P-N junction diode
Diode current equation

Zener diode with V-I characteristics
Zener diode acts as voltage regulator
Tunnel diode

Static - dynamic
Varactor diode
Diode Capacitances

Called positive carriers or p-type semi conductor material

In p-type semi conductor majority carriers are holes and minority carriers are electrons.

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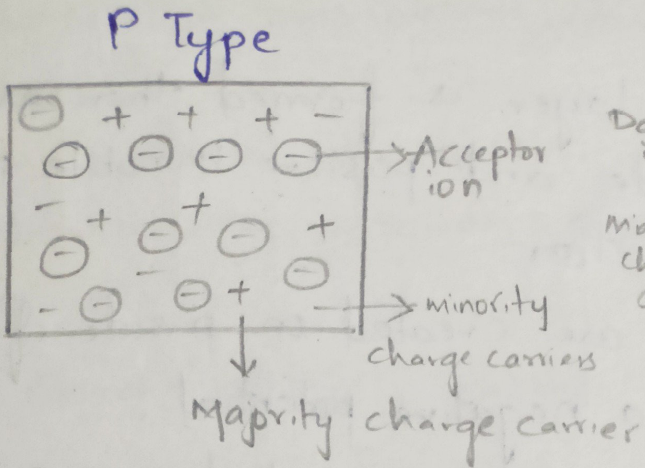
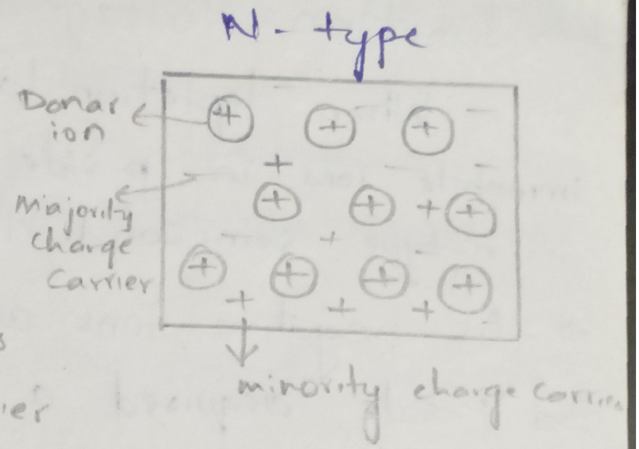
→ PN Junction diode:

If donar impurities are diffused in one side of pure semi conductor and acceptor impurities are diffused to another side, a P-N junction is formed.

* P-type semi conductor has negative acceptor ions positively charged particles and minority charged carriers are electrons

* N-type semi conductor has positive donar ions negatively charged free electrons and minority ~~charged~~ charged carriers are holes.



