Vision

To be the centre of excellence in the field of technical education.

Program Code:- First Semester – All Program

Course Name:- Basic Science (PHYSICS)

Course Code : - BSC (22102)

Course coordinator: Mr. S. K. Rawat

Course Name:- Basic Science (PHYSICS)

Unit No:2

Unit Name: Electricity, Magnetism & Semiconductors.

Unit Outcomes (UO2e): Distinguish the given conductors, semiconductors and insulators on the basis of energy bands.

Learning Outcomes (LOs):

LO9: Student will be able to discuss conduction in semiconductors – charge carriers, intrinsic/extrinsic, p-type, and n-type.

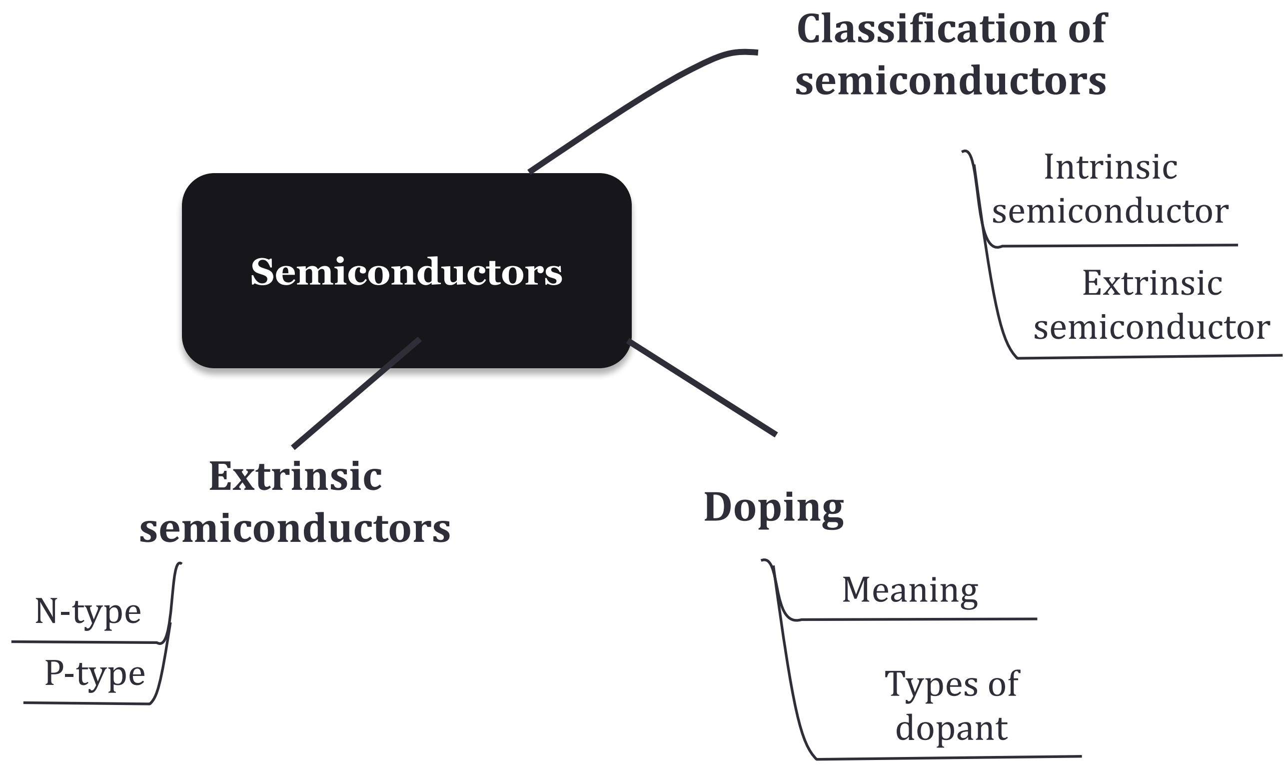
CONTENT

- Classification of semiconductors
    - Intrinsic semiconductors
    - Extrinsic semiconductors
- Doping
- Types of extrinsic semiconductors
    - N-type semiconductors
    - P-type semiconductors

LEARNING OBJECTIVES

- Student will be able to discuss conduction in semiconductors – charge carriers, intrinsic/extrinsic, p-type, and n-type.

