hence the colour of emitted light is dependent on material used. (4)

SR NO	Material	colour of emitted light
1.	Gallium Arsenide →	Infrared
2.	Ga As P →	Red or Yellow..
3.	Ga P →	Red or Green.



Process oF Electroluminscence

* The bestway of Controlling the LED brightness is to drive LED with a constant current source.



Advantages of LED:- ① LEDs are light in weight.
② LEDs are available in various colours.
③ LEDs have long life.
④ LEDs are cheap and readily available.

Disadvantages:- ① Characteristics are affected by temp.
② Need large power for the operation.
③ Luminous efficiency of LEDs is low.

Applications:- ① As an ON-OFF indicator in various electronic devices.
② In Infrared remote controls.
③ In seven-segment displays.
④ In optocouplers.

Liquid crystal display :- (LCD)

* LCDS are very special type of displays because they don't convert the electrical energy into light like LED displays.

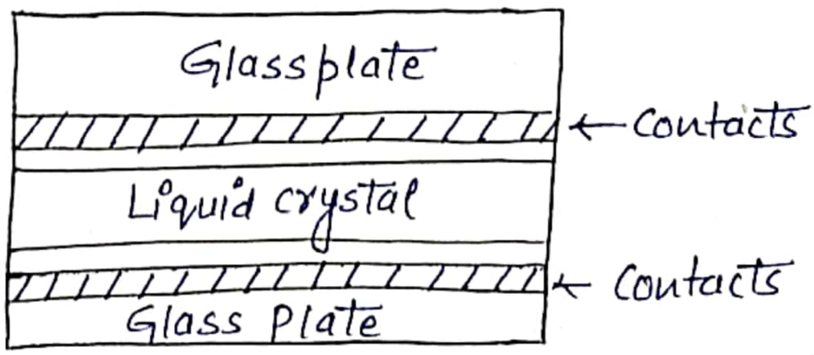
* LCDS use special type of material called liquid crystals. These materials are unique as they have the properties of liquids as well as solid crystals.

Types of Liquid crystals Displays :-

① **Dynamic Scattering Display :-** Fig. shows the Construction of LCD display.

The Liquid crystal fluid is contained between two glass plates. The back glass plate has a coating of transparent Conductive material and front plate has a Conductive coating.

→ when the display is not activated with the external Source, the liquid crystal remains transparent and allows the light to pass through it without any reflection.



→ When electrical signal is applied to the display, the molecule orientation will collapse, This is called as dynamic scattering.

→ Dynamic scattering type LCDS are of two types
- Transmittive type
- Reflective type

Dynamic scattering Display

② Field Effect Display :- It consists of two glass plates and a liquid crystal fluid is sandwiched between them.

When the electrical excitation is applied, the crystal molecules will get aligned. and the light passing through them will not be twisted at all.

→ Field type LCD.

Advantages :- ① Power saving takes place.
② All the segments have uniform brightness.
③ Low cost.

Disadvantages :- ① Backlighting is necessary.
② Poor Reliability.
③ Low switching speed.

Applications of LCD :- (1) 7-Segment LCDS are used in wrist watches and Calculators.

(2) Alphanumeric LCD displays are used in digital diaries, Pagers, mobile phones etc.

Comparision OF LED And LCD's:-

Parameter	LED	LCD
Contrast Ratio	→ 10:1	20:1
speed	→ Fast	slow
Life span	→ Long Life	short Life
colours	→ Red, Green, yellow and orange	depends on the illumination
Power Required per digit	→ More	Less

(Not to do)

N.P. QNo A 320 W carrier is simultaneously modulated by two audio waves with modulation % of 45 and 60 respectively. What is the sideband power radiated.