Semiconductor Diodes

Presented by

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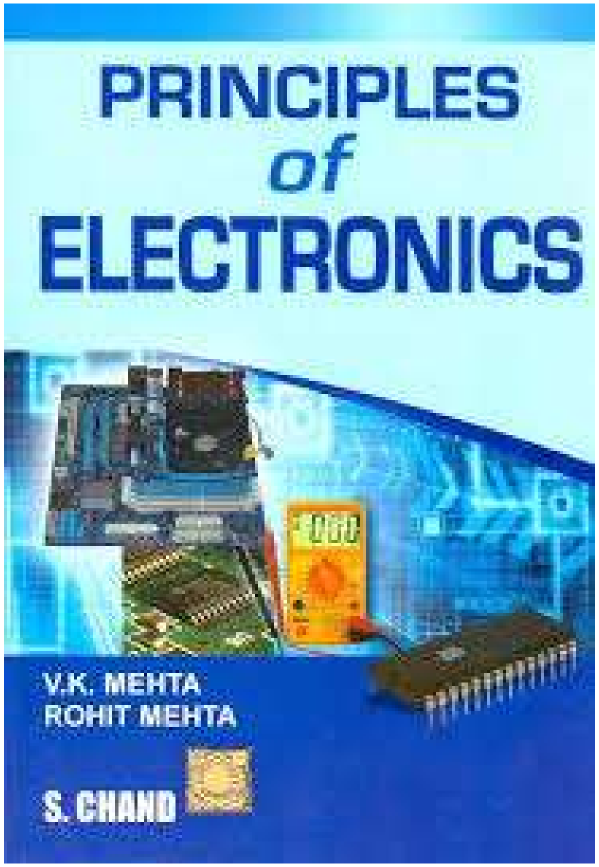
Book References



Electronics

The branch of engineering which deals with current conduction through a vacuum or gas or semiconductor is known as **electronics.**

The word *electronics* derives its name from electron present in all materials.

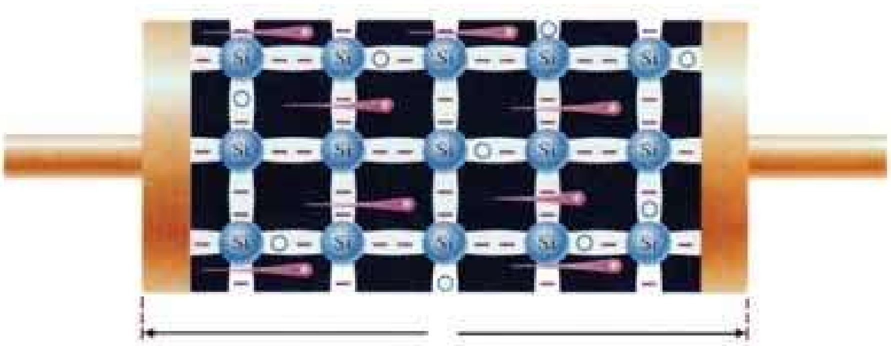


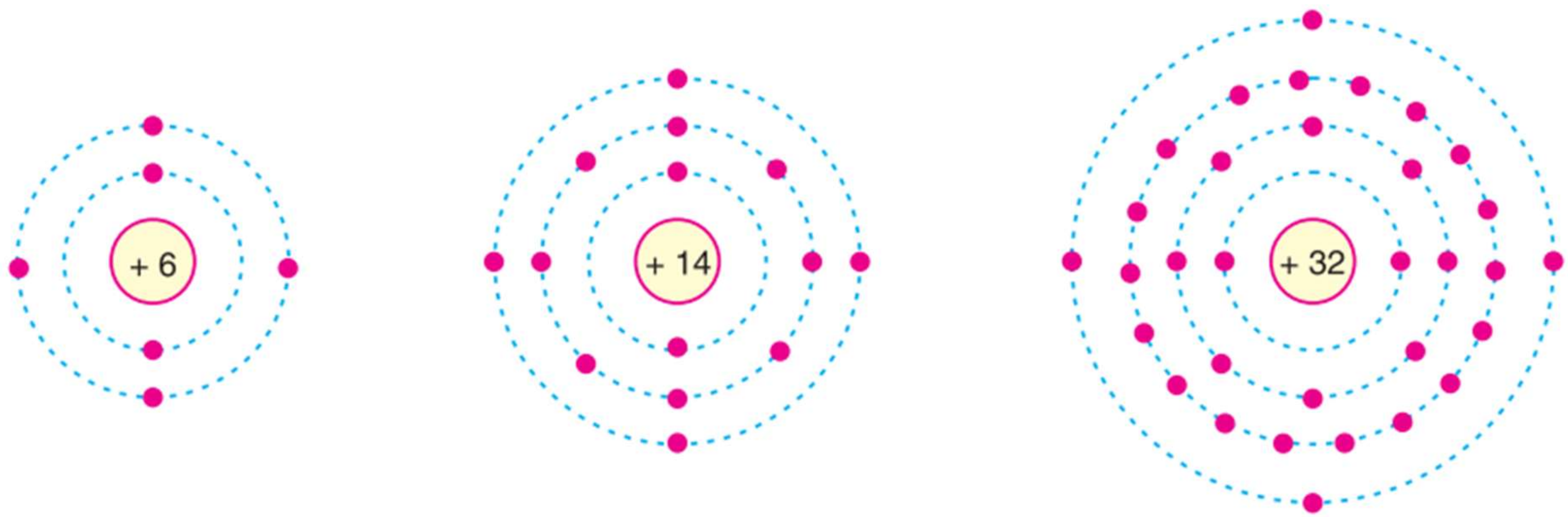
Fig. 1 Current conduction through semiconductor

Importance:

- Rectification
- Amplification
- Control
- Generation
- Conversion of light into electricity
- Conversion of electricity into light