Concept Map


Classification of semiconductors
Intrinsic semiconductor
Extrinsic semiconductor
Semiconductors
Extrinsic semiconductors
N-type
P-type
Doping
Meaning
Types of dopant

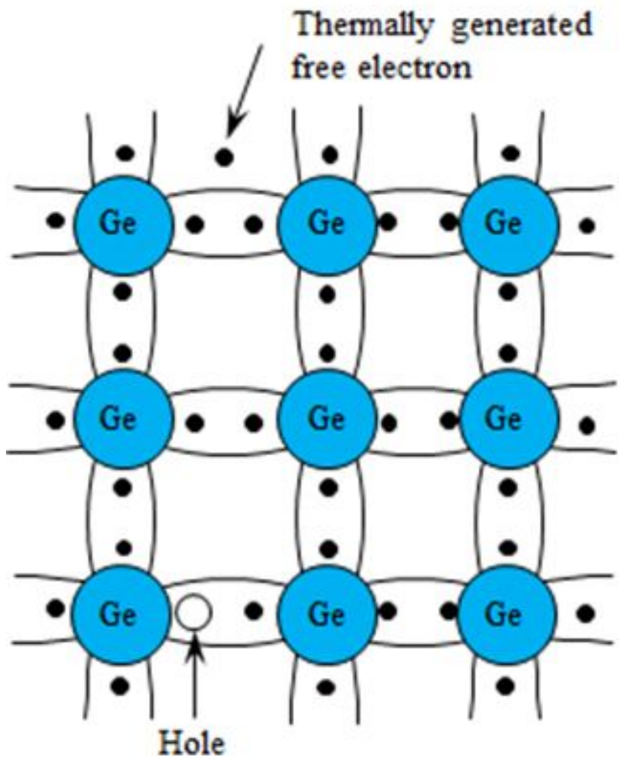
Classification of semiconductors

There are two types of semiconductors such as –

- (i) Intrinsic Semiconductor and
- (ii) Extrinsic Semiconductor

Intrinsic Semiconductors

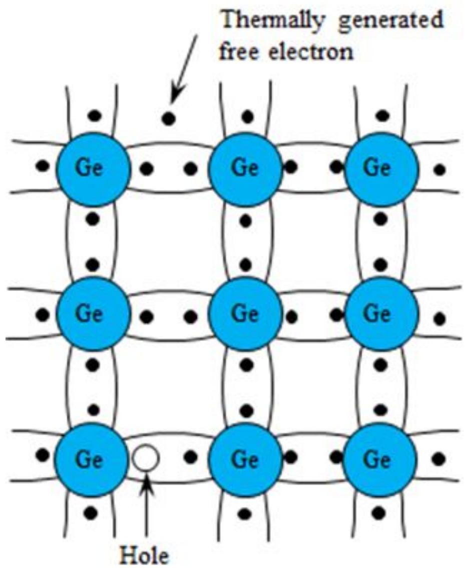
- A semiconductor in an extremely pure form is known as intrinsic semiconductor. Silicon and Germanium in extremely pure form is known as intrinsic semiconductor.
- When electric field is applied across an intrinsic semiconductor, the electron-hole pairs are generated. The conduction of current takes place by two processes, namely, by free electrons and holes as shown in fig.



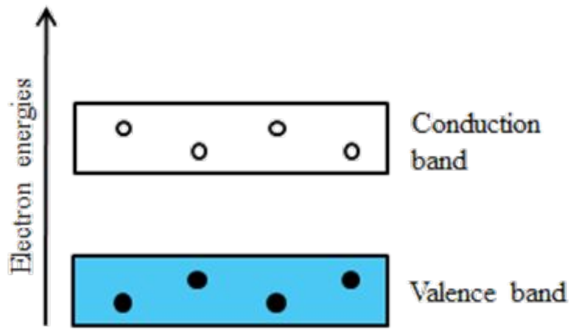
Intrinsic semiconductor with broken bond

Intrinsic Semiconductors

- The free electrons are produced due to breaking of some covalent bonds. At the same time, holes are generated in the covalent bonds.
- Due to application of electric field, conduction through the semiconductor is by both free electrons and holes.
- The energy required to break such a covalent bond is equal to the band gap energy Eg.
- If the temperature of an intrinsic semiconductor is increased, beyond room temperature, a large number of electron-hole pairs are generated.
- Thus for an intrinsic semiconductor, concentration of free electron ‘ne’ is equal to the concentration of holes ‘np’, i.e., ne = np.
- Fig. shows the energy band diagram for an intrinsic semiconductor at room temperature



Intrinsic semiconductor with broken bond



Energy band diagram for intrinsic semiconductor

Extrinsic Semiconductors

- At room temperature, the conductivity of intrinsic semiconductor is too small to be useful for any practical applications.
- Conductivity of intrinsic semiconductor can be increased by adding suitable impurities to it.
- The purpose of adding impurity is to increase current carrying capacity of pure semiconductor, by increasing either the number of free electrons or holes in the semiconductor.
- Thus the process of adding impurities to pure semiconductors are called doping and the impurity atom are called dopants.

