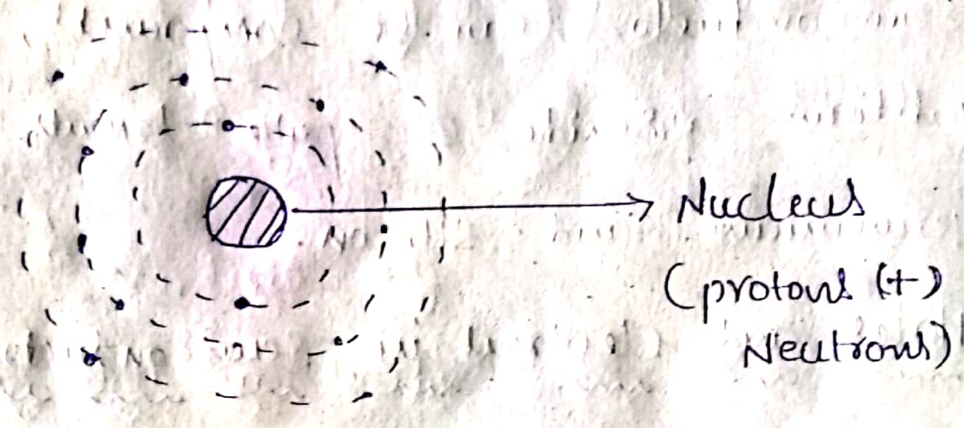
Basic Electronics

Semiconductor Basics:

Atomic Structure:



Silicon atomic structure in this structure have 14 electrons. Electrons have negative charge.

The orbit have $2n^2$ formula it means

$2 \times 1^2 = 2$

$2 \times 2^2 = 8$

$2 \times$

Semiconductors: Semiconductors are materials which have a "conductivity b/w conductors" (generally metals) and "Non conductors" (generally ceramics) means insulators.

Semiconductors can be compounds, such as gallium arsenide, or pure elements such as germanium and silicon.

Holes and Electrons in Semiconductors:

Holes and electrons are the types of charge carriers accountable for the flow of current in semiconductors. Holes (valence electrons) are the positively charged electric charge carrier, whereas electrons are the negatively charged. Both electrons and holes are equal in magnitude but opposite in polarity.

Mobility of Electrons and Holes:

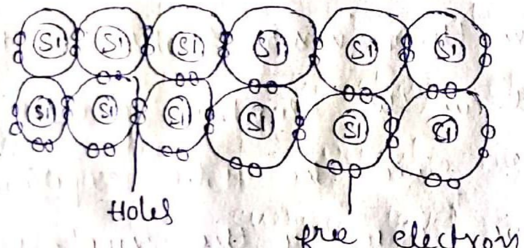
In a semiconductor, the mobility of electrons is higher than that of the holes. It is mainly because of their different band structures and scattering mechanisms. electrons travel in the conduction band whereas holes travel in the valence band. When an electric field is applied, holes cannot move as freely as electrons due to their restricted movement. The elevation of electrons from their inner shells to higher shells results in the creation of holes in semiconductors. Since the hole experience stronger atomic force by the nucleus than electrons, holes have lower mobility.

The mobility of a particle in a semiconductor is more, if

* The effective mass of particles is lesser
* The time b/w scattering events is more

for intrinsic silicon at 300 K, the mobility of electrons is 1500 $cm^2 (V-s)^{-1}$, and the mobility of holes is 475 $cm^2 (V-s)^{-1}$.

The band model of electrons in silicon of valency 4 is shown below. Here, when one of the free electrons (blue dots) leaves the lattice position, it creates a hole (grey dots). This hole that created takes the opposite charge of the electron and can be imagined as positive charge carriers moving in the lattice.



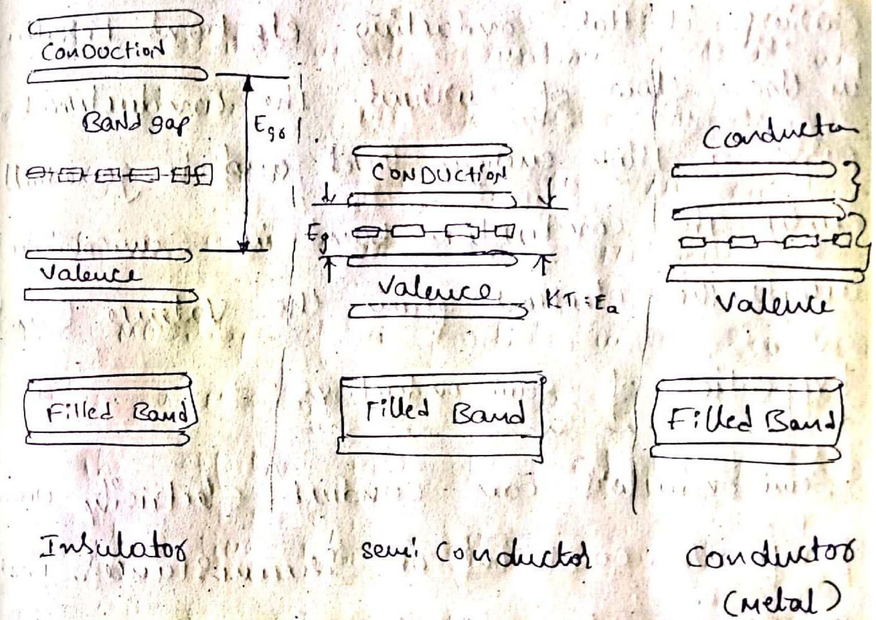
Concept of Electrons and Holes in Semiconductors

Band theory of semi-conductors:

The introduction of band theory happened during the quantum revolution in science. Walter Heitler and Fritz London discovered the energy bands.

We know that the electrons in an atom are present at different energy levels. When we try to assemble a lattice of a solid with 'N' atoms, each level of an atom must split into N levels in the solid. This splitting of sharp and tightly packed energy levels form energy Bands. The gap b/w adjacent bands representing a range of energies that possess no electron is called a Band gap.

Energy Band gaps in Materials



Conduction Band and Valence Band

Valence band: The energy band involving the energy levels of valence electrons is known as the valence band. It is the highest occupied energy band. When compared with insulators, the band gap in semiconductors is smaller. It allows the electrons in the valence band and to jump into the conduc

Band on receiving any external energy.

Conduction Band :- It is the lowest, unoccupied band that includes the energy levels of positive (Holes) or Negative (free electrons) charge carriers. It has conducting electrons resulting in the flow of current. The conduction band posses a High energy level and is generally empty. The conduction band in semiconductors accepts the electrons from the valence band.

Properties of semiconductors :

Semiconductors can conduct electricity under preferable conditions or circumstances. This unique property makes it an excellent material to conduct electricity in a controlled manner as required.

Unlike conductors, the charge carriers in semiconductors arise only because of external energy. It causes a certain No. of "valence electrons" to cross the energy gap and jump into the conduction band, leaving an equal amount of unoccupied energy states, i.e, Holes. The conduction due to electrons and holes is equally important.

- Resistivity : 10^{-5} to 10^{6} Ω m
- Conductivity : 10^{5} to 10^{-6} mho/m
- Temperature Coefficient of resistance : -'ve
- Current flow : due to electrons and Holes

Some important properties of semiconductors:

1. Semiconductors act like insulators at zero kelvin. On increasing the temperature that they work as conductors.
2. Due to their exceptional electrical properties semiconductors can be modified by doping to make semiconductor devices suitable for energy conversion, switches and amplifiers.
3. Less power losses.
4. Semiconductors are smaller in size and posses less weight.
5. Their resistivity is higher than conductors but lesser than insulators.

6. The Resistivity of semiconductor materials decreases with an increase in temperature and vice-versa

Types of Semiconductors:

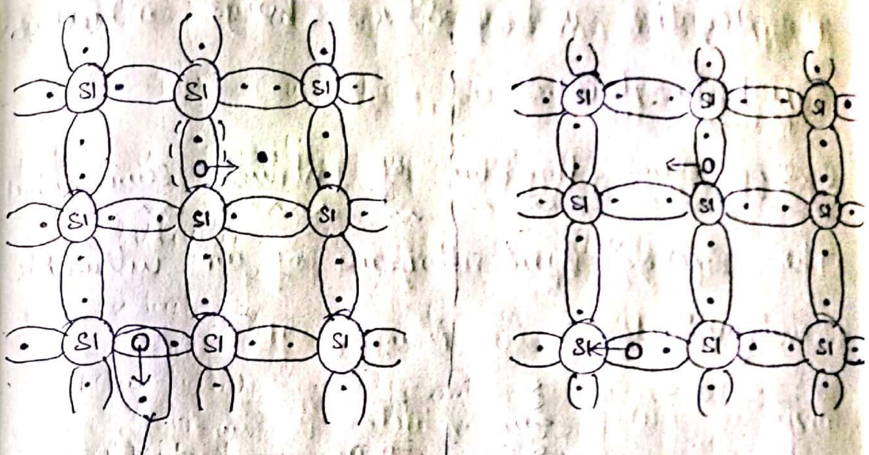
1. Intrinsic Semiconductor
2. Extrinsic Semiconductor.

