CHAPTER 3

BASIC PRINCIPLES OF ELECTRONICS

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LEARNING OBJECTIVES

A student can understand the following in this Chapter

1. **Knowledge about basic electronic principles**
2. **Atomic structure of elements**
3. **Classification of Elements**
4. **Detailed knowledge of Semiconductors and its working**
5. **Working of PN-junction**

INTRODUCTION

In this fast developing world, "Electronic" is the most important branch of engineering. Electronic devices are used in day to day common man life to big industrial activities. At its peak now robot are replacing human in areas where criticality and safety of human become risk.

The fast growth of this electronic technology offers a great challenge to the beginner, who likes to learn about electronics. This fundamental knowledge about electronics can make easy and simple learning process. The purpose of this chapter is to give basic elementary knowledge in order to understand the following chapters.

Few important activities of electronic devices are

1. Rectification
2. Amplification
3. Control
4. Oscillations
5. Conversion of light into electricity and
6. Conversion of electricity into light etc.

The first step to understand the principles of electronics starts from knowing about an atom, since everything is made up of atom.

3.1. ATOMIC STRUCTURE

According to modern theory, matter is electrical in nature. All the materials are composed of very tiny particles called atoms. The atoms are the root cause for all the matter or material existing in this world.

The atom consists of a central nucleus, contains protons and neutrons as shown in Figure 3.1. A proton is a positively charged particle, where neutron does not have any charge. There is yet

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another particle called electrons which is negative in charge and it is not reside inside the nucleus rather revolving around the nucleus. This is termed as extra nucleus.

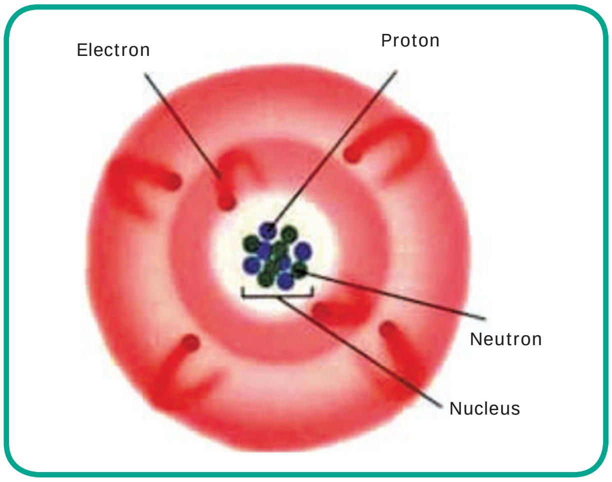

Figure 3.1 **Atomic structure**

The character of any atoms can be defined by three factors.

1. Atomic number
2. Atomic weight
3. Electrical charge (Nucleus and Extra Nucleus)

3.1.1 Atomic Number

Normally at ordinary conditions the number of electrons in the extra nucleus (i.e, orbits) are equal to number of protons present in the nucleus.

Therefore, an atom is neutral as a whole. The number of electrons or protons in an atom is called atomic number.

∴ Atomic Number = No. of Protons (or) No. of Electrons in an atom.

3.1.2 Atomic Weight

The sum of the protons and neutrons decides the entire weight of an atom and is called atomic weight. The electrons are not taken for consideration because it is having negligible mass as compared to protons or neutrons.

Atomic Weight = No. of Protons + No. of Neutrons

The electrons present in the atom is root cause for the action of any type of conduction (say electricity, heat etc).The electrons in an atom revolve around the nucleus in different orbit or paths. The number and arrangement of electrons in any orbit is determined by the following rules.

1. The number of electron in any orbit is given by $2n^2$ where n is the number of orbit.

For Example:

First orbit contains	$2x1^2$ = 2 electrons
Second orbit contains	$2x2^2$ = 8 electrons
Third orbit contains	$2x3^2$ = 18 electrons and so on

2. The last orbit cannot have more than 8 electrons.
3. The last but one orbit cannot have more than 18 electrons.

3.2. STRUCTURE OF ELEMENTS

We have seen all atoms are made up of protons, neutrons and electrons. The difference between types of elements is due to the different number and arrangement of these particles within their atoms. The structure of copper atom is different from carbon atom and hence the two elements have different properties.

The atomic structure can be easily drawn if we know the atomic weight and atomic number of an element.

For example:

We take copper atom,

Atomic weight = 64
Atomic number = 29
No. of Protons = No of Electrons = 29 and
No of Neutrons = 64-29=35.

The Figure 3.2 shows the structure of copper atom. It has 29 electrons which are arranged in different orbits as follows. The first orbit will have 2 electrons, the second 8 electrons, the third 18 electrons and fourth orbit will have 1 electron. The atomic structure of all known elements can be shown in this way and we can refer few elements.

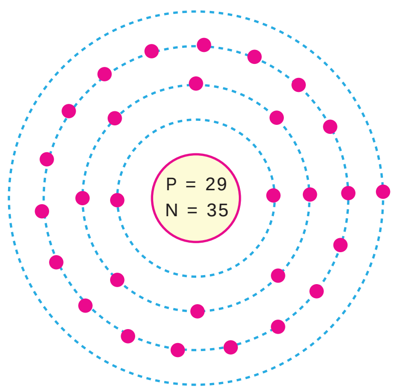

Figure 3.2 **Atomic structure of copper**

3.2.1 Electron

Since electronics deals with tiny particles called electrons, these small particles require detailed study. *An electron is a negatively charged particle having negligible mass.* Some of the important properties of an electron are:

1. Charge of an electron,
   e= 1.602×10^{-19} coulomb
2. Mass of an electron,
   n=9.0×10^{-31} kg
3. Radius of an electron,
   r = 1.9×10^{-15} meter

3.2.2 Energy of an Electron

An electron moving around nucleus possesses two types of energies, viz.

Kinetic Energy -due to its motion (relativity)
Potential Energy - due to the charge in the nucleus

The total energy of the electron is the sum of these two energies. The total energy of the electron increases as its distance from the nucleus increases. Hence, the electron in the last orbit possesses high energy than the electrons in the previous orbits. The last orbit electron plays important role in determining the physical, chemical and electrical properties of a material.

Valence Electron

The electrons in the outermost orbit of an atom are known as valence electrons.

The outermost orbit can have maximum of 8 electrons. i.e., the maximum number of valence electrons can be 8. The valence electron determines the physical, chemical and electrical properties of material.

Atomic Structure of Materials

On the basis of electrical conductivity, materials are generally classified into conductors, insulators and semi-conductors. In general one can determine the electrical behaviour of a material from the number of valence electron as under.

Conductor

When the number of valence electron of an atom is less than 4 (i.e., half of the maximum of 8 electron) the material is usually a metal and a conductor. Examples are sodium, magnesium and aluminium which have 1,2 and 3 valence electrons respectively. Is shown in Figure 3.3.