Comparison
intrinsic semiconductor and extrinsic semiconductor

Intrinsic semiconductor	Extrinsic semiconductor
1. It is pure semi-conducting material and no impurity atoms are added to it.	1. It is prepared by doping a small quantity of impurity atoms to the pure semiconducting material.
2. Examples: crystalline forms of pure Si and Ge.	2. Examples: Si and Ge crystals with impurity atoms of As, Sb, P etc. or B, Aℓ etc.
3. The number of free electrons in the conduction band and the number of holes in valence band is exactly equal.	3. The number of free electrons and holes is not equal. There is excess of electrons in n-type semiconductors and excess of holes in p-type semiconductors.
4. Its electrical conductivity is low.	4. Its electrical conductivity is high.
5. Its electrical conductivity depends on temperature alone.	5. Its electrical conductivity depends upon the temperature as well as on the quantity of doped impurity atoms.

Attempt Set 1 MCQs

Question No	Question No. 1	Question No. 2	Question No. 3
Statement of Question	A doped semiconductor is also known as ________________	At absolute temperature, an intrinsic semiconductor has ______________________	Intrinsic semiconductor at room temperature will have _________________ available for conduction.
Level of Question	Remembering	Understanding	Applications
Option (a)	a) Intrinsic semiconductor	a) a few free electrons	a) electrons
Option (b)	b) Extrinsic semiconductor	b) many holes	b) holes
Option (c)	c) Diffused semiconductor	c) many free electrons	c) both electrons and holes
Option (d)	d) None of the above	d) no holes or free electrons	d) None of the above
Correct Option	**Extrinsic semiconductor**	**no holes or free electrons**	**both electrons and holes**

START

Doping

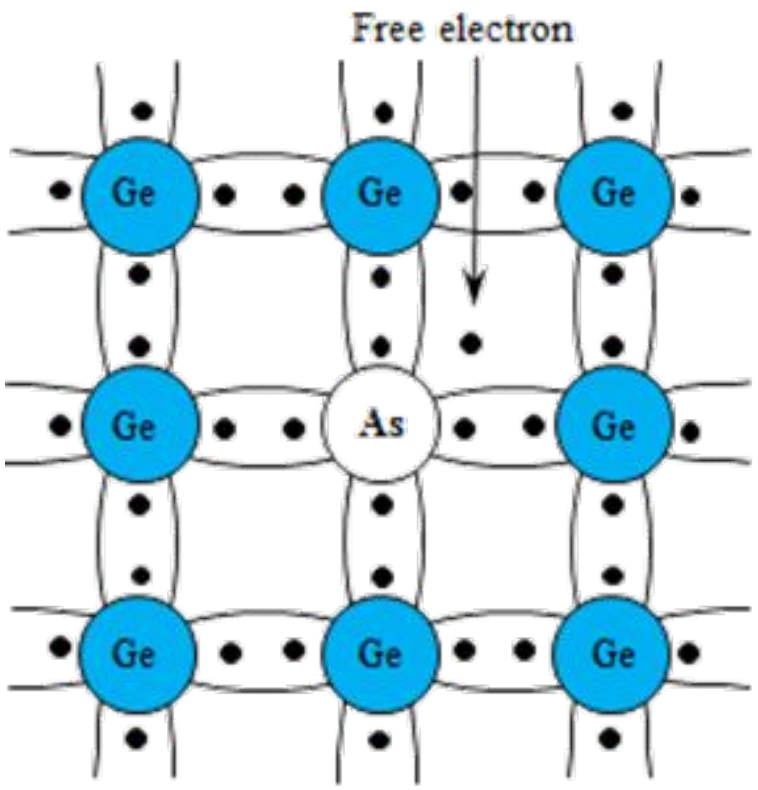
- The process of adding impurities to pure semiconductors is called doping.
- “When any trivalent or pentavalent impurity is added to pure semiconductor, then it is called as extrinsic semiconductor”.
- Doped semiconductors are called extrinsic semiconductors.
- Depending upon the type of impurity added, extrinsic semiconductors are classified as:
- (i) N-type semiconductor and
- (ii) P-type semiconductor

n-type semiconductor

Definition: When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n-type semiconductor.