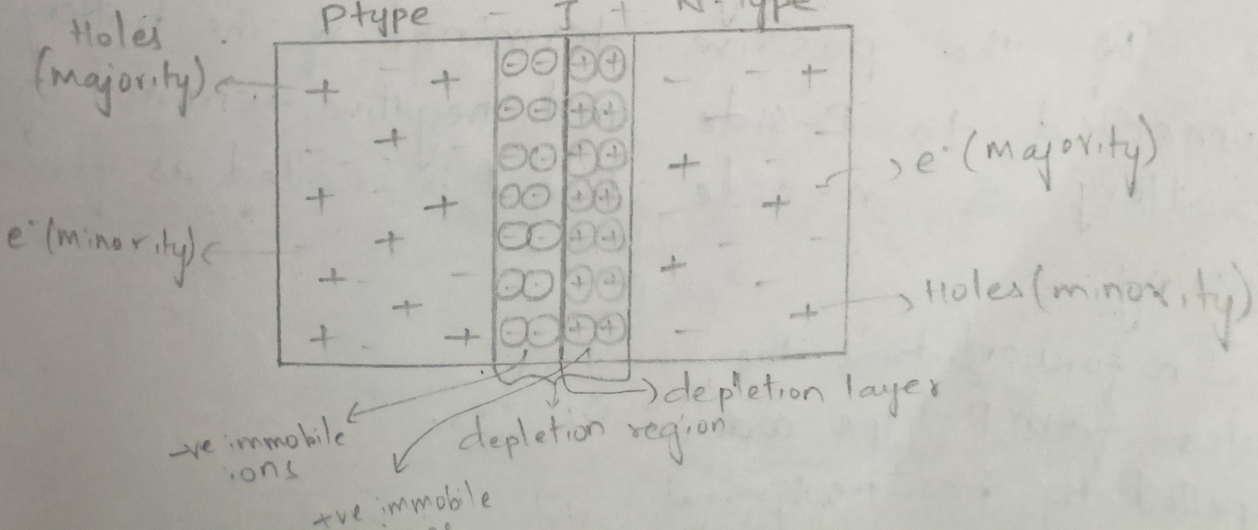


→ Formation of depletion layer:-

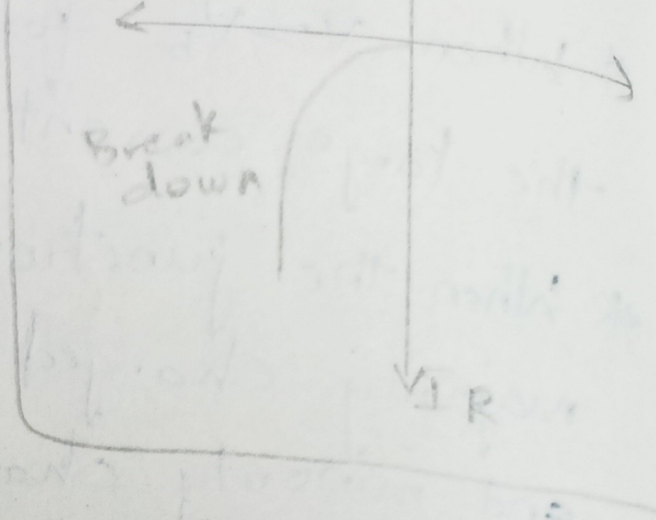
* P-type material has high concentration of holes and N-type material has high concentration of electrons due to this high concentration holes are diffusing from ptype to N-type, and electrons diffusing N-type to ptype. This process is known as diffusion.

* Due to diffusion some of holes from p-side cross-over to N-side where they combine with electrons and become neutral. Similarly some of electrons from N-side cross over to p-side where they combine with holes and becomes neutral. After sometime near the junction acceptor ions in p-side, donar ions in N-side are formed. This region is called as depletion region or space charge region

* The region around the junction from which charge carriers are depleted is called as depletion layer



→ Voltage-Current :-
V-I characteristics of P-N
Junction diode :-



* Forward bias :-

When the applied voltage is below the barrier voltage then the current will not flow in the circuit.

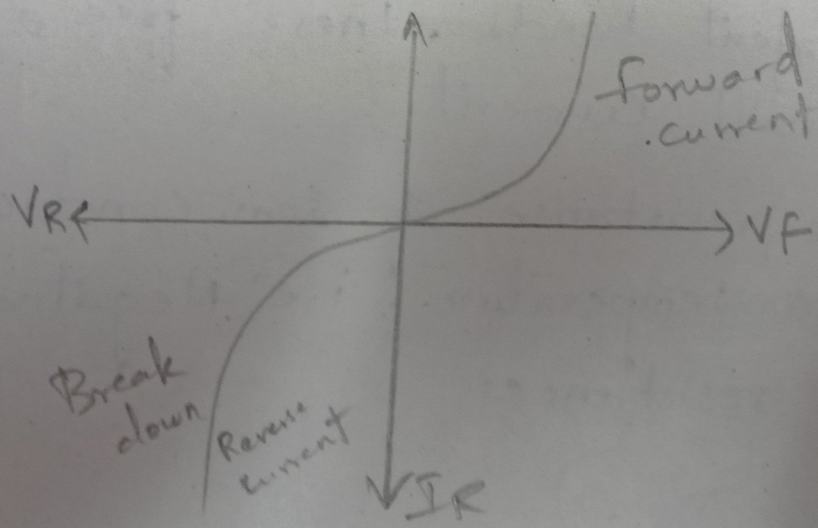
When the applied voltage is more than the barrier voltage then the current flows in the circuit

In P-N-junction diode the current is directly proportional to the applied voltage

* Reverse bias :-

In Reverse bias the barrier potential at the junction increases and offers very high resistance path due to this path their is no current flow in the Circuit

* However a very small amount of current flows in the Circuit due to minority Carries this is current is known as Reverse Saturation current.