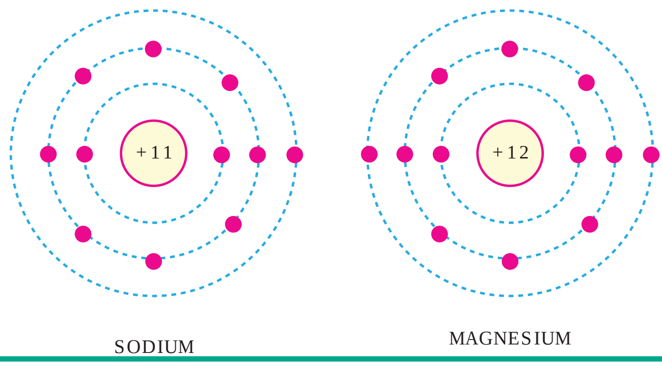

Figure 3.3 Atomic structure of sodium, magnesium and aluminium

Insulator

When number of valence electron of an atom is more than 4, the material is usually a non-metal and an insulator.

Examples are nitrogen, sulphur and neon which have 5, 6 and 8 valence electrons respectively as shown in Figure 3.4.

Semi-Conductor

When the number of valence electrons of an atoms is 4 (i.e., exactly one-half of the maximum of 8 electron), the material has both metal and non-metal properties and is usually a semiconductor. Examples are carbon, silicon and germanium as shown in below Figure 3.5.

3.2.3 Free Electrons

The valence electron of different material possesses different energies. The greater the energy of a valence electron, the lesser it is bound to the nucleus. In certain substance,

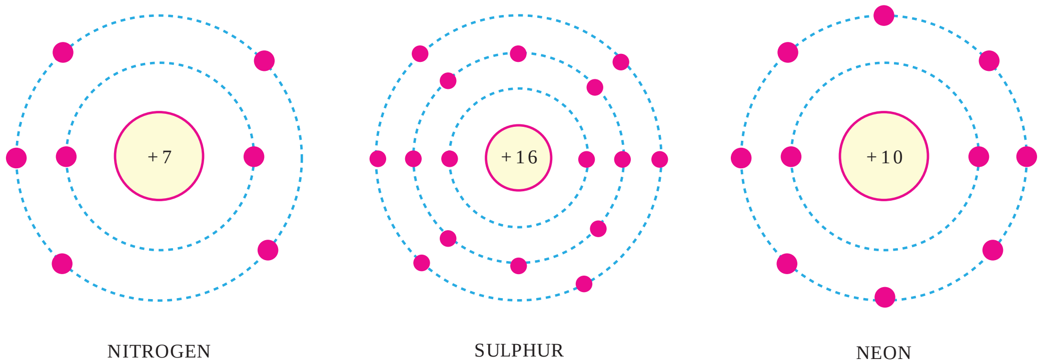

Figure 3.4 Atomic structure of nitrogen, sulphur and neon

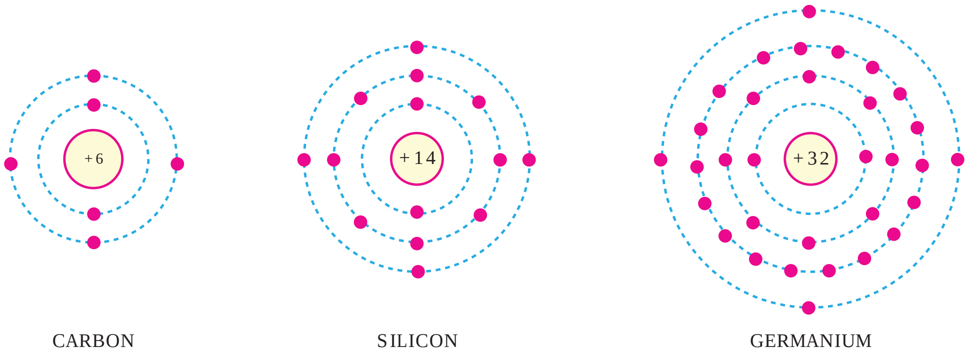

Figure 3.5 Atomic structure of carbon, silicon and germanium

particularly metals, the valence electron possess so much energy that they are very loosely attached to nucleus. These loosely attached valence electron move at random within the material and are called free electrons.

The valence electrons which are very loosely attached to the nucleus are known as free electron.

The free electrons can be easily removed or detached by applying a small amount of external energy. As a matter of fact, these free electrons which determine the electrical conductivity of the material. On the basis of free electron concept, the conductors, insulators and semiconductors can be defined as under:

1. A conductor is a substance which has a large number of free electrons. When potential difference is applied across a conductor, the free electron move towards positive terminal of supply constituting electric current.
2. An insulator is a substance which has practically no free electrons at ordinary temperature. Therefore an insulator does not conduct current under the influence of potential difference.
3. A semiconductor is a substance which has very few free electrons at room temperature. Under the influence of potential difference, a semi-conductor practically conducts no current.

Vacuum Tubes

Early days of electronics made successful strides by the introduction and working efficiency of the vacuum tubes. During 20th century, a new branch of engineering called "electronics" originated from the electrical engineering, due to the arrival of the vacuum tubes. These tubes have been finding wide applications in radio, television, long distance telephones, sound motion pictures, radar and electronic computers. A typical vacuum tube having three electrodes called triode is shown in Figure 3.6

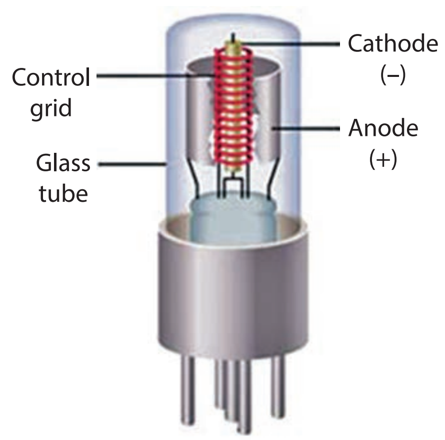

Figure 3.6 **Parts of the vacuum tube**

Due to its size, slowness in working-speed, cost of production, and above all the emission of heat while on working reduced the life of many electronic instruments.

Continuous research was going on, which paves the way for arrival of semiconductors.

Before studying about semiconductor, it would be better to know about the structure of atom and characteristics of electrons.

Atomic Model

The study of atomic structure is very important for electronics engineering. The size of an atom is so small that it is virtually impossible to see it even through the most powerful microscope. Therefore, we have to employ indirect method for the study of its structure. Though many scientists derived atomic theories, Bohr's atomic model is adequate to understand the electronics.