Formation of n-type semiconductor

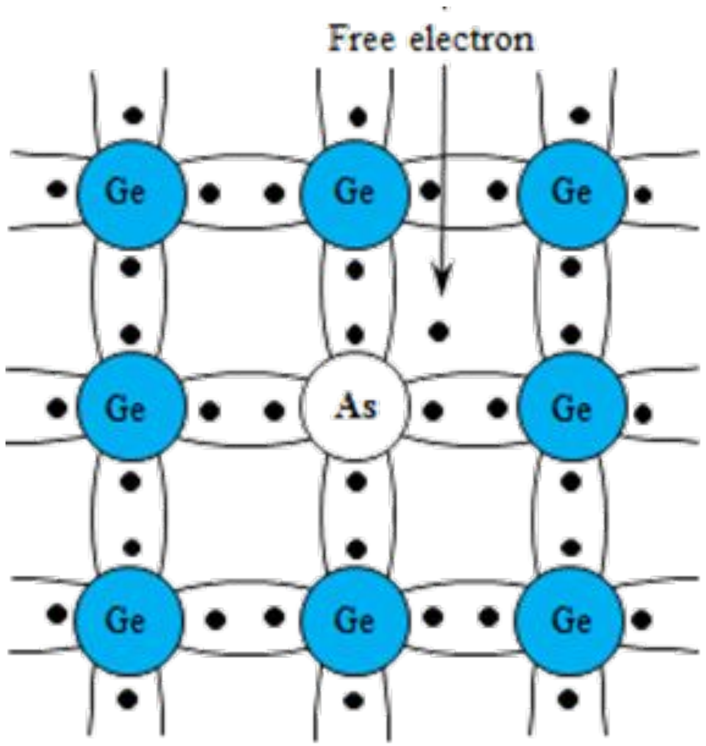
- When Si or Ge crystal is doped with pentavalent impurity such as As, Sb, P, we get n-type semiconductor. Pentavalent atom has 5 electrons in its valence orbit. Fig. shows the structure of n-type semiconductor.



Structure of n-type semiconductor

n-type semiconductor

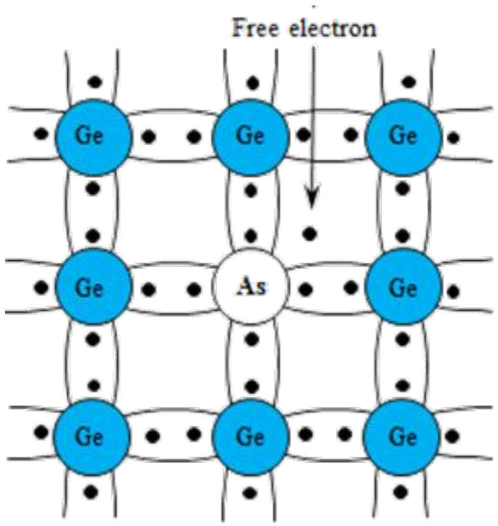
- Germanium (Ge) atom has 4 valence electrons (atomic no. 32)
- When a small amount of pentavalent impurity like arsenic (As) is added to germanium (Ge) semiconductor, a large number of free electrons become available in the semiconductor.
- The reason is simple, arsenic is pentavalent impurity (5 valence electrons) and its 4 valence electrons form covalent bonds with 4 germanium atoms.
- The fifth valence electron of arsenic remains free.



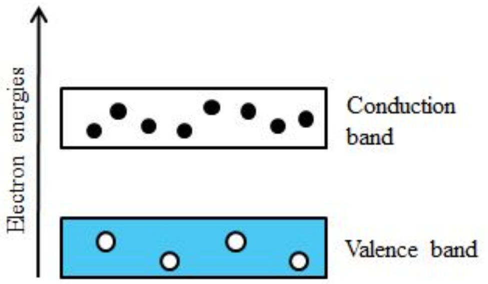
Structure of n-type semiconductor

n-type semiconductor

- Therefore, for each arsenic atom added, one free electron will be available in the Ge semiconductor.
- Since every pentavalent dopant atom donated one electron for conduction; it is called donor impurity.
- As this semiconductor has large numbers of electrons in conduction band and the conductivity is due to negatively charged electrons it is called n-type semiconductor.
- Fig. displays energy band diagram for n-type semiconductor at room temperature.



