Introduction

* **Engineering**: Engineering is the science of transforming knowledge in physics, chemistry and mathematics into products & system.

* **Electronics**: The branch of Engineering which deals with current conduction through a vacuum (or) gas (or) semiconductor is known as electronics.

* **Electronic device**: The device in which current flows through a vacuum (or) gas (or) semiconductor is called electronic device.

* **Applications of electronics (or) Importance of electronics**

(1) Rectification (2) Amplification (3) Conversion of light into electricity (4) Conversion of electricity into light etc

* **Structure of Solids**:

Solid (or) material (or) matter consists of atoms (or) molecules.

* **Atomic Structure**:

The atoms are the building bricks of all matter. An atom consists of a central nucleus of positive charge around which small negatively charged particles called electrons revolve in different paths (or) orbits.

Nucleus consists of protons & neutrons. A proton is a positively charged particle, while the neutron has no charge.

Note: ① Matter is also known as Material.

② Four states of matter are solid, liquid, gas & plasma.

③ An atom is the smallest unit consists of proton, neutron & electron.

④ A Molecule is formed when two (or) more atoms join together chemically.

⑤ A Compound is a molecule that contains at least two different elements.

⑥ An atom (or) molecule with a net electric charge due to the loss (or) gain of one (or) more electrons, is ion

⑦ A minute portion of matter is Particle (or) A particle is a small piece of anything

Ex: ① Atoms are particle for matter

② protons, neutrons & electrons are particles of an atom.

⑧ Mass of the proton = Mass of the neutron = 1.672×10^{-27} kg

⑨ Mass of electron = 9.1×10^{-31} kg

⑩ Charge of an electron = 1.602×10^{-19} C.

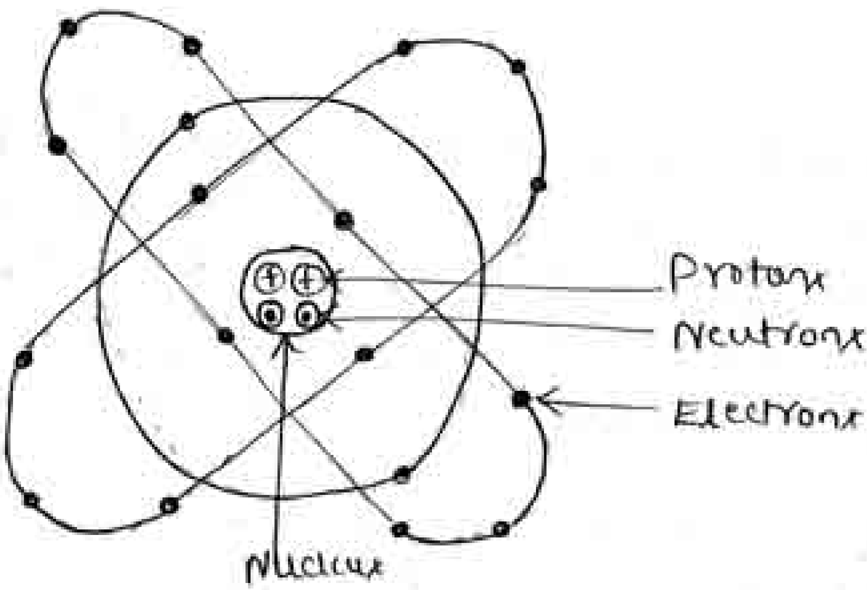
⑪ Some basic arrangement of atoms is repeated throughout the entire solid material is called crystal lattice. Such solids are called crystalline solids.

- Solid materials which donot have crystalline structure are called non-crystalline or amorphous solids.

Ex: All metals & elements like Silicon & germanium are crystalline materials.
Wood, Plastic, Paper, glass etc are amorphous materials.

⑫ Atomic weight (Atomic mass) = no of Protons + no of neutrons.
Atomic number = no of protons or electrons in an atom.

⑬ In a normal atom the number of Protons = no of electrons. (Atom is neutral)



Structure of an atom.