3.3 BOHR'S ATOMIC MODEL

In 1913, Neil Bohr, Danish Physicist gave clear explanation of atomic structure. Bohr postulated the following points about the structure of the atom:

Neil Bohr
(1885 – 1962)

1. An atom consists of positively charged nucleus around which negatively charged electrons revolve in different circular orbits.
2. The electrons can revolve around the nucleus only in certain permitted orbits i.e., orbits of certain radii are allowed.
3. The electrons in each permitted orbit have a certain fixed amount of energy. The larger the orbit (i.e., larger radius), the greater is the energy of electrons.
4. If an electron is given additional energy (e.g., heat, light, etc.), it is lifted to the higher orbit. The atom is said to be in a state of excitation. This state does not lost long, because the electron soon falls back to the original lower orbit. As it falls, it gives back the acquired energy in the form of heat, light or other radiations.

Figure 3.5 shows the structure of silicon atom. It has 14 electrons, 2 in the first, 8 in the second and remaining 4 electrons in third orbit. The first, second, third orbits are also known as K, L and M orbits, respectively.

These electron can revolve only in permitted orbits (i.e., orbits of radii r_1, r_2 and r_3) and not in any orbit. Thus, all radii between r_1 and r_2 or between r_2 and r_3 are forbidden. Each orbit has fixed amount of energy associated with it. If an electron in the first orbit is to be lifted to the second orbit, just the right amount of energy should be supplied to it. When this electron jumps from second orbit to first, it gives back the acquired energy in the form of electromagnetic radiations.

Energy Level

It has already been discussed that each orbit has fixed amount of energy associated with it. The electrons moving in a particular orbit possess the energy of that orbit. The larger the orbit, greater is its energy. It becomes clear that outer orbit electrons possess more energy than the inner orbit electrons.

Figure 3.7 shows the energy of different orbits. This is one way of the representing the energy in orbits and is known as energy band diagram. The first orbit represents first energy level; the second orbit indicates the

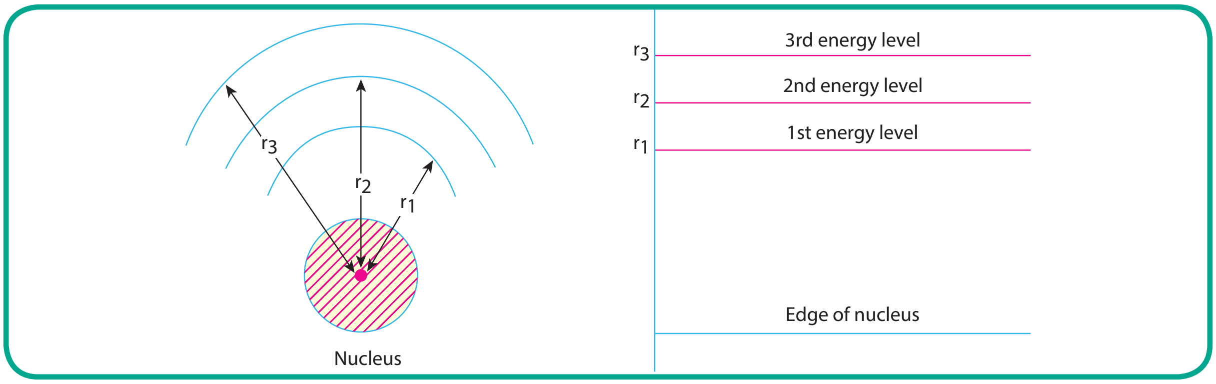

Figure 3.7 Energy level diagram

second energy level and so on. The larger the orbit of the electron, the greater is its energy and higher is the energy level.

You might have heard about many types of energies used in our day-today life. For all those, electron energy is the base.

Important Energy Bands in Solids

Though there are number of energy bands in the solids, the following are of the important ones.

1. Valence Band

The range of energies (i.e., bands) possessed by valence electron is known as valence band.

The electron in the outermost orbit of an atom is known as valence electron. In a normal atom, valence band has the electron of highest energy. This band may be completely or partially filled. For instance, in case of inert gas, the valence band is full, whereas for other material, it is only partially filled. The partially filled band can accommodate more electrons.

2. Conduction Band

In certain material (e.g. metals) the electrons are loosely attached to the nucleus. Even at ordinary temperature, some of the valence electron may get detached to become free electrons. In fact, these free electrons are responsible for conduction of current in a conductor. For this reason, they are called conduction electrons.

The range of energy (i.e., band) possessed by the conduction electron is known as conduction band.

All electrons in the conduction band are free electrons. If a substance has empty conduction band, it means current conduction is not possible. Generally, insulators have empty conduction band. On the other hand, it is partially filled for conductors.

3. Forbidden Energy Gap

The energy gap between conduction band and the valence band on the energy level diagram is known as forbidden energy gap.

No electron of a solid can stay in a forbidden energy gap as there is no allowed energy state in this region. The width of the forbidden energy gap is a measure of bondage of valence electrons to the atom. The greater the energy gap, more tightly the valence electron are bound to the nucleus. In order to push an electron from the valence band to conduction band (i.e., to make the valence electron free), external energy must be supplied equal to the forbidden energy gap.

a) **Conductors:** Metals (e.g. Copper, Aluminium) or conductors allow the passage of electric current through them, because of large number of free electrons available in a conductor. In terms of energy band, the valence and conduction bands overlap each other as shown in Figure 3.8.

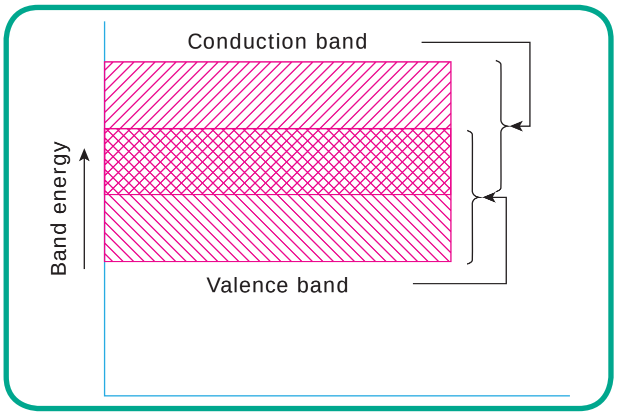

Figure3.8 Energy band of conductors

(b) Insulators: Figure3.9 shows the forbidden energy gap of the insulators which is very large (15eV), e.g. wood, glass, etc.