Valence Electrons

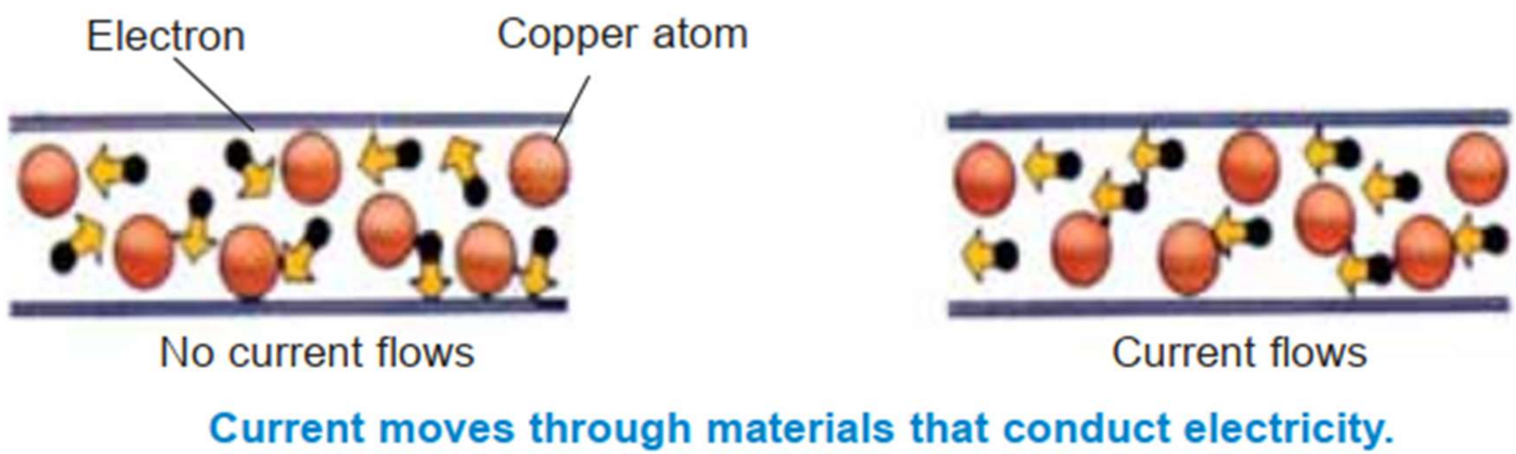
The electrons in the outermost orbit of an atom are known as valence electrons.



CARBON (*i*)   SILICON (*ii*)   GERMANIUM (*iii*)

Free Electrons

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

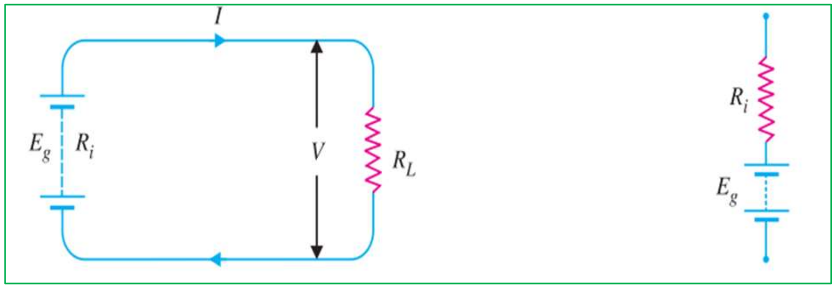


Voltage Source

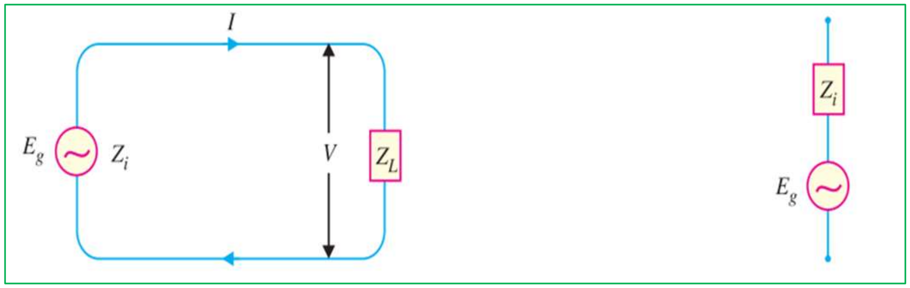
Any device that produces voltage output continuously is known as a voltage source.

There are two types of voltage sources:

- Direct voltage source
- Alternating voltage source.



DC Voltage Source



AC Voltage Source

Electron Emission

The liberation of electrons from the surface of a substance is known as **electron emission.**

The process of electron emission by supplying thermal energy at surface of a metal is known as Thermionic emission.

>strong electric field/ light

Types of Electron Emission:

- Thermionic emission: The process of electron emission from a metal surface by supplying thermal energy to it is known as thermionic emission.
- Field emission: The process of electron emission by the application of strong electric field at the surface of a metal is known as field emission.
- Photo-electric emission: Electron emission from a metallic surface by the application of light is known as photo electric emission.
- Secondary emission: Electron emission from a metallic surface by the bombardment of high-speed electrons or other particles is known as secondary emission.

Gas-Filled Tubes

A **gas-filled** tube is essentially a vacuum tube having a small amount of some inert gas at low pressure.

They may be classified into two types namely; *cold-cathode type* and *hot-cathode type:*

- Cold-cathode type
- Hot-cathode type

Gas-Filled Tubes (Applications)

Gas-filled tubes have various applications across different fields. Some common applications include:

i. **Lighting:** Gas-filled tubes such as neon lights and fluorescent tubes are used for illumination in signs, displays, and indoor lighting fixtures.

ii. **Voltage Regulation:** Gas discharge tubes can be used in surge protectors and voltage regulators to protect electronic devices from power surges and transient voltages.

iii. **Communication:** Gas-filled tubes like thyratrons and krytrons are used in high-speed switching applications in telecommunications and radar systems.

iv. **Gas Lasers:** Gas-filled tubes serve as the active medium in gas lasers, which are used in various applications such as cutting, welding, medical procedures, and scientific research.