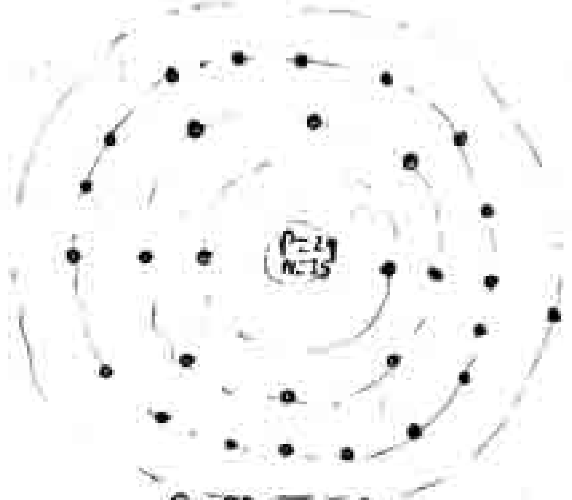
⑭ The electrons in an atom revolve around the nucleus in different orbits or Paths. The numbers and arrangement of electrons in any orbit is determined by the following rules:

(i) The number of electrons in any orbit $= 2n^2$.

$n \rightarrow$ number of the orbit.

First orbit contains $2 \times 1^2 = 2$ electrons etc

(ii) The last orbit cannot have more than 8 electrons.
(iii) The last but one orbit cannot have more than 18 electrons.



Copper P=29
N=35
e=29

---

* **Energy of an electron:**

An electron moving around the nucleus possesses two types of energies viz. kinetic energy due to its motion & potential energy due to the charge on the nucleus. The total energy of the electron is the sum of these two energies.

The energy of an electron increases as its distance from the nucleus increases. The electron in the last orbit possess very high energy as compared to the electrons in the inner orbits.

* **Electron orbits:**

The orbits are represented by the letters K, L, M, N, etc counted from the nucleus to outwards. Sometimes K, L, M, N etc are also designated as 1, 2, 3, 4 etc

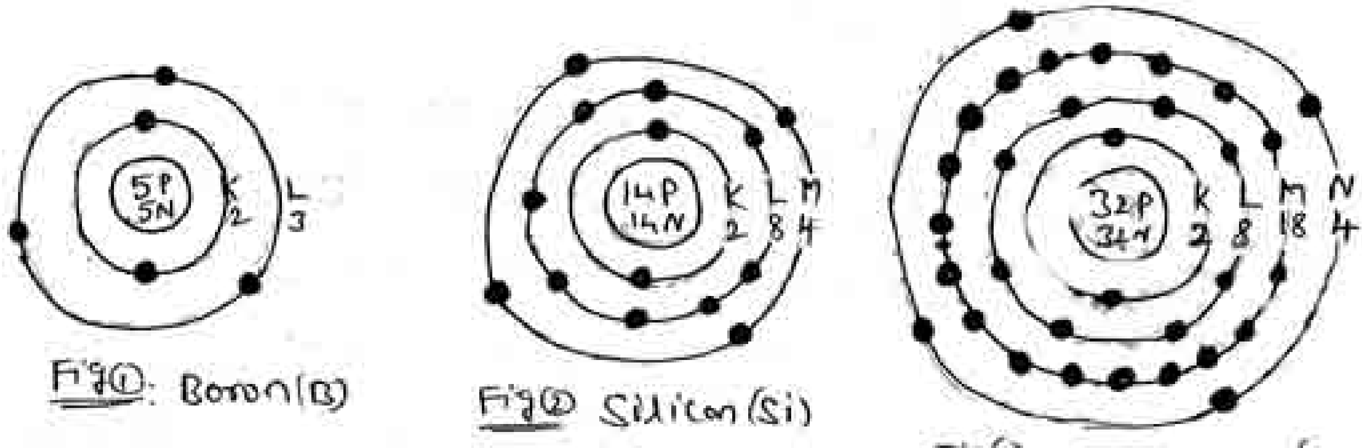
* **Distribution of electrons in atoms**

→ Atomic number of boron is 5.

It has 5 protons & 5 electrons.

Two electrons occupy the K-shell, which is then said to be completely filled. The other 3 electrons occupy the L-shell as shown in fig ①

→ Atomic number of Silicon is 14.



Fig①: Boron(B)   Fig② Silicon(Si)   Fig③: Germanium(Ge)

It has 14 protons and 14 electrons.

2 electrons occupy the K-shell, 8 in L-shell & 4 in the M-shell as shown in fig ②.