→ Drift Current :-

It is defined as the flow of electric current

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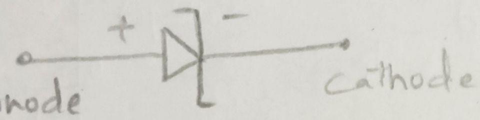
Unit - 2

Special purpose Devices:

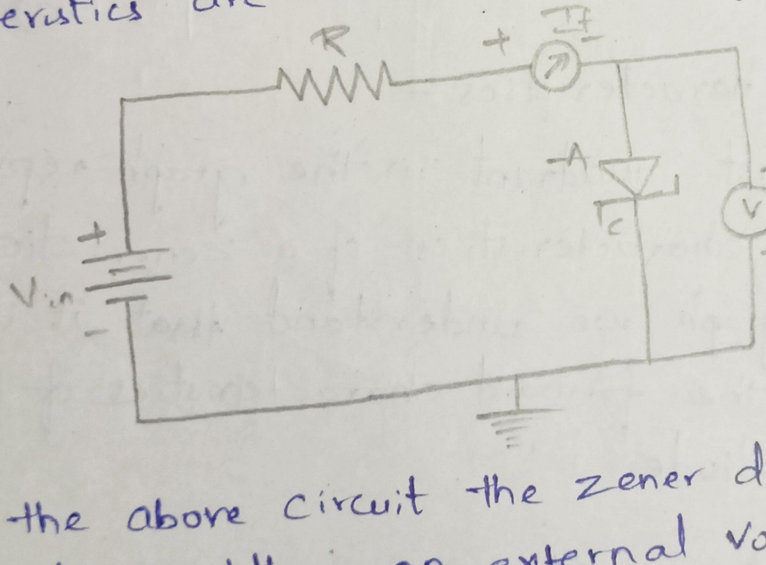
→ Zener diode:

Zener diode is a reverse biased heavily doped silicon or P-N Junction diode which is operated in the breakdown region

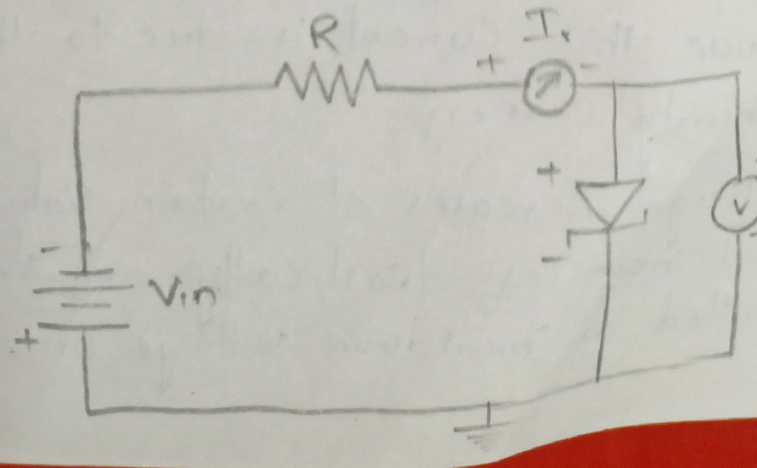
This is similar to a normal diode except the line representing on the cathode is bent at both ends that is like the letter 'Z'. The symbol of zener diode is as shown below.



When a zener diode is in forward bias its characteristics are same as ordinary diodes.



In the above circuit the zener diode is connected in forward bias. When an external voltage is applied to the diode the zener forward voltage and zener forward currents are increases gradually same like p-n junction diode



When reverse biased voltage is applied to a zener diode it allows only a small amount of leakage current until the voltage is less than zener voltage. When the external voltage is increases a value is reached at which the current increases greatly from its normal cutoff value then this voltage is called as zener voltage or breakdown voltage.