Structure of n-type semiconductor



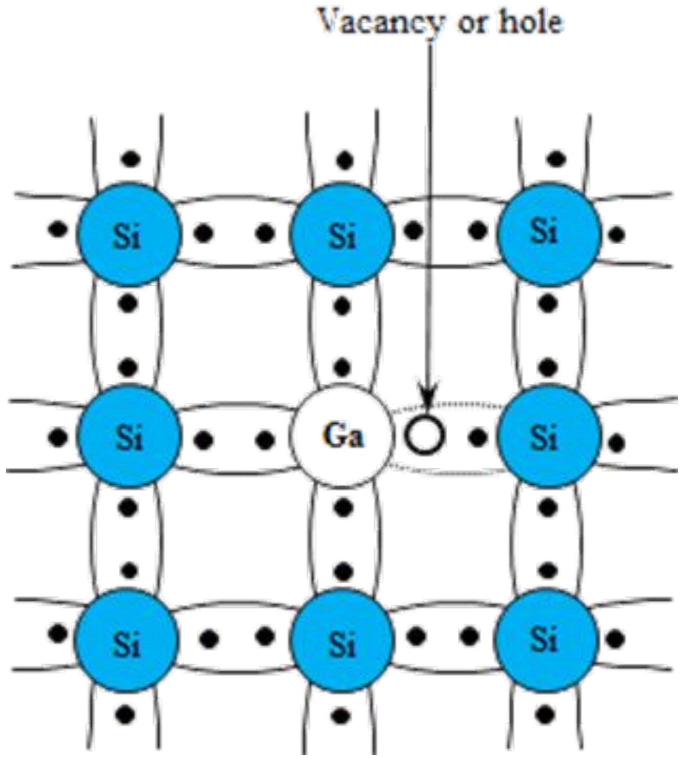
Energy band diagram of n-type semiconductor

P-type semiconductor

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

Formation of n-type semiconductor

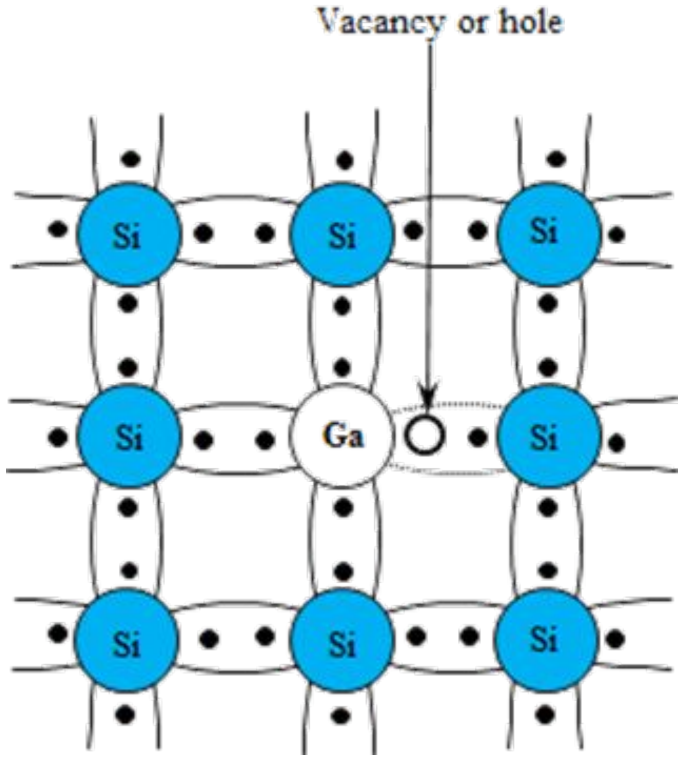
- When Si or Ge crystal is doped with trivalent impurities such as gallium (Ga), indium (In), boron (B) and aluminum (Al) we get p-type semiconductor. Trivalent atom has 3 electrons in its valence orbit. Fig. shows the structure of p-type semiconductor.