→ Atomic number of germanium is 32.

It has 32 protons and 32 electrons.

2 electrons occupy the K-shell, 8 in L-shell, 18 in M-shell and 4 in N-shell as shown in fig ③

Note:

① Each electron orbit (main shell) in an atom consists of no of sub-orbits (or) sub-shells. The no of sub-orbits is equal to the no of its principal quantum no (n).

Ex: K-shell → one sub-orbit

L shell (n=2) → 2 sub-orbits

M shell (n=3) → 3 sub-orbits etc

* Energy possessed by an electron in the orbit

→ Some energy is emitted by an electron, when it moves from a higher orbit to a lower orbit.

→ Similarly, some energy is absorbed by an electron when it moves from a lower orbit to a higher orbit.

→ The amount of energy emitted (or absorbed) is.

$$W_2 - W_1 = hf \quad \text{Joules}$$

- Where.
  - W_1 → Energy of the initial orbit
  - W_2 → Energy of the final orbit.
  - h → Planck's constant $= 6.626 \times 10^{-34}$ Js
  - f → frequency of radiation.

→ The total energy (both kinetic and potential) possessed by an electron, when it revolves in the nth orbit of an atom, with atomic number Z, is.

$$W_n = -21.76 \times 10^{-19} \frac{Z^2}{n^2} \quad \text{Joules}$$

→ Energy of an electron (in electron volts) is.

$$E_n = \frac{-21.76 \times 10^{-19}}{1.6 \times 10^{-19}} \frac{Z^2}{n^2} = -13.6 \times \frac{Z^2}{n^2} \text{ eV}$$

Smaller unit of energy is electron volt. $1 \text{ eV} = 1.602 \times 10^{-19}$ Joules

* Energy levels & Energy level diagram :

→ Electrons can occupy only certain orbital rings or shells at fixed distances from the nucleus.

→ The electrons in the outer shell determine the electrical and chemical properties of a material.

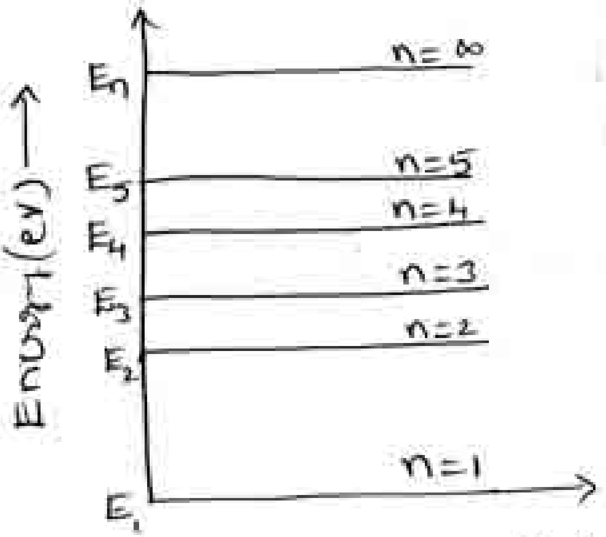
→ The closer an electron is to the nucleus, the stronger are the forces that bind it to the atom.

→ Each shell has an energy level associated with it that represents the amount of energy required to extract an electron from the atom.

→ Least amount of energy is required to extract the electrons from valence shells.

→ Greatest energy is required to extract the electrons from the orbits which are closest to the nucleus.

→ The diagram in which we plot the energies corresponding to K, L, M... etc shells is known as energy level diagram (fig *)



Fig(*) : Energy level diagram

→ When the electron is present in the first orbit (n=1), it is said to be in its normal (or) ground state.