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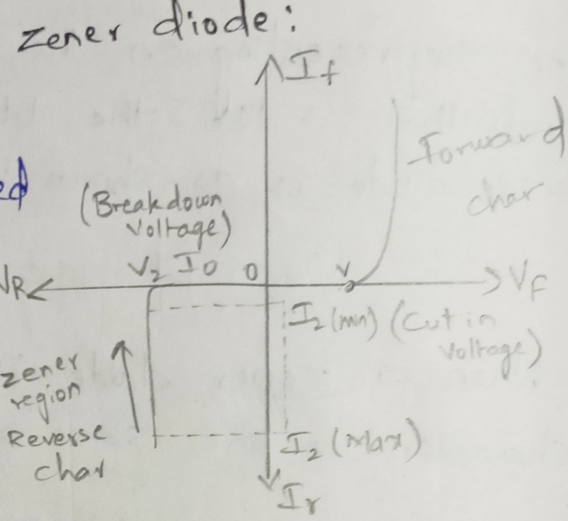
→ V-I characteristics of zener diode:

V-I characteristics of zener diode can be divided into two parts forward characteristics

1. Forward characteristics
2. Reverse characteristics



1. Forward characteristics :-

The first quadrant in the graph represents the forward characteristics of a zener diode. From the graph we understand ~~that~~ it is almost identical to the forward characteristics of any other P-N junction diode

2. Reverse charcteristics :

When a reverse voltage is applied to a zener diode a small reverse saturation current flows across the diode this current is due to thermally generated minority carriers

As the voltage increases at certain value the reverse current increases drastically and sharply this voltage is called as breakdown voltage or zener voltage

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→ Zener diode as a Voltage Regulator:

A zener diode is used as voltage regulator with the help of resistance

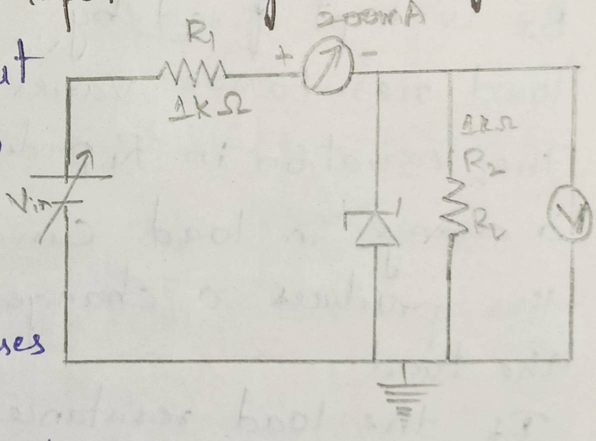
The principle of this regulator is when a diode Operates in ~~Not~~ breakdown region

$V_{in} > V_z$ then the Voltage across zener diode is constant for a large change in current through it

The working of zener diode is classified into two types

1. Regulation with Varying input voltage (line Regulation)
2. Regulation with Varying input Voltage (load Regulation)

→ 1. Regulation with Varying input voltage (line Regulation):



Let us consider the input Voltage is increases within the limits while the load resistance R_L being fixed as input voltage (V_{in}) increases the input current I is also increases. i.e; $I = \frac{V_{in} - V_z}{R}$

Now more current flows through the zener diode as a result the voltage drop across resistance is also increases in such a way that the voltage across R_L remains Constant

On the other hand if input Voltage decreases the Current (I) is also decreases. Now the current (I_z) through zener also decreases. Consequently the voltage drop across resistance also decreases

For a fixed values of R_L, input voltage must be large to turn on the zener diode

$$V_Z = V_{in\,min} \frac{R_L}{R+R_L}$$

$$V_{in\,min} = V_Z \frac{R+R_L}{R_L}$$

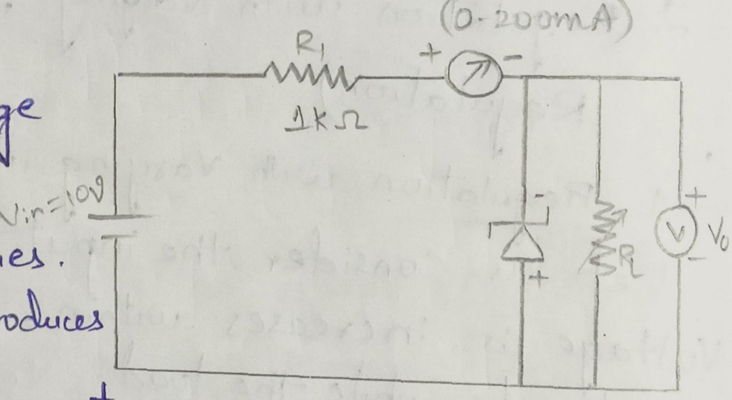
$$I_R = I_Z + I_L$$

$$I_{max} = I_{Z\,max} + I_L$$

$$V_{in\,max} = V_{R\,max} + V_Z$$

So, $R_{min} = \dfrac{V_{in\,max} - V_Z}{I_{max}} = \dfrac{V_{in\,min} - V_Z}{I_{Z\,max} + I_{L\,min}}$

