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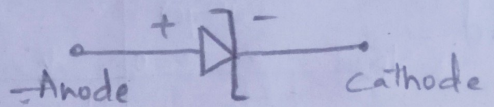
Unit - 2

Special purpose Devices :

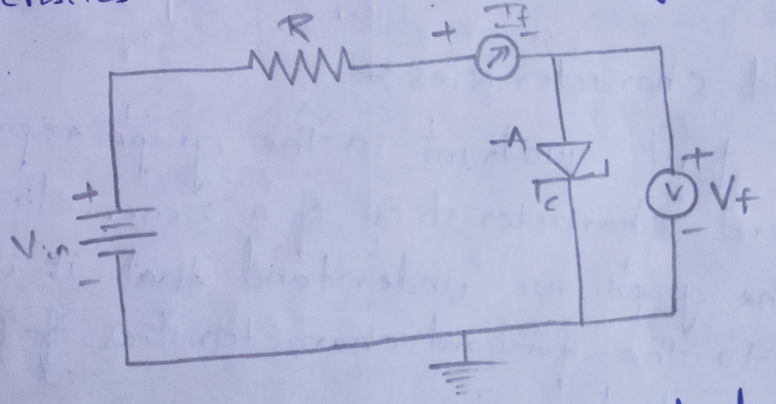
→ Zener diode:

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

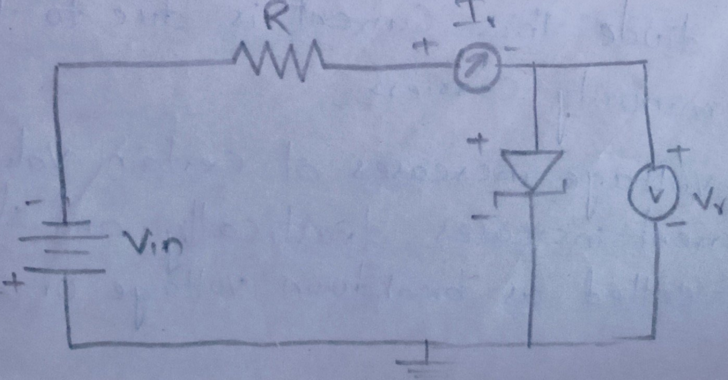
This is similar to a normal diode except the line representing on the cathode is bent at both ends that is like the letter 'Z'. The symbol of zener diode is as shown below.



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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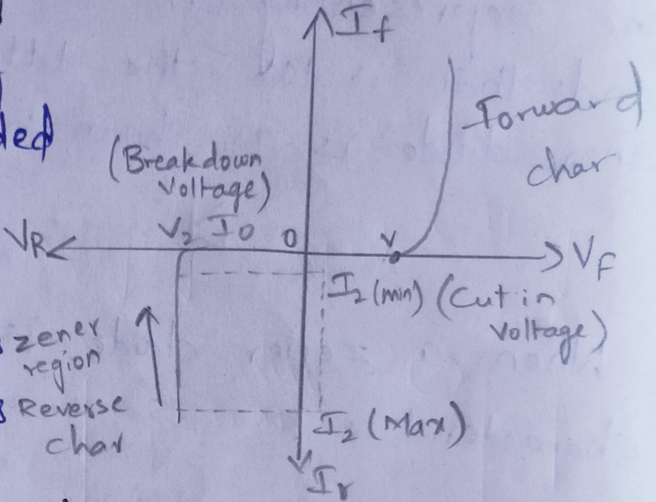
→ V-I characteristics of zener diode:

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

→ Zener diode as a Voltage Regulator:

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

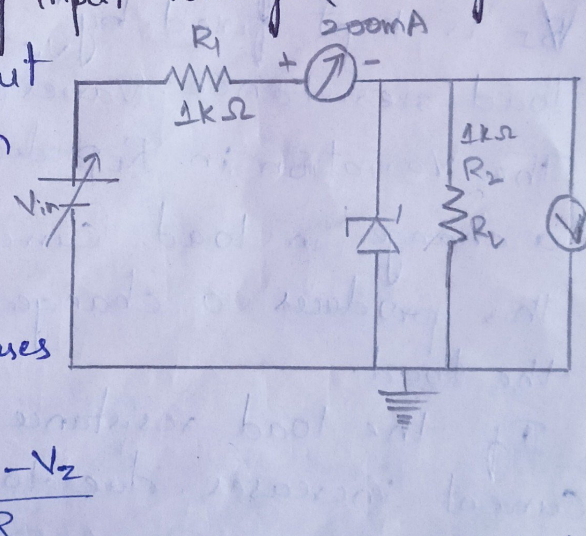
The principle of this regulator is when a diode Operates in ~~Not~~ breakdown region