Semi conductor

- Intrinsic
  - pure form of Ge, Si
  - ($n_e = n_h = n_i$)
- Extrinsic
  - N-type
    - pentavalent impurity
    - P, AS, Sb etc.
    - Donor impurity - N_D
    - ($N_e >> n_h$)
  - P-type
    - Trivalent impurity
    - Ga, B, In, Al
    - Donal impurity - N_D
    - ($n_h >> n_e$)

1. Intrinsic Semi conductor

An intrinsic type of Semiconductor material is Made to be very pure chemically. it is Made up of only a single type of Element.



free Electron and its corresponding Hole

(a) (b)

o → Hole | → Direction of Electron

• → Electron | → Direction of Hole

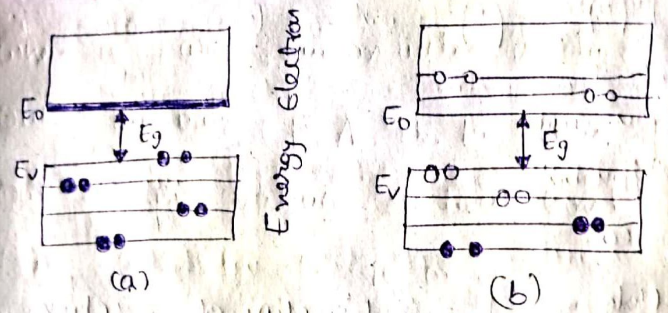
germanium (Ge) and Silicon (Si) are the most common types of "Intrinsic Semiconductors". They Have 4 Valence Electrons (tetravalent). They are Bound to them atom by a covalent bond at absolute zero temperature.

When the temprature Rises due to collisions, few electrons are unbounded and become free to move through the lattice, thus creating an absence in its original position (Hole). These free Electrons and Holes contribute to the conduction of electricity in the semiconductor.

The Negative and positive charge carriers are equal in number.

Energy band diagram of Intrinsic Semi-conductor

The Energy Band diagram of an intrinsic Semiconductor



(a) intrinsic Semiconductor at T=0 Kelvin, Behave likes an insulator

(b) at $t > 0$, four thermally generated electron pairs.

In intrinsic Semiconductors, current flows due to the motion of free electrons, as well as Holes. The total current is the sum of the electron current (I_e) due to thermally generated electrons and the Hole current (I_h).

total current (I) = $I_e + I_h$

For an intrinsic semiconductor, at finite temperatures, the probability of electrons existing in a conduction band decreases exponentially with an increasing band gap (E_g).

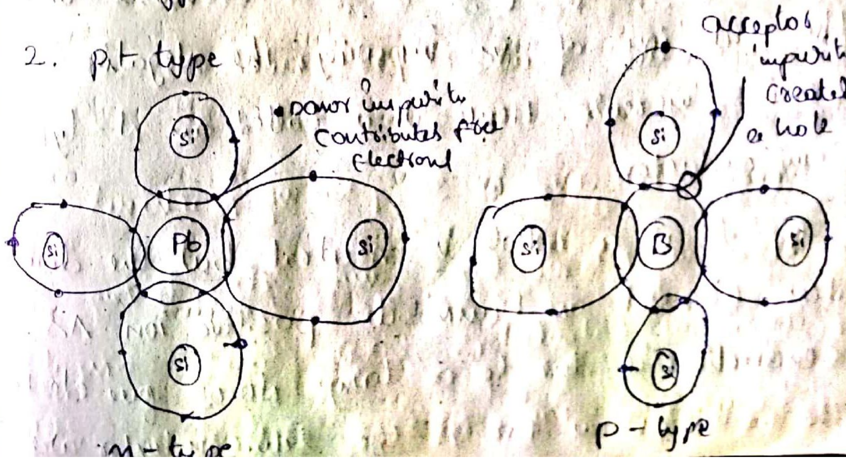
$$n = n_0 e^{-E_g/2K_b T}$$

- E_g = Energy band gap
- K_b = Boltzman's Constant

Extrinsic Semi Conductor:

The Conductivity of semi Conductors can be greatly improved by introducing a small No. of suitable Replacement atoms called IMPURITIES. The process of adding impurities atoms to the pure semi conductor is called "doping". Usually only one atom in 10^7 is Replaced by a dopant atom in the doped semiconductor.

1. N - type
2. P - type



N-type Semi Conductor:

- Mainly due to Electrons
- Entirely Neutral
- $I = I_h$ and $n_h >> n_e$
- Majority - Electrons, Minority - Holes

When a pure semiconductor is doped by "pentavalent" impurity (P, As, Sb, Bi), then four electrons out of five valence electrons bond with the four electrons of Ge or Si.

The fifth electron of the dopant is set to be free. Thus, the impurity atom donates a free electron for conduction in the lattice and is called a "Donar".

Since the No. of free electrons increases with the addition of an impurity, the Negative charge carriers increase. Hence it is called an N-type Semiconductor.

Crystal as a whole is neutral, but the donor atom becomes an immobile positive ion. As conduction is due to a large No. of free electrons the electrons in the N-type semiconductor are the Majority carriers, and Holes are the Minor[ity]

P-type Semi Conductor:

- Mainly due to Holes
- Entirely Neutral
- $I = I_h$ and $n_h >> n_e$
- Majority - Holes, Minority - electrons.

When a pure semi conductor is dopped with a trivalent impurity (B, In, Ga) then the 3 valence electrons of the impurity bond with 3 of the four valence electrons of the semiconductor.

This leaves an absence of electrons (Hole) in the impurity. These impurity atoms which are ready to accept bonded electrons are called "Acceptors".

With an increase in the No. of impurities, Holes are increased. Hence, it is called p-type semi conductor.

Crystal as a whole, is neutral, but the acceptors becomes an immobile negative ion. As conduction is due to a large No. of Holes, the Holes in the p-type semiconductor are Majority carriers.

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Difference B/w Intrinsic and extrinsic Semi Conductors:

Intrinsic	Extrinsic
1. pure semi conductor	1. Impure semi conductor
2. The density of electrons is equal to the density of Holes	2. The density of electrons is not equal to the density of Holes.
3. Electrical Conductivity is low	3. Electrical Conductivity is High.
4. Depends on temperature only.	4. Depends on temp as well as on the amount of impurity
5. No impurities.	5. Trivalent, pentavalent impurities.

Uses of Semi Conductors:

1. temperature sensors are made with semiconductor devices.
2. They are used in 3D printing machines.
3. Used in Micro chips and self-driving cars.
4. Used in Calculators, solar plates, computers
5. transistors and MOSFET used as a switch in electronic circuits are manufactured using semiconductors.

Importance of Semi Conductors:

1. Here, we have discussed some advantages of Semi-Conductors, which make them Highly useful everywhere.

1. They are Highly portable due to their small size.
2. They require less i/p power.
3. semi conductor devices are shock proof.
4. They Have long lifespan.
5. They are Noise-free while operating.

Covalent Bond:

→ formed B/w 2 atoms by mutual sharing of electrons of valence shell, so both atoms attain octet in valence shell.

Ex: $F_2 \rightarrow 9 \rightarrow 1s^2 2s^2 2p^5$

Difference B/w conductor, Semi conductor, Insulator

parameter	conductor	Insulator	Semi conductor
Conductivity	High very	Very low	Moderate
resistivity	very low	very low	Moderate
Forbidden gap	No gap	very large (= 15 ev)	very small (= 1 ev)
No. of Electrons	very high	very low	Moderate
Temperature of Co-efficient.	Positive	Negative	Negative
Effect of dopping	Resistance increases	No change in resistance	Resistance decreases

1. Conductor: The Materiall in which Current can flow easily called conductor.

Ex: Iron, Copper

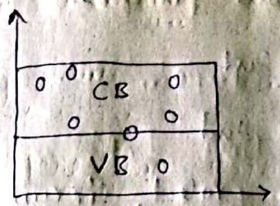
2. Insulator: The materials in which current cannot flow, this is called insulator.

Ex: paper, wood

3. Semi Conductor: The materiall which Having Both behaviour of Conductor and insulator are called Semi-conductors.

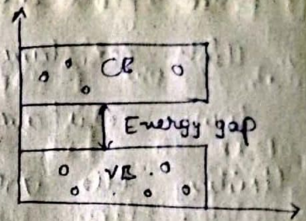
Ex: Silicon, Germanium.

1.



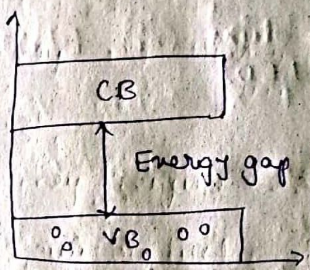
Conductor

2.



Semi Conductor

3.



