UNIT I

Introduction to Electronics

* Evolution of Electronics and Impact of Electronics in Industry:
- In the 21^{st} century we are enjoying very well developed electronics.
- In some form or the other, in day to day life, we deal with the many advanced electronic devices for several times.
- The history can be divided in two parts.
  I) The beginning of electronics.
  II) Solid state electronics.

I) The beginning of electronics:
- In 18^{th} century many electrical experiments were conducted by many scientists. This research and the information obtained from it is the base of modern electronics.
- The beginning of electronics starts with the invention of electric currents in vacuum tubes.
- But the actual history of electronics ~~starts~~ began with the invention of vaccum ~~tube~~ diode which allowed the flow of current in one direction.

~~II~~) Solid state electronics:
- The scientists were desperately looking for some alternative to the vaccum diodes and triodes for the communication technology in Bell labs.

- And finally in 1947, Walter Brattain, John Bardeen and William Shockley invented the famous device the transistor.
- The modern electronics what it is called today was actually started after the discovery of the transistor.
- Jack Kilby in Texas Instruments found a very nice solution to such problems, by making first integrated circuits (IC).
- And the trend further carried forward with the JFETS and MOSFET s that were developed during 1951 to 1958 by improving the device designing process and by making more reliable and powerful transistors.

* Impact of Electronics in Industry and in Society
- Electronics has become an integral part of our lives.
- From the start of the day we use various electronic devices such as washing machine, microwave oven, computers, mobiles, CD players, televisions etc.
- Digital camera technology has changed everything drastically.
- The modern equipments helps in medicinal research work.
  CT scan and MRI machine is a good example of modern electronic impact.
- LEDs and their usage improved picture quality tremendously due to this modern technology.

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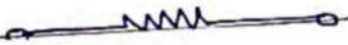
- Due to the impact of electronics in industry, it is growing very fast Many new occupations are getting created due to modern technology
- It is creating good job opportunities in industries like entertainment, mobile phones, computer industry, television, laptops, tablets etc
- Electronic engineers can work in research, design, development, manufacturing, repairing and maintenance of various modern electronics devices and equipments.

Active and Passive components:

- Active Components :- Deliver power/energy
- The components which supply energy in the circuit in the form of voltage or current, produce amplification and behave actively in the circuit are called active components.
- e.g. voltage sources, current sources, diodes, transistors, op-amps

- Passive components :-
- The components which consume energy in the circuit or store energy without producing any amplification are called passive components.
- e.g. resistors, inductors, capacitors, potentiometers.

Resistors :-
- A two terminal circuit element which introduces opposition to the flow of electric current in a circuit is called a resistor.



Introduction to Semiconductors and P-N Junction Diode.

* Atomic Structure :-
- The smallest particle of matter is an atom, which is made up of three fundamental particles.
  - Neutron, Proton, Electron
- The proton is positively charged
- electron is negatively charged
- while neutron is unchanged i.e. electrically neutral.
- The number of protons in an atom is called its atomic number
- The total number of protons and neutrons in the nucleus of an atom is called its atomic weight

* Concept of Energy levels and Energy Bands

Fig. Concept of energy level.

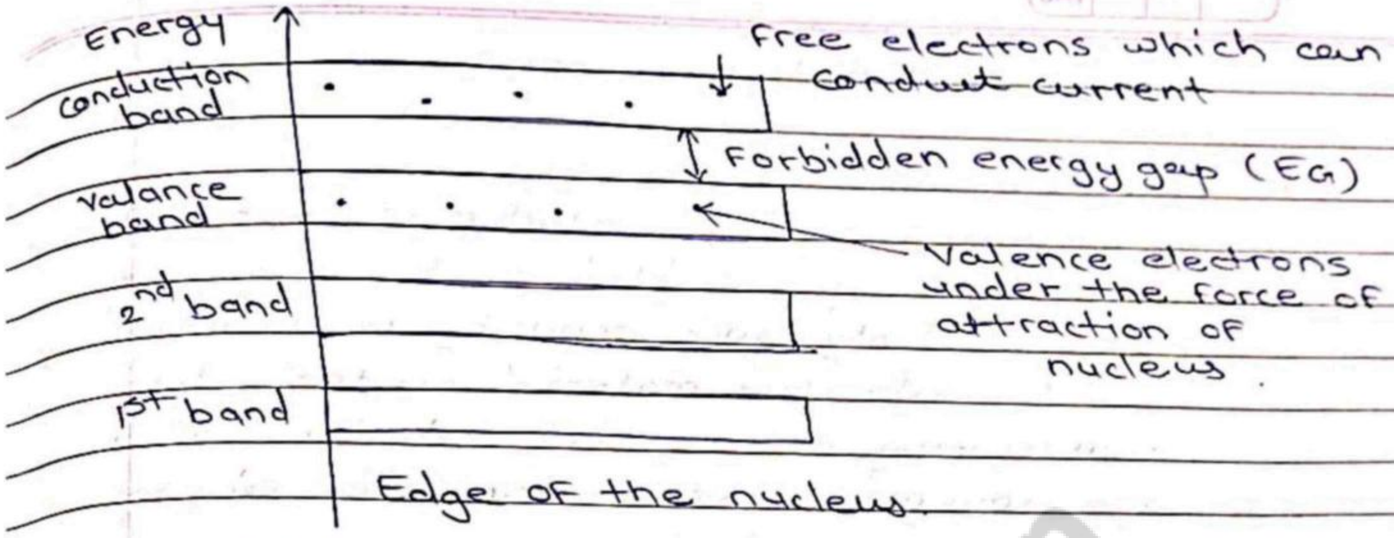
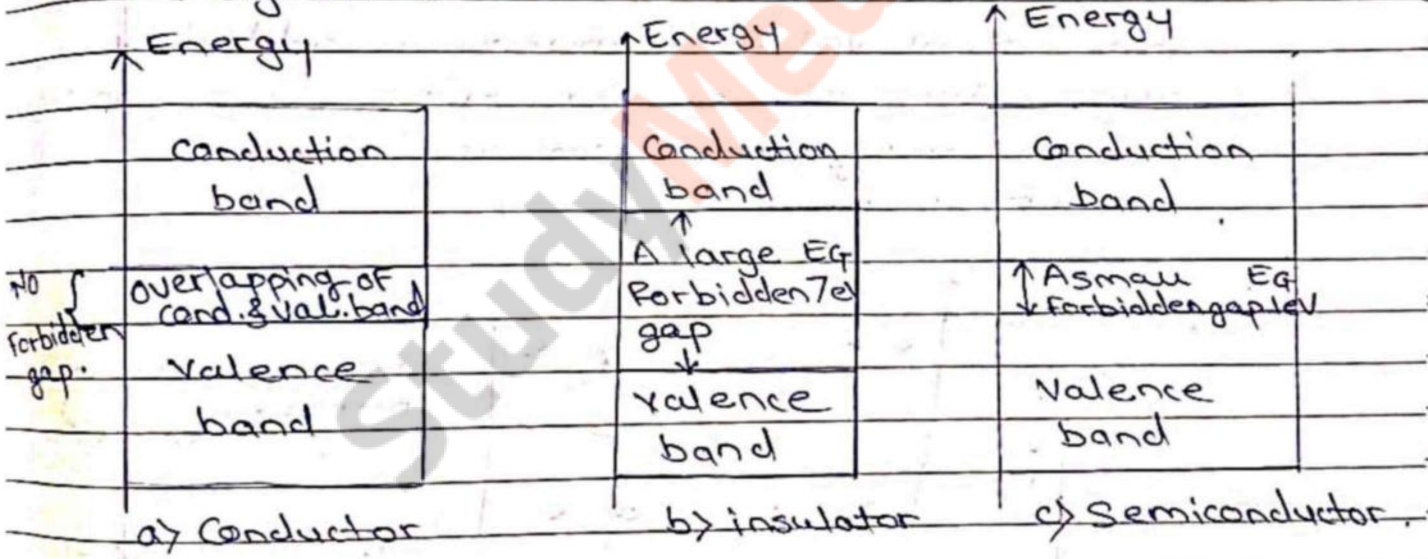


Fig. Energy band diagram.

* Classification of materials based on Energy band Diagram :-



* Intrinsic Semiconductor :-

- A sample of semiconductor in its purest form is called an intrinsic semiconductor.
- The conductivity of such intrinsic semiconductor is very poor and practically can not be used for manufacturing of a semiconductor devices.
- In the outermost shell of intrinsic semiconductor

there are 4 electrons.

* Extrinsic Semiconductor:-
- As pure intrinsic semiconductor has poor conductivity some impurity is added to it to increase the conductivity such impurity is purposely added to make the material suitable for manufacturing of the semiconductor devices.
- Such impure semiconductor is called an extrinsic semiconductor.

• N-type Semiconductor:
- In intrinsic semiconductor, the number of free electronics and holes is same. But when pentavalent impurity is added in large extent, the number of free electrons becomes very high compared to the number of holes.

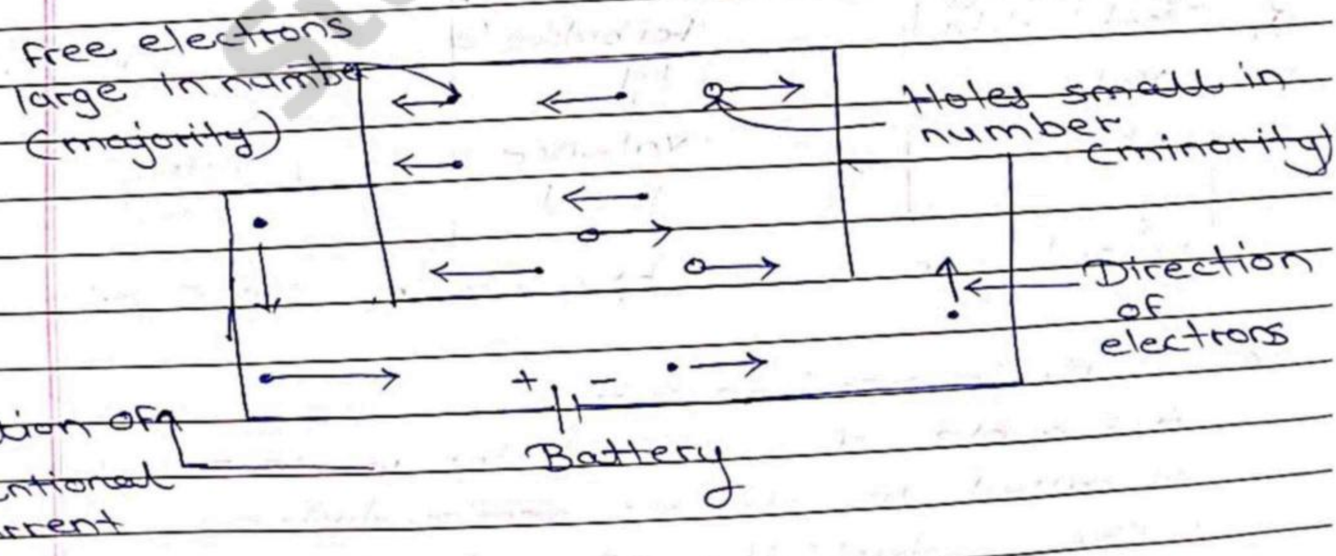
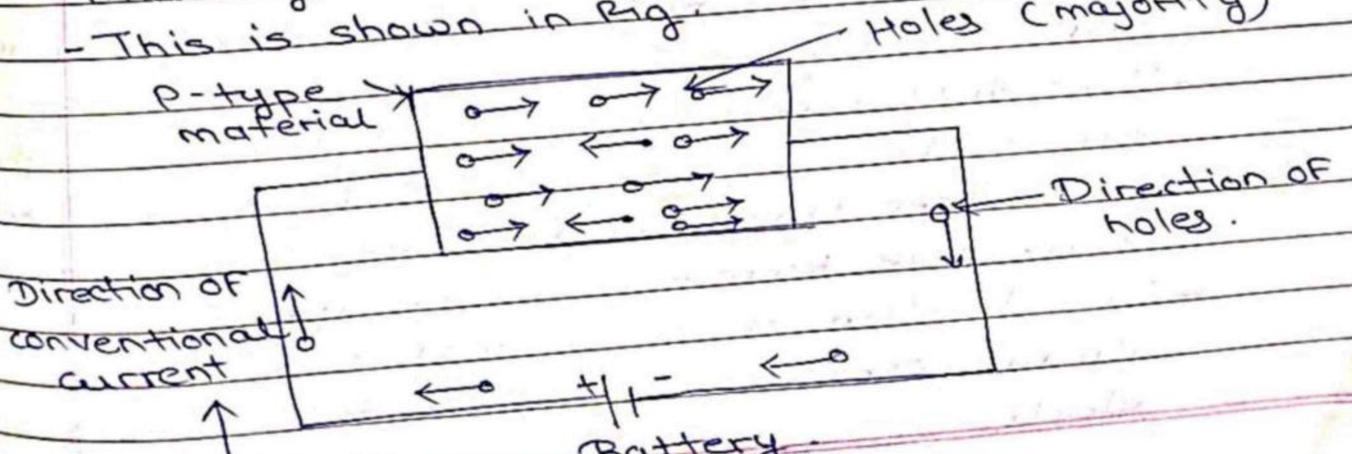


Fig. Conduction in n-type

• ~~p-type Semiconductor~~:

- Thus if voltage is applied, the current is mainly because of free electrons which are large in number. Hence the free electrons are called majority carriers in n-type material. While there is small current due to less number of holes. Hence the holes are called minority carriers in n-type material.
- This shows in above fig.

* p-type Semiconductor:-
- When large trivalent impurity is added to silicon or germanium, the number of holes becomes very high as compared to free electrons.
- Thus if voltage is applied, the holes which are large in number move towards negative of battery and mainly responsible for the current. Hence the hole are called majority carriers in p-type material while there is small current due to the movement of less number of free electrons. Hence the free electrons are called minority carriers in p-type material.
- This is shown in fig.



* Majority & Minority Carriers :-

Material	Majority carriers	Minority carriers
n-type	free electrons	Holes
p-type	Holes	free electrons

* Drift current :-

- When voltage is applied to a semiconductor, the free electrons try to move in a straight line towards the positive terminal of the battery.
- The electrons, moving towards positive terminal collide with the atoms of semiconductor and connecting wires, along its way. Each time the electron strikes an atom, it rebounds in a random direction
- But still the applied voltage make the electrons drift towards the positive terminal.
- This drift causes current to flow in a semiconductor, under the influence of the applied voltage
- This current produced due to drifting of free electrons is called drift current and the velocity with which electrons drift is called drift velocity.
- Thus drift current means the flow of current due to bouncing of electrons from one atom to another, travelling from negative terminal to positive terminal of the applied voltage.
- The direction of conventional current is always opposite to the direction of drifting electrons.

- This is shown in Fig.

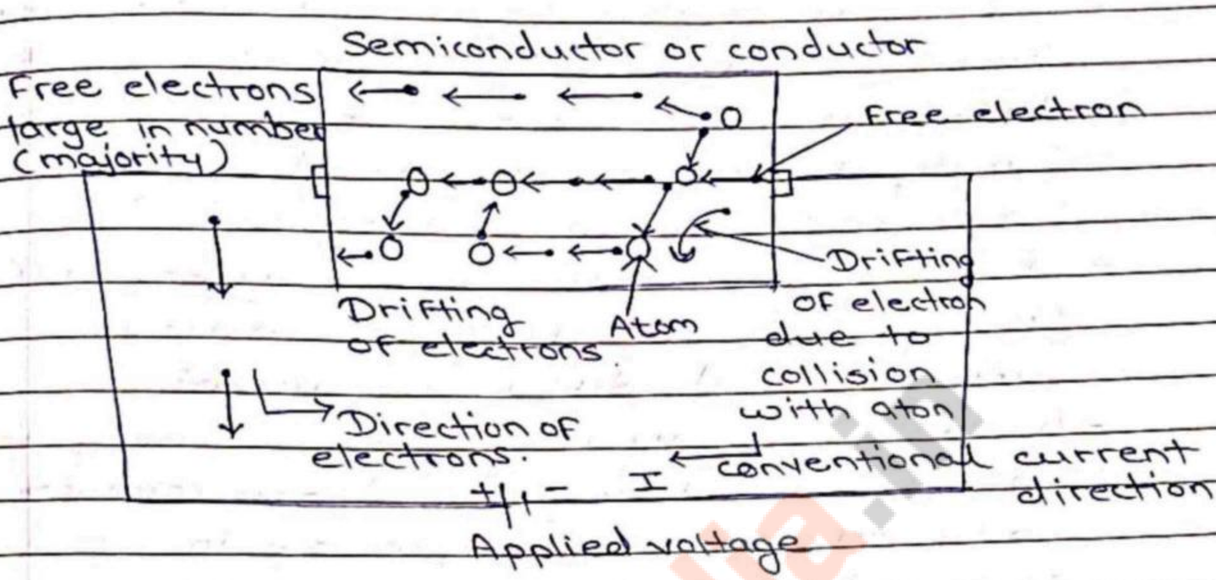


Fig. Drift mechanism causing drift current.

* Diffusion current :-
- This is the current which is due to the transport of charges occuring because of nonuniform concentration of charged particles in a semiconductor.

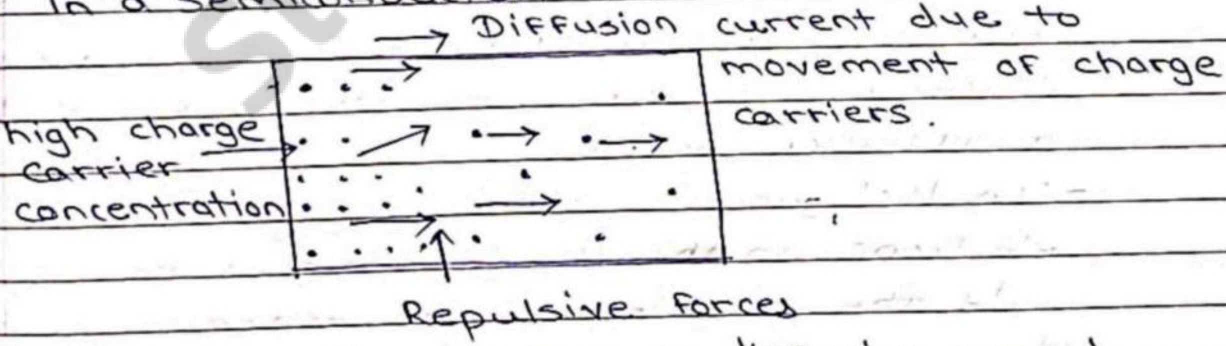


Fig. Process of diffusion current.

- The charge carriers are either electrons or holes, of one type depending upon the impurity used.
- They have the same polarity and hence

experience a force of repulsion between them.
- The result is that there is a tendency of the charge carriers to move gradually i.e. to diffuse from the region of high carrier density to the low carrier density.
This process is called diffusion.
- This movement of charge carriers under the process of diffusion constitutes a current called diffusion current.
- A diffusion current is possible only in case of nonuniformly doped semiconductors while drift current is possible in semiconductors as well as conductors.

* P-N Junction Diode :-
- The two 'P' type and 'N' type materials are chemically combined with a definite fabrication technique to form a p-n junction which is called a diode.
- As we seen earlier, the movement of charge carriers from high concentration to low concentration area to acheive uniform concentration over the material is called as a diffusion process.
- In P-N junction, there is large number of electrons on the N side, whereas on the P side the concentration of electrons is very low.
- Due to this non-uniform concentration, diffusion starts and electrons start moving from N side towards P side.
Similarly the holes from p-region diffuse into

contacts.

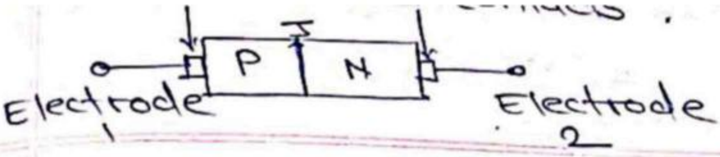


Fig. Two electrodes

the N-region across the junction. This is shown in Fig. below

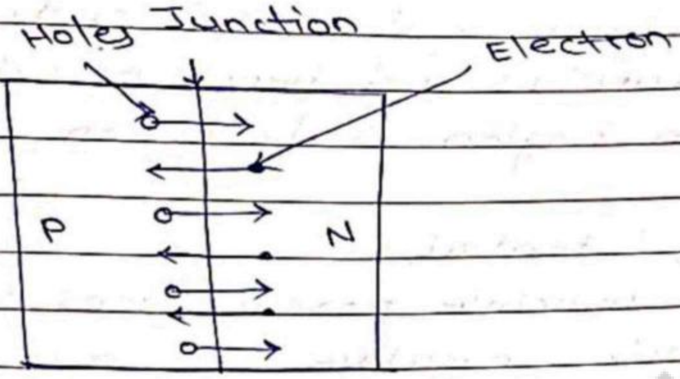


fig. Initial Diffusion in P-N junction.

- When the P-N junction is formed, the N side donor atoms accept additional holes and they become positively charged immobile ions.
- Similarly, P-side acceptor atoms accept additional electrons and they become negatively charged immobile ions.
- The formation of immobile ions near the junction is shown in fig.

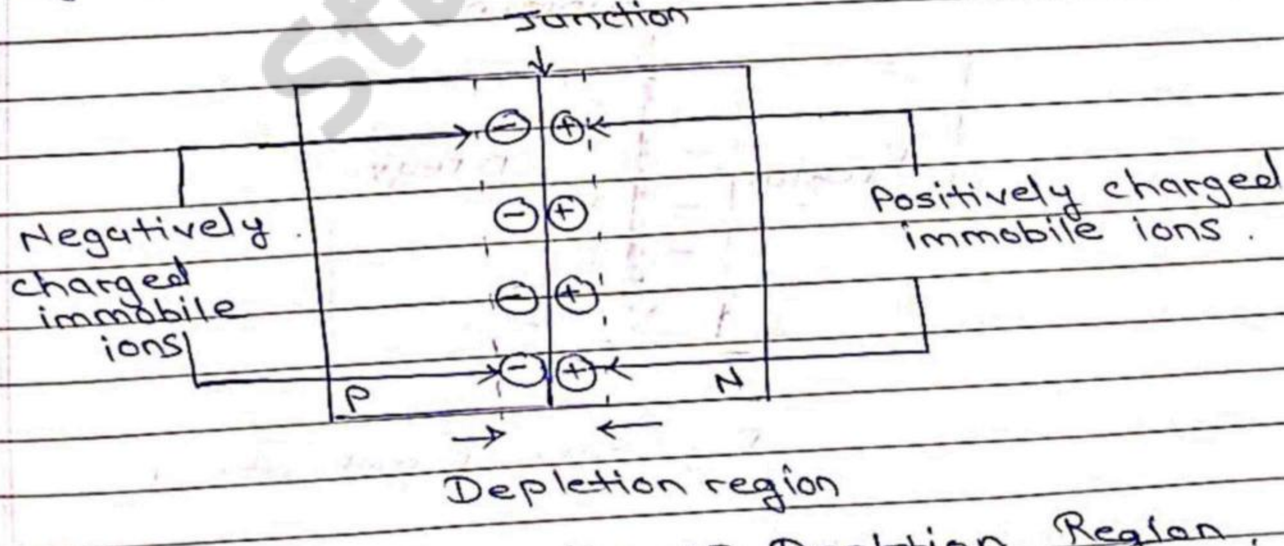
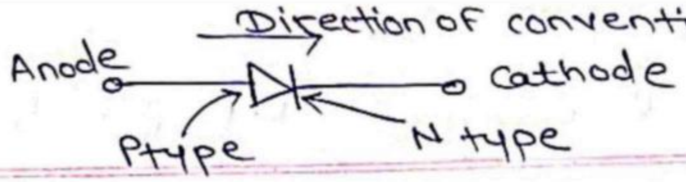


Fig. Formation of Depletion Region.

symbol of diode



- In this region, there exists a wall in which there are no mobile charge carriers. Such a region is depleted of the free mobile charge carriers and hence is called as depletion region or depletion layer.

Barrier Potential:-

- Due to immobile positive ions on n side and immobile negative ions on p side, there exists an electric field across the junction.
- This creates potential difference across the depletion region which acts as a barrier.
- This is called barrier potential, junction potential, built-in potential or cut-in potential of p-n junction.
- It is denoted as V_J and is shown in fig below
- It is also called height of the depletion region and also denoted as V_o or V_γ

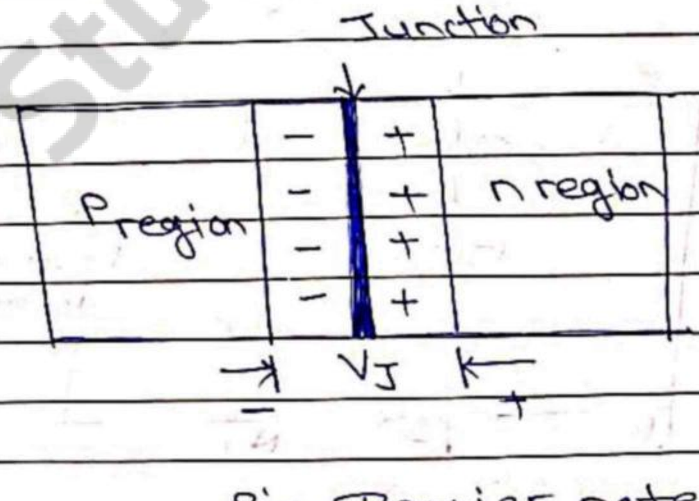


Fig. Barrier potential.

- Barrier potential depends on.

a) Type of semiconductor

b) Donor impurity added.

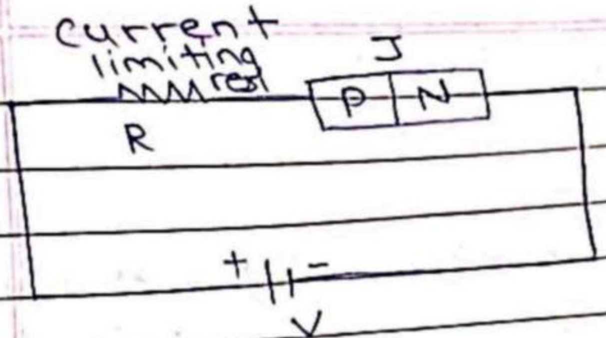
c) Acceptor impurity added
d) Temperature.

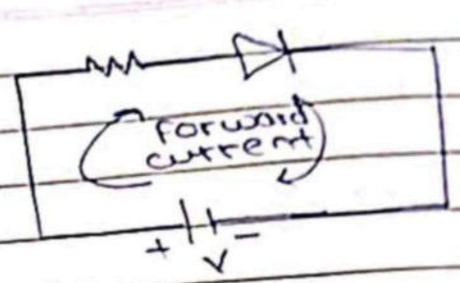
Material	Symbol	Value of barrier potential
Silicon	Si	0.6 V
Germanium	Ge	0.2 V.

Effect of Temperature on Barrier Potential :-
- As temperature increases, the width of the depletion region decreases.
- Thus as temperature increases, the barrier potential decreases.
- The barrier potential decreases by approximately 2.5 mV per degree celcius rise in temperature.

* Biasing the Diode :
- Applying external d.c. voltage to the p-n junction diode is called biasing.
- The usefulness of p-n junction depends on the way of biasing it.
- Depending on the polarity of the d.c. voltage externally applied to the diode, the biasing is classified as,
1) Forward biasing
2) Reverse biasing.

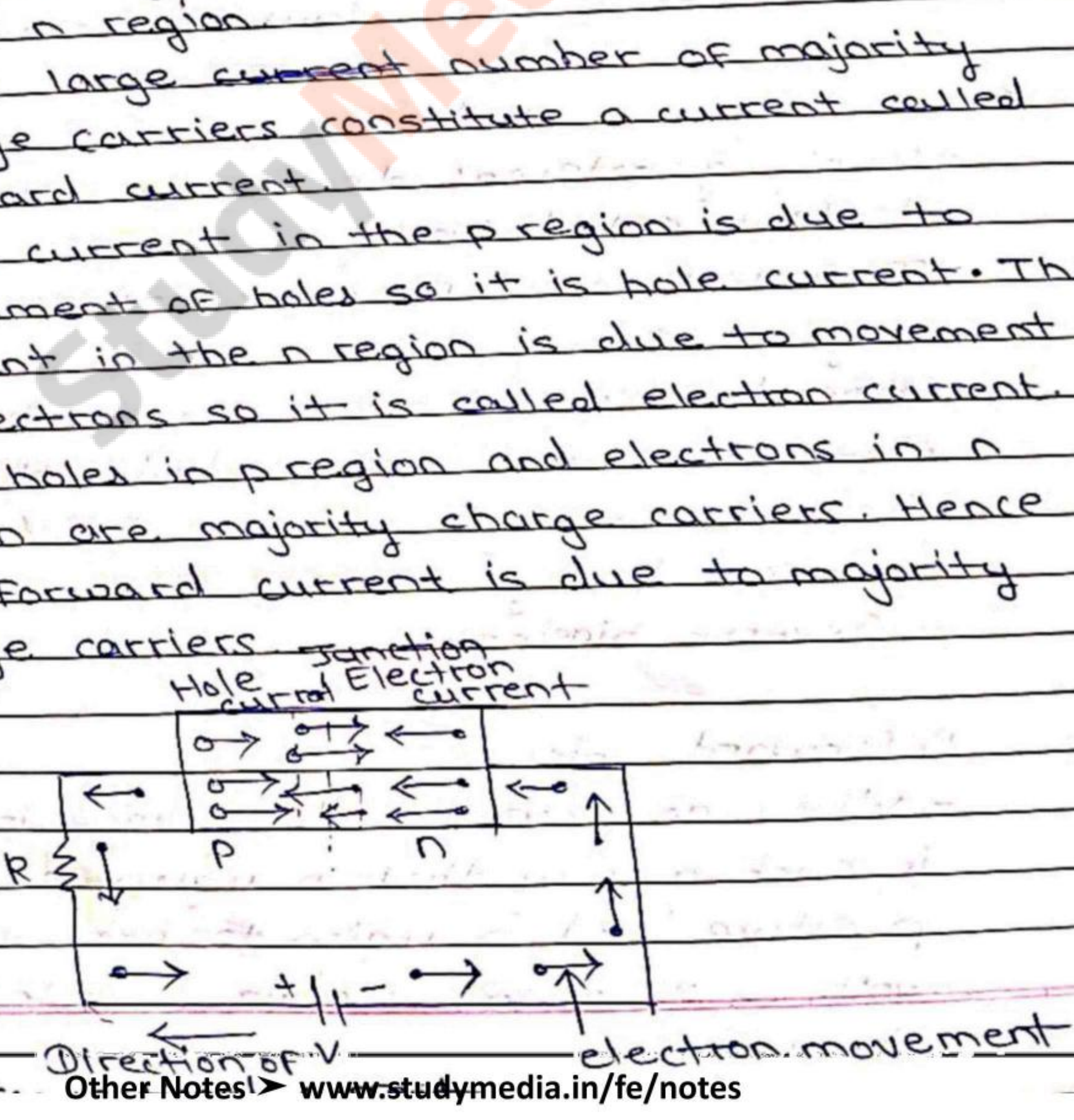
1) Forward Biasing of Diode :
- When an external d.c. voltage is connected in such a way that p region is connected to positive and n region to negative of the d.c. voltage then the biasing is called forward biasing.





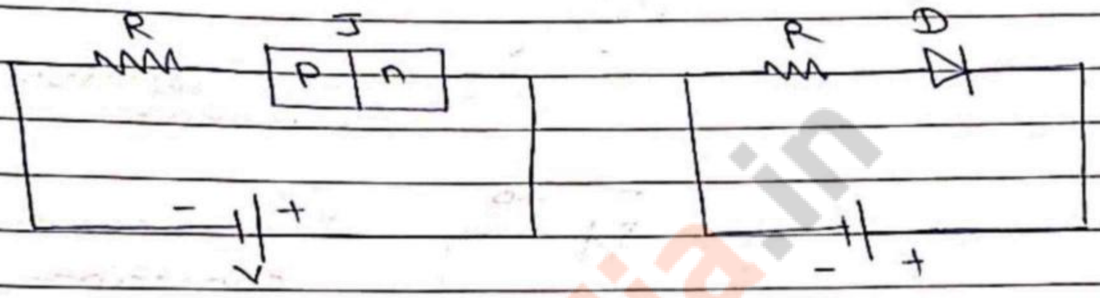
forward biasing. Symbolic representation

- When applied voltage V is more than barrier potential, it overcomes the barrier potential and reduces the width of depletion region.
- This is because the negative of battery pushes the free electrons against the barrier from n to p region while positive of battery pushes holes against barrier from p to n region.
- This large ~~current~~ number of majority charge carriers constitute a current called forward current.
- The current in the p region is due to movement of holes so it is hole current. The current in the n region is due to movement of electrons so it is called electron current. The holes in p region and electrons in n region are majority charge carriers. Hence the forward current is due to majority charge carriers.

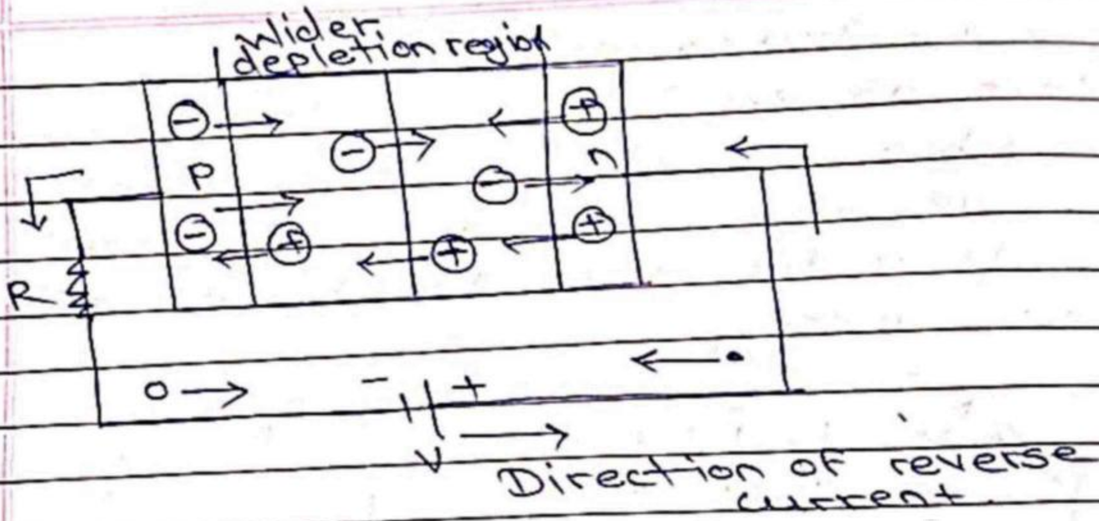


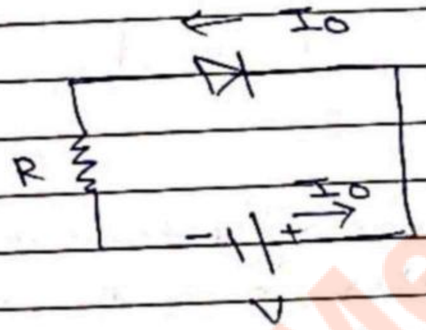
2) Reverse Biasing of Diode:

- When an external d.c. voltage is connected in such a way that p region is connected to negative and n region to positive terminal of the d.c. voltage then the biasing is called reverse biasing.



- In reverse biasing, negative of battery attracts the holes in p region and positive of battery attracts the electrons in n region away from the junction.
- This widens the depletion region and barrier potential increases. No majority charge carrier can cross the junction.
- The resistance of the reversed biased diode is very high and the diode is said to be nonoperative in the reverse biased.
- The current called reverse current flows due to minority charge carriers and hence its magnitude is very very small.
- For constant temp, the reverse current is almost constant though applied reverse voltage is increased upto certain limit.
- Hence it is called reverse saturation current denoted as I_o.





I_0 is constant at constant temp.

* Breakdown Mechanism in Diode:

- If reverse voltage is increased beyond particular value, large reverse current can flow damaging the diode. This is called reverse breakdown of diode.
- It can be takes place due to following two effects.
  a) Avalanche Effect
  b) Zener effect.

a) Breakdown due to the Avalanche Effect:

- If reverse bias voltage is increased, the kinetic energy of the minority carriers gets increased.
- While travelling, the minority carriers collide with stationary atoms, which in turn result

in breaking some of the covalent bonds and generating free electrons.

- This electrons acts as minority carriers. Again they get accelerated by the strong reverse bias field, thereby increasing the collision and also the number of free electrons. This is known as carrier multiplication.
- This process continues leading to a very swift multiplication effect and giving rise to a large reverse current in just a few picoseconds. This effect is called as Avalanche breakdown effect.
- This effect causes reverse breakdown in the p-n junction. Due to large power dissipation, the junction temperature increases and may destroy the semiconductor device permanently.
- To limit this reverse current, a series resistance of exactly calculated value must be used in series with the diode for its protection.

b) Zener Breakdown:

- This type of breakdown occurs in heavily doped p-n junctions in which the depletion region is very narrow.
- All the applied reverse voltage appears across the depletion layer. The electric field is voltage per unit distance. It is very intense at the depletion region.
- Therefore it can pull the electrons out of the valance band by breaking the covalent bonds and producing the free electrons. This process is known as zener effect.

- A large number of such free electrons can result into a large reverse current through the diode.
- Due to large current, there is large power dissipation. This increases the junction temperature beyond certain limit and may damage the diode permanently.
- To limit the current, a series resistance is added in the circuit to protect the diode.

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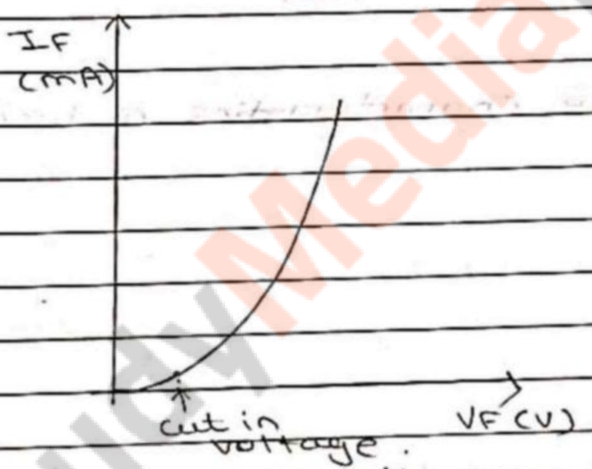
* V-I Characteristics of P-N Junction Diode:-

- The graph of voltage applied across the p-n junction diode and the current flowing through the p-n junction diode is called V-I characteristic of a p-n junction diode.
- It is divided into two parts.

A) Forward characteristics.

B) Reverse characteristics.

A) Forward characteristics:-



- The forward characteristic may be divided into two parts:

a) Region A to B:

This is the region where VF is less than the cut-in voltage and the current flow is very small so IF is assumed to be zero. (The cut in voltage is 0.3 V for Germanium diode and for Silicon diode it is 0.7 V)

b) Region B to F:

As the applied forward voltage (VF) increases, at point B it exceeds the cut-in voltage. The curve B to F is exponential in nature.

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- The resistance offered by the diode in forward biased condition is called as forward resistance, which is very small in nature. There are two types of forward resistances viz. static and dynamic

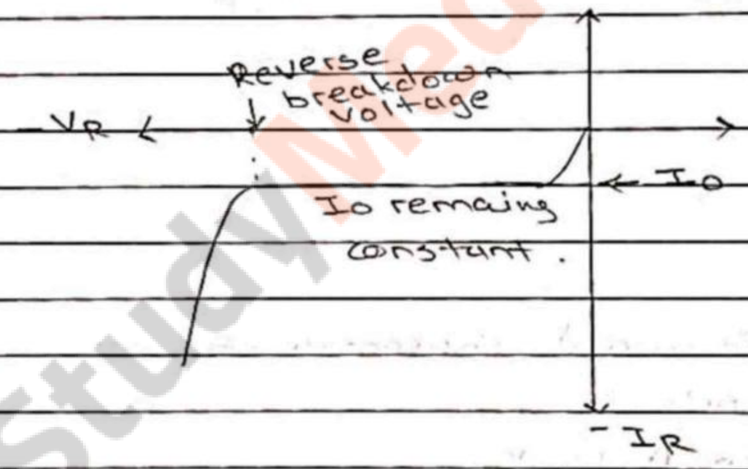
i) Static forward resistance (RF)

$$RF = \frac{Vdc}{Idc}$$

ii) Dynamic forward resistance (rF)

$$rF = \frac{\Delta VF}{\Delta IF}$$

B) Reverse Characteristics of Diode :-



- The graph of reverse voltage VR verses the reverse current IR is the reverse characteristics of diode.
- At constant temperature, if the reverse voltag is increased the reverse saturation current(I remains constant showing that it is independe of reverse voltage.
- But if the reverse voltage is increased beyond the breakdown voltage, a large current flows through the diode. Typically.