→ 2. Regulation with Varying input Voltage (Load Regulation):



Let the input voltage B_I is kept fixed by load resistance varies.

The variation in R_L produces a change in load current.

this produces a change in output voltage across the load.

If the load resistance is decreases then the load current increases. due to this the zener current is decreases $V_o = V_{in} - I_R$

This expression shows that output voltage being constant. Since 'I' is constant

On the other hand if the load resistance increases. Then the load current decreases. Due to this the zener current increases.

→ The zener diode will be in breakdown region when V input is greater than or equal to V_Z

$$\boxed{V_{in} \geq V_Z}$$

We know $V_Z = \frac{V_{in} R_L}{R + R_L}$

$V_o = I_L - R_L$

$R_L min = \frac{R V_Z}{V_{in} - V_Z} \Rightarrow R_{L max} = \frac{V_Z}{I_L min}$ $R_L min = \frac{V_2}{I_L max}$

$I_L max = \frac{V_Z}{R_L min} = \frac{V_{in} - V_Z}{R}$ $I_L min = I -$ $= \left(\frac{V_{in} - V_Z}{R}\right) - I_{Z max}$

$R_{min} = \frac{V_{in} max - V_2}{I_Z max + I_L min} \Rightarrow I_Z min = \left(\frac{V_{in} min - V_2}{R}\right) - I_L max$

$R_{max} = \frac{V_{in} min - V_Z}{I_Z min + I_L max}$ The max power rating of zener diode is

$P_{max} = V_Z I_Z max = I_Z^2 max \, r_Z$

r_Z is zener resistance

diode Specifications:-

transistor

→ Varactor diode (Varicap):

→ We know that the depletion region in a P-N junction forms barrier which separates the positive and negative charges on each side of the junction. Now the charges can be compared to the charges on the opposite plates of the capacitor So the depletion region acting like a dielectric Capacitor So the depletion region acting like a dielectric Capacitor

Varactor diode is a type of diode whose internal capacitance varies with respect to the reverse voltage. It always works in reverse voltage. It always works in reverse bias condition. And it is a voltage dependent semi conductor device

Varactor diode is known by several names as Varicap, Volt cap, Voltage variable capacitance.

diode:-

The circuit
bias Varactor
in above figu

By applying
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Capacitance C_T
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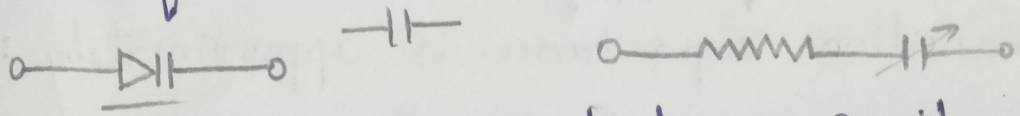
C_T = Transiti

A = Area of

→ Symbol of Varactor diode



→ The Symbol of Varactor diode is Similar to that of P-N junction diode.
The diode as two terminals anode and Cathode.
One end of the symbol consist of the diode.
And the other end has two parallel lines. that represents the conductive plates of the capacitors.
The Gap between these plates shows their di-electric

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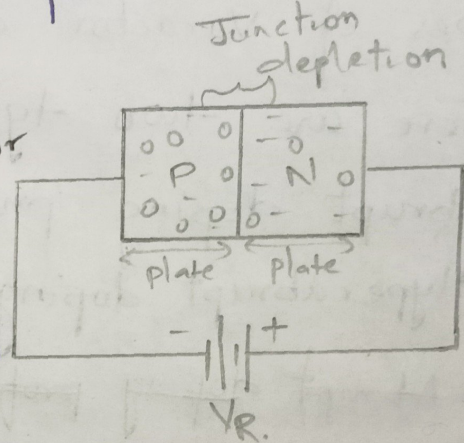
→ Operation of a Varactor diode:-



The Circuit of reverse bias Varactor diode is shown in above figure.