Insulator

1. Diode:

→ Diodes are used to protect circuits by limiting the voltage and to also transform AC to DC. Semi conductors like silicon and germanium are used to make the most of the diodes. Even though they transmit current in a single direction, the way with which they transmit differs.

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→ Two terminal electronic component

→ conducts electricity in one direction

→ High resistance → One End

low resistance → other End

→ limiting the voltage (to protect circuit)

→ also transform AC to DC.

Types of diodes:

1. light Emitting diode (LED)
2. laser diode
3. avalanche diode
4. Zener diode
5. photo diode
6. PN Junction diode

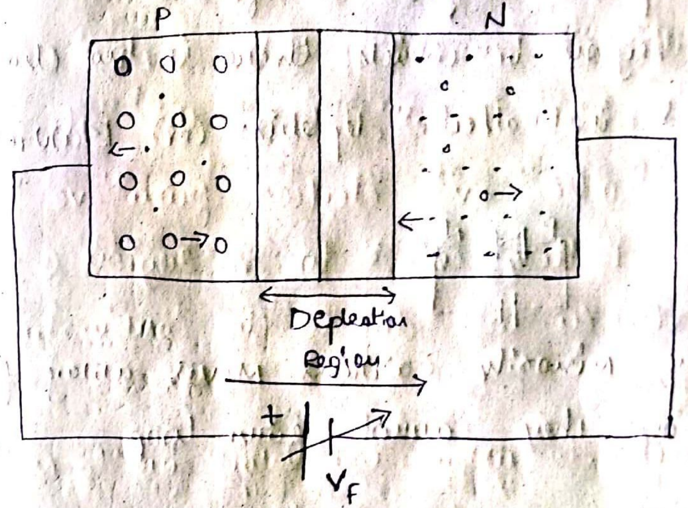
applications:

* As a Rectifier
* in a clipping circuit
* clamping circuit
* logic gates

Diode Biasing:

1. Forward biasing
2. Reverse biasing

1. Forward biasing:



Biasing: In electronics, 'biasing' usually refers to a fixed DC voltage or current applied to a terminal of an electronic component such as a diode or transistor.

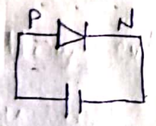
Forward Biasing:

The layer which seperates 'P' & 'n' type Material is Called "Junction".

Due to concentration gradient across the Junction the charged particle diffused from one region to another region i.e, electrons from N-type to P-type and Holes from P-type to N-type.

Due to this recombination takes place and "depletion region" is formed.

The region in which there is no charged particles is called "depletion (or) Barrier."



All the minority carriers moves away from junction they cannot form loop

$I_{minority} = 0$

All the majority carriers moves towards Jn

As $V \uparrow$ → Repulsion forces to the majority

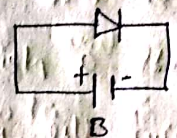
→ Depletion region decreases.

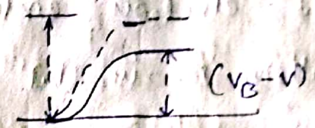
at some particular voltage depletion region width reduces to zero then the charged particle starts crossing the Jn

The voltage at which charged particles starts crossing the Jn is called "cut in (or) Barrier (or) depletion region (or) knee voltage.

V_γ for Si - 0.7V

V_γ for Ge — 0.2V





In forward biasing forward voltage oppo the potential Barrier V_B. So potential Barri Height is reduced and width of depletion region is decreased. The effective Height of pote-tial Barrier in forward biasing is $(V_B - V)$.

The electrons (majority carriers) in the N-region are repelled with by -ve terminal of Battery B. so these electrons move towards PN-junction. similarly Holes in P-region are repelled by +ve termi nal of the Battery B, towards the junction

positive potential of p-region attracts the electrons from n-region & negative potential of N-region attracts the Holes from p-region When electrons & holes cross the junction

They combine with each other.

for each electron-Hole combination a covalent Bond is Broken in P-region Neare the +ve terminal of battery. So liberated electron enters the +ve terminal of battery B. in this process a New Hole is formed which moves toward the PN-Junction

At the other End electron from -ve terminal of Battery enters to n-region & replace the electron lost due to the combination near the Jn.

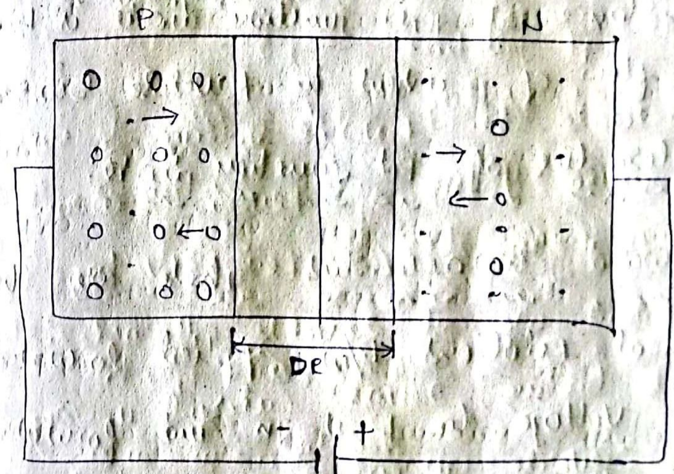
So, electric current will flow due to migration of majority carriers across the PN-Junction this current is called forward current. This forward current usually milliampere (mA)

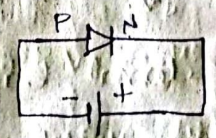
for small increase in forward voltage, there is large increase in forward current. So, in forward biasing Resistance of a PN-Junction is low for the flow of current.

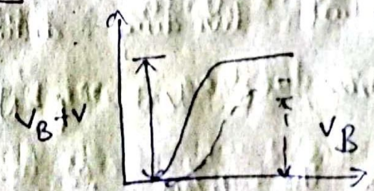
② Reverse Biasing:

A PN-Junction is said to be reverse Biased if the positive terminal of battery B is connected to N side & negative terminal of Battery B is connected to P-side of PN-Jn.

In Reverse biasing direction of applied voltage & and potential barrier is same. So, the Reverse bias Voltage supports the potential barrier so in reverse biasing effective Barrier potential is $(V_B + V)$.







Reverse Biasing

In Reverse Biasing, there is no Conduction across the Junction due to Majority Carriers. But due to High reverse bias voltage, a few minority carriers of P-N Junction diode cross the junction. They constitute a current that flows in the opposite direction. This current is called Reverse current or leakage current.

for large increase in current reverse voltage there is very small increase in reverse current, so resistance of PN-Junction diode is high to the flow of current in Reverse biased.

Characteristics of PN-Junction diode:

① forward Characteristics: These are the graphical relations B/w applied forward biased voltage to P-N Jn and forward Current through P-N Jn.

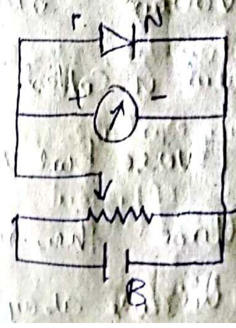
We Connect the External battery with a potential dividing arrangement, to the P-N Junction, so that P-N Jn is forward biased.

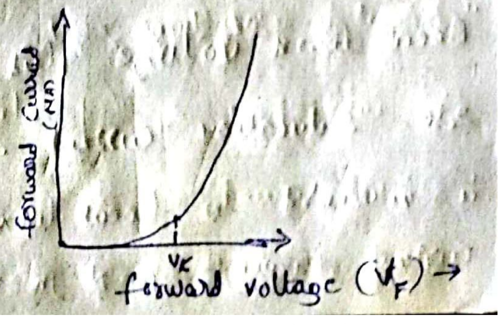
for the given forward bias voltage we Note the corresponding forward current. forward voltage is increased slowly in steps & corresponding forward current is Noted. Now we plot variation of forward current with forward voltage on graph. This is called forward characteristics.

Below a certain voltage (knee voltage) the forward current increase very slowly & Non linearly with increase of forward voltage. But beyond the knee voltage (V_K) Conductivity is very high and current through Jn increases Rapidly with voltage & show linear variation.

Knee Voltage / Threshold voltage / Cut-in Range

it is the forward voltage beyond which current through Junction start increasing Rapidly & Linearly.





(i) V-I graph for diode is not straight line. So, diode does not obey Ohm's law & are called Non-ohmic device.

(2) Below knee voltage, resistance across the Jn of diode is large & above the knee voltage resistance is low.