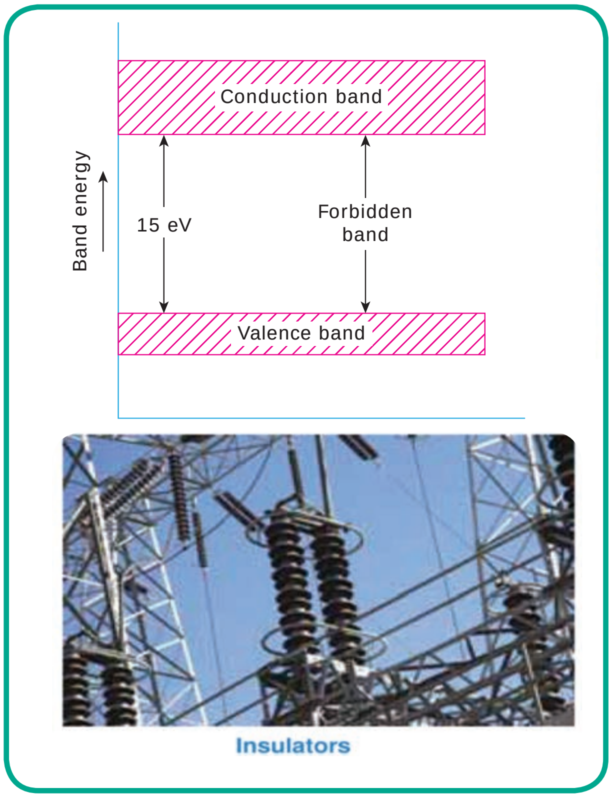

Figure3.9 **Insulator and its energy band**

c) Semiconductors: Semiconductors (e.g. Germanium, Silicon, Graphene, etc.)are those substance whose electrical property lies in between conductors and insulators. In terms of energy band, the valence band is almost full but the conduction band is empty. Further, the energy gap between valence band and conduction band is very small ($\simeq$, 1eV) as shown in Figure 3.10. Hence, smaller electric field is required to push the electron from the valence band to conduction band.

At low temperature, the valence band is completely full and conduction band is completely empty. Therefore at low temperature semiconductor behaves like an insulator. However, even at room temperature some of electrons cross-over to conduction band giving little conductivity to the semiconductor. As temperature increases, more number of electrons cross-over to the conduction band and the conductivity increases. Because of this, the entire characteristics of semiconductors get changed.

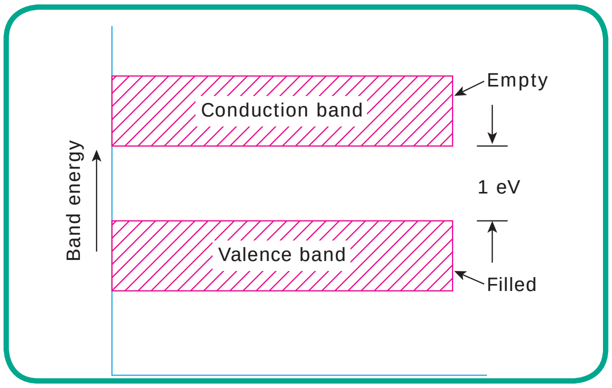

Figure3.10 **Energy band of semiconductor**

3.4 SEMI-CONDUCTOR

In lower standards you might have studied about the characteristics and principle of conductors, insulators. But you may not studied about semiconductors. Based on its character, it has been defined as semiconductor. But now, this semiconductor is the Back Bone of modern electronics. The character of semiconductor lies in between conductor and insulator.

The earlier period of (1950) electronics (communication equipments like Radio, Television and Amplifiers) which was dominated by vacuum tubes, gas filled tubes were replaced by this semiconductors. Thus reducing the size of equipment considerably. Let we see in detail about this much important semiconductors.

It is not easy to define a semiconductor, if we want to take into account all its physical characteristics. However, generally a semiconductor is defined on the basis of electrical conductivity as under. A semiconductor is a substance which has resistivity (10^{-4} Ωto 0.5Ω) between conductors and insulators, e.g. Germanium, Silicon, Selenium, Carbon, Graphene, etc. Table 3.1 shows the resistivity of various semiconducting materials.

Table 3.1 Resistivity of Semiconductor Materials

SI. No.	Substance	Nature	Resistivity
1.	Copper	good conductor	1.7×10^{-8} Ωm
2.	Germanium	semicon-ductor	0.6 Ωm
3.	Glass	insulator	9×10^{11} Ωm
4.	Nichrome	resistance material	10^{-4} Ωm

3.4.1 Properties of Semiconductors

The resistivity of a semiconductor is less than an insulator but more than a conductor.

Semiconductors have negative temperature co-efficient of resistance, i.e., the resistance of the semiconductor decreases with the increase in temperature and vice-versa. For example, germanium is usually an insulator at low temperature but it becomes good conductor at high temperature.

When metallic-impurity (e.g. Arsenic, Gallium, etc.) material is added to the semiconductor material then the current conduction property of the material changes, appreciably. This property is most important and is discussed later in detail.

3.4.2 Bonds in Semiconductors

In semiconductors, bonds are formed by sharing of valence electrons. Such bonds are called covalent bond. In the formation of a covalent bond, each atom contributes equal number of valence electrons and the contributed electrons are shared by the atoms engaged in the formation of the bond. The covalent bond of Germanium is shown in Figure 3.11.

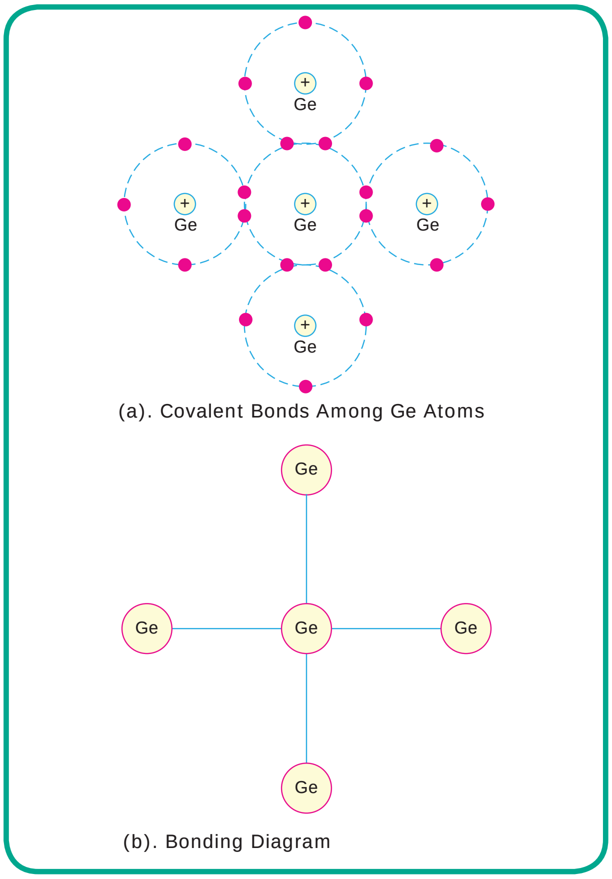

Figure 3.11 Formation of covalent bond

The following points may be noted regarding the covalent bonds:

1. Covalent bonds are formed by sharing of valence electrons.

2. In the formation of covalent bond, each valence electrons of an atom forms direct bond with the valence electrons of an adjacent atom. For this reason, valence electrons in a semiconductor are not free.

3.4.3 Crystals

A substance in which the atoms or molecules are arranged in orderly pattern is known as a crystal.

All semiconductors have crystalline structure. From the Figure 3.11, it is clear that each atom is surrounded by neighbouring atoms in a repetitive manner; therefore, a piece of Germanium is generally called crystalline structure.

3.4.4 Commonly Used Semiconductor

There are many semiconductors available, but very few of them have practical application in Electronics. The two most frequently used materials are Germanium (Ge) and Silicon (Si). These two are widely used because the energy required to break their covalent bond is very small (i.e., energy required to release an electron from their valence bonds) being about 0.7eV for Germanium and 1.1eV for Silicon. Let us see about these two.

1. **Germanium:** Germanium is the model substance among the semiconductors. The main reason being that it can be purified well and crystallized easily. It is discovered in 1886. It is recovered from the ash of certain coals. The atomic number of germanium is 32, i.e., it has 32 protons and 32 electrons. It is clear that germanium atom has 4 valence electrons i.e., tetravalent element.

2. **Silicon:** Silicon is an element available in most of the common rocks. Actually sand is silicon dioxide. The silicon compounds are chemically reduced to silicon which is 100% pure for use as semiconductors. The atomic number of silicon is 14 and hence it has 14 protons and 14 electrons. It is very clear that silicon atom has four valence electrons i.e. tetravalent element.

3.4.5 Hole Current

At room temperature some of the covalent bond in pure semiconductors breaks, setting up free electrons. Under the influence of electric field, these free electrons constitute electric current. At the same time, another current, the hole current also flows in the semiconductors. When the covalent bond is broken due to thermal energy, the removal of one electron leaves a vacancy, i.e., a missing element in covalent bond. This missing electron is called a hole, which acts as a positive charge. For one electron set free, one hole is created. Therefore, thermal energy creates hole-electron pairs. Hence, as many holes as free electrons are generated. The current conduction by holes can be explained as follows.

The hole shows a missing electron. Suppose the valence electron at L (Figure 3.12) has free electrons due to thermal energy.

This creates a hole in the covalent bond L. Now the hole becomes strong centre of attraction for the electron. So a valence electron (say at M) from nearby covalent bond comes to fill in the hole at L. This results in creation of hole at M.

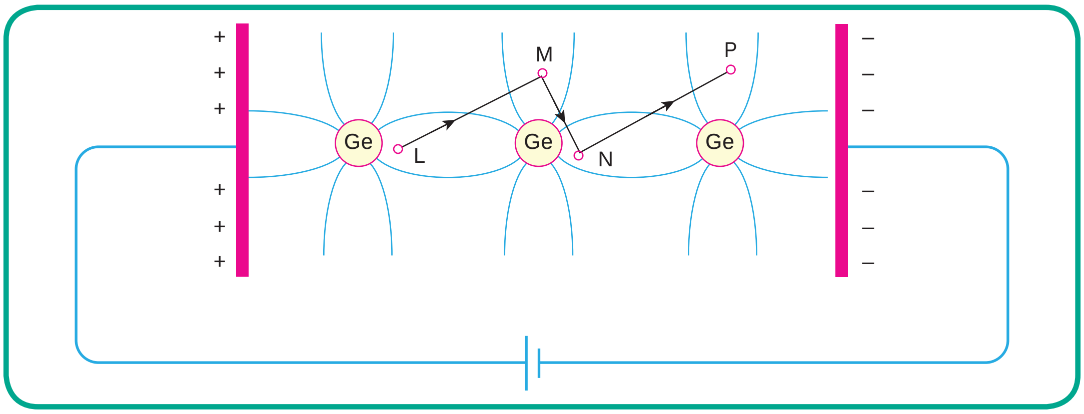

Figure 3.12 Electron and hole current formation in Ge

Another valence electron (say at N) in turn may leave its bond to fill the hole at M, thus creating a hole at N. Thus, the hole having positive charge has moved from L to N i.e., towards the negative terminal of supply. This constitutes the hole current.

Though the hole current is happening due to the movement of electrons from one covalent bond to another bond, it is quite understandable why to call it as hole current. The basic reason for current flow is the presence of holes in the covalent bonds. Therefore, it is more appropriate to consider the current as the movement of holes.

3.4.6 Energy Band description of Hole Current

The hole current can be beautifully explained in terms of energy bands. Suppose due to thermal energy, an electron leaves the valence band and enter into the conduction band as shown in Figure 3.13.

This leaves a vacancy at L. Now, the valence electron at M comes to fill the hole at L. The result is that hole disappears at L and appears at M. Next, the valence electron at N moves to hole at M, consequently a hole is created at N. It is clear that valence electrons move along the path PNML whereas holes move in opposite direction i.e., along the path LMNP as shown in Figure 3.13.

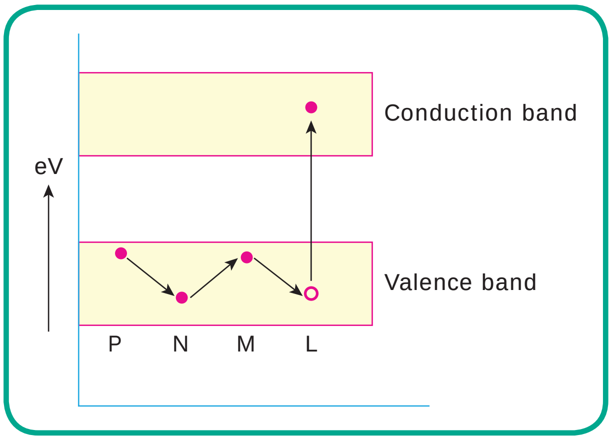

Figure 3.13 Hole movement across the band

3.5 INTRINSIC SEMICONDUCTOR

A semiconductor in an extremely pure form is known as an intrinsic semiconductor. In an intrinsic semiconductor, even at room temperature, hole-electron pairs are created. When electric field is applied across the semiconductor, the current conduction takes place by two processes such as (i) by free electrons and (ii) by holes as shown in the Figure 3.14. The free electrons are produced due to the breaking up of some covalent bonds by thermal energy.

At the same time, holes are created in the covalent bonds, under the influence

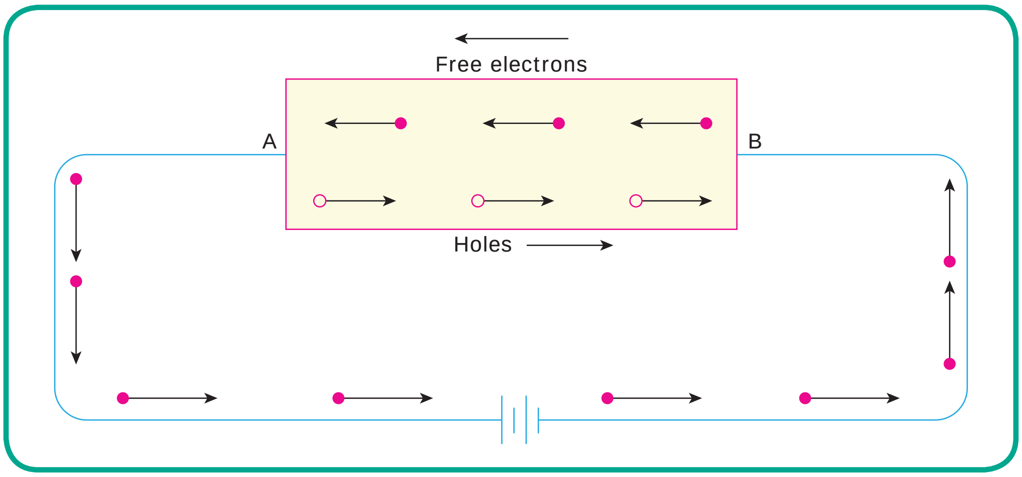

Figure 3.14 **Electron-hole current**

of electric field. Thus, the conduction in semiconductors is by both electrons and holes. Therefore, the total current inside the semiconductors is the sum of currents due to free electrons and holes.

It may be noted that current in the external wires is fully electronic i.e., by electrons. Then what about holes? Referring to the Figure 3.14, holes being positively charged and move towards the negative potential of supply. As the holes reach the negative terminal B, electrons enter the semiconductor crystal near the terminal and combine with holes, thus cancelling each other. At the same time, the loosely held electrons near by the positive terminal *A* are attracted away from their atoms into the positive terminal. This creates new holes near the positive terminal which again drift towards the negative terminal.

3.5.1 Extrinsic Semiconductors

The pure semiconductor must be altered so as to significantly increase its conductive properties. This is achieved by adding a small amount of suitable impurity to semiconductors. It is then called impurity or extrinsic semiconductors.

The process of adding impurities to a semiconductor is known as doping.

Generally, for 108 atoms of semiconductor, one impurity atom is added.

The purpose of adding impurity is to increase either the number of free electrons or holes in the semiconductor crystal. If the pentavalent impurity (having 5 valence electrons) is added to the semiconductor, a large number of electrons are produced in the semiconductor. On the other hand, addition of trivalent impurity (Having 3 valence electron) to semiconductor generates large number of holes.

Depending upon the type of impurity added extrinsic semiconductors are classified into:

1. N-type Semiconductor
2. P-type Semiconductor

3.6 N-TYPE SEMICONDUCTOR

When a small amount of pentavalent element is added to pure semiconductor, it is known as N-type semiconductors.

The addition of pentavalent impurity provides a large number of free electrons in the semiconductor crystal. Typical examples of pentavalent impurities are Arsenic (Atomic No. 33), Antimony (Atomic No.51) and Phosphorous(Atomic No. 15) Such impurities that produce n-type semiconductor are known as donor impurities, because they donate or provide free electrons to the semiconductor crystals.

To explain the formation of n-type semiconductor, consider a pure germanium crystal. We know that germanium atom has four valence electrons. When small amount of pentavalent impurity, like Arsenic is added to Germanium crystal, large number of free electrons available in the crystal. Arsenic is pentavalent i.e., its atom has five valence electrons. An Arsenic atom fits in the Germanium crystal in such a way that its four valence electron form covalent bonds with four Germanium atoms. The fifth valence electron of Arsenic atom finds no place in covalent bond and is thus become free electron as shown in Figure 3.15. Therefore, for each Arsenic atom added, one free electron will be available in the Germanium crystal. Hence, an extremely small amount of Arsenic impurity provides enough atoms to supply millions of free electrons.

Figure 3.15 shows the energy band description of n-type semiconductor. The addition of pentavalent impurity has produced a number of conduction band electrons, i.e., free electrons. Therefore, valence electrons of pentavalent atom form covalent bonds with four neighbouring Germanium atoms. The fifth left-over valence electron of the pentavalent atom cannot be accommodated in the valence band; hence travels to the conduction band.

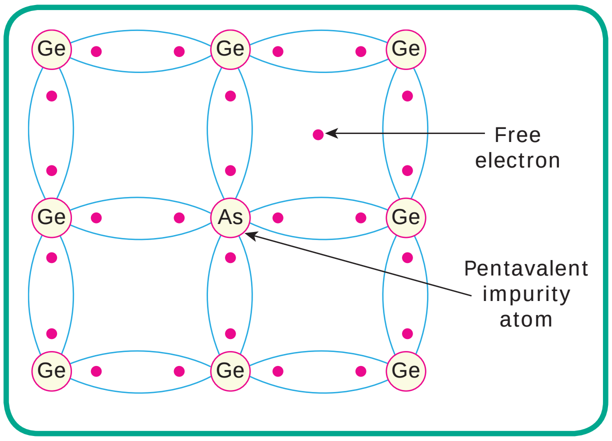

Figure 3.15 Doping of Ge with pentavalent impurity Atom As

The current flow in n-type semiconductor is shown in Figure 3.16. The following points may be noted carefully:

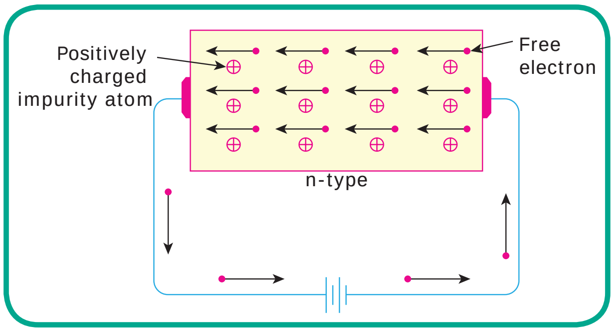

Figure 3.16 Current flow in n-type semiconductor

i. Many new free electrons are produced by the addition of pentavalent impurity.

ii. Thermal energy at room temperature still generates few hole-electron pairs.

However, the number of free electrons provided by the pentavalent impurity far exceeds the number of holes. It is due to this predominance of electrons over holes, hence it is called n-type semiconductors (n-stands for negative).

3.6.1 P-Type Semiconductors

When a small amount of trivalent impurity is added to a pure semiconductor, it is called p-type semiconductor.

The addition of trivalent impurity provides a large number of holes in the semiconductor. Typical examples of trivalent impurities are Gallium (Atomic No: 31) Indium (Atomic No: 49) and Boron (Atomic No: 5) Such impurities produce p-type semiconductors are known as acceptor impurities, because the holes created can accept the electron.

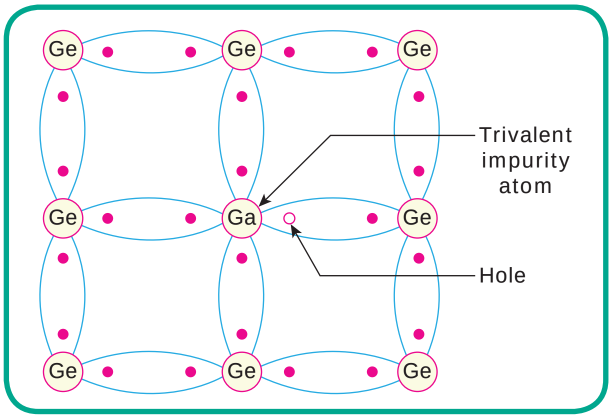

Figure 3.17 **P-type semiconductor**

In Figure 3.17, Gallium is added with Germanium crystal to form p-type semi-conductor. Each atom of gallium fits into the germanium crystal. But, only three covalent bonds can be formed. The fourth bond is incomplete, being short of one electron. The missing electron is called a hole. Therefore, for each Gallium atom added, one hole is created. A small amount of Gallium provides millions of holes.

Hence, in p-type semiconductor, holes are the majority carriers. When potential difference is applied to the p-type semiconductor the holes are shifted from one covalent bond to another. As the holes are positively charged, they are directed towards the negative terminal, constituting what is known as "hole current". The p-type semiconductor and its band structure are shown in Figure 3.18.

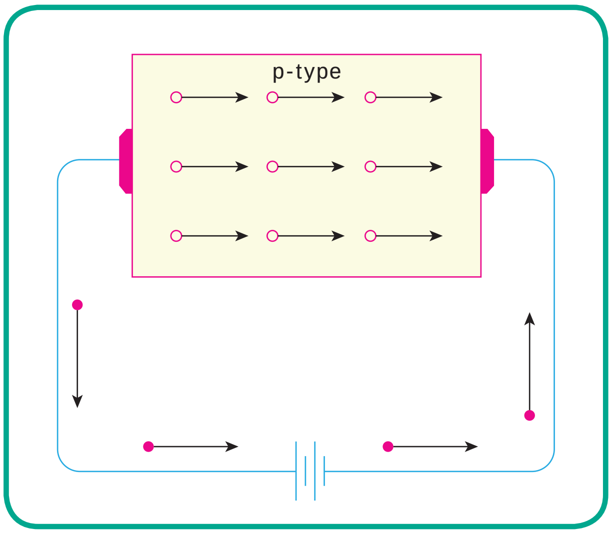

Figure 3.18 **Energy band and current flow of P-type semiconductor**

3.7 PN JUNCTION

"When a p-type semiconductor is suitably joined to n-type semiconductor, the contact surface is called pn junction"

Figure 3.19 shows the formation of pn junction. To explain the properties of a pn junction, p-type and n-type semiconductor are suitably joined. Keep in mind that n-type material has a high concentration of free electrons while p-type material has a high concentration of holes. Therefore, at the junction, there is a tendency for the free electrons to diffuse over to the p-side and holes to the n-side.

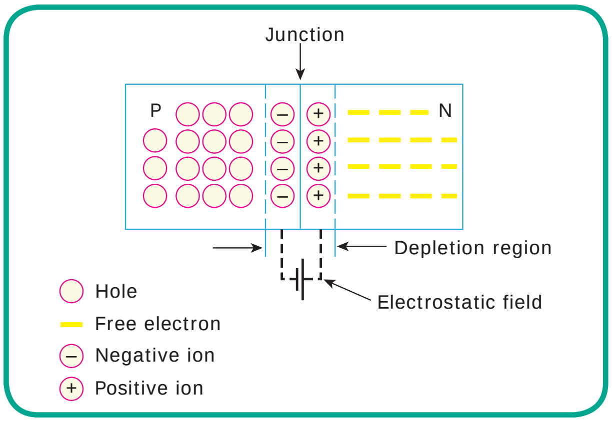

Figure 3.19 **PN Junction**

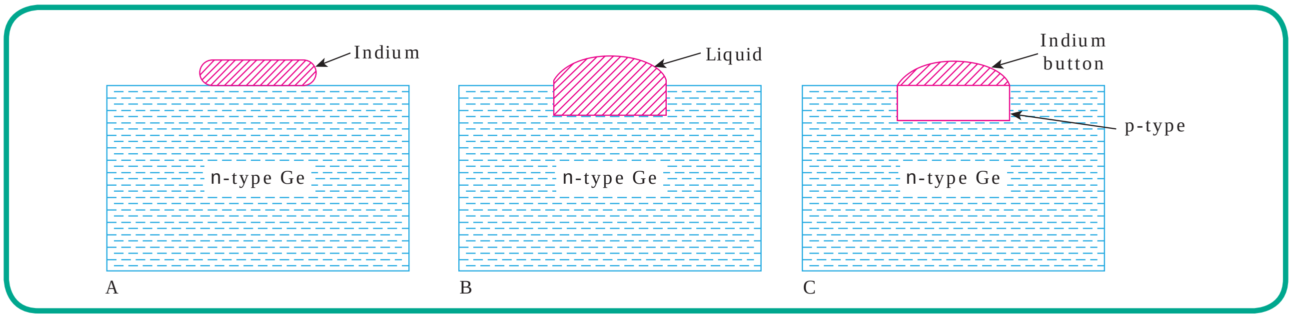

Figure 3.20 Diffusion process

This process is called diffusion as shown in Figure 3.20. The combination of these holes and electrons create a new region between the two layers. This region is called "depletion layer". Only inside this, there is positive charge on 'n' side and negative charge on 'p' side. Because of this a potential is produced in this layer which is called "barrier potential". The barrier potential in directly related to depletion layer.

The barrier potential opposes the flow of majority carriers through the junction and it aids the flow of minority carriers. For both of these opposite effects, no charge carriers will flow through the junction at normal condition. The potential difference across a pn junction can be applied in two ways namely, forward biasing and reverse biasing.

3.7.1 Forward Biasing

To apply forward bias, connect positive terminal of the battery to p-type and negative terminal to n-type as shown in Figure 3.21. Due to this, barrier potential is very much reduced. Positive terminal of the battery repels holes in p-side and negative terminal of the battery repels electrons in n-side. Because of this, current flows in the circuit. This is called "forward current". The magnitude of current depends upon the applied forward voltage.