By applying reverse bias voltage to the junction the depletion layer created and acts as a capacitor dielectric and P and n regions are the capacitor plates.

When the reverse bias Voltage is increases the depletion layer becomes wide end, this increases the dielectric thickness as a result the capacitance is reduced, on the other hand when reverse bias voltage is decreases the depletion layer becomes narrower. This decrease the dielectric thickness, in this case the capacitance is increased. The transition Capacitance C_T of a reverse biased P-N junction diode is given by $\boxed{C_T = \frac{\varepsilon A}{x}}$

C_T = Transition Capacitance; ε = Permitivity
A = Area of cross section of P-N diode x = width of the depletion region

In terms of apply the reverse bias voltage the transition capacitance is approximately by the following expression $C_T = \frac{K}{(V_T+V)^n}$

where K is constant determined by S.C material.

V_T is Volt equivalent temperature

V = Reverse biased applied voltage

$n = 1/2$ for alloyed junction

$= 1/3$ for diffused junction

→ Types of Varactor diodes:

There are two types of Varactor diode profiles

1. Abrupt doping profile
2. Hyperabrupt ~~doping~~ profile

→ ~~1. Abrupt doping profile:~~

In Abrupt doping profile the doping is uniform on both sides of junction while in case of Hyperabrupt ~~doping~~ profile the doping level increases towards the junction

In case of reverse biased applied voltage the depletion layer is narrower a larger capacitance occurs at the junction. So in this case a small change in reverse Voltage makes a larger variation in capacitance

The tuning range for hyper abrupt junction is 10:1 this range is enough to tune a broadcast type receive over the medium wave band of 550kHz to 1650 kHz

It should be remembered that the tuning range of an

abrupt profil

→ Applicati

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* Varactor controller

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2. Bi-direc

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Eg: TRIA

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→ Silicon C

The silicon
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abrupt profile diode is only uniform doing.

→ Applications of Varactor diode:

* It can be used as frequency multiplier

* It is used in tv receiver

* It is used in tuning circuits

* It is used as adjustable bandpass filters.

* Varactor diode is used in automatic frequency controller

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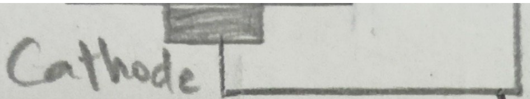
→ Thyristers :-

Thyristers are solid state devices which have

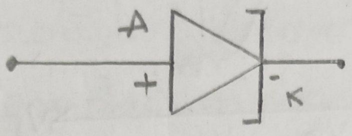


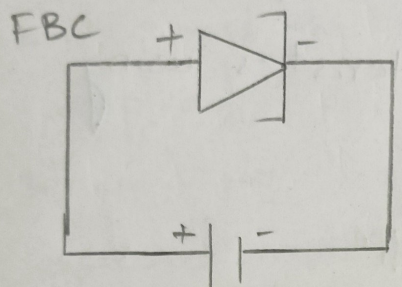
→ Tunnel Diode (or) Esaki diode :-

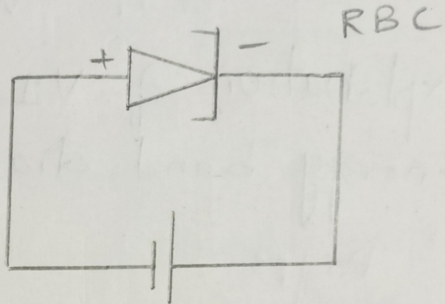
= A tunnel diode is a heavily doped diode about 1000 times higher than a normal PN diode

* Esaki is a janapese scientists in 1970's invented such a new diode. If doping concentration is increases its depletion width is decreases under this condition many charge

carriers flows through the junction for small amount of forward voltage i.e; Less than 0.3V (or) 0.7V, Consequently a large current is produced this phenomeon is known as tunnelling. This phenomeon utilizes the diode, that diode is called as tunnel diode or esaki diode.