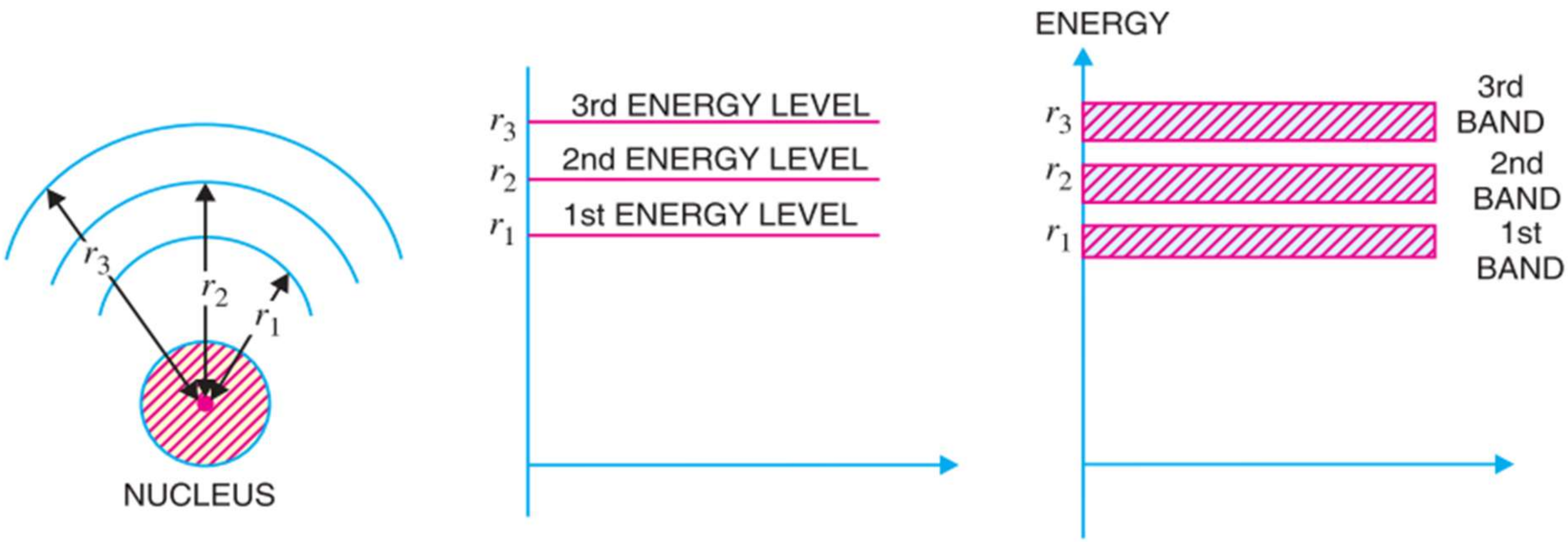
v. **Particle Detectors:** Gas-filled tubes are utilized in particle detectors for experimental physics research and in medical imaging devices like positron emission tomography (PET) scanners.

vi. **Ignition Systems:** Gas discharge tubes are used in ignition systems for gas-powered equipment such as gas stoves, water heaters, and gas-powered vehicles.

These are just a few examples, and there are many other specialized applications for gas-filled tubes depending on their specific properties and characteristics.

Energy Bands

The range of energies possessed by an electron in a solid is known as energy band.



(i) (ii) (iii)

Energy Bands

- The range of energies (i.e. band) possessed by valence electrons is known as valence band.
- The range of energies (i.e. band) possessed by conduction band electrons is known as conduction band.
- The separation between conduction band and valence band on the energy level diagram is known as forbidden energy gap.

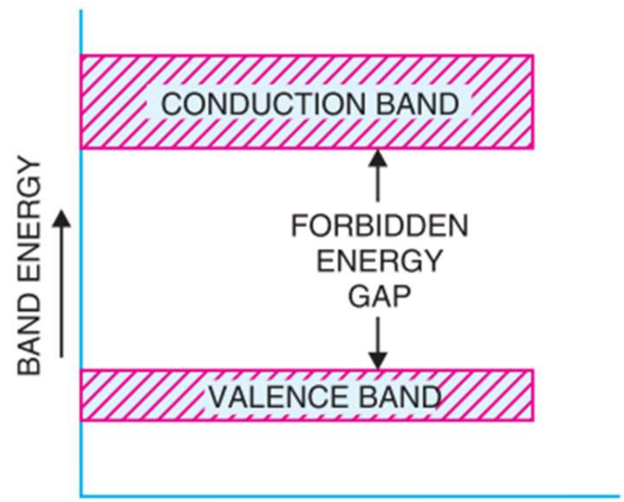
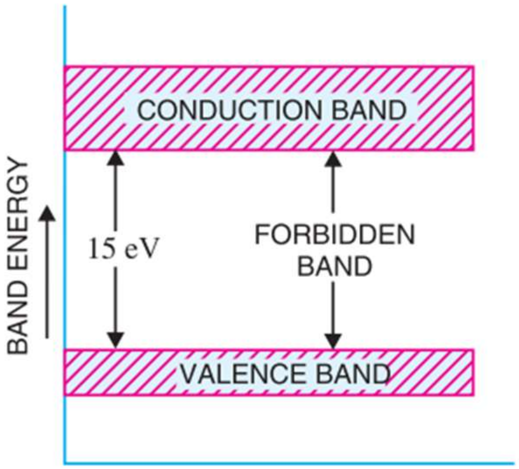
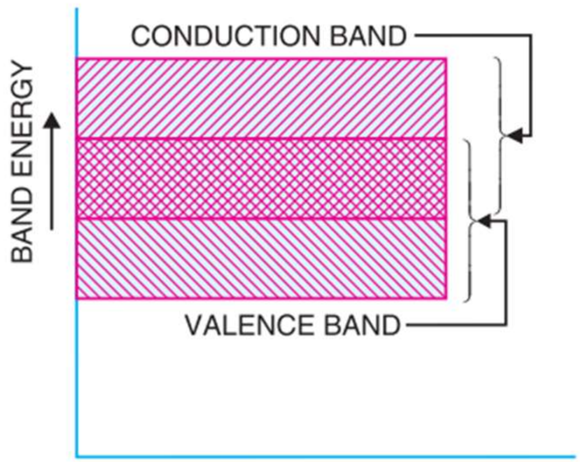