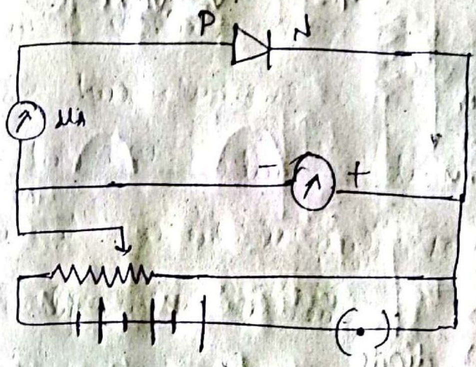
(ii) Reverse characteristics

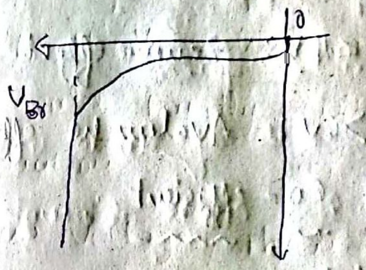
It is the graphical relation B/w the reverse bias voltage & corresponding reverse current through p-n junction

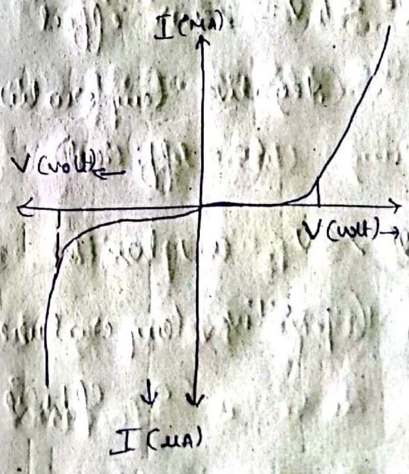
We increase the Reverse voltage & note the corresponding value of Reverse current. On plotting a graph B/w Reverse voltage & reverse current we get reverse characteristics.

In Reverse biasing, reverse current is very small (≈ μA). reverse current is independent of voltage upto certain reverse voltage called "Break down voltage". This current is called "reverse saturation current". If Reverse bias voltage is increased to break down voltage then reverse current through p-n Jn will increase abruptly due to breaking down of large no. of covalent bonds in P & N region.

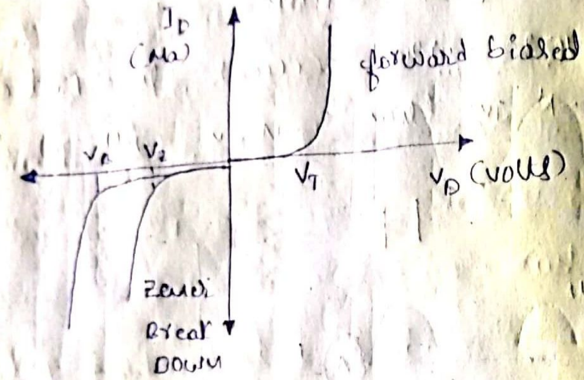
If reverse current exceeds the rated value of P-N Jn then P-N Jn will get damaged.

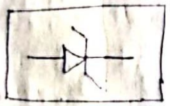






Avalanche and Zener Breakdown:





Zener diode

Breakdown voltage < 4V: Zener effect

Break-down voltage > 6V: Avalanche effect

Temperature Co-efficient

Breakdown voltage < 4V: Zener effect
(Negative temperature co-efficient)

Breakdown voltage > 6V: avalanche effect
(positive temperature co-efficient)

Avalanche Breakdown	Zener breakdown
occurs in lightly doped diodes	occurs in Heavily doped diodes
occurs due to impact ionization	occurs due to strong electric effect (Quantum tunnelling)
The effect is seen at Higher breakdown voltages (> 6V)	The effect is seen at lower breakdown voltages (< 4V)
with temperature, breakdown voltage increases	with temperature, breakdown voltage reduces.

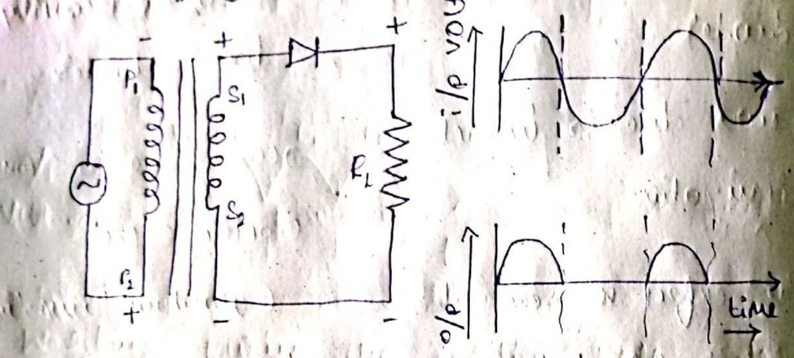
Rectifier: It is a device which is used to convert alternating current/voltage into Direct current/voltage.

1. Half wave Rectifier:

Principle: Working of a rectifier is based on the fact that Resistance of PN-Junction Becomes low when it is forward biased and resistance becomes High in reverse

Biasing.

Circuit diagram:



A.C. voltage to be rectified is connected to primary P_1P_2 of stepdown transformer S_1S_2 is secondary coil of same transformer S_1 is connected to P-side of diode & S_2 is connected to N-side of diode through a Resistance R. O/p is taken across R.

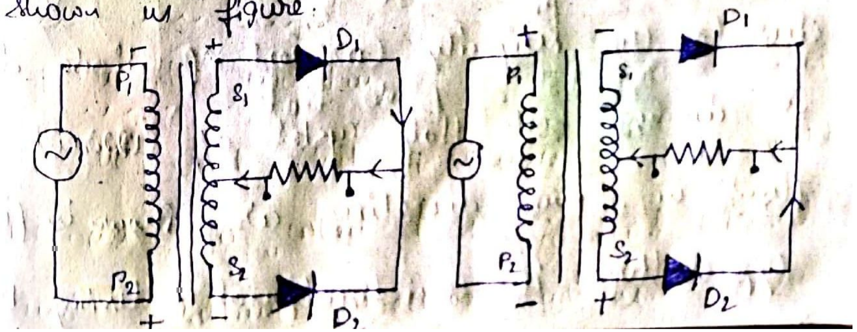
Working: During the positive Half cycle of i/p A.C i.e. during the +ve Half cycle of AC P_1 is Negative & P_2 is positive. Due to the induction S_1 becomes +ve & S_2 become -ve. So PN-Junction diode is forward biased. In forward biasing resistance of diode become low & forward current flow in direction shown by arrow Heads. So, we get O/p across load.

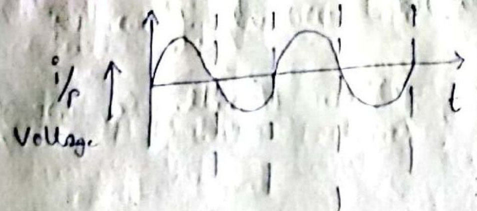
During Negative Half cycle of i/p A.C - P_1 is positive & P_2 is Negative. Due to the mutual induction, S_1 become Negative & S_2 become positive so P-N Junction is Reverse biased. Due to High resistance, no current flows & no O/p is obtained across load.

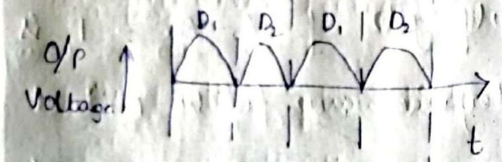
Note: Half wave rectification has not much use. O/p signal is not continuous.

2. Full-wave Rectifier:

Circuit diagram: In full wave Rectifier two diodes D_1 & D_2 are used. arrangement is shown in figure.







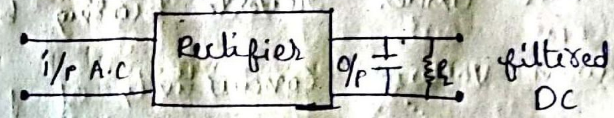
Working: During the positive Half cycle of i/p A.C, P_1 is +ve & P_2 is −ve. So by Mutual induction $S_1 \to$ +ve & $S_2 \to$ −ve. So diode D_1 is forward biased & D_2 is reverse biased. So forward current flows due to Majority carriers of diode D_1.

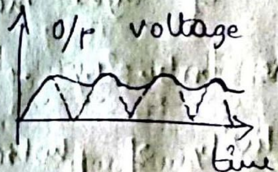
During the Negative Half cycle of input A.C diode D_1 is reverse biased & D_2 is forward biased. So forward current flows due to the majority carriers of diode d_2. So, during both Half cycles o/p current flows in same direction as shown in fig-c.

O/P voltage is unidirectional having D.C components & A.C components of voltage. DC voltage can be obtained by filtering it through filter circuit.

Capacitor offers low impedance to A.C component ($\because X_C \propto 1/f$) & it offers infinite impedance to DC component.

So AC components are filtered out with the Help of capacitors. So we get O/P DC voltage.