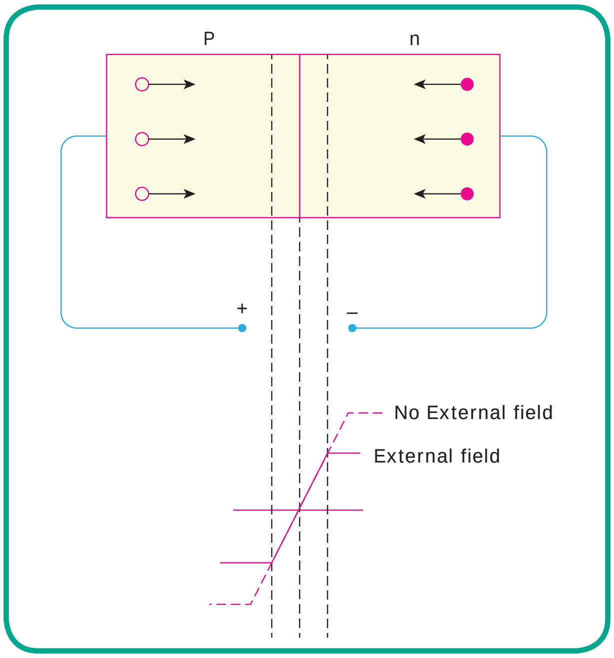

Figure 3.21 Forward bias

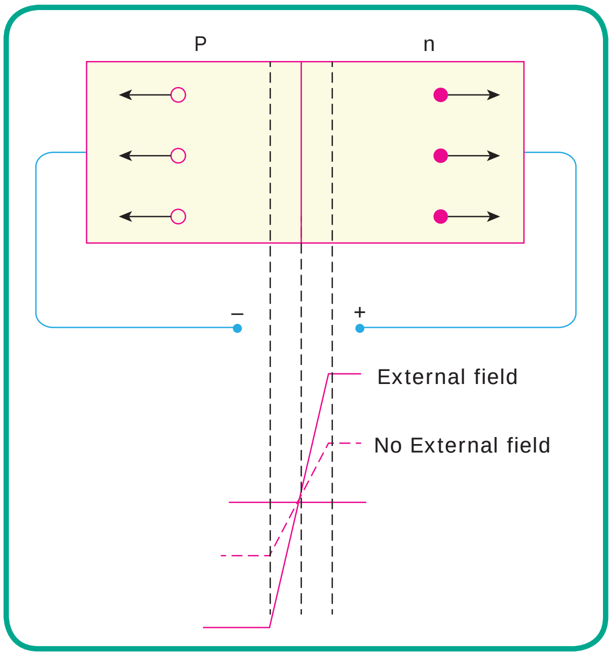

Figure 3.22 Reverse bias

3.7.2 Reverse Biasing

> *"When the external voltage applied to the junction is in such a direction that potential barriers is increased, it is called reverse biasing"*

To apply reverse bias, connect negative terminal of the battery to p-type and positive terminal to n-type as shown in Figure 3.22. Because of increase in barrier potential the width of the depletion layer is also increased. As a result, the increased potential barrier prevents the flow of charge carriers (majority carriers) across the junction and hence the current does not flow.

LEARNING OUTCOMES

After studying this Chapter, a student can understand the following

1. **Knowledge about basic electronic principles**
2. **Atomic structure of elements.**
3. **Classification of Elements**
4. **Detailed knowledge of Semiconductors and its working**
5. **Working of PN-junction**

GLOSSARY

S. No	Terms	Explanation
1	Acceptor atoms	Trivalent atoms that accept free electrons from pentavalent atoms
2	Atomic number	The number of positive charges or protons in the nucleus of an atom
3	Covalent bond	The way some electrons complete their valence shells by sharing valence electrons with neighbouring atoms
4	Electron	Smallest sub atomic particle of negative charge that orbits the nucleus of an atom
5	Hole	A gap left in the covalent band when a valence electron gains sufficient energy to jump to the conduction band
6	Semiconductor	An element which is neither a good conductor or a good insulator, but rather lies somewhere between the two
7	Proton	Sub atomic particle within the nucleus of an atom. Has a positive charge

QUESTIONS

I. Choose the right answer from the following questions 1 Mark

1. The atomic weight of an atom is determined by
   (a) No of protons
   (b) No of neutrons
   (c) No of Protons and No of neutrons
   (d) No of Protons or No of electrons

2. The number of protons present in an atom is called as
   (a) isotope number (b) atomic number
   (c) atomic weight (d) none of the above

3. Atomic number of Germanium
   (a) 6 (b) 14
   (c) 29 (d) 32

4. Which of the following element does not have three valence electrons?
   (a) Boron (b) Indium
   (c) Germanium (d) Gallium

5. Which of the following element does not have five valence electrons?
   (a) Phosphorous (b) Arsenic
   (c) Antimony (d) Indium

6. A semiconductor in its pure form is called
   (a) Intrinsic semiconductor
   (b) Extrinsic semiconductor
   (c) P-type semiconductor
   (d) N-type semiconductor

7. Which of the following is donor impurity element?
   (a) Aluminium (b) Boron
   (c) Phosphorous (d) Indium

8. Which of the following is acceptor impurity element?
   (a) Antimony (b) Gallium
   (c) Arsenic (d) Phosphorous

9. In N-type semiconductor free electrons are the ……. Carriers
   (a) Minority (b) Majority
   (c) Magnetic (d) Neutral

10. A doped semiconductor is called
    (a) impure semiconductor
    (b) intrinsic semiconductor
    (c) Pure semiconductor
    (d) Extrinsic semiconductor

II. Answer in one or few Sentences 3 Marks

1. What is an atomic number?
2. What is atomic weight?
3. What is valence electron?
4. Draw the atomic structure of germanium atom.
5. What is called energy band?
6. What is meant by electron emission?
7. Define Hole current
8. What is meant by doping?
9. What is Semiconductor? Give Example
10. Give Examples for trivalent and pentavalent impuruties.

III Explain the following questions in one or two paragraph. 5 Marks

1. Write short notes on free electrons.
2. Explain energy bands.
3. Explain conductor, semiconductor and insulator.
4. Explain formation of n-type semiconductor with diagram.

IV Describe the following questions in a page. 10 Marks

1. Explain the Bohr's atomic model with neat diagram.
2. Explain the different types of electron emission with neat diagrams.
3. Write formation of pn junction with neat diagram.

Answers

1) **c**	2) **b**	3) **d**	4) **c**	5) **d**
6) **a**	7) **c**	8) **b**	9) **b**	10) **d**