Fig. 4.4

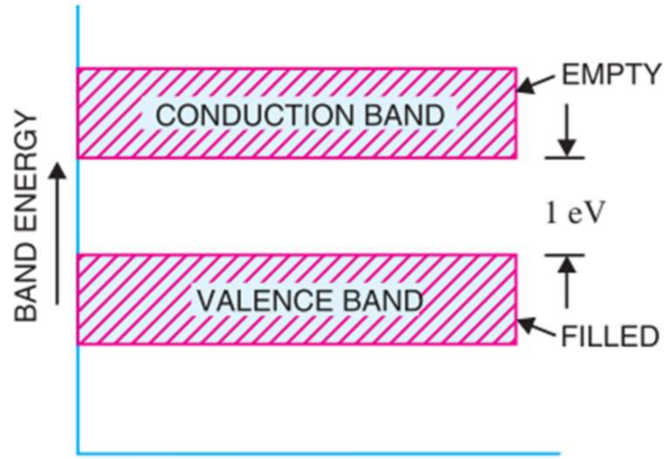
Energy Bands



Insulators

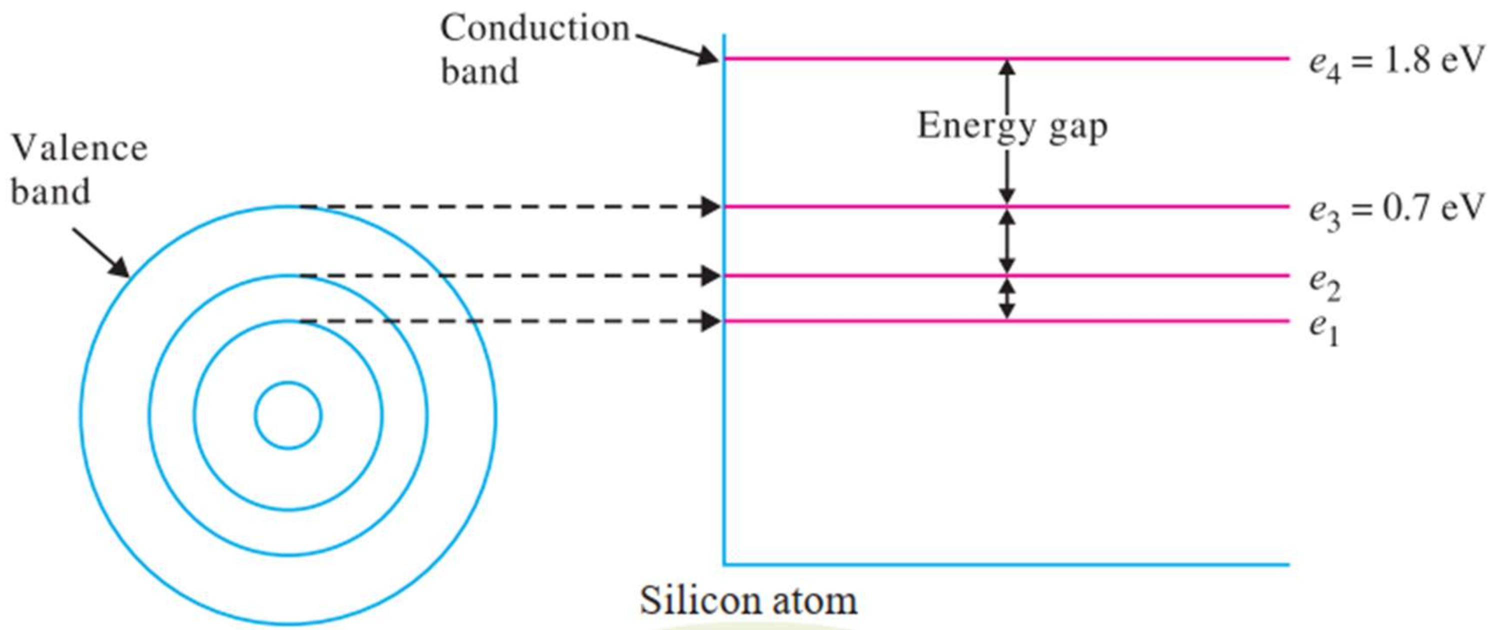


Conductor



Semiconductor

Energy Bands



For example, the valence band is shown to have an energy level of 0.7 eV. The conduction band is shown to have an energy level of 1.8 eV. Thus for an electron to jump from the valence band to the conduction band, an energy = 1.8 – 0.7 = 1.1 eV must be supplied.

Work Function

In physics, the work function refers to the minimum amount of energy required to remove an electron from the surface of a material and move it to a point just outside the material. It is typically denoted by the symbol Φ (phi) and is measured in electron volts (eV) or joules.

The work function of silicon, typically denoted by the symbol Φ, is approximately 4.85 electron volts (eV) at room temperature.