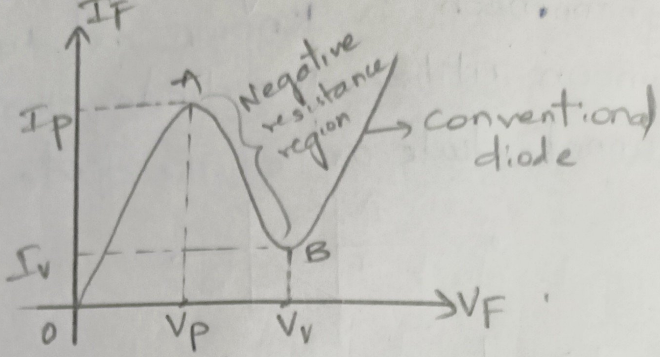
When a small forward voltage is applied a large current is produced the current quickly reaches to its peak value (I_p). By applying forward voltage reaches to a peak value (V_p) It is denoted by 'A'

When the forward voltage is further increased the diode current starts decreasing. The current decreases to I_v corresponding to Vallied Voltage V_v

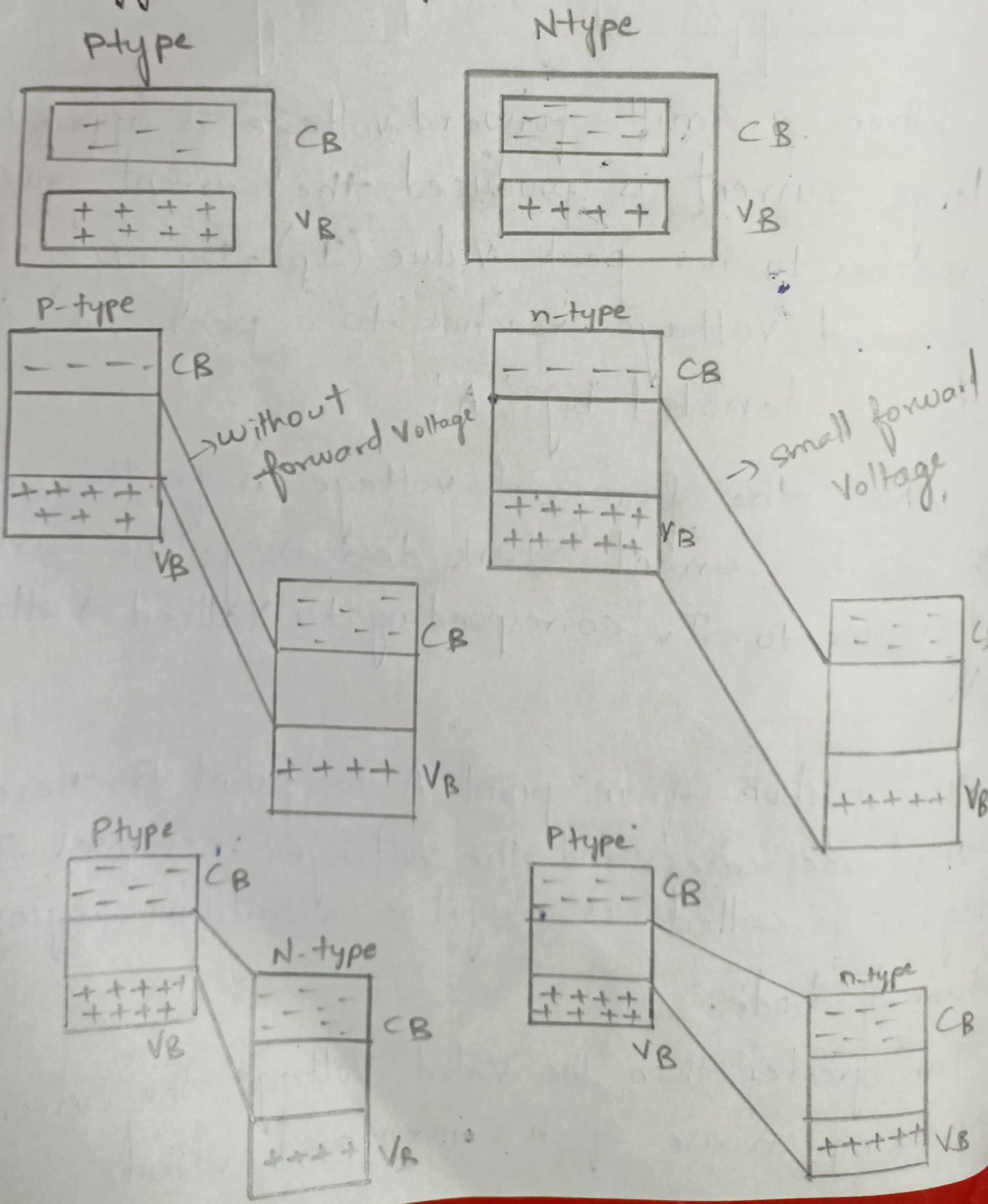
The portion from point A to point B. Here the Current decreases and the voltage increases. This region is called as negative resistance region of tunnel diode.

