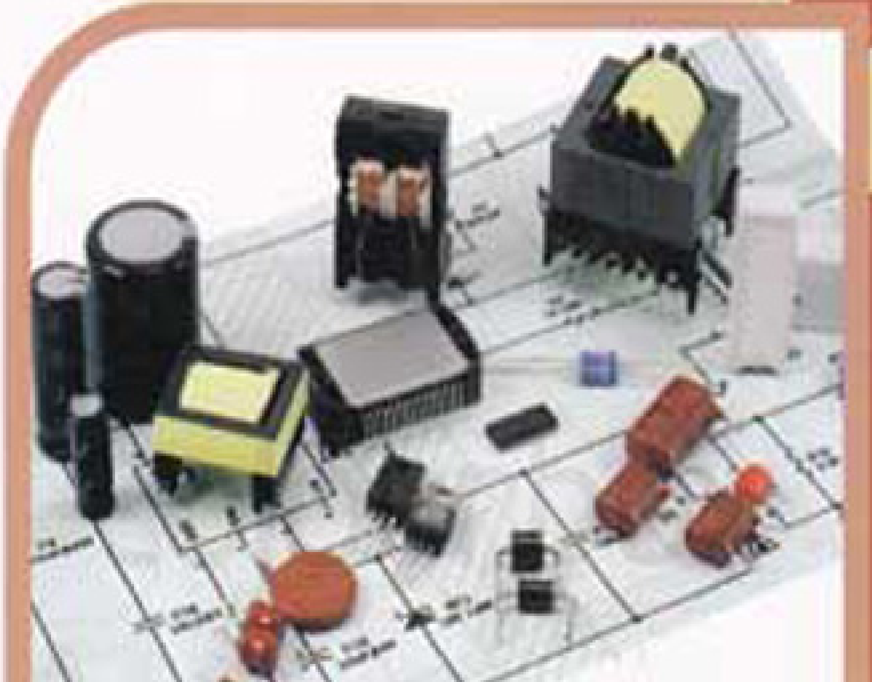
FIRST YEAR DIPLOMA
Engineering and Technology
SEMESTER-II

ELECTRICAL AND ELECTRICAL POWER
ENGINEERING GROUPS

MSBTE's
I
SCHEME

ELEMENTS OF ELECTRONICS



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GANESH B. AKOLIYA

NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

A TEXT BOOK OF

ELEMENTS OF ELECTRONICS

For
Semester II

First Year Diploma in Electrical and Electrical Power Engineering Groups
(EE, EP)
As per MSBTE's 'I-Scheme' Syllabus, w.e.f. 2017-18

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PREFACE

With tremendous advancement in the field of Electronics since last few decades, a number of semiconductor devices have come up in electronic field. This rapid development made significant change in the field of electrical engineering. The field of electrical engineering is generally segmented into three major areas Electronics, Power and Control. The function of electronics is to process and control the electrical energy by supplying voltage and current in the form that is optimally suited to the load. Electronics plays a vital role in many domestic and industrial appliances. Electrical machines are controlled by electronic devices. Various conventional controls and relays are replaced by electronic system consisting of electronic circuits.

Electronics is popular for technical as well as economical reasons. Electrical power generation, transformation, transmission and distribution are in a.c. but almost all terminal equipments used in industries, laboratories, agriculture and domestic require d.c. power. In order to satisfy these requirements, easy conversion of power is essential. Electronics provides the solution for all such requirements.

By considering these facts, **Elements of Electronics** subject is included in the curriculum of degree and diploma engineering in Electrical Engineering group. This book is intended for imparting fundamental knowledge to diploma students of electrical engineering group for studying electronics related subjects such as basic electronics and E.D.C. This book is mainly designed as per the 'I' scheme of semester pattern syllabus for second semester diploma in electrical engineering group. This book is an outcome of the author's realization of the fact that the important subject **'Basic Electronics'** must be learnt by every students with clarity and ease. It is written in a simple straightforward style, emphasizing the core concepts underlying various electronic circuits without deriving complex mathematical equations. This book is expected to serve as a student friendly text to students of electrical engineering diploma programme.

This text book is divided into six chapters. The text begins with introductory chapter related to semiconductor devices with main focus on diode. The next three chapters explain basic concepts of semiconductor diodes, rectifiers and filters, and transistors. The fourth chapter is devoted to the discussion on the concept of regulators and power supply. Oscillators are also discussed in fifth chapter. Sixth chapter is reserved for digital electronics. At the end of each chapter, few review questions are given for self feedback. Appendices are included for practice purpose.

It is our proud privilege to record indebtedness to the publisher **Mr. Dineshbhai Furia** and **Mr. Jigneshbhai Furia** for their kind interest in the entire work and publishing this book in a very short span of time. We also express our thanks to **Mr. Kiran Velankar** and staff of Nirali Prakashan especially Mr. Santosh Bare and Mrs. Prachi Sawant for completion of this book in short span of time.

Every care has been taken to check mistakes and misprints. Yet it is very difficult to claim perfection. Any constructive criticism and suggestions from professionals, teachers and students are most welcome that help us in improving this book.

AUTHORS

SYLLABUS

1. SEMICONDUCTOR DIODES (Hrs. 06, Marks 08)

1.1 Construction, Symbol, Working principle, Specifications, Applications, Forward and Reverse biasing and V-I characteristics of following semiconductor diodes : P-N junction diode, Zener diode.

1.2 Special Diodes : LED, Photodiode, LASER diode and Power diode.

2. RECTIFIERS AND FILTERS (Hrs. 08, Marks 12)

2.1 Types of Rectifiers : Half wave, Full wave (Bridge and Centre tapped) : Circuit operation, I/O waveforms for voltage and current.

2.2 Parameters of Rectifiers : Average DC value of current and voltage ripple factor, Ripple frequency, PIV of diode, TUF and efficiency of rectifier.

2.3 Types of Filters : Shunt capacitor, Series inductor, LC and π filters.

3. TRANSISTORS (Hrs. 12, Marks 18)

3.1 Different types of transistors : PNP and NPN.

3.2 Transistor configurations : CB, CE, CC.

3.3 Transistor CE configurations : Circuit diagram, Input and output characteristics, Different points of characteristics (Cut-off, Active and Saturation), Input resistance, Output resistance, Current gain.

3.4 BJT biasing : DC load line, Operating point, Voltage divider bias.

3.5 Single-stage and Multi-stage CE amplifier : Circuit diagram, Function of each component, Frequency response and bandwidth.

3.6 Transistor as a switch.

3.7 Construction of FET (N-channel and P-channel), Symbol, Working principle and characteristics. Circuit diagram for drain and transfer characteristics, Operating regions of characteristics.

4. REGULATORS AND POWER SUPPLY (Hrs. 08, Marks 12)

4.1 Load and Line regulation.

4.2 Basic Zener diode voltage regulator.

4.3 Transistorized Series and Shunt regulator – Circuit diagram and Working.

4.4 Regulator ICs : ICs 78XX, 79XX, IC 723 as fixed, variable and dual, Regulated DC power supply.

4.5 Construction and Operation of DC Regulated power supply.

5. OSCILLATORS (Hrs. 08, Marks 10)

5.1 Types of feedback : Positive feedback, Negative feedback, Barkhausen's criterion.

5.2 Oscillators : Circuit diagram and Working of LC, RC and Crystal oscillator.

5.3 Hartley oscillator, Colpitt's oscillator, Wien Bridge and Phase shift oscillator.

6. DIGITAL ELECTRONICS (Hrs. 08, Marks 10)

6.1 Number system : Binary, Octal, Decimal and Hexadecimal number systems.

6.2 Boolean Algebra : DeMorgan's theorems.

6.3 Logic Gates : Logic symbol, Logical expression and Truth table of AND, OR, NOT, EX-OR and EX-NOR gates.

6.4 Universal Gates : NAND and NOR.

6.5 Flip-Flop : Symbol, Truth table and Working of SR, JK, MS JK, T and D flip-flop.

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UNIT-I

Chapter 1

SEMICONDUCTOR DIODES

(Theory Hrs. 12, Total Marks 14)

INTRODUCTION

Definition :

- The word *'Electronics'* is basically derived from a Greek word *'Elektron'*.
- It is also derived from ***'Electron Mechanics'*** which means the study of the behaviour of an electron under different conditions of externally applied fields.
- The *Institution of Radio Engineers* (IRE) has given a standard definition of electronics in the proceedings of IRE Vol. 38 of 1950 as ***the field of science and engineering, which deals with the study, design and use of devices, which depends on conduction of electricity through a vacuum, gas or semiconductor media.***
- ***Electronics is also defined as the branch of science and engineering, which deals with the electronic devices in which the flow and control of electrons takes place through a vacuum, gas or semiconductor media.***

Fields of Applications of Electronics :

Following are the major fields of applications of electronics :

1. Communication.
2. Entertainment.
3. Instrumentation.
4. Control.
5. Industrial.
6. Traction system
7. Military
8. CAD/CAM.
9. Automation.
10. Robotics.
11. Medical
12. Agriculture
13. Power generation, transmission and distribution.

Classification of Solid Materials :

We may classify the solid materials into three groups as under :

1. **Conductors :** *The solid which have very low resistivity of the order of 10^{-8} ohm-meter or lower, is called conductor.* It includes metals such as Silver, Copper, Aluminium, Iron etc.
2. **Insulators :** *The solid, which have very high resistivity of the order of 10^{7} ohm-meter or greater is called insulator.* It includes dielectrics having dielectric constant between 1 to 10 like Plastic, Glass, Mica, Rubber, Wood, Ceramics, Diamond, Quartz etc.
3. **Semiconductors :** *The solid, which has resistivity in between 10^{-9} ohm-meter and 10^{7} ohm-meter is called semiconductor.* It includes Silicon, Germanium, Gallium, Selenium etc.

1. Electronic Structure :

Structure of an Atom :

- Atom is a Greek word for *'**indivisible**'*. In older days, an atom was considered as the smallest particle, which was indivisible.
- An atom consists of two parts, namely nucleus and electrons.
- The structure of an atom is as shown in Fig. 1.1.
- All the electrons of an atom do not revolve in the same orbit, but revolve around the nucleus in different orbits as shown in Fig. 1.1.
- The number and arrangement of electrons in any orbit is determined by $2n^2$, where n is the number of orbit.
- The last but one orbit cannot accommodate more than 18 electrons. The last orbit can accommodate not more than 8 electrons.

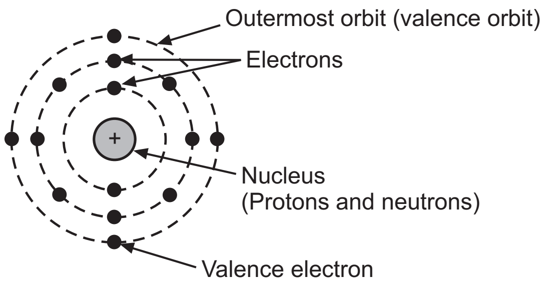
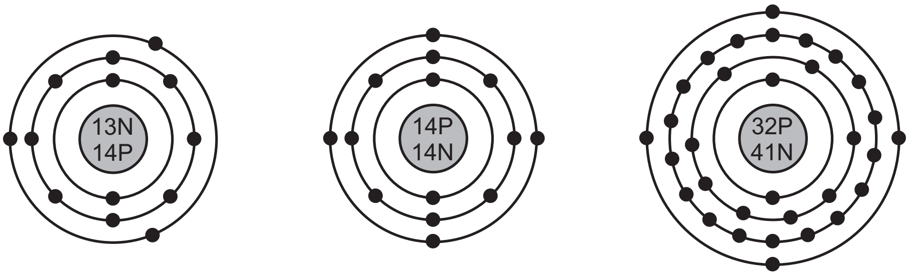


Fig. 1.1 : Structure of an atom

Atomic Structure of Elements :

- Fig. 1.2 shows the representations of the atomic structure of different elements e.g. Aluminium, Silicon and Germanium atoms.



(a) Al atom (b) Si atom (c) Ge atom

Fig. 1.2 : Atomic structure of elements

2. Semiconductors :

Definition :

- ***The materials, whose electrical conductivity lies between those of conductors and insulators and have negative temperature coefficient of resistance, are known as semiconductors.***

Semiconductor Materials :

- The few examples of semiconductor materials are as under :

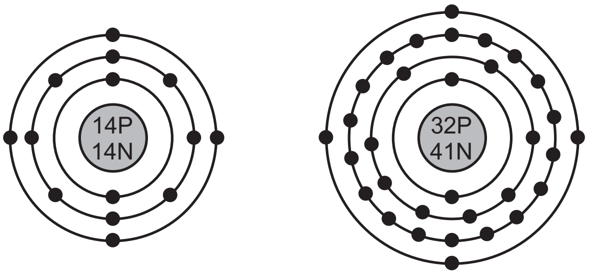
  1. Carbon (C)
  2. Silicon (Si)
  3. Germanium (Ge)
  4. Selenium (Se)
  5. Gallium Arsenide (GaAs)
  6. Cadmium Sulphide (CdS).

- *The commonly used semiconductor materials are Germanium and Silicon*. These are tetravalent elements i.e. materials having four valency.

Atomic Structures of Germanium and Silicon :

(i) Atomic structure of Germanium and Silicon atoms :

- Fig. 1.3 (b) shows the atomic structure of a Germanium atom in which first, second, third and fourth orbits have 2, 8, 18 and 4 electrons respectively, with the result that the atomic number for Germanium is 32.
- Fig. 1.3 (a) shows the atomic structure of a Silicon atom in which first, second and third orbits have 2, 8, and 4 electrons respectively, with the result that the atomic number for Silicon is 14.



(a) Si atom (b) Ge atom

Fig. 1.3 : Simple atomic structures

(ii) Atomic structure of Germanium and Silicon crystals :

- Fig. 1.4 shows a simplified two-dimensional representation of crystalline structure of Germanium or Silicon crystal.
- Each Germanium atom is surrounded by 4 neighbouring Germanium atoms and each atom has 4 valence electrons. The core represents the nucleus and filled orbits.
- At absolute zero, all the valence electrons are tightly bound to the nucleus of the parent atoms and hence no free electrons are available for electrical conduction.

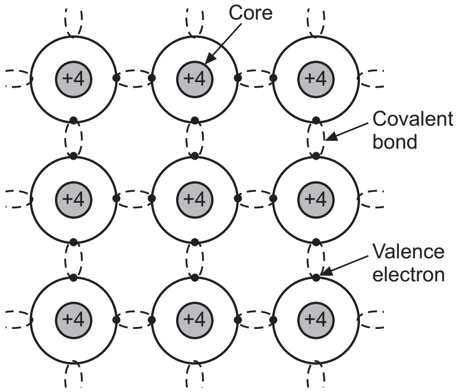


Fig. 1.4 : Atomic structure of Ge and Si crystals

Classification of Semiconductors :

The classification of semiconductors is as under :

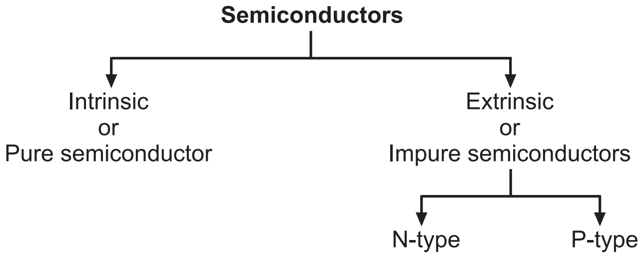


Fig. 1.5 : Classification of semiconductors

Types of Semiconductors :

The semiconductors are of the following two types :

1. Intrinsic semiconductor. 2. Extrinsic semiconductors.

3. Intrinsic Semiconductors :

Definition :

- ***A semiconductor in an extremely pure form (i.e. without any impurity) is known as an intrinsic semiconductor.***

Conduction of Current :

- When electric field V_B is applied across an intrinsic semiconductor, the current conduction takes place due to free electrons and holes.
- The free electrons are generated due to the breaking up of some covalent bonds by thermal agitation (or energy). At the same time, the same number of holes are created in the covalent bonds.
- The free electrons drift towards the positive terminal of the battery V_B and the holes towards the negative terminal.
- This movement of charge carriers constitute the electric current I under the influence of electric field V_B and it flows through the intrinsic semiconductor.

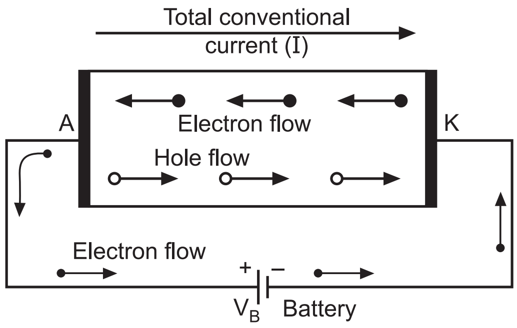


Fig. 1.6 : Conduction of current in an intrinsic semiconductor

- Since the electrons are negatively charged, the direction of electric current (conventional) I is opposite to the direction of their motion of free electrons and in the direction of holes.
- The two types of charge carriers i.e. free electrons and holes move in opposite direction.
- ***When the flow of charge carriers is due to an applied voltage (as shown in Fig. 1.6), the resultant current is called a drift current.***
- A second type of current may also exist in an intrinsic semiconductor. This current is called ***diffusion current*** and it flows as a result of a gradient of carrier concentration (i.e. the difference in carrier concentration from one region to another).
- The diffusion current may also be due to the motion of both free electrons and holes.

4. Extrinsic Semiconductors :

Definition :

- As the intrinsic semiconductor materials have negligible and poor conductivity at room temperature, it is not useful for practical applications of electronics.
- For improving the electrical conductivity of intrinsic semiconductor, certain amount of desired impurity atoms are to be added into it to make the imbalance of free electrons and holes. They are called dopands.
- ***The intrinsic semiconductor containing small amount of desired impurity atoms is known as an extrinsic semiconductor.*** **It is also defined as a *doped intrinsic semiconductor*.**
- *The impure form of a semiconductor is known as an extrinsic semiconductor.*

Doping :

- ***The process of deliberately adding or diffusing impurity atoms to the intrinsic semiconductor crystal is called doping.***
- *The purpose of adding impurity is to increase either the number of free electrons or holes in the semiconductor crystal i.e. to increase the conductivity of intrinsic semiconductors.*

Types of Impurity Elements :

- To increase the conductivity of the intrinsic semiconductor, trivalent or pentavalent impurity elements are doped to it.
- There are two types of impurity elements, namely trivalent and pentavalent.

(i) Trivalent (Acceptor) impurity elements :

- ***The impurity elements that accept the free electrons from the intrinsic semiconductor is called trivalent impurity elements.*** These are third group elements.
- Typical examples are Boron (B), Gallium (Ga), Aluminium (Al) and Indium (In).
- These impurities are also called ***acceptor impurities*** because the holes created have affinity to accept free electrons.

(ii) Pentavalent (Donor) impurity elements :

- ***The impurity element that provides (or donates) excess of free electrons to the intrinsic semiconductor is called pentavalent impurity elements.*** These are pentavalent group elements.
- Typical examples are Phosphorus (P), Arsenic (As) and Antimony (Sb).
- These impurities are also called ***donor impurities*** because these impurities donate or provide excess of free electrons.

Types of Extrinsic Semiconductors :

- The extrinsic semiconductors are of the following two types :
    1. P-type semiconductors,
    2. N-type semiconductors.

5. P-type Semiconductor :

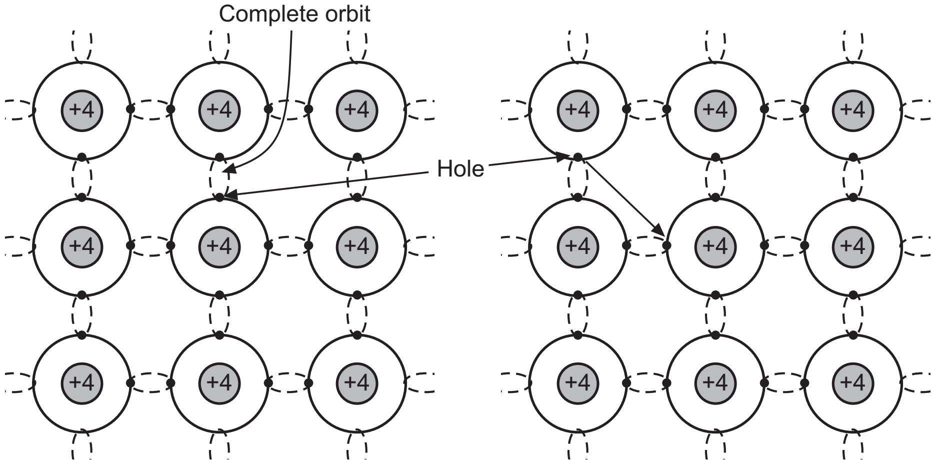
Definition :

- ***When a small amount of trivalent (acceptor) impurity is added to the intrinsic semiconductor, then it is known as P-type semiconductor.***
- The P-type semiconductor is formed by adding a small amount of trivalent (*Boron, Gallium or Aluminium*) impurity element to the intrinsic semiconductor (pure Silicon or Germanium) material which acts as a base material.
- The addition of trivalent impurity provides a large number of holes in the intrinsic semiconductor.

Working Principle :

- Consider the structure of a P-type semiconductor as shown in Fig. 1.7 (a).
- The Boron atom in the crystal has only 3 valence electrons.
- Each Boron atom is surrounded by 4 neighbouring Germanium (or Silicon) atoms.
- Three valence electrons of Boron atom share with the 3 electrons of 3 neighbouring Germanium atoms forming 3 covalent bonds.
- The fourth neighbouring Germanium atom is unable to form a covalent bond with Boron atom, because Boron atom does not have fourth electron in its valence orbit.
- The fourth covalent bond remains incomplete for want of fourth electron in Boron atom. This deficit of one electron in the Boron atom gives rise to a hole.
- The number of holes generated in the Germanium crystal depends upon the amount of Boron atoms added to the crystal.
- The hole has a great tendency to snatch valence electron from the neighbouring atom to form a covalent bond.
- This tendency is so great that an electron in an adjacent covalent bond, having very small additional energy, can jump to occupy the vacant position.
- This electron then completes the covalent bond around the Boron atom.
- At room temperature, the thermal energy is sufficient to provide this energy so as to fill the incomplete bond around all the Boron atoms.
- To make up the fourth covalent bond, Boron atom takes one electron from the neighbouring Germanium atom by breaking a covalent bond. Now two things happen.

1. A vacancy is created in the adjacent covalent bond from where the electron had jumped. This vacancy has a positive charge associated with it, hence, it is a *hole* as shown in Fig. 1.7 (b).
2. Due to the filling of the incomplete fourth covalent bond around the Boron atom, it now becomes a *negative ion.*



(a) Addition of Boron **(b) Creation of hole**

Fig. 1.7 : P-type semiconductor

- At absolute zero temperature, there is no movement of electrons and holes due to zero thermal energy.
- Hence P-type semiconductor behaves as a perfect insulator at absolute zero temperature.
- At room temperature, some of the covalent bonds may get broken, because of thermal energy.
- This gives rise to electron-hole pairs. These holes add to the existing holes.
- There exist a large number of holes (i.e. positively charged carriers).
- *In P-type semiconductor, holes are majority carriers, whereas free electrons are minority carriers.*
- In energy band diagram, Fermi level is nearer to the valence band.

6. N-type Semiconductor :

Definition :

- ***When a small amount of pentavalent (donor) impurity is added to the intrinsic semiconductor, then it is known as N-type semiconductor.***
- The N-type semiconductor is formed by adding a small amount of pentavalent impurity (Phosphorus or Arsenic or Antimony) to the intrinsic semiconductor (pure Silicon or Germanium) material which acts as a base material.
- The addition of pentavalent impurity provides a large number of electrons in the intrinsic semiconductor.

Working Principle :

- Consider the structure of an N-type semiconductor as shown in Fig. 1.8.
- The fifth valence electron of Phosphorus atom finds no place in the covalent bond and is unable to form a covalent bond with Germanium atom for want of an additional electron in their orbit.
- Since it is not associated with any covalent bond and is quite far from the nucleus, it is very loosely bound. It requires very little energy to free itself from the attractive force of its nucleus.
- The Phosphorus atom in the crystal has only five valence electrons.
- Each Phosphorus atom is surrounded by 4 neighbouring Germanium (or silicon) atoms.