Ripple factor of Rectifier $= \dfrac{\text{Value of AC compo}}{\text{Value of DC compo}}$

$$= \frac{I_{ac}}{I_{dc}} = \frac{E_{ac}}{E_{dc}} = \sqrt{\left(\frac{I_{r.m.s}}{I_{dc}}\right)^2 - 1}$$

Ripple factor for Half wave rectifier is 1.21 and for full wave rectifier is 0.4

* Efficiency of Rectifier, $\eta = \dfrac{O/p \text{ DC power}}{I/p \text{ AC power}} \times 100$

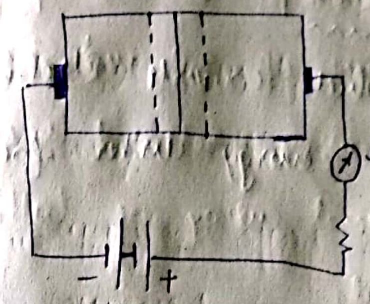
for Half wave Rectifier ; $\eta = 40.6\%$

for full wave Rectifier $\eta = 81.2\%$

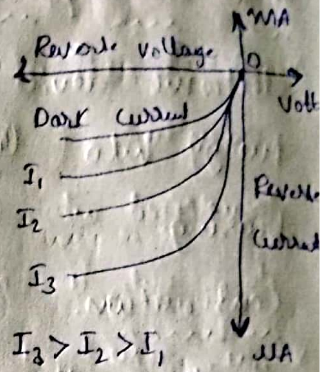
photo Diode: photo diode is a p-n junction which is an optoelectronic device in which current carriers are generated by photons through photoconduction by light.

→ it operates under reverse biasing below the Break down voltage. Conductivity of photo diode depends on absorption of light near the depletion layer. As the intensity of incident light increases, conductivity of photodiode also increase.

Symbol of photo diode



Experimental arrangement for the study of V-I characteristics of photodiode



V-I characteristics.

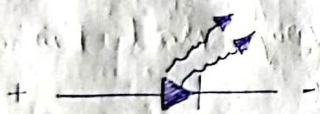
When the photodiode is Reverse biased with a voltage less than its break down voltage & no light is incident on its junction then the Reverse current is very small. This current is called Dark current.

When the energy of incident light is more than forbidden energy gap ($h\nu > E_g$) & diode is reverse biased then electron-Hole pairs are Created in depletion Region layer. These charge carriers will be separated by Jn field. So, charge carriers will flow across the Jn & Create reverse current

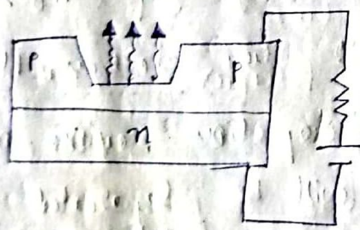
Light Emitting Diode (LED): It is a photo electronic device which converts electrical energy into light Energy under forward biasing

Construction:

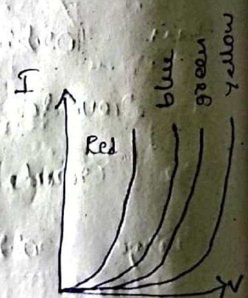
- it is a Heavily doped PN-Jn diode which under forward biasing Emits spontaneous radiations. The diode is covered with a transparent cover so that the emited light can come out.



Symbol of LED



LED Circuit diagram



V-I characteristics.

→ In an LED upper layer of p-type semiconductor is deposited by diffusion on N-type layer of semiconductor. The metallic contacts are provided to apply the forward bias voltage to the diode from battery B through resistance R which controls the Brightness of light Emitted.

WORKING OF LED:

When a PN-Jn is forward biased then size of depletion region layer decreases. The movement of majority carriers takes place across the Junction. The electron moves from N-side of Junction to P-side of Junction. The Holes moves from P-side to N-side through Junction. Due to this movement concentration of the minority carriers increases rapidly on the two sides of PN-Jn Boundary. These excess of minority carriers Recombine with majority carriers. Due to the electron-Hole Recombination, a photon is released whose energy is nearly equal to energy gap (E_g)

$$E_g = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E_g}.$$

wave length of emitted photon

* for a PN-Junction of Ge and Si, large percentage of this energy released is mainly transferred into thermal energy of lattice. So No light is emitted.

* in some PN-Jn diodes like GaAs, GaP & GaAsP large percentage of released energy is mainly in the form of visible light so the Jn become light source.

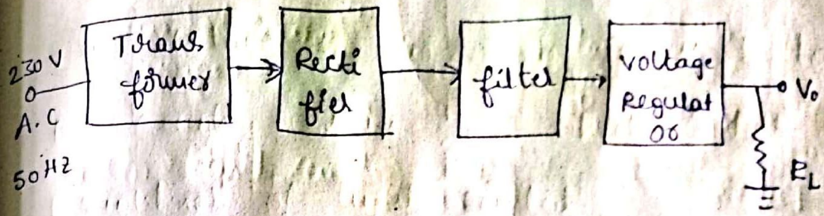
* The color of light emitted by LED depend upon the type of material used used to make LED & its energy band gap

1. GaAs - infrared Radiation
2. GaP - red or green light
3. GaAsP - Red or Yellow light

Advantages of LED:

1. it Has less power & low operating voltage.
2. LED Has fast action
3. it is cheap & easy to Handle.

Voltage Regulators:



→ Step up ⇒ AC increased

→ step down ⇒ AC decreased.

Rectifier: TO Convert AC to pulsating DC

1. Half wave 2. Centre tapped full wave
3. Bridge Rectifier

Filter: TO Convert pulsating DC to pure DC

Regulator: TO maintain Constant O/P Voltage

In 2 conditions

1. change in I/p
2. load changes

UNIT - 2

SPECIAL PURPOSE DIODES

Zener Diodes:

→ Zener diodes are designed to operate in reverse break down

1. Avalanche
2. Zener

→ Avalanche Breakdown occurs in Both Normal and Zener diodes at a sufficiently high Reverse Voltage.

→ Zener Breakdown occurs in a Zener diode at low reverse voltages.

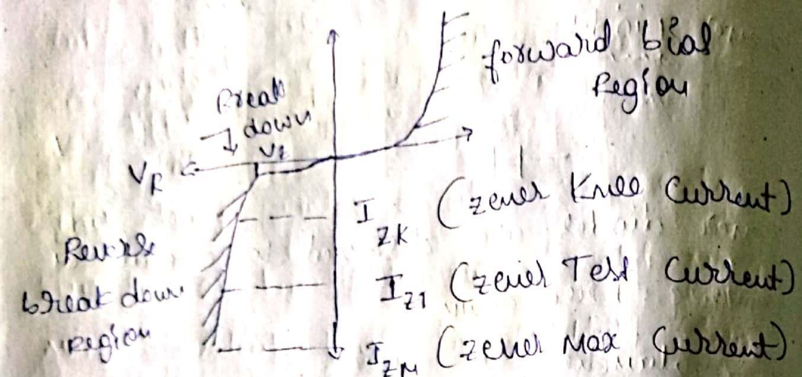
* Zener diode Heavily doped to Reduce the Breakdown voltage. This causes a very depletion Region

1: 10^6

* The zener diode breakdown characteristics are determined by the doping process.
* Zeners are commercially available with Voltage 1.8 V to 200V.

Scanned with CamScanner

WORKING OF ZENER:



Zener Break down:

* less width of depletion Region will cause High intensity of electric field to develop in the depletion Region at low voltages.
* Let say the width of depletion Region is 200 Å (very small) & a reverse bias voltage of Just 4V is applied to the diode, then the electric field intensity in the depletion Region will be

$$E = \frac{V}{d} = \frac{4}{200 \times 10^{-10}} = 2 \times 10^{8} \ V/m$$

* This electric field is sufficient to Rupture Bonds and separate the valence electrons large No. of electrons get seperated from their atoms, resistivity in sudden increase in the value of reverse current.

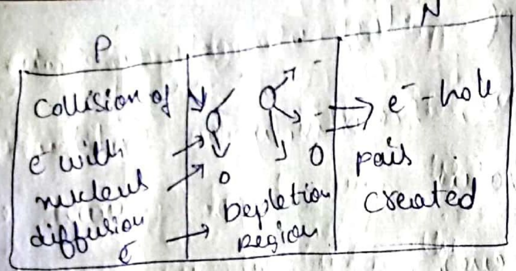
C.E. zener

* Zener effect predominates in diodes whose Break down voltage is below 6V.

Avalanche Breakdown:

* The width of depletion Region is large when impurities concentration is less
* when a reverse bias voltage is applied across the terminals of diode
* the electrons from p-type and Holes from N-type accelerates through the depletion region.
* This Results in collision of intrinsic particles (e^- and Holes) with the bound e^- in the depletion Region.

→ with enough energy to break its covalent bond and create the electrons - Holes pairs.



→ This Newly created e^- also gets accelerated due to electric field and breaks many more covalent bond to further create more e^- - hole pair. This process keeps on repeating and it is called carrier multiplication.

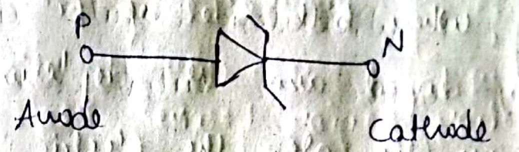
This process of carrier multiplication is quit and in very large numbers that there is apparently an avalanche of charge carriers thus the breakdown is called avalanche breakdown

Zener Diode:

Zener diode is a reversed biased heavily dopped silicon p-N junction diode which is operated in the break down region.

Due to higher temperature and current capability, silicon is better than germanium

The symbol of Zener diode is



Zener diode allows electric current in forward direction like a normal diode but also allows electric current in the reverse direction because it is specially designed to work in a reverse direction.

The Zener diode was named after the american physicist "clarance melvin zener."

Voltage current characteristics of Zener diode:

* There are 2 types of reverse breakdown regions in a zener diode.

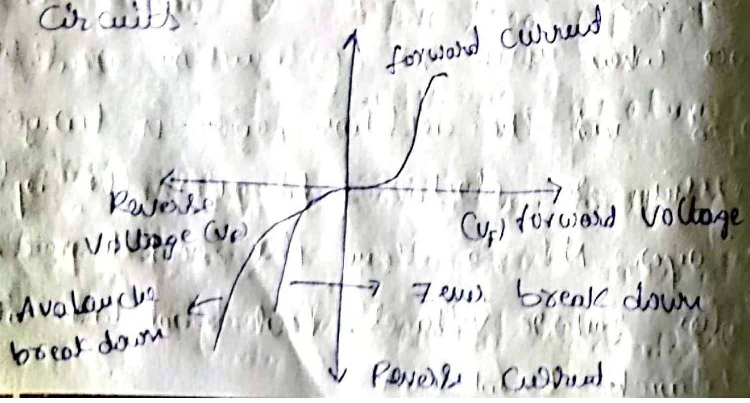
1. Avalanche 2. zener

1. Avalanche: This type of breakdown takes place when both sides of junction are lightly doped and the depletion region is large. In this case, electric field across the depletion layer not so strong. This breakdown occurs at higher reverse voltages. That break down called Avalanche break down.

2. Zener break down :- This type of break down takes place when both sides of pn - Junction are heavily doped and the depletion layer is narrow. In this case, the Electric field across the depletion layer so strong. That break down is called Zener break down.

Applications of Zener diode:

1. It Normally used as voltage reference
2. Zener diodes are used in voltage stabilizers or shunt Regulators.
3. Zener diodes are used in switching devices
4. Zener diodes are used in clipping and clapping circuits.
5. Zener diodes are used in various protection circuits.



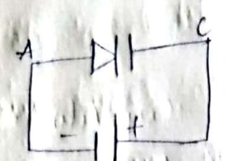
Varactor Diode:

→ Varactor Means variable capacitor
→ Simply we defined varactor diode as its acts like a variable capacitor under Reverse bias condition.
→ It also Refers
ⓐ varicap diode
ⓑ Tuning diode
ⓒ Variable Reactance diode
ⓓ variable capacitance diode
→ The schematic symbol of varactor diode

* It is similar to the Normal pn Junction diode
* Two parallel lines at the cathode side represents two conductive plate and space B/w them.
* It show better transition capacitance property than the ordinary diodes.

WORKING:

→ It is operated in the reverse bias



→ The depletion Region becomes negligible in the forward bias so the current flows through diode.

→ Varactor diode is designed to store electric charge not to conduct electric current.

→ When a reverse bias voltage is applied, the electrons from N- region and holes from P- region moves away from the junction.

* then depletion Region increases and the capacitance decreases.

→ very low reverse bias voltage is applied then capacitance is very large.

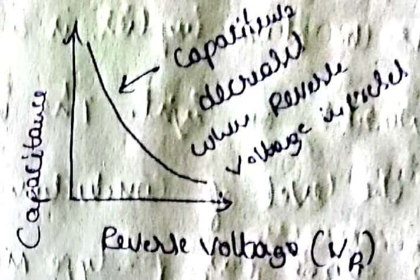
$$\text{Capacitance} \propto \frac{\text{Surface Area of P \& N region}}{\text{width of depletion Region}}$$

→ Reverse voltage increases then width of depletion Region increases.

↳ Capacitance further decreases.

→ In varactor diode, the capacitance is varied when the voltage is varied so it is known as "variable capacitor".

Characteristics:



Applications:

1. Used in frequency multipliers
2. in parametric amplifiers
3. in voltage - controlled oscillators.

Optical Diodes:

These are the diodes which operated on light. The word "OPTO" means "light". There are types of conduction depending upon the light intensity and other types where conduction delivers some light. Each type has got applications of their own.

Some diodes conducts according to the

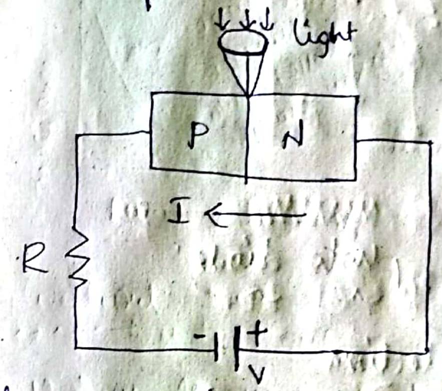
Intensity of light falls on them. There are 2 main types of among these ones in this category. They are photo diode and LED. solar cells.

1. photo diode: As the Name implies, is a PN Junction which works on light. The intensity of light affects the level of conduction in this diode. The photo diode has P-type material and N-type material with an Intrinsic material or a depletion Region in B/w.

The diode is generally operated in Reverse bias condition. The light when focused on the depletion Region, electron-Hole pairs are formed and flow of electron occurs. The conduction of electrons depends upon the intensity of light focussed.

When diode is connected to Reverse bias, a small Reverse saturation current flow due to thermally generated electron-Hole pairs.

As the current in Reverse bias flow due to minority carriers, The o/p voltage depends upon this Reverse current. As the light intensity focused on the junction increases, the current flow due to minority carriers increases.



The photo diode is encapsulated in a glass package to ~~follow~~ allow the light to fall onto it. In order to focus the light exactly on the depletion Region of the diode, a lens is placed above the Junction. Even when there is No light, small amount of current flows which is termed as a "Dark current". By changing the illumination level, Reverse current can be changed.

Advantages of photo diode:

1. Low Noise
2. High gain
3. High Speed operation
4. High sensitivity to light
5. Low cost
6. Small size
7. Long life

Applications of photo diodes:

1. character detection
2. objects can be detected
3. Used in circuits that require high stability and speed.
4. Used in demodulation
5. Used in switching circuits
6. Used in Encoders
7. Used in Optical Communication equipment.

LED (Light Emitting Diode):

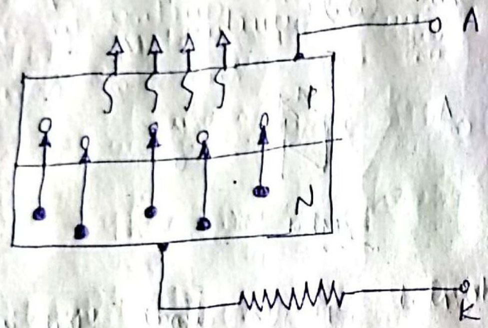
This one is the most popular diodes used in our daily life. This is also a normal pn-jn diode except that instead of silicon and germanium, the materials like gallium arsenide, gallium arsenide phosphide are used in this construction.

Symbol

Like a normal pn-jn diode this is connected in forward bias condition so that the diode conducts. The conduction takes place in LED when the free electrons in the conduction band combine with the Holes in the valence band. This process of Recombination emits light. This process is also called as "electroluminiscence". The color of the light emitted depends upon the gap b/w the energy bands.

The materials used also the colors like, gallium arsenide phosphide emits either red or yellow, gallium phosphide emits red or green, gallium nitrate emits blue. whereas

Gallium arsenide emits infrared light. The LEDs for NON-visible infrared light are used mostly in remote controls.



Basic Structure of LED

advantages of LED:

1. High efficiency
2. High Speed
3. High reliability
4. low Heat dissipation
5. longer life span
6. low Cost
7. No UV Radiation

IV - UNIT

FIELD - EFFECT TRANSISTORS

The field effect Transistors is a unipolar transistor in which current is controled by the variation of electric field.

→ it Have Three terminals

1. source
2. gate
3. Drain

1. Source: it is the first terminal of the transistors (FET) through which charge carriers are enter into the bar

2. gate: it is the second terminal of the FET through which charge carriers are move source to drain

3. DRain: it is the third terminal of the FET through which charge carriers Have the bar

Types of FET: There are 2 types of FET

1. JFET (Junction field effect transistor)

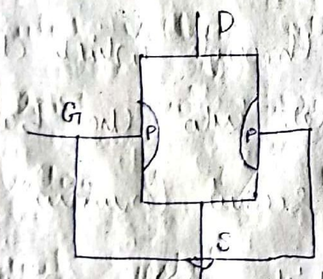
2. MOSFET (Metal Oxide Semiconductor effect transistor)

1. JFET: There are 2 types of JFET

(i) n- channel JFET

(ii) P- channel JFET

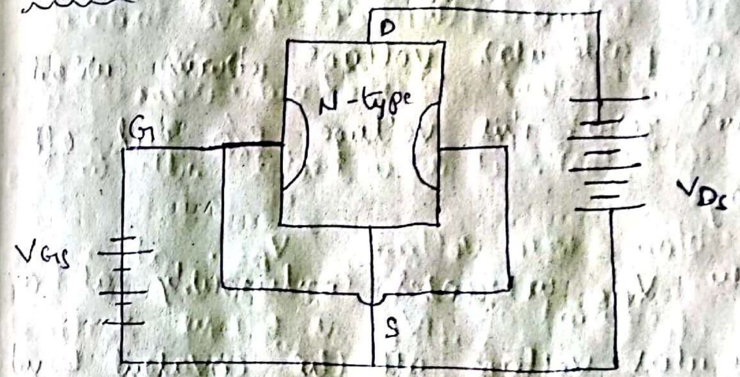
(i) N- channel JFET:



The N - channel JFET consist by N-type lightly doped semiconductor I/O channel and a p - type material are diffused on the both side of channels which are internally connected with a terminal R/O gate, so the both side of channel conducting material are attached. known as source and drain.