$V_{in} > V_z$ 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

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

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

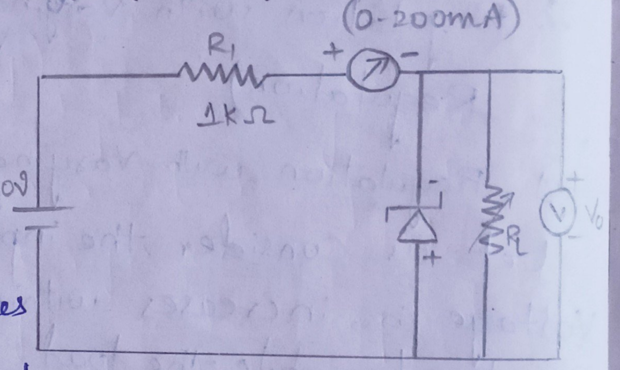
$$I_R = I_Z + I_L$$

$$I_{max} = I_{Z\,max} + I_{L\,min}$$

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

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

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



Let the input voltage V_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 $V_Z = \frac{V_{in} R_L}{R + R_L}$

$V_0 = I_L - R_L$

$R_L\,min = \frac{R V_Z}{V_{in} - V_Z} \Rightarrow R_L\,max = \frac{V_Z}{I_L\,min}$ $\quad R_L\,min = \frac{V_Z}{I_L\,max}$

$I_L\,max = \frac{V_Z}{R_L\,min} = \frac{V_{in} - V_Z}{R}$ $\quad I_L\,min = I - I \therefore \left(\frac{V_{in} - V_Z}{R}\right) - I_Z\,max$

$R_{min} = \frac{V_{in}\,max - V_Z}{I_Z\,max + I_L\,min} \Rightarrow I_Z\,min = \frac{(V_{in}\,min - V_Z)}{R} - I_L\,max$

$R_{max} = \frac{V_{in}\,min - V_Z}{I_Z\,min + I_L\,max}$ 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

→ zener diode specifications:-

*1 Zener voltage V_Z:

The reverse voltage at which the reverse current increases shortly that particular voltage is known as zener voltage.

Basically the zener diode is available from 3 volts to 200 volts. The value of breakdown voltage is ~~less~~ depends upon doping. If doping is more then the breakdown voltage is less.

*2. Maximum power decipation:

It is defined as the product of zener voltage V_Z and zener current I_Z. Therefore

$\therefore P_Z = V_Z - I_Z$

Every device has a limited capability to decipate heat energy produced by it. If the power exceeds maximum then the device may burnout

→ Advantages of zener diode:

Less expensive than other diode

- Ability to shift the voltage
- Ability to regulate stabilize circuit voltage
- Protection from over voltage
- Greater control for overflowing current
- Usable in smaller circuits

→ Disadvantages of zener diode:

Zener diode cancels output voltage by applying a larger input voltage in the reverse direction. So it wasting the electricity in this process

- A zener diode has a relatively four regulation ratio and it is generally not as good as the 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.

→ Symbol of Varactor diode

→ The symbol of varactor diode is similar to that of P-N junction diode.
The diode has 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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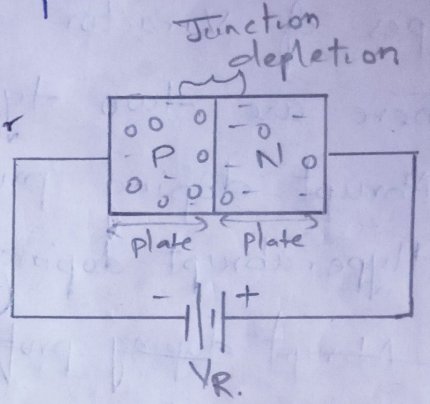
→ Operation of a Varactor diode:-



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 1650kHz

It should be remembered that the tuning range of an 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 two or more junctions and which may be switched from on state to off state and off state to on state between two conducting states they are capable of handling large currents upto hundreds of amperes. The thyristers are divided to two types.