For greater than the valid Voltage the current starts increasing incase of a Convensional diode

If tunnel diode is connected in reverse bias it acts as a good conductor. i.e; reverse current increases with increase in reverse voltage.



→ Explanation of VI characteristics using Energy band diagram.



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Due to heavily doping in p-type material hole concentration is increased in valence band in n type material electron concentration is increased in conduction band.

When ptype and ntype materials are joined the energy level diagrams shown in above figures their is a rough alignment of respective valence band and conduction band, no forward current flows across the junction if no forward voltage is applied.

When a small forward voltage is applied due to upward motions of energy levels in n-region at the same time downward motion of energy levels in p-region

So the electrons in conduction band on n-side crosses the barrier and enters in to valence band resulting some current

- Further increasing the forward voltage. Valence band of p-side and conduction band of n-side these two are in exact alignment

- At this state tunneling through depletion layer with velocity of light and gives rise to large current. This tunnelling current reaches to maximum value at a forward bias voltage Vp

- After peak voltage Vp further increase the applied forward voltage the current starts decreasing because of n-region energy levels are raised again there is out of aligament in b/w two energy level. Now the forward Voltage(V_p) reaches to Vary Voltage(V_v)

- Now the tunnelling is stoped. The current reaches to minimum value because of out of alignment in between P-type and n-type energy levels.

Between the peak current I_p and V. Current I_v negative dynamic resistance is Obtained

For voltage greater than vally voltage it acts as a normal P-N junction diode

The tunnelling diode is to switch on and off function is much faster than Ordinary P-N diode

→ Advantages of tunnel diode:

High speed in operation

Low noise and bandwith

Low power consumption

Disadvantages of tunnel diode:

This is current independent of applied reverse bias

→ Diode Resistance.

The diode resistance is classified into two types based on supply voltage. i.e; DC and AC supply voltages. 1 Static and 2. Dynamic resistance

** Static Resistance : (DC)

It is defined as ratio of DC voltage across diode to current flowing through the diode

In Forward bias condition

$$R_f = \frac{V_f}{I_f}$$

In Reverse bias condition

$$R_r = \frac{V_r}{I_r}$$

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* Dynamic Resistance (AC):

It is defined as the ratio of change in voltage to the change in current

In forward bias condition

$$R_f = \frac{V_{f_2} - V_{f_1}}{I_{f_2} - I_{f_1}}$$

In Reverse bias condition

$$R_r = \frac{V_{r_2} - V_{r_1}}{I_{r_2} - I_{r_1}}$$

$$R_{ac} = \frac{dv}{dI}$$

We know that,

$$I = I_0 (e^{v/\eta V_T} - 1) \Rightarrow I + I_0 = I_0 e^{v/\eta V_T}$$

Diff above eqn w.r.t v

$$\frac{dI}{dv} = \frac{d}{dv}\left[I_0 (e^{v/\eta V_T} - 1)\right]$$

$$\Rightarrow \frac{dI}{dv} = I_0 \frac{d}{dv}(e^{v/\eta V_T} - 1) = I_0 \frac{e^{v/\eta V_T}}{\eta V_T}$$

$$\Rightarrow \frac{dI}{dv} = \frac{I + I_0}{\eta V_T} \Rightarrow \boxed{\frac{dv}{dI} = \frac{\eta V_T}{I + I_0}}$$

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→ Load line Analysis: