UNIT-I
SEMICONDUCTORS

PAGE No.
DATE

* Semiconductor

The materials, whose electrical conductivity lie between those of conductors and insulators, are known as semiconductors. The conductivity is in the range of 10^{-3} to 10^{-8} S/cm. The semiconductors are the foundation of modern electronics including radio, television, computers, telephones and many more.

Common semiconductors are crystalline solids but but amorphous and liquid semiconductors are also known. The examples of such materials are germanium (Ge), silicon (Si), gallium arsenide (GaAs), cadmium sulfide (CdS), lead telluride etc.

In terms of energy bands, the semiconductors may be defined as those materials, which at room temperature, have:

(i) Partially filled conduction band.

(ii) Partially filled valence band.

(iii) A very narrow energy-gap, ($E_g \simeq 1$ eV) between conduction and valence bands.

At absolute zero temperature (i.e 0K) there are no electrons in the conduction band of the semiconductors and the valence band is completely filled. Thus the semiconductors behave like perfect insulators at 0K. As the temperature is increased, the width of energy gap reduces. consequently, some of the electrons jump into conduction band and semiconductor show some conductivity. The conductivity of semiconductors increases with the increase in temperature. The electrical conductivity of semiconductors is in the range of 10^{-3} to 10^{-6} per ohm per cm.

* Types of semiconductors

The semiconductors are of the following two types.

1. Intrinsic semiconductors
2. Extrinsic semiconductors

(1) Intrinsic semiconductors

A semiconductor, which is in its extremely pure form is known as an intrinsic (or pure) semiconductor. The nature of semiconductor is such that even a small amount of certain impurities can change their electrical properties drastically. Due to this fact a semiconductor would not be called truly intrinsic, unless the impurity level is very small. For germanium, the impurity level is less than 1 part in 10^8 parts, and for silicon it is less than 1 part in 10^{12} parts.

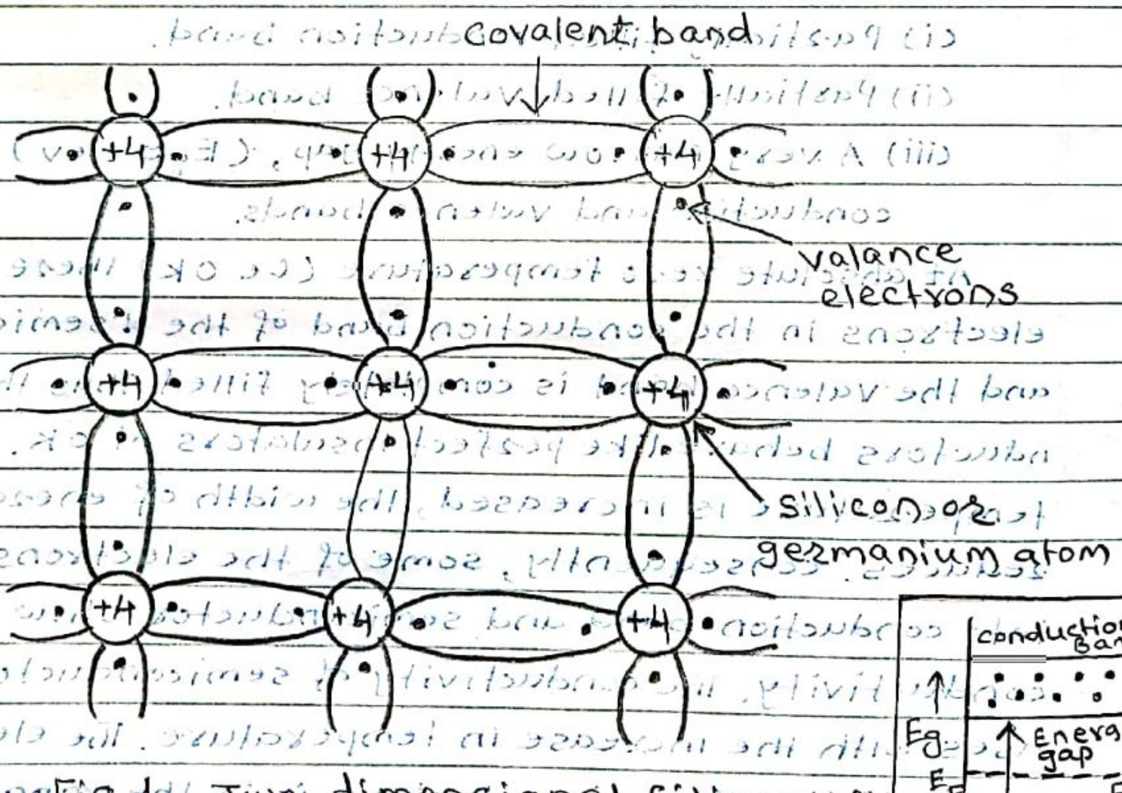


Fig. 1 Two dimensional silicon or germanium crystal

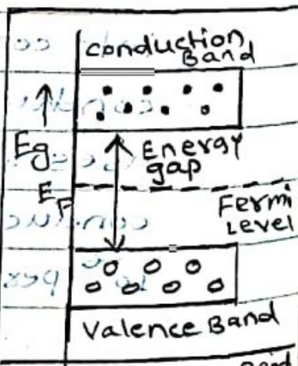


Fig 2. Energy Band Diagram

The silicon and germanium are the two most widely used intrinsic semiconductors. The crystal structure of these materials consists of a regular repetition in three dimensions of a unit cell having the form of tetrahedron, with one atom at each vertex. The silicon has a total of 14 electrons in its atomic structure. Each atom in a silicon crystal contributes 4 valence electrons, so that the atom is tetravalent. The four valence electrons are shown by the dots in the above Fig. 1. The circle, with +4 represents the central portion of the atom, including the nucleus and the electrons except those in the outermost orbit. This portion is often known as core of the atom. These atoms are bonded together by a force, which results from the sharing of the neighbouring atoms. This bonding force is called a covalent bond is and is shown by pair of curved lines in the above figure.

→ Generation of Electrons and Holes

Consider that the temperature of the semiconductor is increased to room temperature (i.e. 27°C or 300 K). At this temperature, some of the covalent bonds are broken. Here an electron, which was a part of covalent bond earlier is dislodged electron. This electron is free to move anywhere within the crystal. The energy required to break such a covalent bond is equal to the band gap energy (E_g). The value of E_g at room temperature for germanium is about 0.72 eV and for silicon is 1.1 eV. The vacancy of an incomplete covalent bond, left behind the dislodged electron (represented by a small circle), is called a hole. A hole can be serve as a carrier of electricity like the free electron. A combination of such a free electron and a hole is known as electron-hole pair.

<2> Extrinsic Semiconductors

An intrinsic or pure semiconductor has a negligible conductivity at room temperature. so, it is not of any practical signification. In order to make the intrinsic semiconductor useful, their characteristics have to be changed, by adding a certain amount of desired impurity atoms. The resulting semiconductors are called impure or extrinsic semiconductors.

The process of adding impurity atoms, to the intrinsic semiconductor is called doping. Generally, the impurities are added at the rate of only one atom of impurity per 10^6 to 10^{10} semiconductor atoms. As a result of this, the impurity atoms are seperated in the crystal by hundreds or thousands of semiconductor atoms in all directions. These impurity atoms do not exert any influence on the manner in which the crystal grows. It may be noted that an impurity atom enters the crystal by substituting for one of germanium or silicon atom.

The purpose of adding impurity is to increase either the number of free electrons or holes in a semiconductor. Generally, two types of impurity atoms are added to the semiconductor namely the impurity atoms containing 5 valence electrons (called pentavalent impurity atoms) and the impurity atoms containing 3 valence electrons (called trivalent impurity atoms). Depending upon the type of impurity atoms added to the semiconductor, the resulting semiconductor may be of two types):

<1> N-type semiconductors.

<2> P-type semiconductors.

⟨I⟩ N-type semiconductors

The semiconductors, which are obtained by introducing pentavalent impurity atoms (i.e. atoms containing 5 valence electrons) are known as N-type semiconductors. The pentavalent impurity is an element from Group V of the periodic Table. The elements in this group contain 5 valence electrons. The typical examples of such elements are phosphorus (P), antimony (Sb), arsenic (As) and bismuth (Bi). These elements donate excess electron carriers, so, such elements are known as donor of N-type impurities.

Table 1 pentavalent impurities

Sr. No.	Element	Symbol
1	Phosphorus	P
2	Antimony	Sb
3	Arsenic	As
4	Bismuth	Bi

When a pentavalent impurity is added to a pure semiconductor, it displaces some of its atoms. The below Fig. shows the structure of a silicon crystal lattice containing an antimony atom at the central position.

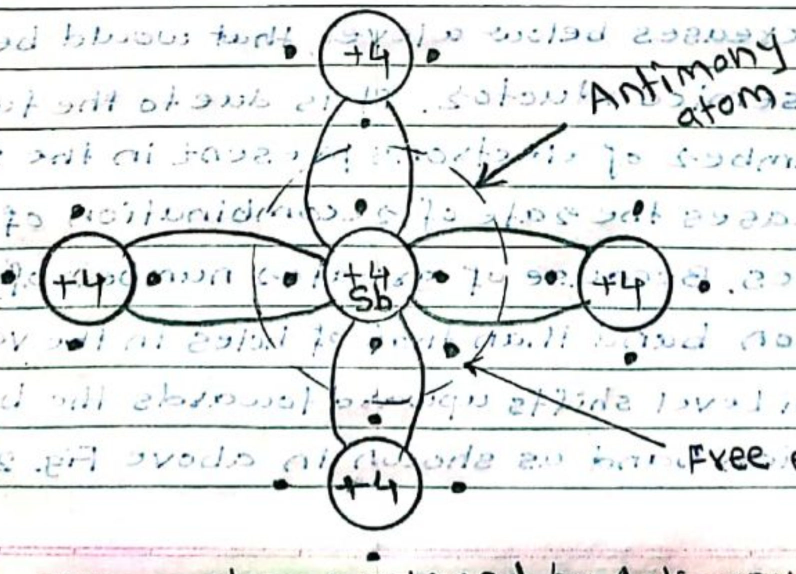


Fig 1 Silicon atom replaced by Antimony atom

It may be noted that out of 5 valence electrons, 4 electrons will form covalent bonds by sharing one electron each with the electrons of the neighbouring atoms. The 5th electron is an extra electron, and is loosely bound with the antimony atom. This extra electron, if detached from the antimony atom, will be available as a carrier of the current. The energy required to detach this electron is of the order of 0.05 eV for silicon and 0.01 eV for germanium.

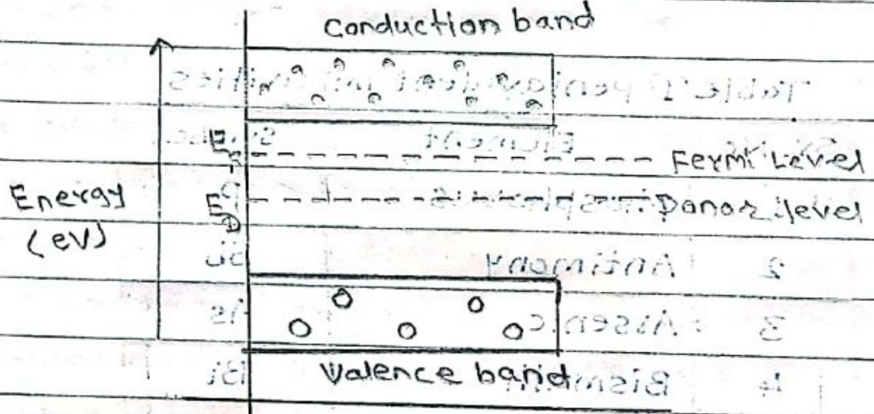


Fig 2. Energy band diagram of N-type semiconductor

If a pure semiconductor is doped with N-type impurities the number of electrons in the conduction band increases above a level, that would be available in pure semiconductor. However, the number of Holes in the valence band decreases below a level, that would be available in pure semiconductor. It is due to the fact that a large number of electrons present in the semiconductor increases the rate of recombination of electrons with holes. Because of greater number of electrons in conduction band than that of holes in the valence band, the Fermi Level shifts upward towards the bottom of the conduction band as shown in above Fig. 2.

(II) P-type Semiconductors

The semiconductors, which are obtained by introducing a trivalent impurity atoms (i.e. atoms containing 3 valence electrons) are known as P-type semiconductors. The trivalent impurity is an element of Group III of the periodic table. The elements in this group contain 3 valence electrons. Typical examples of such elements are gallium (Ga), Indium (In), aluminium (Al), Boron (B) etc. These elements make available positive charge carriers because they create holes, which can accept the electrons. Therefore, such elements are known as acceptor or P-type impurities.

Table 1: Trivalent impurities

Sr. No.	Elements	Symbol
1	Gallium	Ga
2	Indium	In
3	Aluminium	Al
4	Boron	B

When a trivalent impurity is added to a pure semiconductor, it displaces some of atoms. The below Fig. 1 shows the structure of a silicon crystal containing an Indium atom at the central position.

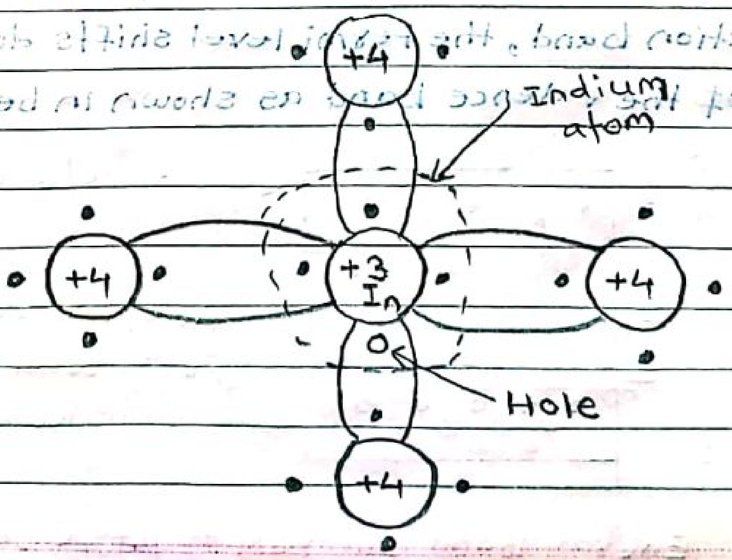


Fig. 1. Silicon atom replaced by Indium atom

(II) P-type Semiconductors

The 3 valence electrons, of an indium atom, forms 3 covalent bonds by sharing one electron with the electrons of neighbouring atoms. However, the fourth covalent band is incomplete. A vacancy, which exist in the incomplete covalent bond constitutes a hole. Now, the indium atom seeks its surroundings atoms so as to acquire the 4th electron, to complete the covalent bond. It does so by taking an advantage of thermal motion, which brings one electron from the surrounding atoms. Thus an electron, which is in a favourable position, is captured by an indium atom. After doing this, the indium atom becomes an immobile ion. The energy, involved in capturing the electron to 0.05 ev for silicon and 0.01 ev for germanium.

If a pure semiconductor is doped with p-type impurities, the number of holes in the valance band increases above a level, which would be available in a pure semiconductor. However, the number of electrons in the conduction band decreases below a level. It is due to the fact that a large number of holes present in the semiconductor increases the rate of recombination of holes with electrons. Because of the greater number holes in the valence band than that of electrons in the conduction band, the Fermi level shifts downwards towards the top of the valence band as shown in below Fig. 2

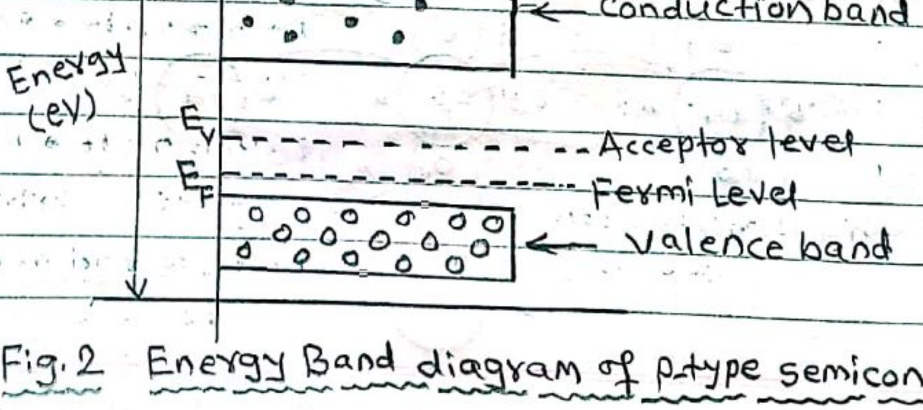


Fig. 2 Energy Band diagram of p-type semiconductor

* P-N Junction Diode *

As a matter of fact, the P-type and N-type semiconductors, taken seperately, are of little use in actual practice. If we join a piece of P-type semiconductor to a piece of N-type semiconductor such that the crystal structure remains continuous at the boundary as shown in below Figure 1, a PN junction is formed. Such a PN junction fors a very useful device and is called a semiconductor diode, PN junction diode or simply a crystal diode.

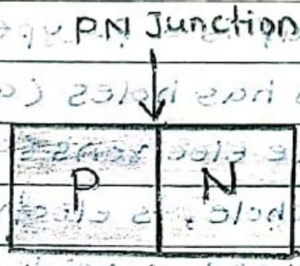
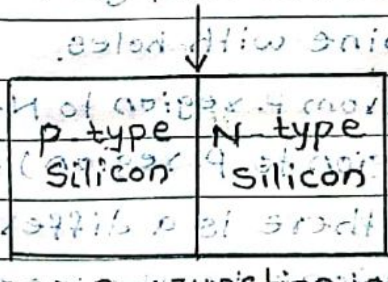


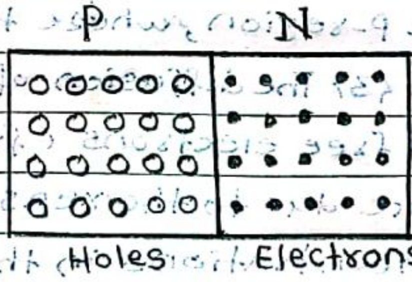
Fig 1. PN Junction

A PN junction cannot be formed by simply joining or welding the two pieces together, because it would produce a discontinuous crystal structure. Special fabrication techniques are used to prepare PN junctions.

The PN junction is an important device. Beside this, all semiconductor devices contain at least one PN junction. Therefore, it is very important to understand the behaviours of a PN junction, when connected in an electric circuit.



(a) P-N Junction in a diode



(b) The N region has many electrons and the P region has many holes.

* Formation of Deplation Layer in a PN Junction

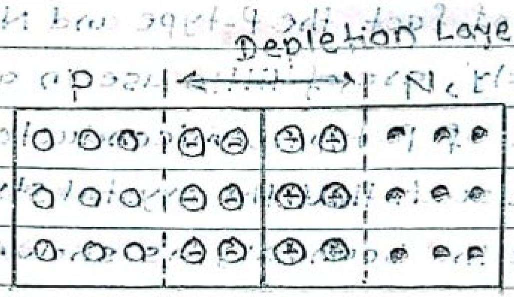


Fig. 1 Formation of Depletion layer in PN Junction

From Fig. 1 it is noted that the entire sample is a single crystal. Its left half is a P-type and the right half is a N-type. The P-region has holes (as majority carriers) and the N-region has free electrons (as majority carriers).

The sample, as a whole, is electrically neutral and so are the P- and N- regions, considered seperately. Thus in the P-region, the total positive charges on the holes is equal to the total negative charges on free electrons. Similarly, in the N-region, the total negative charge on free electrons is equal to the total positive charge on holes and immobile ions.

As soon as the junction is formed, the conduction and valence bands of P and N-type materials overlap. As a result of this the following process take place:

⟨1⟩ The holes, from the P-region diffuse to the N-region, where they combine with the free electrons.

⟨2⟩ The free electrons, from the N-region diffuse to the P-region, where they combine with holes.

⟨3⟩ The diffusion of holes (from P-region to N-region) and free electrons (from N-region to P-region) takes place due to the reason that there is a difference of concentrations in the two regions i.e the P-region has more number of holes, whereas N-region has more number of free electrons. This difference in concentration creates a concentration gradient across the junction.

(4) The diffusion of holes and free electrons across the junction takes place for a short time. After a few recombination of holes and free electrons, in the vicinity of the junction, a restraining force is automatically setup. This force is produced due to depletion region, which exists on either side of the junction. As a result of this further diffusion of holes and free electrons from one region to the other is stopped by this depletion layer.

* Biasing the PN Junction

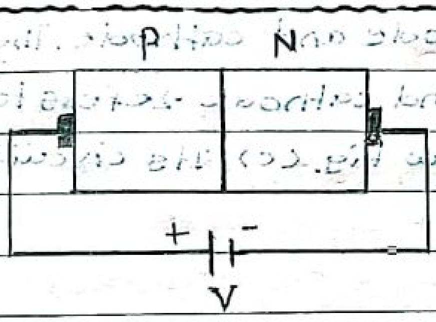


Fig. (a) Forward bias

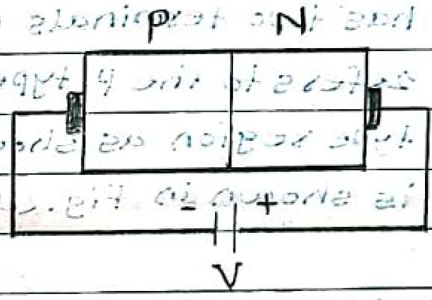


Fig. (b) Reverse bias

If no external voltage is applied to the PN junction, there is no net flow of current across the junction. As a result, the unbiased PN junction is of no use in actual practice. A PN junction connected to an external voltage source is called a biased PN junction. Such a PN junction finds a variety of applications in semiconductor devices.

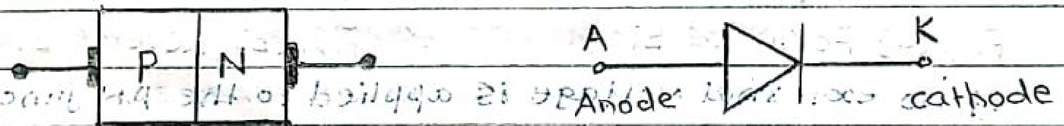
By applying an external voltage across a PN junction, we are able to control the width of the depletion layer. This allows us to control the resistance of the PN junction and also the amount of current that can pass through the device.

There are two ways of connecting voltage source to a PN junction as:

⟨I⟩ Forward Bias: In this case, positive terminal of the voltage source is connected to the P-side and negative terminal to the N-side as shown in Fig.(a). A large amount of current flows through the junction under this condition.

⟨II⟩ <u>Reverse Bias</u>:- In this case, positive terminal of the voltage source is connected to the N-side and negative terminal to the p-side as shown in Fig. (b). practically, no current flows through the junction under this condition.

A PN junction diode consists of a PN junction, formed either in germanium or silicon crystal. The diodes has two terminals namely anode and cathode. The anode refers to the p-type region and cathode refers to the N-type region as shown in below Fig. (c). Its circuit symbol is shown in Fig. (d).



(c) construction (d) symbol

Fig: PN Junction diode

The arrow head, shown in the circuit symbol, points the direction of current flow, when it is forward biased. It may be noted that it is the same direction in which the movement of holes take place.

The most common function of a diode is to allow an electric current to pass in one direction (called forward direction) while blocking current in the opposite direction (called reverse direction).

* V-I Characteristics of a PN Junction Diode

It is very important to know how a device responds (or behaves) when it is connected in an electrical circuit. This information is obtained by means of a graph known as its volt-ampere (or V-I) characteristics or simply characteristics.

It is a graph between the voltage applied across the terminals of a device and the current that flows through it. Figure 1 shows the V-I characteristics of a typical PN junction diode with respect to break down voltage (V_{BR}). It may be noted that the complete graph can be divided into two parts namely forward characteristics and reverse characteristics.

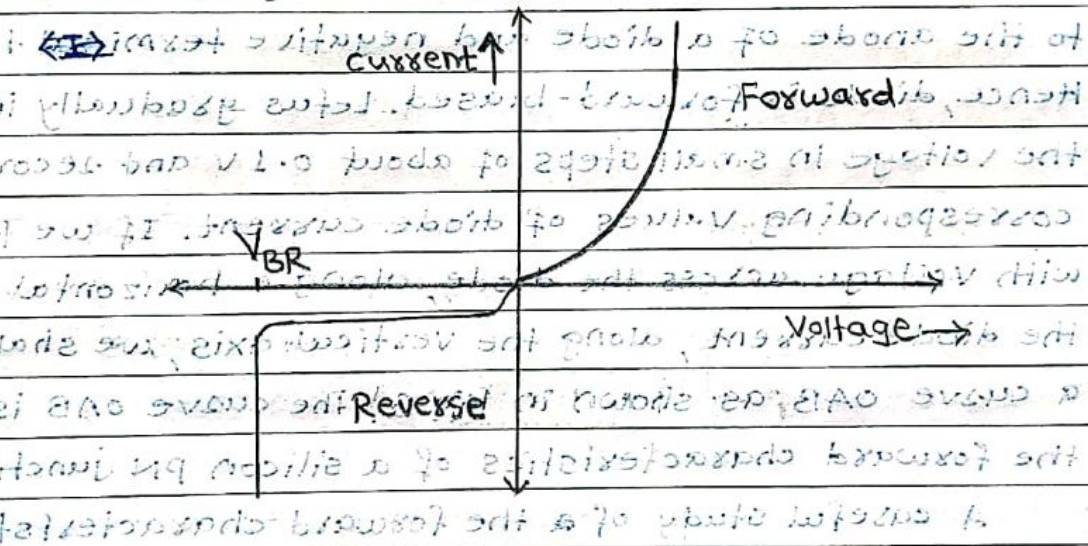


Fig 1 V-I characteristics of a PN junction diode

<I> Forward Characteristics

Fig (2) shows the circuit arrangement for obtaining the forward characteristic of a diode. In this circuit, the diode is connected to a d.c (V_{AA}) through a potentiometer (P) and a resistance (R). The potentiometer helps in varying the voltage applied across the diode. The resistance (R) is included in the circuit, so as to limit the current through the diode.

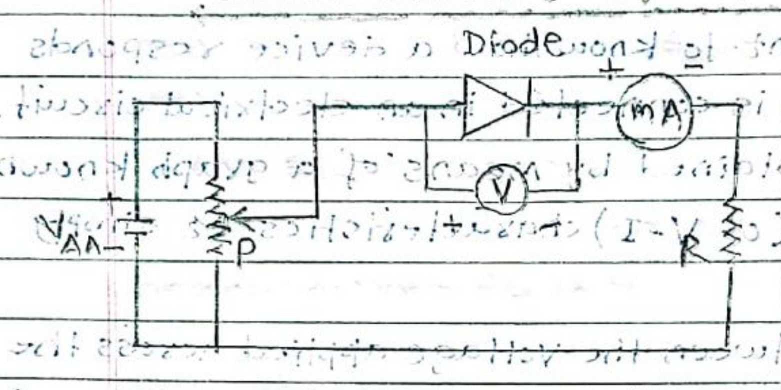


Fig 2: Circuit arrangement

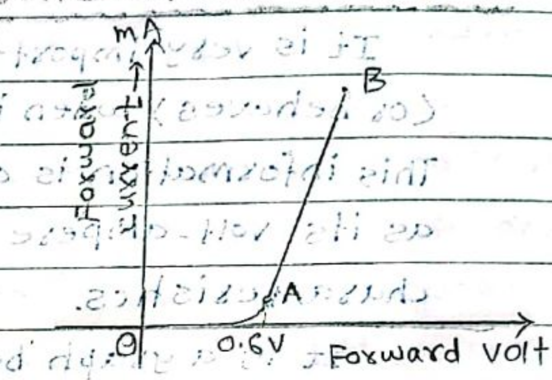


Fig 3: Forward characteristic

A voltmeter is connected across the diode to measure the voltage, where as a milliameter measures current in the circuit.

The positive terminal of the voltage source is connected to the anode of a diode and negative terminal to the cathode. Hence, diode is forward-biased. Let us gradually increase the voltage in small steps of about 0.1 V and record the corresponding values of diode current. If we plot a graph with voltage across the diode, along a horizontal axis and the diode current, along the vertical axis, we shall obtain a curve OAB as shown in Fig. 3. The curve OAB is called the forward characteristics of a silicon PN junction diode.

A careful study of the forward characteristics indicates that there is no diode current till the point A is reached. It is because of the fact, that the external applied voltage is being opposed by the junction voltage, whose value is 0.7 V for silicon and 0.3 V for germanium. However, as the voltage is increased above that of point A, the diode current increases rapidly. It has been observed that a voltage of about 1 volt produces a forward current of about 20 to 50 mA. The applied voltage should not be increased beyond a certain safe limit, otherwise the diode is likely to burn out.

Cut-in Voltage of Si and Ge

The voltage, at which the diode starts conducting, is called a knee voltage, cut-in voltage or threshold voltage. The knee voltage is designated as V_K. Its value is equal to 0.6V for silicon and 0.2V for germanium. The knee voltage may be obtained from the forward characteristic by extending the curve AB backwards, till it meets the horizontal axis. The value on the horizontal axis is equal to the knee voltage.

<II> Reverse Characteristics

The circuit arrangement for obtaining the reverse characteristics of a diode is shown in below Fig. 4.

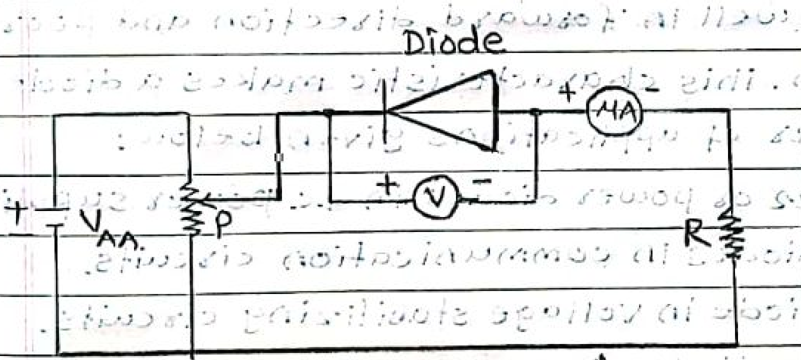


Fig.4. Circuit arrangement

Fig.5. Reverse characteristics

It may be noted that negative terminal of the voltage source is connected to the anode of a diode and positive terminal to the cathode. Hence the diode is reverse biased. The applied reverse voltage is gradually increased above zero in suitable steps and the values of diode current are recorded at each step. Now if we plot a graph with reverse voltage along the horizontal axis and the diode current along vertical axis, we shall obtain a curve marked OCD as shown in Fig.5. The curve OCD is called reverse characteristic of the diode.

A careful study of the reverse characteristic indicates that when the applied reverse voltage is below the breakdown voltage (V_{BR}), the diode current is small and remains constant. This value of current is called reverse saturation current (I_o). It is of the order of nanoamperes for silicon diode and microamperes for germanium diode. When the reverse voltage is increased to a sufficiently large value, the diode reverse current increases rapidly as shown by the curve CD in the Fig. 5. The applied reverse voltage, at which this happens, is known as breakdown voltage (V_{BR}) of a diode

* Diode Applications:

A PN junction diode has an important characteristics that it conducts well in forward direction and poorly in reverse direction. This characteristic makes a diode very useful in a number of applications given below:

<1> As rectifier or power diodes in d.c power supplies.

<2> As signal diodes in communication circuits.

<3> As zener diode in voltage stabilizing circuits.

<4> As varactor diodes in radio and TV receivers.

<5> As a switch in logic circuits used in computers.

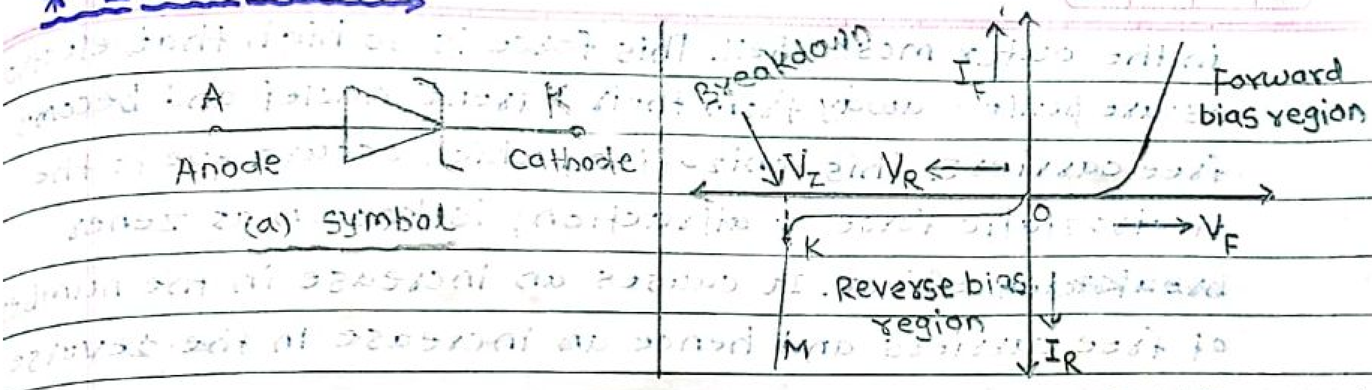
<6> As over-voltage protection device in integrated circuits & motor controllers.

<7> As a ionizing radiation detector.

<8> As a steering device in uninterruptable power supplies.

<9> As an electronic musical keyboards.

* Zener Diode



(b) V-I characteristic

Fig. 1. Zener Diode

A zener diode is also called a voltage reference, voltage regulator or breakdown diode. Like a rectifier diode it is also important in many power applications. Fig. 1 (a) shows a schematic symbol for a zener diode. It will be interesting to know that the line at the end of the arrow looks like the letter Z.

The zener diode is a silicon PN junction device, which differs from a rectifier diode that it is operated in the reverse break down region. The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture. A zener diode is made by heavily doping p and N sides of the junction. Due to this, the depletion region formed in the diode is very thin (less than 0.000001 m). Consequently, electric field for such a very thin depletion region is very high (about 500000 V/m) even for a small reverse bias voltage of about 5V. When a reverse voltage across a diode is increased, a critical voltage called breakdown voltage is reached at which the reverse current increases sharply as shown by the curve KM in Fig. 1 (b).

The zener breakdown occurs when the electric field across the junction, produced due to reverse voltage, is sufficiently high. This electric field exerts a force on the electrons in the outer most shell. This force is so high that electrons are pulled away from their parent nuclei and become free carriers. This ionization, which occurs due to the electrostatic force of attraction, is known as zener ~~breakdown~~ effect. It causes an increase in the number of free carriers and hence an increase in the reverse current.

The zener diodes, with breakdown voltages of less than 6V, operates predominantly in zener breakdown. Those with breakdown voltages greater than 6V operates predominantly in avalanche breakdown. The first one should be called a zener diode and the second an avalanche diode. But in actual practice, both the types are called zener diodes.

* Reverse Characteristic of a Zener Diode

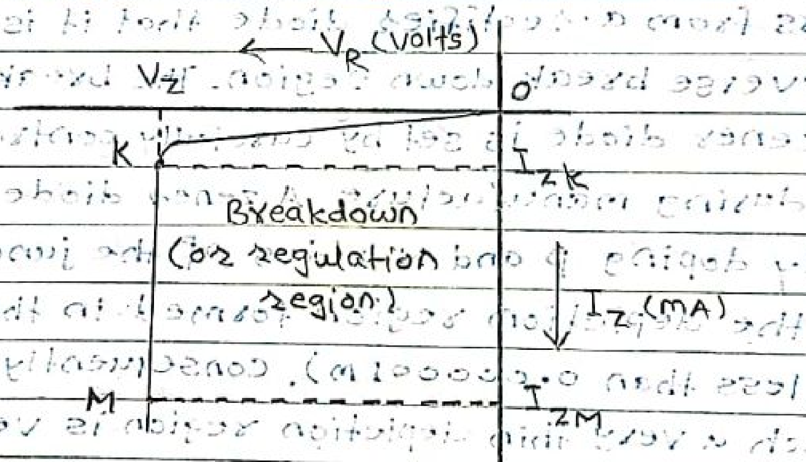


Fig 1 Reverse characteristic of zener diode

The Fig. 1 shows the reverse portion of the V-I characteristic of the zener diode. It may be noted from this figure that as the reverse voltage (V_R) is increased, the reverse current (I_Z) remains negligibly small up to the 'knee' of the curve (point K in fig. 1). At this point, the effect of breakdown process begins. From the bottom of the knee, the breakdown voltage (V_Z) remains essentia lly constant. This ability of diode is called regulating ability and is an important feature of a zener diode. It maintains an essentially a constant voltage across its terminals over a specified range of zener current values. Following two points are important from the characteristics of a zener diode:

<I> There is a minimum value of zener current called breakover current designated as I_{ZK} or $I_{Z(min)}$ which must be maintained in order to keep the diode in breakdown (or regulation) region. When the current is reduced below the knee of the curve, the voltage changes drastically and the regulation is lost.

<II> There is a maximum value of zener current designated as I_{ZM} or $I_{Z(max)}$ above which the diode may be damaged. The value of this current is given by the maximum power dissipation of the zener diode. As long as the maximum power dissipation is not exceeded, the diode will not be damaged. It will come out of the breakdown region, when the applied reverse voltage is reduced below the breakdown voltage.

* **Zener Diode Applications**

The zener diodes have a number applications, some of them are as below:-

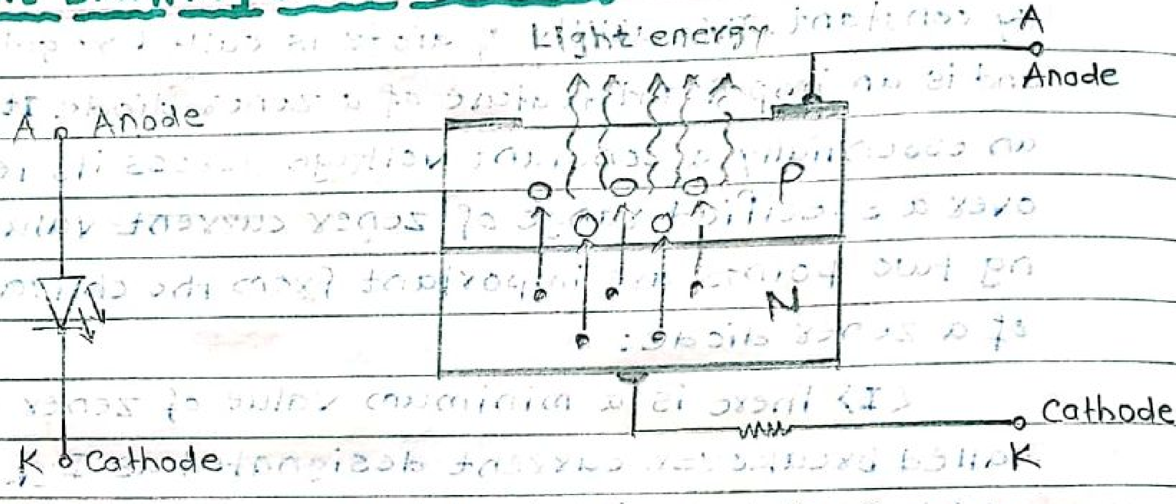
<1> As a voltage regulator.

<2> As a fixed reference voltage in transistor biasing circuits.

<3> As peak clippers or limiters in waveshaping circuits.

<4> For meter protection against damage from accidental applications.

* Light Emitting Diode (LED).



(a) symbol (b) Basic structure

Fig. 1 Light emitting diode (LED)

A PN junction diode, which emits light when forward biased, is known as a light emitting diode (LED). The emitted light may be visible or invisible. The amount of light output is directly proportional to the forward current. Thus, higher the forward current, higher is the light output. The schematic symbol of a light emitting diode is shown in Fig. 1 (a). The arrows, pointing away from the diode symbol of a light emitting diode is represent the light, which is being transmitted away from the junction.

Fig. 1 (b) shows the basic structure of light emitting diode. Here, an N-type layer is grown on a p-type substrate (not shown in figure) by diffusion process. Then a thin P-type layer is grown on the N-type layer. The metal connections to both the layers make anode and cathode terminals as indicated. The light energy is released at the junction, when the recombination of electrons with holes take place. After passing thro' the p-region, the light is emitted through the window provided at the top of the surface.

When the LED is forward biased, the electrons and holes move towards the junction and the recombination takes place. After recombination, the electrons, lying in the conduction bands of N-region, fall into the holes lying in the valence band of a P-region. The difference of energy between the conduction band and valence band is radiated in the form of light energy. In ordinary diodes, this energy is radiated in the form of heat.

The semiconducting materials used for manufacturing light emitting diodes are Gallium phosphide, gallium arsenide phosphide, zink selenide and boron nitride. The silicon and germanium is not used for manufacturing light emitting diodes because these are heat producing materials. Moreover, these materials are very poor in emitting light radiations.

The LED's radiate light in different colours such as red, green, yellow, blue, orange etc. some of the LED's emitt infrared (i.e. invisible) light also. The colour of the emitted light, depends upon the type of the semiconductor used. Thus gallium arsenide emits infrared radiations, gallium arsenide phosphide produces either red or yellow light, gallium phosphide emits red or green light and gallium nitride produces blue light.

* LED Applications

The LED's operate at low voltages i.e. from 1.5 V to 2.5 V. They have a long life about 10,000 hours, and can be switched 'ON' and 'OFF' at a very fast speed (≈ 1 nsec.) These features make LED's very important electronic device some of the important applications of the LED's are as below.

1. In optical switching applications.
2. In 7-segment, 16-segment and dot matrix displays.
3. For indicating power ON/OFF conditions, power level indicators or sterio amplifiers.
4. For image sensing sensing circuits in picturephon.

5. In the field of optical communication, where LED's are used to transfer energy from one circuit to other.

6. LED's are also used to send energy to fibre optical cable, which transmits energy by means of total internal reflection.

7. For solid state video displays, which are rapidly replacing cathode ray tubes (CRT's).

8. In burglar alarm systems.

9. LED's are used for backlighting of automobile dashboards and backlighting of keypads on cellular phones.

10. Widely used in traffic signal management.

11. Aviation lighting, Automotive lighting, advertising and general lighting.

12. Infrared LED's are used in remote control units of many commercial products including television, DVD players and other domestic appliances.

* Photodiode

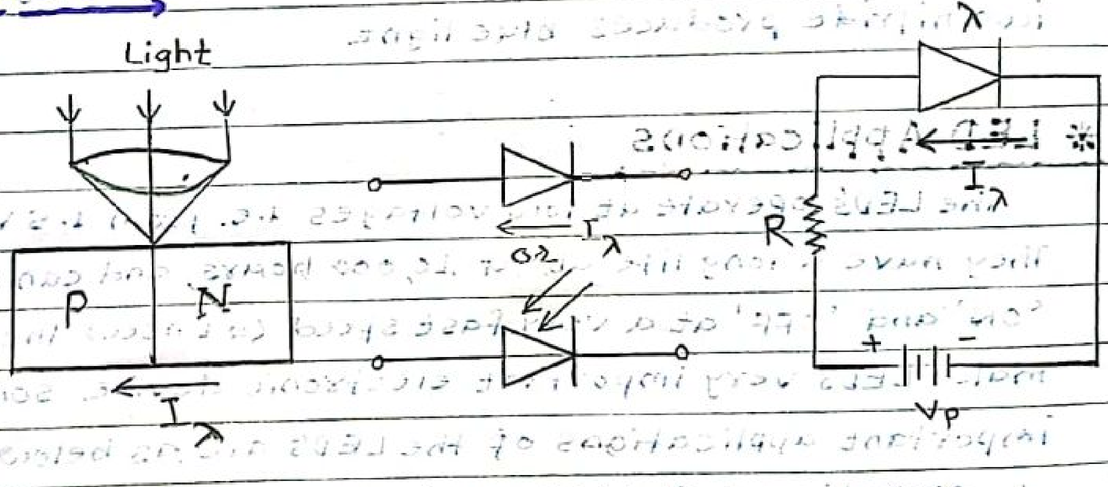


Fig.1: Photodiode.

A photodiode is a type of photodetector capable of converting light into either current or voltage depending upon the mode of operation. The common traditional solar cell is used to generate electric solar power is a large area of application of photodiode.

A photodiode is a two terminal PN junction device, which operates in a reverse bias. It has a small transperent window, which allows light to strike the P,N junction Fig. 1 (a) and (b) shows the structure and schematic symbol of a photodiode. The basic biasing arrangement of a photodiode is shown in Fig. 1 (c).

A PN junction diode has a very small reverse-current, when it is reverse biased. The same is true for photodiode also. The reverse biased current is produced by thermally generated electron-hole pairs in the depletion layer, which are swept across the junction by the electric field created by the reverse voltage. In a PN junction diode, the reverse-current increases with temperature due to an increase in the number of electron-hole pairs.

A photodiode differs from a PN junction diode in a sense that its reverse current increases with the light intensity at the PN junction. When there is no incident light, the reverse current is almost negligible and is called the dark current. An increase in the amount of light energy produces an increase in the reverse current for a given value of reverse-bias voltage. Fig. 2 shows the characteristic curves for a typical diode

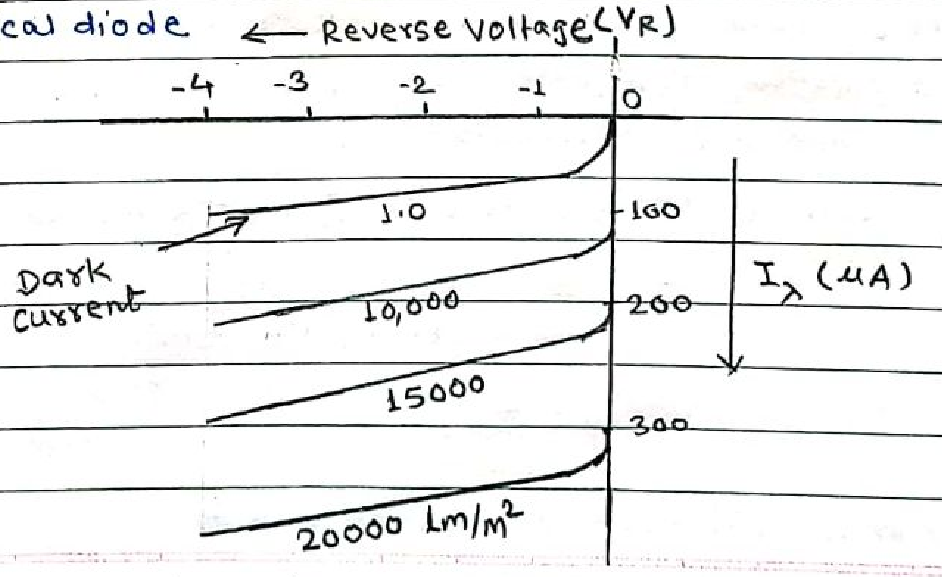


Fig. 2 characteristic curves of a photodiode

* Photodiode Applications

Photodiodes are used in similar applications to other photodetectors, such as photo conductors, charge couple devices and photo multiplier tubes. They may be used to generate an analog output which is dependent upon the illumination or to change the state of digital circuiting.

Following are some of the important applications of photodiodes -

1. Used in consumer electronic devices such as compact disc (CD) players, smoke detectors, and the receivers for infrared remote control equipments.
2. Used for accurate measurement of light intensity in science and industry.
3. Widely used in medical applications such as detectors for computer tomography, instruments to analyze samples pulse oximeters.
4. Because of fast switching speed, used for optical communication and in lighting regulation.
5. optical communication systems
6. character recognition
7. Encoders etc

* Varactor Diode

A varactor diode is a reverse biased PN junction, which utilizes the inherent capacitance of the depletion layer. It is also known as varicap, voltcap or tunning diode. It is used as a voltage variable capacitor.

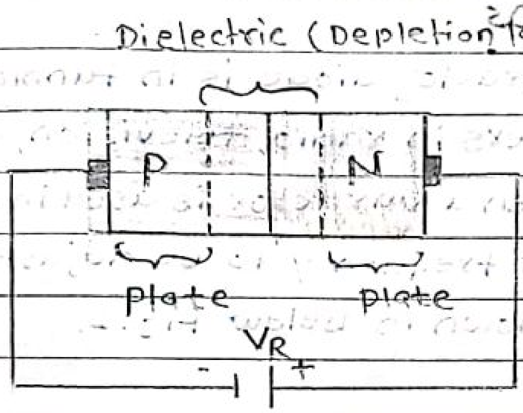


Fig 1. Reversed biased PN junction.

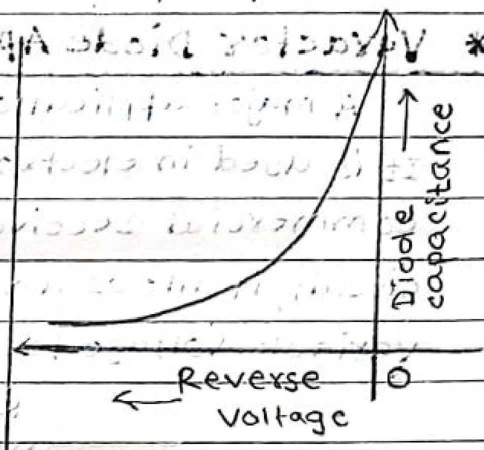


Fig.2. capacitance versus reverse voltage

In PN junction the depletion layer created by the reverse bias acts as a capacitor dielectric, whereas the P- and N-regions acts as the capacitor plates as shown in Fig 1.

When the reverse bias voltage increases, the depletion layer widens. This increases the dielectric thickness, which in turn, reduces the capacitance. When the reverse bias voltage decreases, the depletion layer narrows down. This decreases the dielectric thickness, which in turn increases the capacitance. Fig. 2 shows the variation of capacitance with the reverse voltage. This indicates that the variation of capacitance is maximum, when the reverse voltage is equal to zero. It reduces in a non-linear manner, as the value of reverse voltage is increased

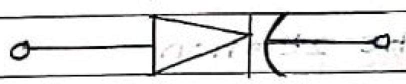


Fig. 3 Symbol

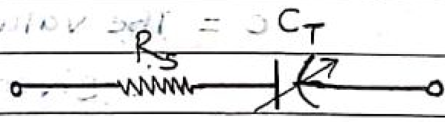


Fig 4. Equivalent circuit

The Fig. 3 shows a schematic symbol for a varactor diode and Fig.4 shows its equivalent circuit. Here, R_S is a reverse series resistance and C_T is a variable capacitance. The value of C_T ranges typically from 2pF to 100pF.

* Varactor Diode Applications

A major application of varactor diode is in tunning circuits. It is used in electronic tuners in radio, television, and other commercial receivers. When a varactor is used in a tuning circuit, it allows a resonant frequency to be adjusted by a variable voltage level as shown in below Fig.1.

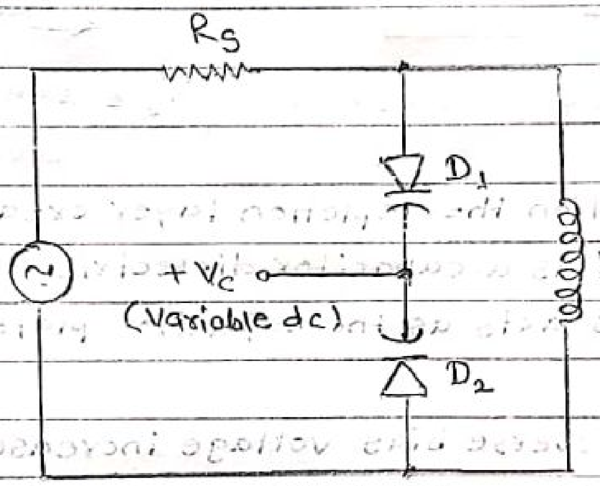


Fig. 1

In this circuit, two varactor diodes D_1 and D_2 provide the total variable capacitances in a parallel resonant circuit and V_c is a variable d.c voltage, which controls the reverse bias and the capacitance of the diodes. The resonant frequency of the tank circuit is given by the relation.

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

where, L = The value of the inductance

C = The value of the total capacitance, which is given by the relation

$$\frac{C_1 \cdot C_2}{C_1 + C_2}$$

where C_1 and C_2 are the maximum and minimum values of the capacitances of diode.