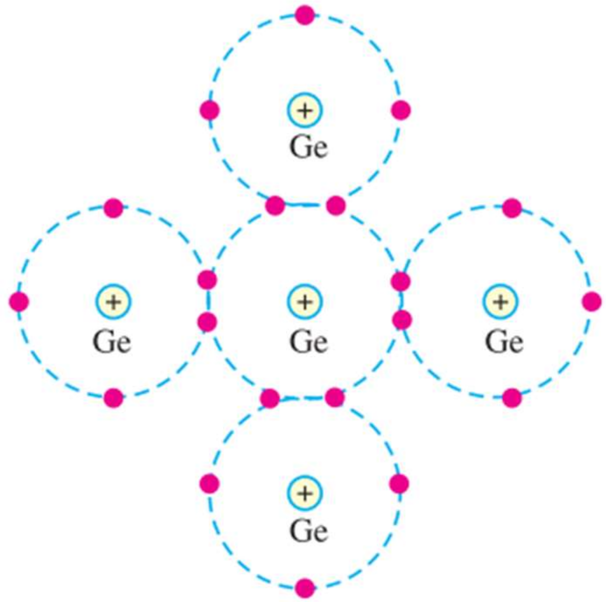
Semiconductor Physics

A semiconductor is a substance which has resistivity (10^{-4} to $0.5\ \Omega$ m) in between conductors and insulators e.g. germanium, silicon, selenium, carbon etc.

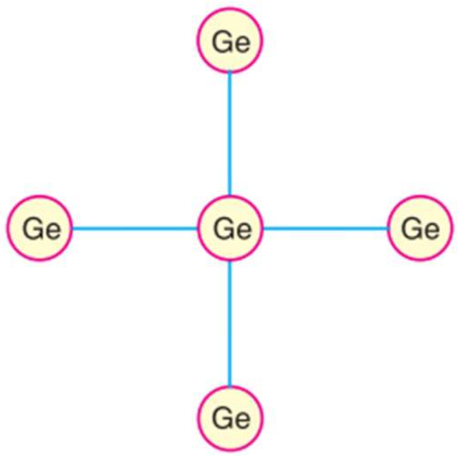
S.No.	Substance	Nature	Resistivity
1	Copper	good conductor	$1.7 \times 10^{-8}\ \Omega$ m
2	Germanium	semiconductor	$0.6\ \Omega$ m
3	Glass	insulator	$9 \times 10^{11}\ \Omega$ m
4	Nichrome	resistance material	$10^{-4}\ \Omega$ m

Semiconductor Physics

Bonds in Semiconductors (germanium atom):