Structure of p-type semiconductor

P-type semiconductor

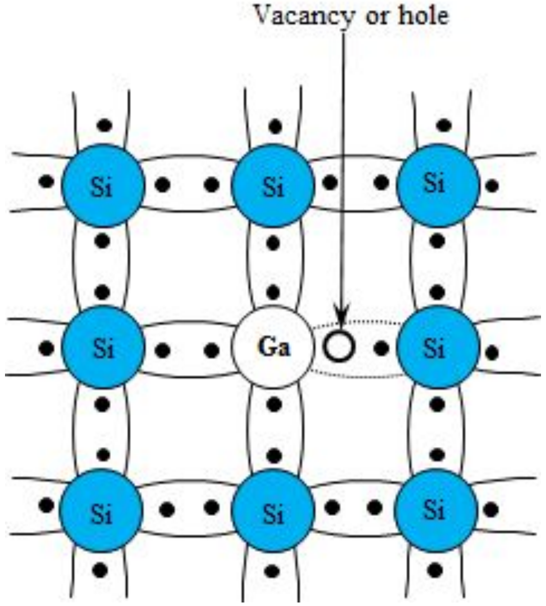
- Every trivalent impurity atom shares its 3 electrons with 3 neighbouring silicon (Si) atoms to form covalent bond.
- But, the bond between the fourth neighbour and the trivalent atom has a vacancy or hole as shown in Fig.
- As the trivalent impurity has a tendency to accept any electron in its close vicinity, they are called acceptor impurity.



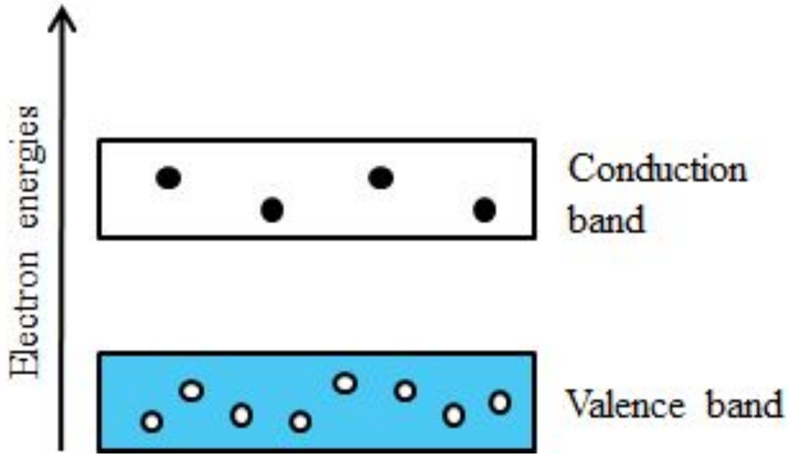
Structure of p-type semiconductor

P-type semiconductor

- As this semiconductor has large number of holes and conductivity is because of positively charged holes, it is called p-type semiconductor.
- Fig. displays energy band diagram for p-type semiconductor at room temperature.



Structure of p-type semiconductor



Energy band diagram of p-type semiconductor

Comparison
n-type semiconductor and p-type semiconductor

N-type semiconductor	P-type semiconductor
1. An extrinsic semiconductor which is obtained by doping the impurity atoms of V^{th} group of the periodic table to the pure Ge and Si semiconductor.	1. An extrinsic semiconductor which is obtained by doping the impurity atoms of III^{rd} group of the periodic table to the pure Ge and Si semiconductor.
2. The impurity atoms added, provide extra electrons in the structure and are called donor atoms.	2. The impurity atoms added, create vaccines of electrons (i.e. holes) in the structure and are called acceptor atoms.
3. The electrons are majority carriers and holes are minority carriers.	3. The holes are majority carriers and electrons are minority carriers.
4. The concentration of electrons is much greater than holes.	4. The concentration of holes is much greater than electrons.
5. The donor energy level is close to the conduction band and for away from the valence band.	5. The acceptor energy level is close to the Valence band and for away from the Conduction band.

Attempt Set 2 MCQs

Question No	Question No. 1	Question No. 2	Question No. 3
Statement of Question	Si atom with its four valence electrons shares an electron with each of its __ neighbouring atom.	What type of material is obtained when intrinsic semiconductor is doped with pentavalent impurity?	Acceptor-type impurities ________
Level of Question	Remembering	Understanding	Understanding
Option (a)	a) 2	a) N-type semiconductor	a) can be added to Si but not to Ge
Option (b)	b) 4	b) Extrinsic semiconductor	b) create excess electrons
Option (c)	c) 6	c) P-type semiconductor	c) must have 3 valence electrons
Option (d)	d) 8	d) Insulator	d) must have 5 valence electrons
Correct Option	**4**	**N-type semiconductor**	**must have 3 valence electrons**

START