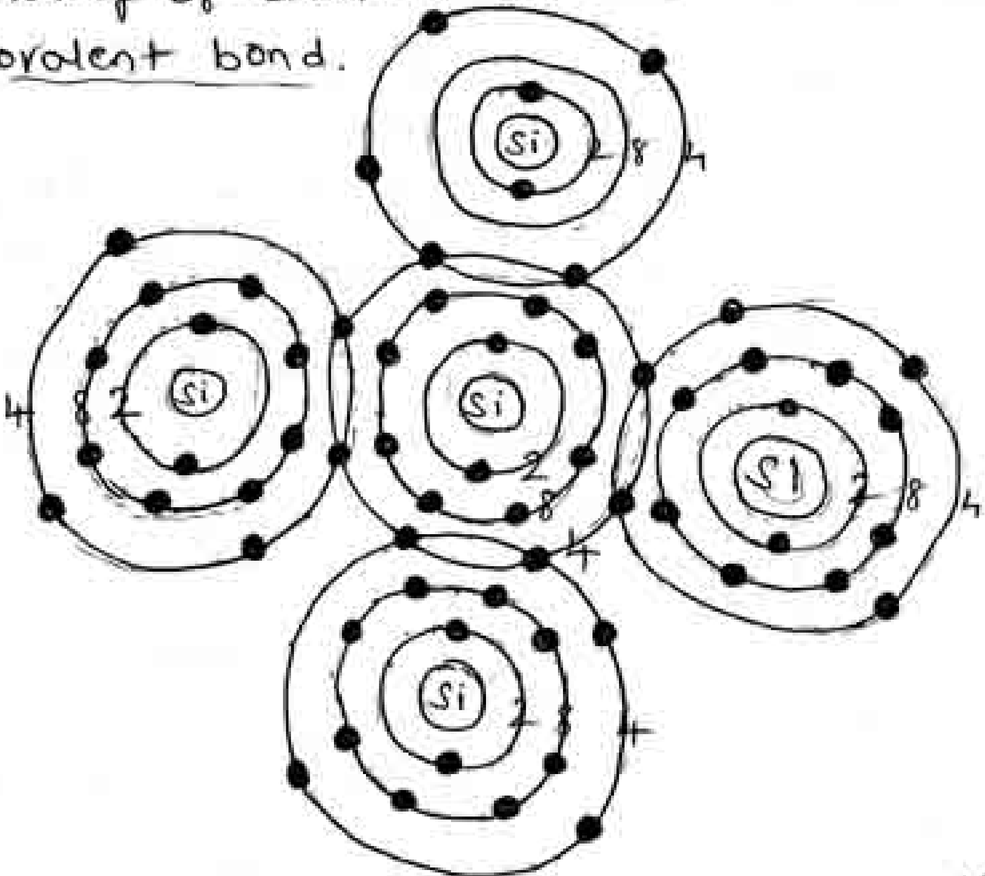
→ If the electron is present in the higher orbits, it is said to be in the excited state.

Note:

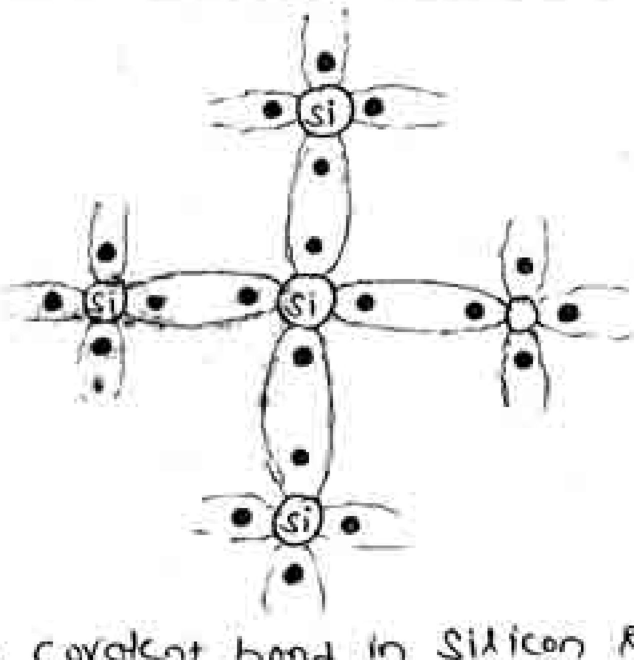
① Interatomic bonds: The bond formed between the atoms in the solid (interatomic forces) is called Interatomic bond.

② <u>Ionic bond</u>: The bond formed between two oppositely charged ions, which are produced by the transfer of electrons from one atom to another, is called <u>ionic bond</u> (or) <u>Electrovalent bond</u>.

③ <u>Covalent Bond</u>: The bond which is formed by the sharing of electrons between two atoms, is called <u>Covalent bond</u>.