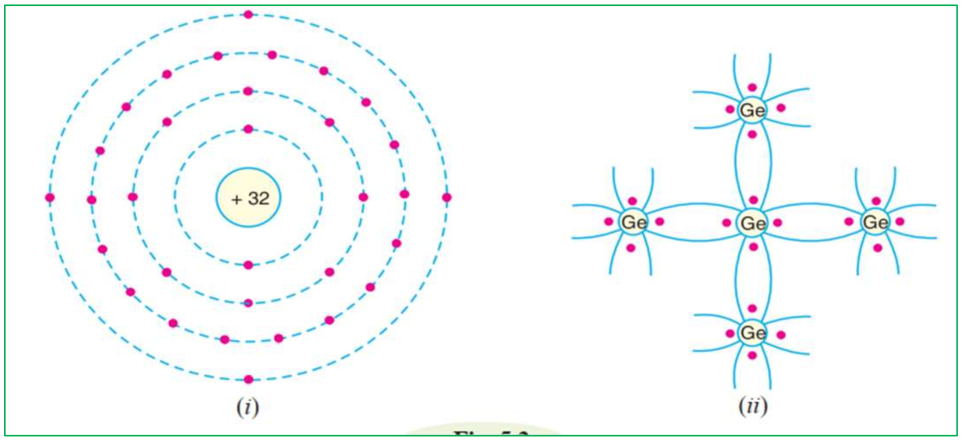
COVALENT BONDS AMONG Ge ATOMS

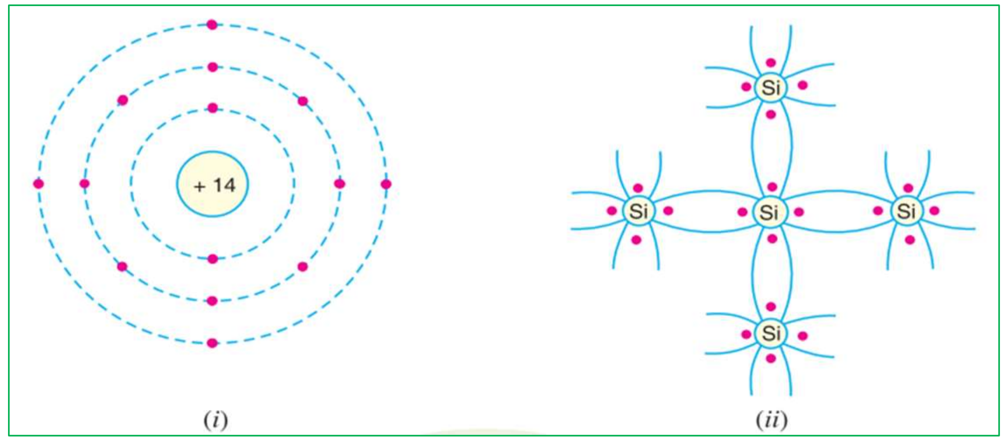


BONDING DIAGRAM

Semiconductor Physics

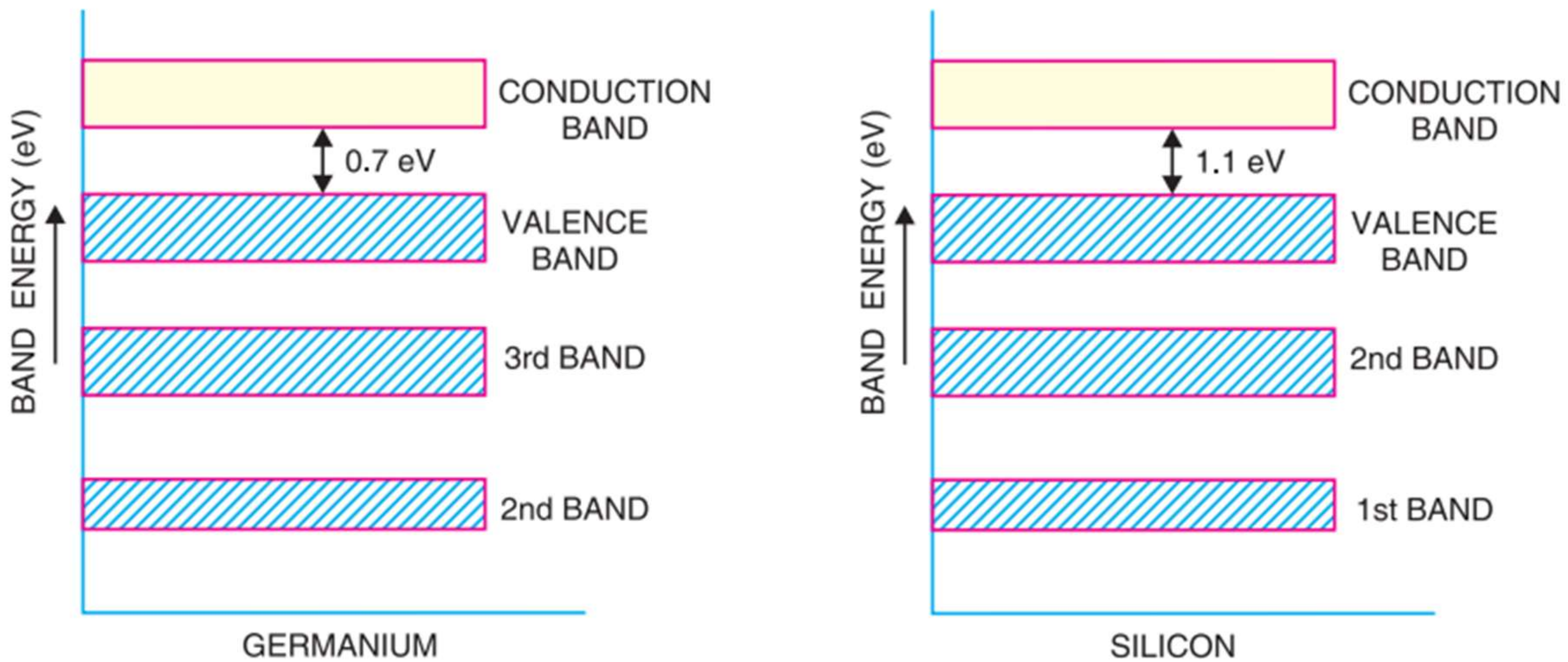
Commonly Used Semiconductors:





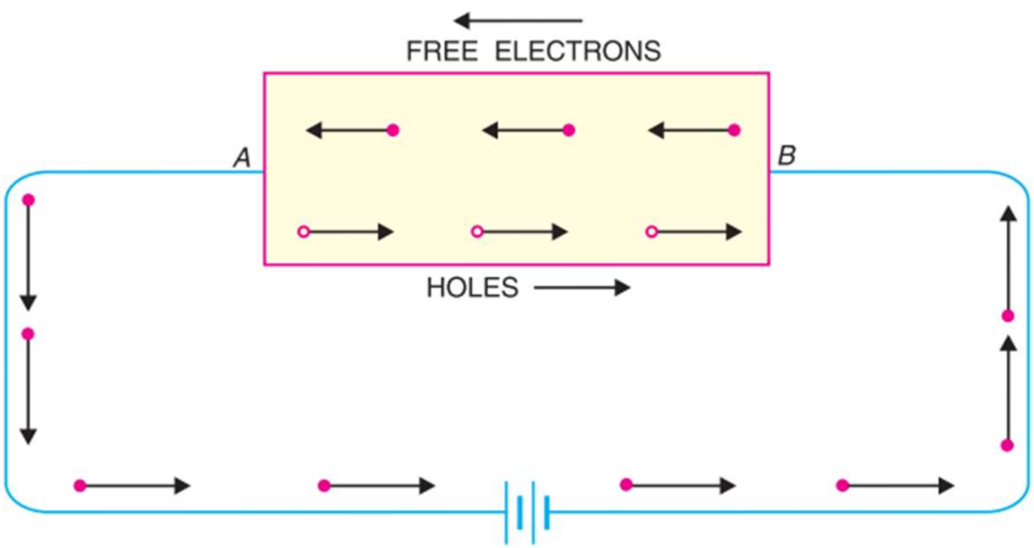
Semiconductor Physics

Energy Band Description of Semiconductors:



Semiconductor Physics

Intrinsic Semiconductor: A semiconductor in an extremely pure form is known as an intrinsic semiconductor.