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the breakdown voltage is about 50V to 100V.
- A very high resistance of about few hundred kilo ohms is connected in series with the diode for protection.
- Reverse Resistance of Diode
i) Reverse static resistance (R_r)
ii) Reverse dynamic resistance (r_r)

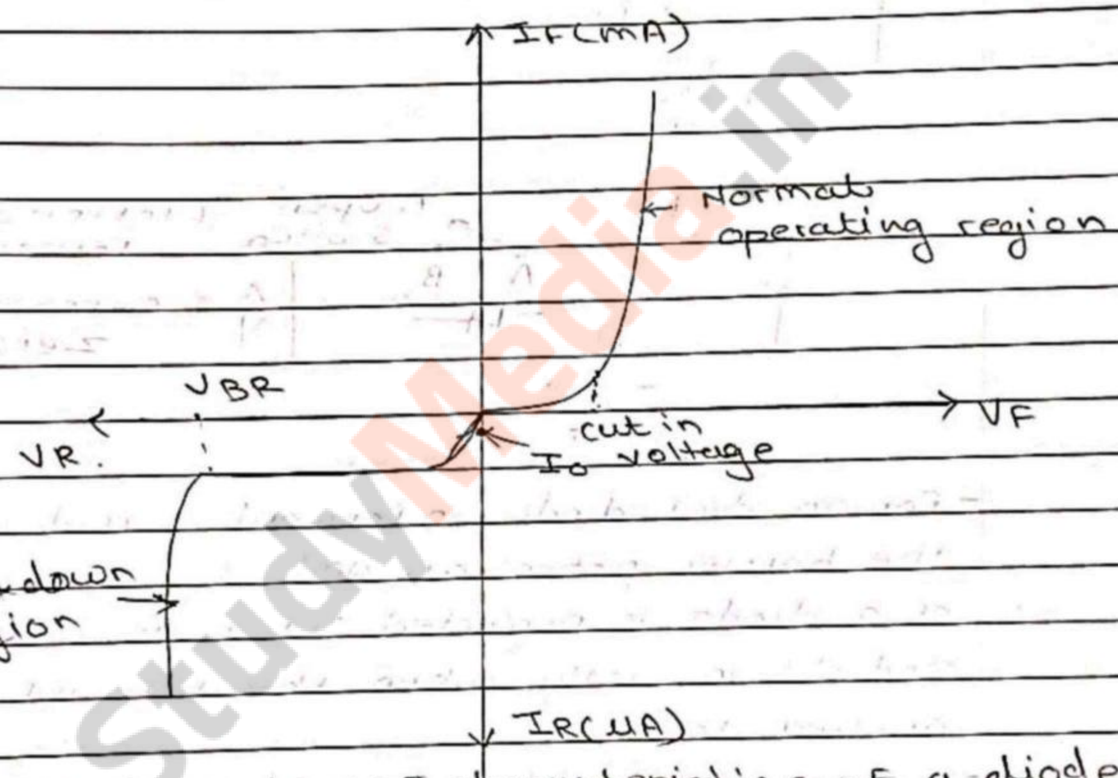
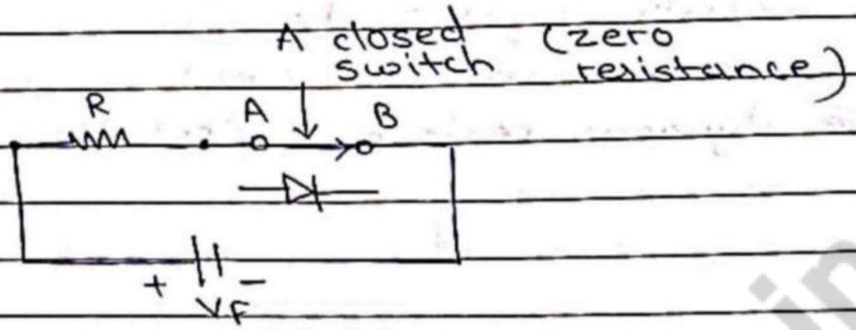
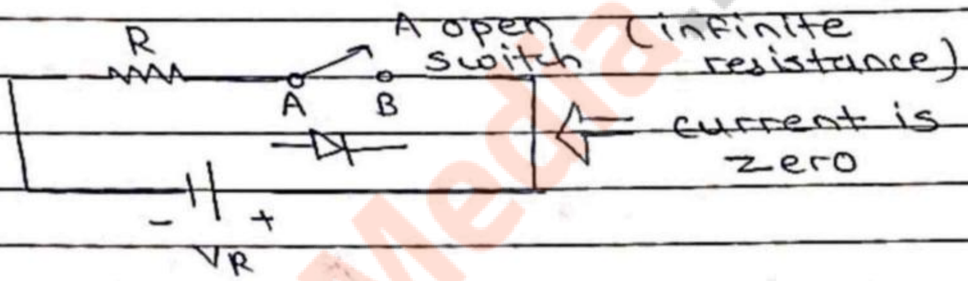


Fig. Complete V-I characteristics of a diode

* Diode as a switch :-
- A diode conducts heavily in one direction and very poorly in other direction.
- In forward biased condition, the forward resistance of a diode is very small and ideally it can be treated to be zero. Thus ideally forward biased diode acts as a zero resistance device which is a closed switch.
- In reverse biased condition, the reverse resistance is very very large and it can be treated to be

infinite. Thus ideally the reverse biased diode can be treated as infinite resistance device which does not allow the flow of current. Such a device is nothing but an open switch.





- For an ideal diode, in forward biased condition, the barrier potential and the forward resistanc of a diode is neglected. It is assumed that it conducts instantly when the forward voltage is applied to it.
- For an ideal diode, in reverse biased condition, the reverse biased condition, the reverse resistanc of a diode is infinite and current is zero.
- Thus the diode can be used as a switch in the circuit to control the flow of current only in one direction and blocks the current in other direction.
- As ideal diode conducts instantly in forward biased condition and does not conduct at all in reverse biased condition.