1. Uni-directional Thyrister:

The thyristers which conducts in forward direction is called as uni-directional Thyrister

Eg:- SCR

2. Bi-directional Thyrister:

The thyristers which conducts in both direction i.e; forward and reverse directions is known as bidirectional thyricters

Eg:- TRIAC.

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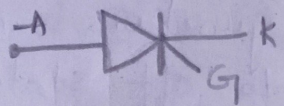
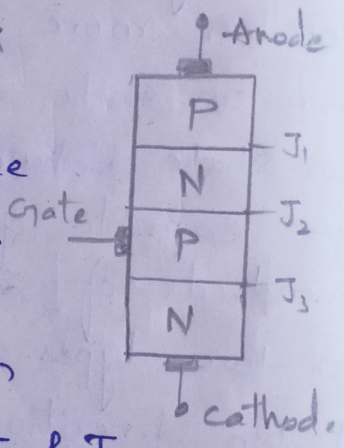
→ Silicon controlled Rectifier (SCR):-

The silicon Contolled Rectifier is the most important and mostly used member of the thyristor family

* SCR can be used for different applications, like rectification, regulation of power and ~~inquotient~~ Inversion etc.
* Like a diode SCR is a uni directional device, it allows the current in one direction and opposes in another direction.
* SCR is a three terminal device anode, cathod and gate
* SCR has build in feature to turn on (or) off and it's switching is controlled by biasing conditions and gate input terminal
* Symbol of SCR is 

* SCR is a four layer and three terminal device. The four layers made up of P and N layers and these are arranged alternately such that they form, 3 junctions J_1, J_2 & J_3



* The Outer layers P and N are heavily doped whereas middle P and N layers are lightly doped the gate terminal is taken at the middle 'p' layer
* Anode is from Outer p layer and cathod is from Outer n layer terminals.
* The SCR is made up of Silicon because compare to Germanium leakage Current in Silicon is very Small.

→ Working of SCR

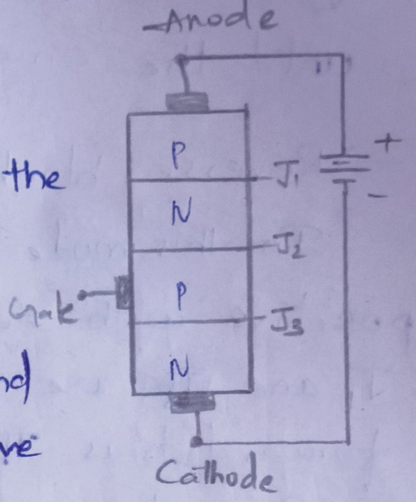
Depending on the biasing given to the SCR the Operation of SCR is divided into three modes.

They are : 1 Forward blocking mode

2. Forward ~~blocking~~ conducting mode

3. Reverse blocking mode

1. Forward blocking mode :

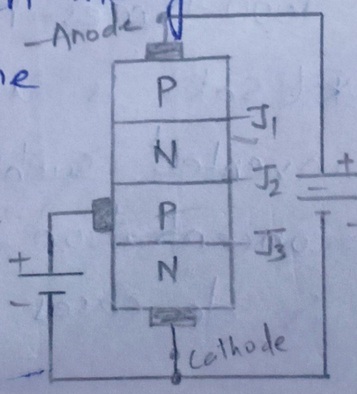


In this mode of operation the SCR is connected such that the anode ~~terminal~~ is connected to positive terminal of battery and cathode is connected to negative terminal of battery and gate terminal is kept open. In this state the junction J_1 J_3 are in forward bias and the junction J_2 Reverse bias. Due to this a small leakage Current flows through the SCR. Until the voltage applied across the SCR is more than the break over voltage of it. It offers a very high resistance to the current flow.