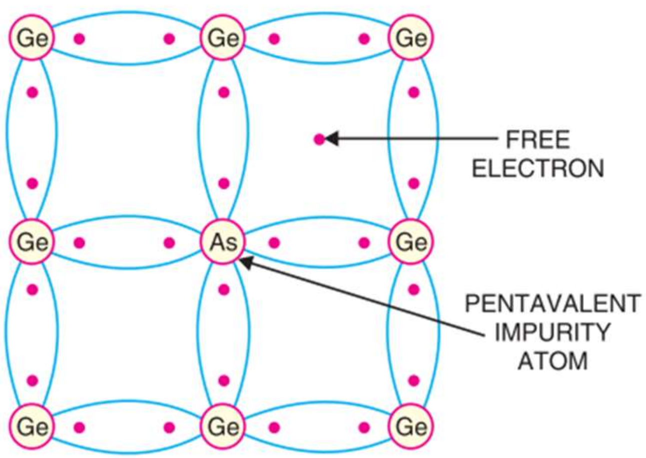
Semiconductor Physics

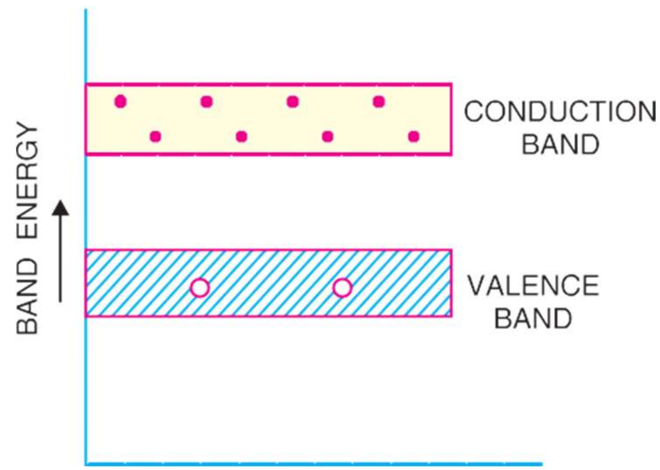
Extrinsic Semiconductor: The intrinsic semiconductor has little current conduction capability at room temperature. To be useful in electronic devices, the pure semiconductor must be altered so as to significantly increase its conducting properties. This is achieved by adding a small amount of suitable impurity to a semiconductor. It is then called impurity or extrinsic semiconductor. The process of adding impurities to a semiconductor is known as doping.

Depending upon the type of impurity added, extrinsic semiconductors are classified into:
(i) n-type semiconductor
(ii) p-type semiconductor

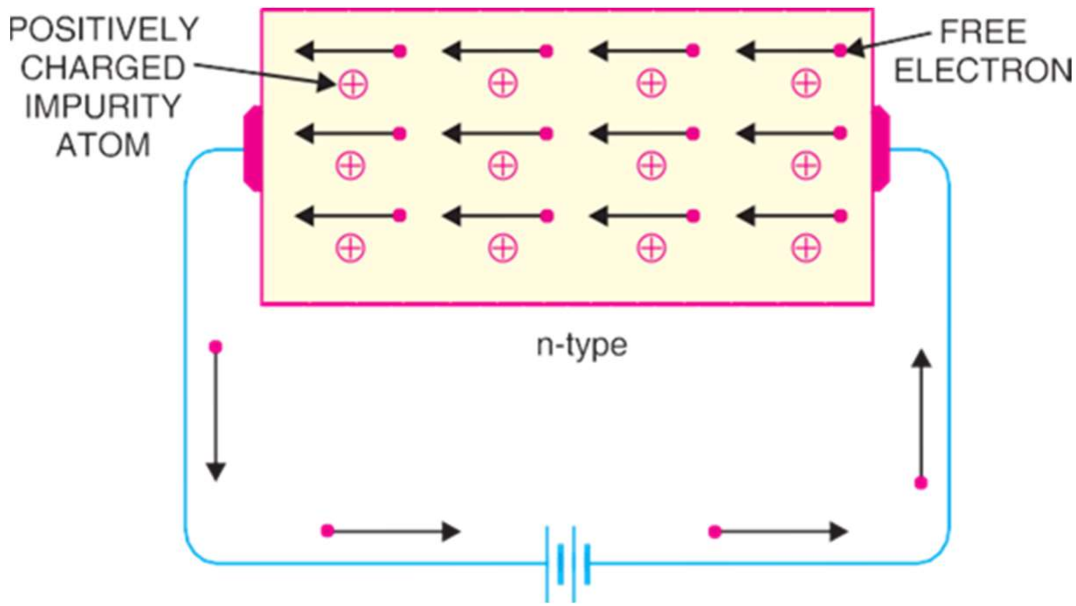
Semiconductor Physics

n-type Semiconductor: When a small amount of pentavalent impurity (arsenic, antimony etc.) is added to a pure semiconductor, it is known as n-type semiconductor. Such impurities which produce n-type semiconductor are known as donor impurities because they donate or provide free electrons to the semiconductor crystal.



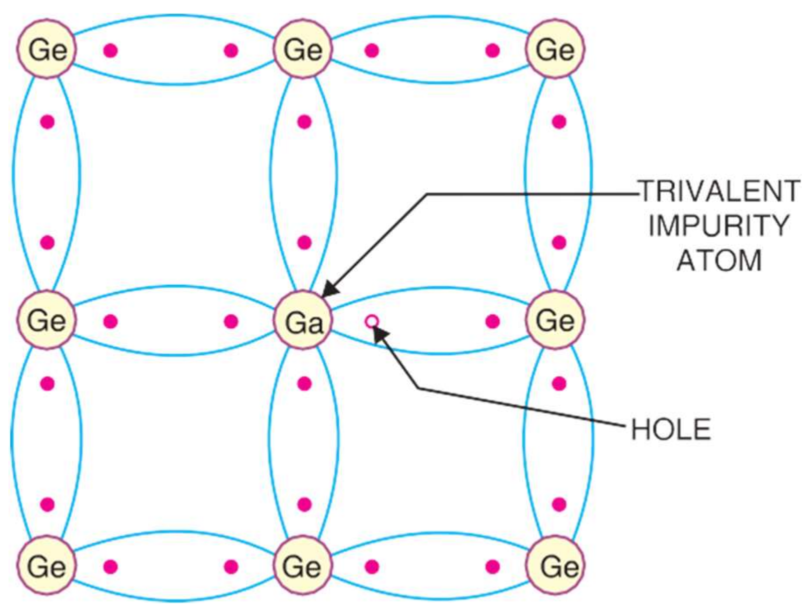


n-type conductivity. The current conduction in an *n*-type semiconductor is *predominantly* by free electrons *i.e.* negative charges and is called *n-type* or *electron type conductivity*.