Note: source and drain both are interchanged.

Working:



Circuit Diagram

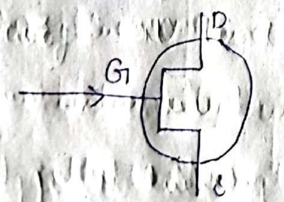
The circuit diagram of N - channel JFET in which gate terminal connects in the Reverse biased with respect to source and source is connect in the forward biasing with respect to drain

when no any potential is applied across the gate terminal the electron moves towards the drain from the source and drain current start to flow it is increases with increasing the drain source voltage (V_{DS}) at a particular potential of V_{DS} is become saturated. But when reverse biasing applying across gate terminal is increases. the width of the depletion layer is increases. Therefore I_D decreases.

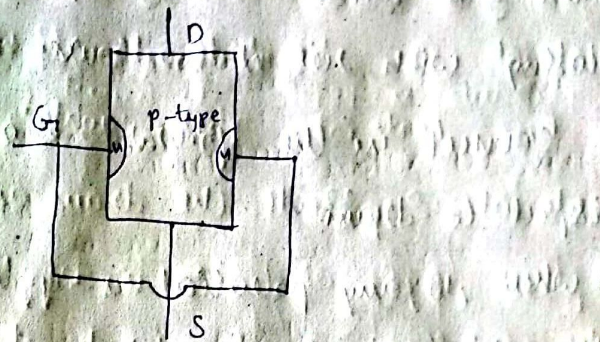
* At a particular voltage drain current (I_D) becomes zero. This voltage R/o cut-off voltage.

* when V_{DS} increases continously at a particular voltage all the covalent bonds are break and current increases majorly this voltage is R/o break down voltage.

Circuit symbol:

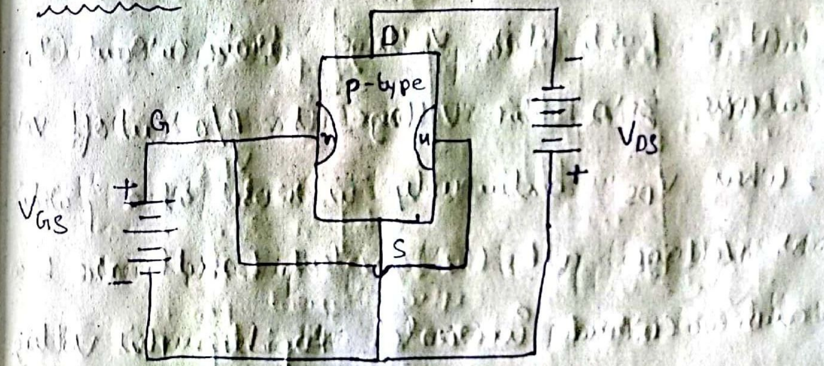


P - channel JFET:



The p-channel JFET carried by p-type lightly doped semiconductor R/o channel and a N-type material are diffused on the both side of channel which are internally connected with a terminal R/o gate. On the both side of channel two conducting material are attached R/o source and drain

WORKing:



The circuit diagram of P-type JFET in which gate terminal connecting in the reverse biasing with respect to source and source is connect in the forward biasing with respect to drain.

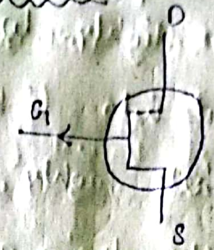
→ when no any potential is applied across the gate terminal the holes move towards the the drain from source and drain current start to flow. it is increases with increasing the drain source voltage (V_{DS}). at a particular potential of V_{DS} is become saturate

→ But when reverse biasing applying across gate terminal is increases. The width of depletion region increases. Therefore I_D decreases

→ at a particular voltage drain current (I_D) become zero this voltage is k/o cutoff voltage

→ when V_{DS} continuously increases at a particular voltage all the covalent bonds are break and current increases rapidly. This voltage is k/o breakdown voltage.

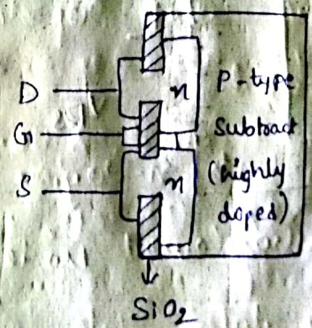
Circuit Symbol:



MOSFET (Metal oxide semiconductor field effect transistor)

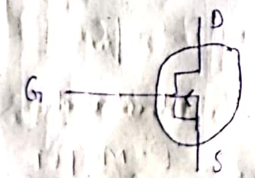
- MOSFET
  - D - MOSFET
    - N - channel D - MOSFET
    - P - channel D - MOSFET
  - E - MOSFET
    - N - channel E - MOSFET
    - P - channel E - MOSFET

① N - channel D - MOSFET

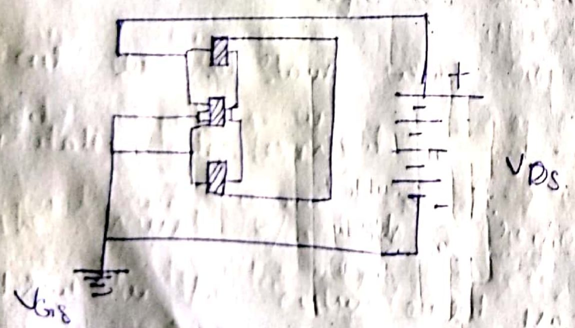


The Basic construction of N-channel D-MOSFET in which two Highly doped N-type material are diffused into lightly doped p-type material. These highly doped n-type material represents the drain and source. A thin layer of SiO_2 is deposited occur the substance (p-type subtract).
and a Metalic contact (metal is deposited) is created which form the gate terminal.

Circuit Symbol:



Working:



The circuit diagram of N-channel D-MOSFET in which gate and source terminal are connect to the -ve pole of the battery and drain is connect with the +ve pole of the battery.

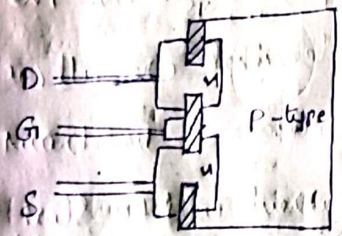
When V_{DS} increases keeping $V_{GS} = 0V$. The free electron of source terminal are attracted toward the positive terminal of the drain terminal and drain current will be start to flow.

→ If Negative potential applied on the gate terminal is increased the gate terminal repell the conduction electrons of the channel and attract Holes from p-type subtract and recombination takes place at the Junction. Therefore the No. of free electron at the Junction is reduces. Therefore current is also Reduces.

Note: If positive potential is applied across the gate terminal then the gate terminal attracted an additional electron from the subtract and

Conductivity of the channel is increases here
D-MOSFET behave as a enhanced MOSFET

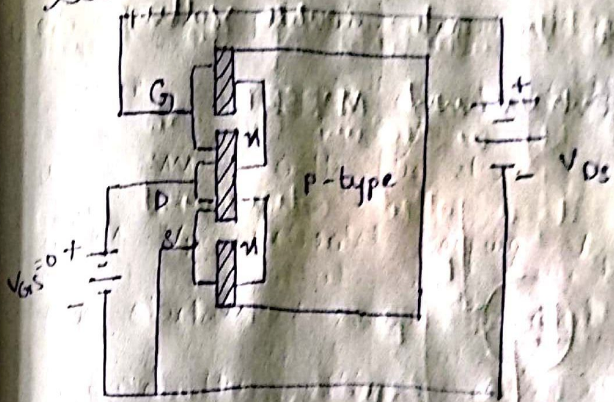
2. Enhance MOSFET - (N-channel E-MOSFET):



→ The Basic Concept of E-MOSFET is shown in fig in which 2 highly doped n-type Semi conductors are diffused into a lightly doped p-type semiconductor. These two highly doped n-region are represent the source and drain terminal. A thin layer of SiO_2 is deposited occur the substrate which represent the insulated gate terminal.