∴ The SCR acts as a open switch in this mode

2. Forward conduction mode :

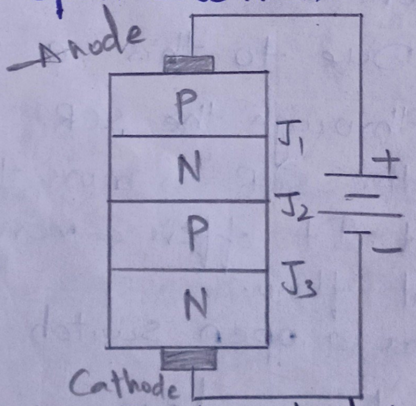
In this mode SCR ~~is~~comes into the conduction mode from blocking ~~bloc~~mode. When the gate terminal is positive with respect to the Cathod then the junction J_3 is in forward bias and J_2 is in reverse bias



When a positive voltage is applied to the inner 'p' layer the holes from p type region are moving to n type region due to the majority charge carriers. Such that by increasing the external gate voltage the current is increasing across the junction J_2. From this the current is flowing indefinately until the circuit is open

→ Reverse blocking mode:-

In this mode of operation cathode is made positive with respect to anode then the junctions J_1 and J_3 are in reverse bias and J_2 is in forward bias. This reverse voltage drives the SCR into reverse blocking region. Results to flow a small leakage current through it and it acts as an open switch.

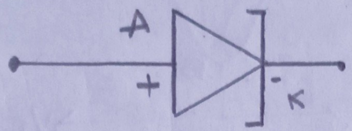


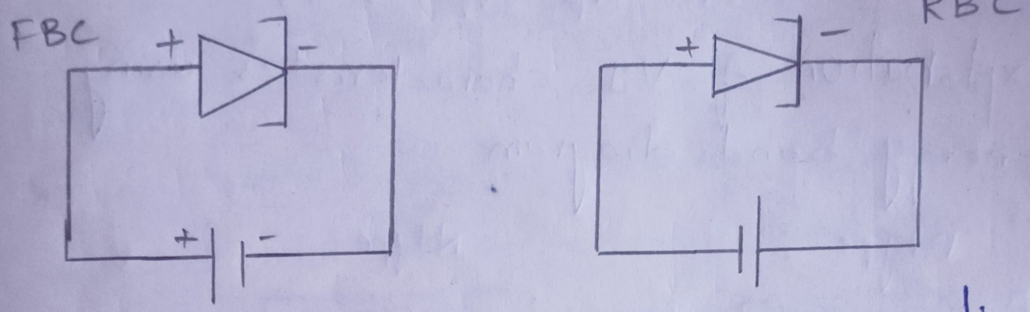
→ Tunnel Diode (or) Esaki diode:-

= 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





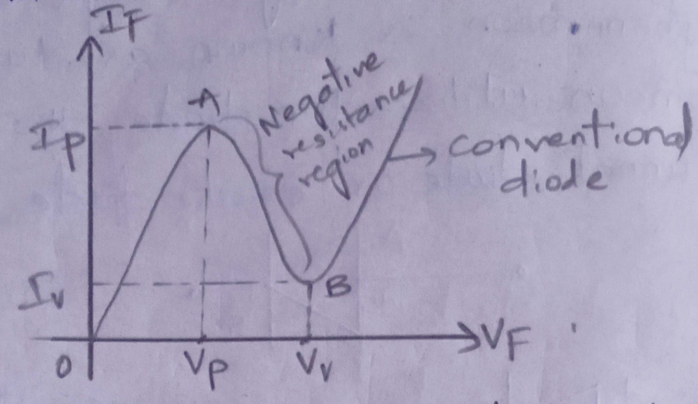
When a small forward voltage is applied a large current is produced the current quickly reaches to its peak value (I_p). By applying forward voltage reaches to a peak value (V_p) It is denoted by '•A'

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

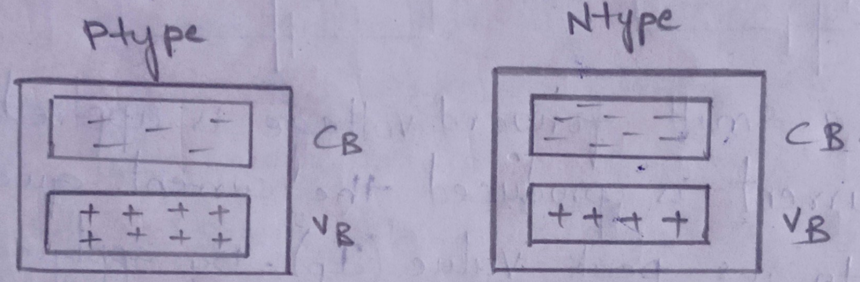
The portion from point A to point B. Here the current decreases and the voltage increases. This region is called as negative resistance region of tunnel diode.