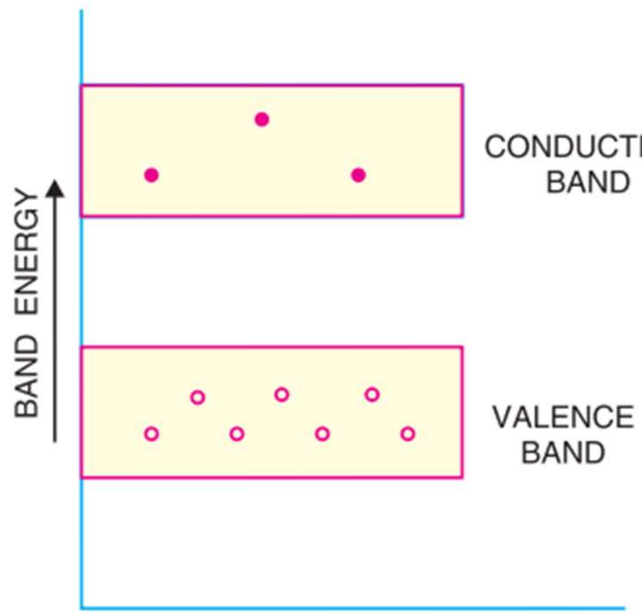
Semiconductor Physics

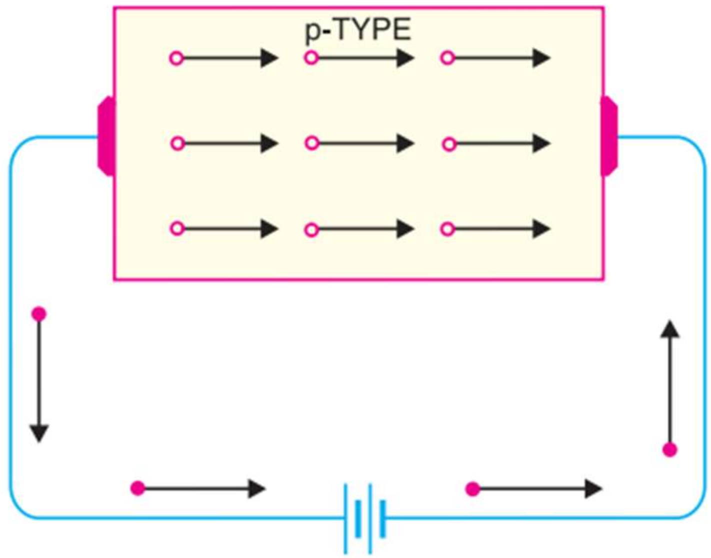
p-type Semiconductor: When a small amount of trivalent impurity (gallium, indium etc.) is added to a pure semiconductor, it is called p-type semiconductor. Such impurities which produce p-type semiconductor are known as acceptor impurities because the holes created can accept the electrons.



Semiconductor Physics

p-type conductivity: The current conduction in p-type semiconductor is predominantly by holes i.e. positive charges and is called p-type or hole-type conductivity.





Semiconductor Physics

Majority and Minority Carriers: An n-type material has its share of electron-hole pairs (released due to breaking of bonds at room temperature) but in addition has a much larger quantity of free electrons due to the effect of impurity. These impurity-caused free electrons are not associated with holes. Consequently, an n-type material has a large number of free electrons and a small number of holes as shown in Fig. 5.17 (i). The free electrons in this case are considered majority carriers — since the majority portion of current in n-type material is by the flow of free electrons — and the holes are the minority carriers.

Similarly, in a p-type material, holes outnumber the free electrons as shown in Fig. 5.17 (ii). Therefore, holes are the majority carriers and free electrons are the minority carriers.

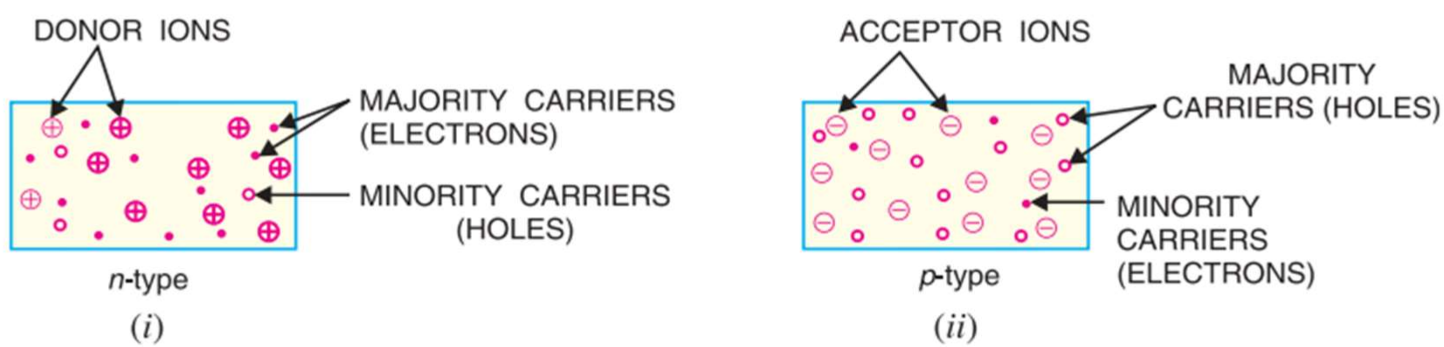


Fig. 5.17

To be continued…………….

Thanks a lot