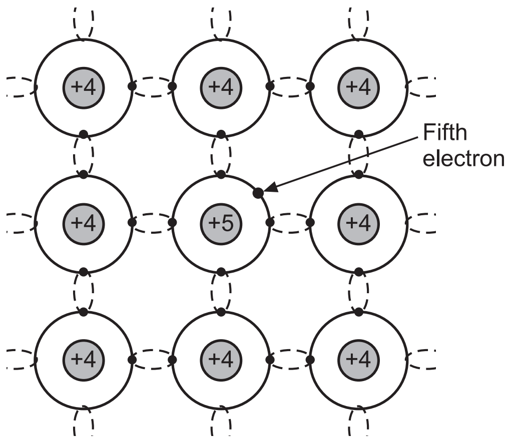


Fig. 1.8 : N-type semiconductor

- This Phosphorus atom fits in the Ge (or Si) crystal in such a way that its 4 valence electrons share with the 4 valence electrons of 4 different neighbouring (or adjacent) Germanium atoms forming 4 covalent bonds with these Germanium atoms.
- At absolute zero temperature, there is no movement of electrons and holes due to zero thermal energy.
- The additional energy required to detach the fifth valence electron from its nucleus is so small that at room temperature practically all such electrons become free.
- At room temperature, all those donated electrons acquire sufficient thermal energy and become detached from its nucleus.
- It then becomes free to move anywhere within the crystal.
- At the time when this electron has become free from the Phosphorus atom, the remaining atom becomes a positive ion.
- The number of thermally generated electron-hole pairs will be very small compared to the number of free electrons donated by impurity atoms.
- Consequently, the concentration of holes is much less than free electrons in its intrinsic value.
- *In N-type semiconductor, free electrons are majority carriers, whereas holes are minority carriers.*
- In energy band diagram, Fermi level is nearer to the conduction band.
- *Thus N-type semiconductor behaves as a perfect insulator at absolute zero temperature.*

7. Comparison of Intrinsic and Extrinsic Semiconductors :

The comparison of intrinsic and extrinsic semiconductors is as per Table 1.1.

Table 1.1

Intrinsic Semiconductor	Extrinsic Semiconductor
1. It is an extremely pure form of semiconductor.	1. It is a doped semiconductor.
2. The number of free electrons and holes generated due to thermal energy are equal.	2. The number of free electrons and holes generated due to thermal energy are not equal.
3. The current conduction is due to free electrons and holes.	3. The major part of current conduction is due to majority carriers, either holes or free electrons.
4. The Fermi level is at the centre of forbidden energy gap and is unchanged with change in temperature.	4. The Fermi level shifts upward or downward as per dopping material and with change in temperature.
5. The electrical conductivity is very poor at room temperature.	5. The electrical conductivity is comparatively high at room temperature.
6. It is less useful.	6. More useful.
7. It has no further types.	7. It is of two types : (a) P-type, (b) N-type.

8. P-N Junction :

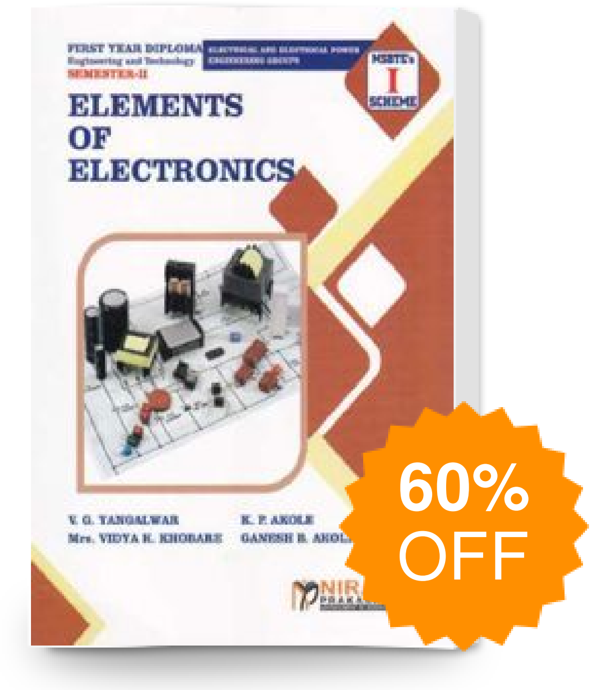
Definition :

- ***When a P-type semiconductor is suitably joined to an N-type semiconductor under suitable condition by using special technique to form a junction, the contact surface is known as a P-N junction.***

Formation of Depletion Region in Unbiased P-N Junction :

- Fig. 1.9 (a) shows a P-N junction just immediately after it is formed. It is a single crystal having P-type and N-type semiconductor made from Germanium or Silicon crystal.
- The P-region has high concentration of holes (i.e. *majority carriers*), whereas the N-region has high concentration of free electrons (i.e. *majority carriers*).
- For simplicity, minority carriers are not shown in Fig. 1.9.
- Holes and free electrons shown by dots and circles respectively are the mobile charge carriers.
- In P-region, the positive charge on holes is equal to the total charges on its free electrons and immobile ions.
- In N-region, the negative charge of its majority carriers is compensated by the charge of minority carriers and immobile ions.
- Therefore, the single crystal (P-N junction) as a whole is electrically neutral, and so the P-region and N-region are considered separately.

Elements Of Electronics



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