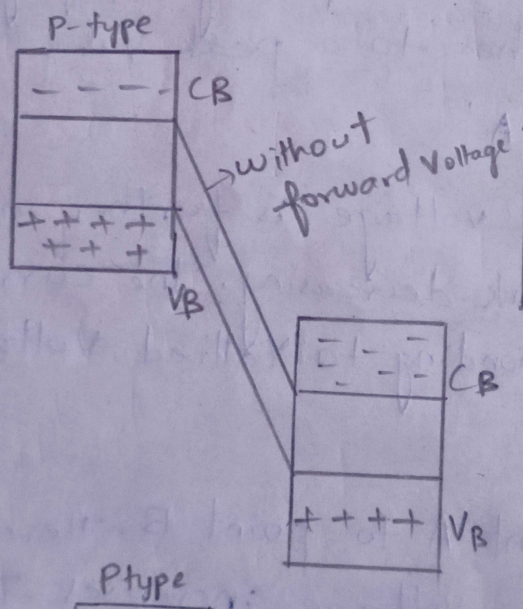
For greater than the valid voltage the current starts increasing incase of a Convensional diode

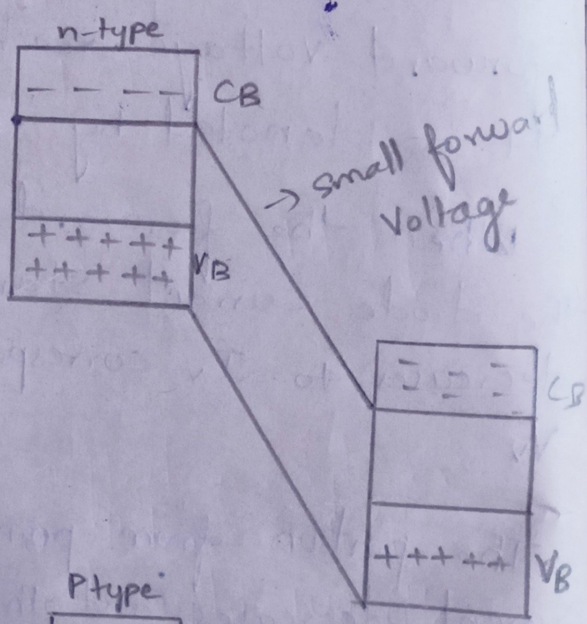
If tunnel diode is connected in reverse bias it acts as a good conductor. i.e; reverse current increases with increase in reverse voltage.

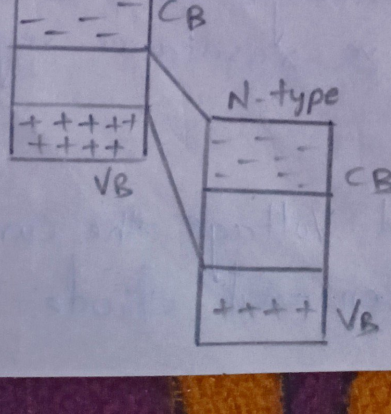


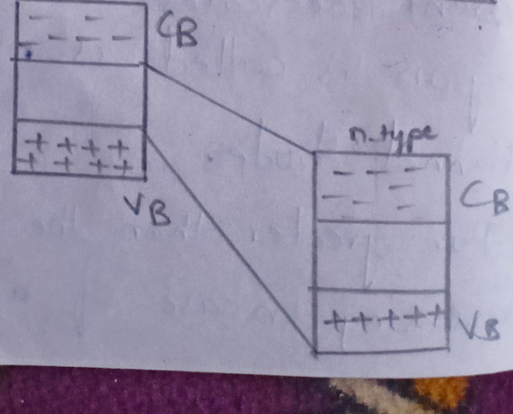
→ Explanation of VI characteristics using Energy band diagram.











8/7/22 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 p type and n type 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 ~~fo~~

- 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 laye with velocity of light and gives rise to large current. This tunnelling current reaches to maximu value at a forward bias voltage V_p

- After peak voltage V_p further increase the appli 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:

- High cost

The input and outputs are not isolated from eachother

→ Applications :-

It can be used as a reflection amplifier

It can be used as an oscillator and it generates microwave signals upto 100GHz

Used as logic memory storage devices

Used as an ultra high speed switch

Used in FM receivers