<u>Fig</u>: Formation of covalent bond in silicon crystal



<u>Fig</u>: covalent bond in silicon structure

4. Metallic bond:

In metal atoms, the electrons in the outer most shells are loosely held by their nucleus. So electrons in the outer shell require a very small amount of energy to detach themselves from their nuclei. At room temp., all the metal atoms lose their outermost shell electrons, which form an electron cloud (or) common pool of electrons. These electrons have a freedom to move any where within the crystal. The atoms, after losing their outermost shell electrons, acquire positive charges and become positive ions. The electrostatic force of attraction b/w the electron cloud and positive ions forms a bond, known as Metallic bond. (It takes place in metals only)

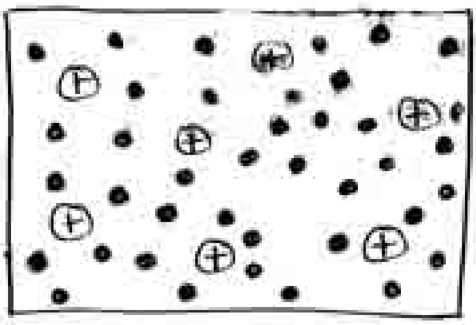
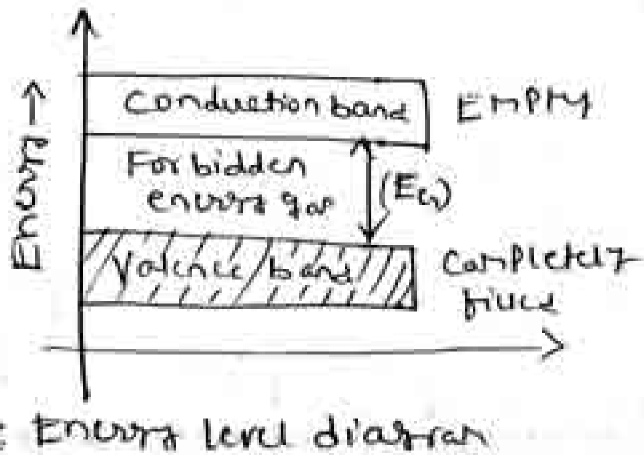


Fig: Metallic bond

5. Energy bands:

→ The energy levels form continuous bands of allowed energy, which the electrons may occupy.



→ Each band consists of a large number of very closely spaced discrete energy levels. (The range of energies possessed by an electron in a solid is known as energy band)

Fig: Energy level diagram

* **Valence electrons :**

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

* **Free electrons:**

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

The free electrons can be easily removed (or) detached by applying a small amount of external energy

* **Classification of Solids (Materials):**

Based on electrical properties, materials are generally classified into conductors, insulators and semiconductors.

① **Conductor:** Metal

→ No of valence electrons of an atom is less than 4. Ex: Sodium, magnesium, aluminium etc

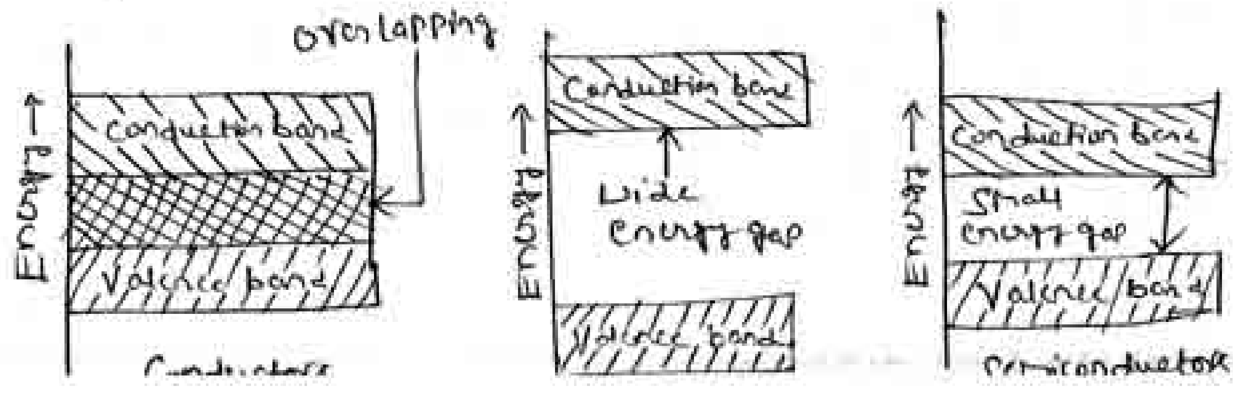
→ Large no of free electrons exists.