The channel b/w both n-region are absent in the enhancement mode

Working:



→ The circuit diagram of E-channel MOSFET is shown in the fig. in which a positive voltage is applied across the gate terminal when the voltage applied across gate source terminal is zero i.e

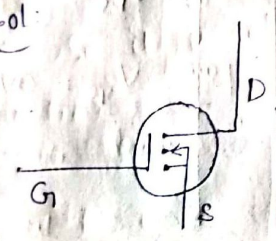
$V_{GS}=0$ no current will be flow due to the absence of channel.

→ when V_{GS} is increases in the positive direction The No of electron near the SiO_2 layer is increases and at a particular voltage a measurable current will be flow to the formation of channel.

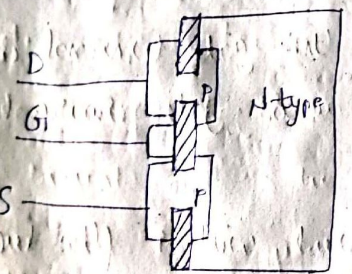
→ The voltage at which measurable current is start to flow is R/o **Threshold voltage**

The conductivity of the channel is enhanced by increasing the gate source voltage so it is called Enhancement MOFSET.

Symbol



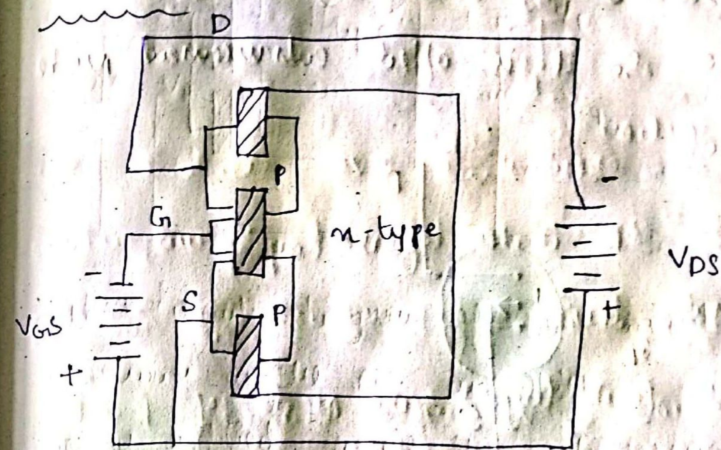
P - channel E - MOSFET:



The E - MOSFET is which two lightly doped P-type semiconductors are diffused into a Highly doped n- type are represented the source and drain terminal. A thin layer of SiO_2 is deposited over the substance which Represents the insulated gate terminal

The channel B/w both p-region are absent in the enhancement mode.

Working:

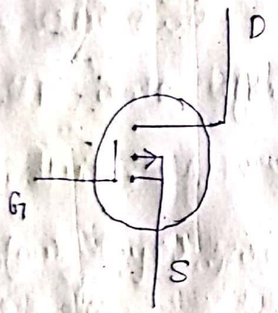


The circuit diagram of p-channel E-MOSFET is shown in the figure. In which a negative voltage is applied across the gate terminal when the voltage applied gate-source terminal is zero i.e $V_{GS} = 0$.

→ No current will be flow due to the absence of channel when V_{GS} is increased in the direction the No. of Holes near the SiO_2 layer is increased and at a particular voltage a measurable current will be flo

~~due to~~ is start to flow is K/o Threshold voltage. The conductivity of the channel is enhanced by increasing the gate + source voltage so it is called enhancement mode.

Symbol



UNIT - 5

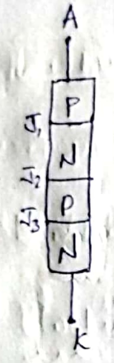
Thyristors

Silicon Controlled Rectifier:

SCR:

* SCR is the most important and mostly used member of the thyristor family.
* Like a diode, SCR is uni directional device that allows the current in one direction and opposes in other direction.
* SCR is three terminal device 1. Anode 2. Cathode 3. gate.
* SCR has built in feature to turn on & OFF and its switching is controlled by biasing conditions and gate i/p terminal
* SCR can handle several thousands of voltages and currents.

SCR SYMBOL and its terminals:

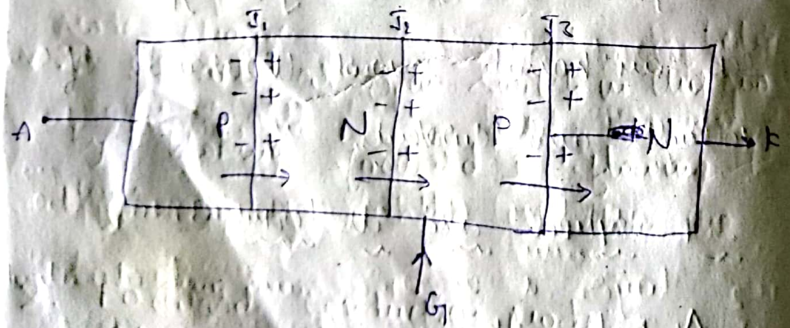


Construction of SCR:

* The SCR is a four layer and three terminal device.

* The four layer are made of P & N layers, are arranged alternatively such that they form three junctions. J_1, J_2, J_3.

* These junctions are either alloyed or diffused based on the type of construction.



* The outer P and N layers are Heavily doped whereas middle P and N layers lightly doped.

* The gate terminal is taken at the middle p-layer. anode is from outer p-layer & cathode is from outer N-layer.

* SCR is made up of silicon because as compared to germanium leakage current in silicon is very low.

* This connection is highly used for high power silicon controlled rectifiers.

* To provide High mechanical strength SCR is braced with plates made of molybdenum or tungsten. And one of these plate is soldered to a copper stud which is further threaded to connect Heat sink.

Working or Modes of operation of SCR:

The operation of SCR is divided into three modes. They are:

1. forward blocking mode

2. forward conduction mode

3. Reverse blocking mode

1. Forward blocking mode:

* anode terminal is (+ve) w.r.t cathode while the gate terminal kept open.

* J_1 & J_3 are forward biased and the Junction J_2 is reverse biased.

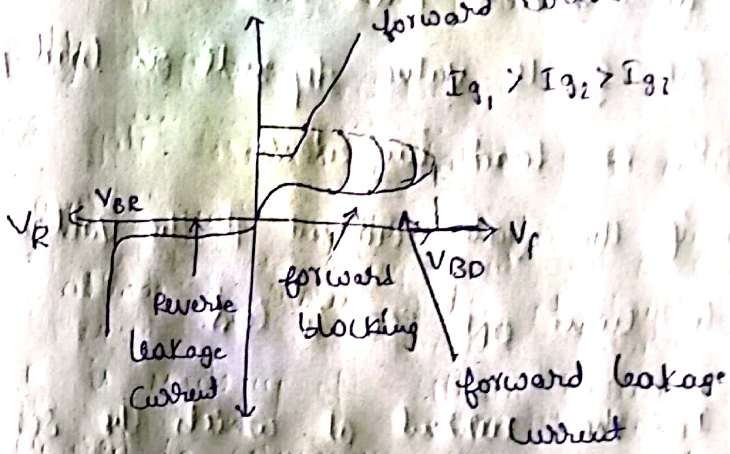
* due to this a small leakage current flows through the SCR

* until the voltage applied across the SCR is ↑ than the breakover voltage SCR offers ↑ resistance to current flow.

* ∴ SCR acts as open switch in this mode by blocking forward I flowing through the SCR.

2. Forward conduction Mode:

V-I characteristics:



* In this mode SCR comes into the conduction mode from blocking mode it can done in two ways

① applying the forward vtg

② beyond the breakover vtg

any one of these methods is applied the avalanche breakdown occurs at J_2.

∴ SCR turns to conduction mode & acts as closed switch. current starts flowing it.

* if the gate current value is ↑ the min will be the time to come in conduction

Mode at $I_{g3} > I_{g2} > I_{g1}$

* In this mode max current flows through SCR & its value depends on load Resistance or load impedence.

* if the gate current ↑ the voltage req to turn ON SCR is less.

I_L: The current at which the SCR turns into conduction mode from blocking mode is called as Latching current.

* I_H: forward current reaches to level at which SCR returns to blocking state is called Holding current.

* at this Holding current level, where no mode change present depletion region starts to develop around J_2.

Hence I_H is slightly less than the Latching current

3. Reverse blocking Mode:

* Cathode +ve w.r.t anode (-ve).

* J_1 and J_3 reverse bias, J_2 forward bias.

* This reverse voltage drives SCR into Reverse blocking Mode which results a small flow of leakage current through it and acts as open switch.

* until applied voltage is less than VBR. (Reverse breakdown voltage) The device offer ↑ impedence.

* if reverse applied vtg ↑ then VBR the avalanche breakdown occurs at J_1 & J_3 which results to ↑ reverse I flow through SCR

* This reverse current causes ↑ loses & even to ↑ heat of it.

* So, there will be considerable damage to SCR when the rever vtg ↑ than VBR.