→ When P.d is applied across a conductor, the free electrons move towards the positive polarity of supply constituting electric current.

→ Positive temperature coefficient of resistance

→ Conduction & valence bands overlap.

→ Resistance is in the order of $10^{-6}\Omega$.



② Insulators: (Non-metal) (Dielectric materials)

→ No of valence electrons of an atom is more than 4.

Ex: Nitrogen, Sulphur, neon etc

→ Insulator has practically no free electrons at ordinary temperature.

→ Conduction and valence bands are seperated by a wide energy gap($\simeq$15eV)

→ have very high resistivity ($10^{14}\Omega$) & low conductivity.

→ If temperature is raised, some of the valence electrons may acquire energy and jump into the conduction band. & hence resistivity decreases. (negative temperature coefficient)

③ Semiconductors:

→ No of valence electrons of an atom is 4.

Ex: Carbon, Silicon, germanium etc

→ Very few electrons at room temperature

→ Very small energy gap ($\simeq$ 1eV)

→ Resistivity is of the order 10^{-4} to 0.5 Ωm. (1eV)

→ Conductivity & resistivity lies btw insulators & conductors.

→ Small amount of energy is required to free the electrons by moving them from the valence band into the conduction band.

→ behave like insulators at 0K (no electrons in the conduction band). However at room temp, a significant no of electrons are available in the conduction band.

→ Semiconductors also have negative temperature coefficient of resistance.

Note:

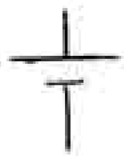
① Voltage source

There are two types of Voltage sources, namely.

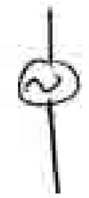
(i) Direct Voltage source (ii) Alternating Voltage source.

Ex: Cell, dc generator | Ex: Ac generator.

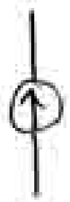
Symbol:



Symbol:



② current source



③ Electric current: The movement of electric charge is called an Electric current, denoted by I (A)

The conventional current flow is opposite to electron flow.

④ Passive elements

(i) Resistance (Ω)

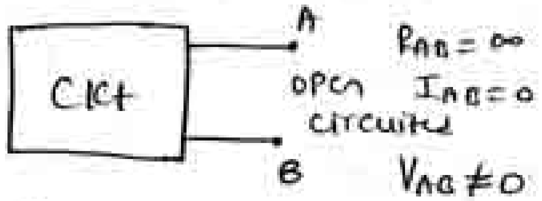
(ii) Capacitance (F)

(iii) Inductance H

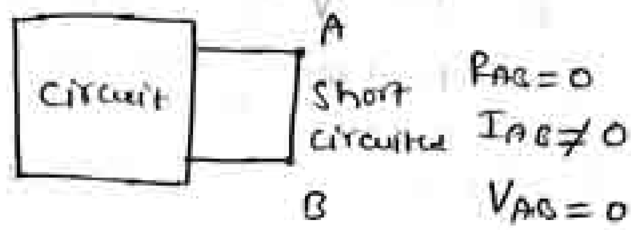
⑤ conductance. $G = \frac{1}{R}$ · siemens (S) or mho

Conductivity · $\sigma = \frac{1}{\rho\,(\Omega\text{-}m)}$ (S/m) or ($℧$/m)

6. Open and Short circuits



Open circuit



Short circuit

7. Kirchhoff's laws:

1. Kirchhoff's current law (KCL):

"In any network, the algebraic sum of currents at any junction is zero"

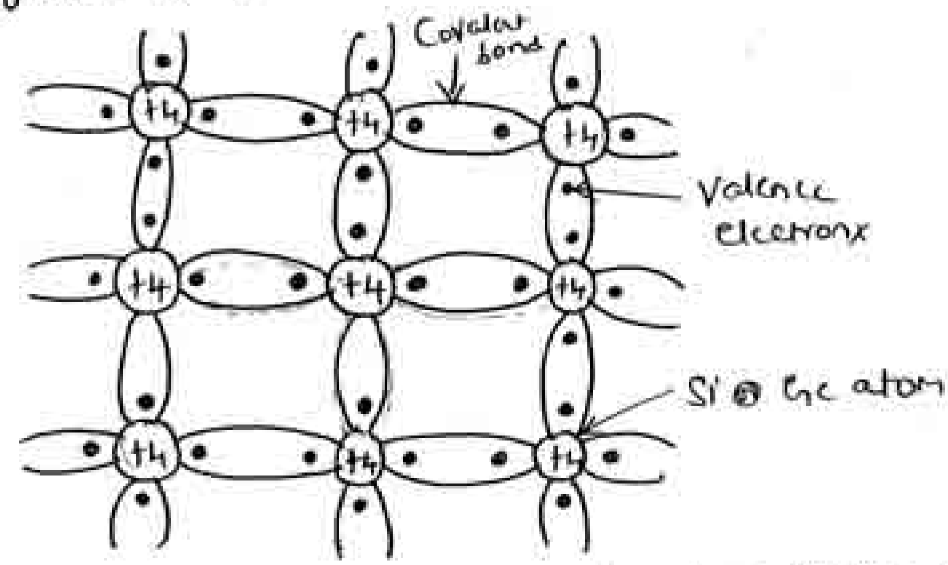
2. Kirchhoff's voltage law:

"In any network, the sum of all the voltages around a closed path (of a loop) is zero".

Types of semiconductors

1. Intrinsic 2. Extrinsic

1. Intrinsic: A semiconductor which is in its extremely pure form is known as an intrinsic or pure semiconductor.



Two dimensional representation of a Silicon or a germanium

→ At 0K ⓞ 273°c (Absolute zero temperature)

All the valence electrons are tightly held by the parent atoms., therefore they cannot conduct electricity.

→ At 27°c (or) 300k (Room temperature)

Some of the covalent bonds are broken, the electrons are free to move anywhere within the crystal. & hence vacancies (holes) are created, therefore they conduct current.

② Extrinsic : The semiconductors which are obtained by adding a certain amount of desired impurity atoms to pure semiconductor are called Extrinsic semiconductors

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

(i) n-type (ii) p-type

(i) n-type: The semiconductors which are obtained by adding pentavalent atoms (ie atoms containing 5 valence electrons) are known as n-type semiconductors

Exs of pentavalent impurities are arsenic (As), antimony (Sb), Phosphorus (P), & Bismuth (B) [Donor]

(ii) P-type : The semiconductors, which are obtained by adding trivalent impurity atoms (ie atoms containing 3 valence electrons) are known as P-type semiconductors

Exs of trivalent impurities are gallium (Ga), indium (In), aluminium (Al), Boron (B) etc [Acceptor]

Note:

① In an n-type material, the electron is called the majority carrier and the hole the minority carrier.

② In a p-type material, the hole is the majority carrier and the electron is the minority carrier.

③ The current produced due to drifting of free electrons is called drift current (when voltage is applied)

④ The current produced due to diffusion (charge carriers move from high charge density to the low carrier (charge) density) is called diffusion current (without voltage)

⑤ The process of adding impurity atoms to a pure semiconductor is called doping.

⑥ The impurity atoms added to pure semiconductor are called dopants

⑦

Si	Ge
① Barrier voltage at 25°c is 0.7V	① Barrier voltage at 25°c is 0.3V.
② The forward Vtg drop is 0.7V	② The forward Vtg drop is 0.3V
③ Atomic number is 14.	③ Atomic number is 32
④ It has 14 protons & 14 electrons	④ It has 32 protons & 32 electrons.
⑤ 4 valence electrons	⑤ 4 valence electrons
⑥ Resistivity at 20°c is 2500 Ω-m	⑥ Resistivity at 20°c is 0.45 Ω-m

7. At room temperature, the intrinsic concentration is $1.5 \times 10^{16}/m^3$	7. At room temperature, the intrinsic concentration is $2.5 \times 10^{19}/m^3$
8. The maximum temperature rating is about 200°c	8. The maximum temperature rating is about 100°c.
9. Higher PIV & current rating compared to Ge	9. Lower PIV & current rating compared to Si
10. Reverse saturation current is less	10. Reverse saturation current is high