APPLIED PHYSICS

Semiconductors

UNIT IV

Semiconductor

- *Semiconductors are materials whose electronic properties are intermediate between those of Metals and Insulators.*

- *They have conductivities in the range of 10^{-4} to 10^{+4} S/m.*

- *The interesting feature about semiconductors is that they are bipolar and current is transported by two charge carriers of opposite sign.*

- *These intermediate properties are determined by*

  1.Crystal Structure bonding Characteristics.

  2.Electronic Energy bands.

- ***Silicon*** *and* ***Germanium*** *are elemental semiconductors and they have* ***four valence electrons*** *which are distributed among the outermost* ***S and p*** *orbital's.*

- *These outer most* ***S and p*** *orbital's of Semiconductors involve in* ***Sp^3 hybridanisation****.*

- *These* ***Sp^3 orbital's*** *form* ***four covalent*** *bonds of equal angular separation leading to a* ***tetrahedral*** *arrangement of atoms in space results* ***tetrahedron*** *shape, resulting crystal structure is known as* ***Diamond cubic*** *crystal structure*

Semiconductors are mainly two types

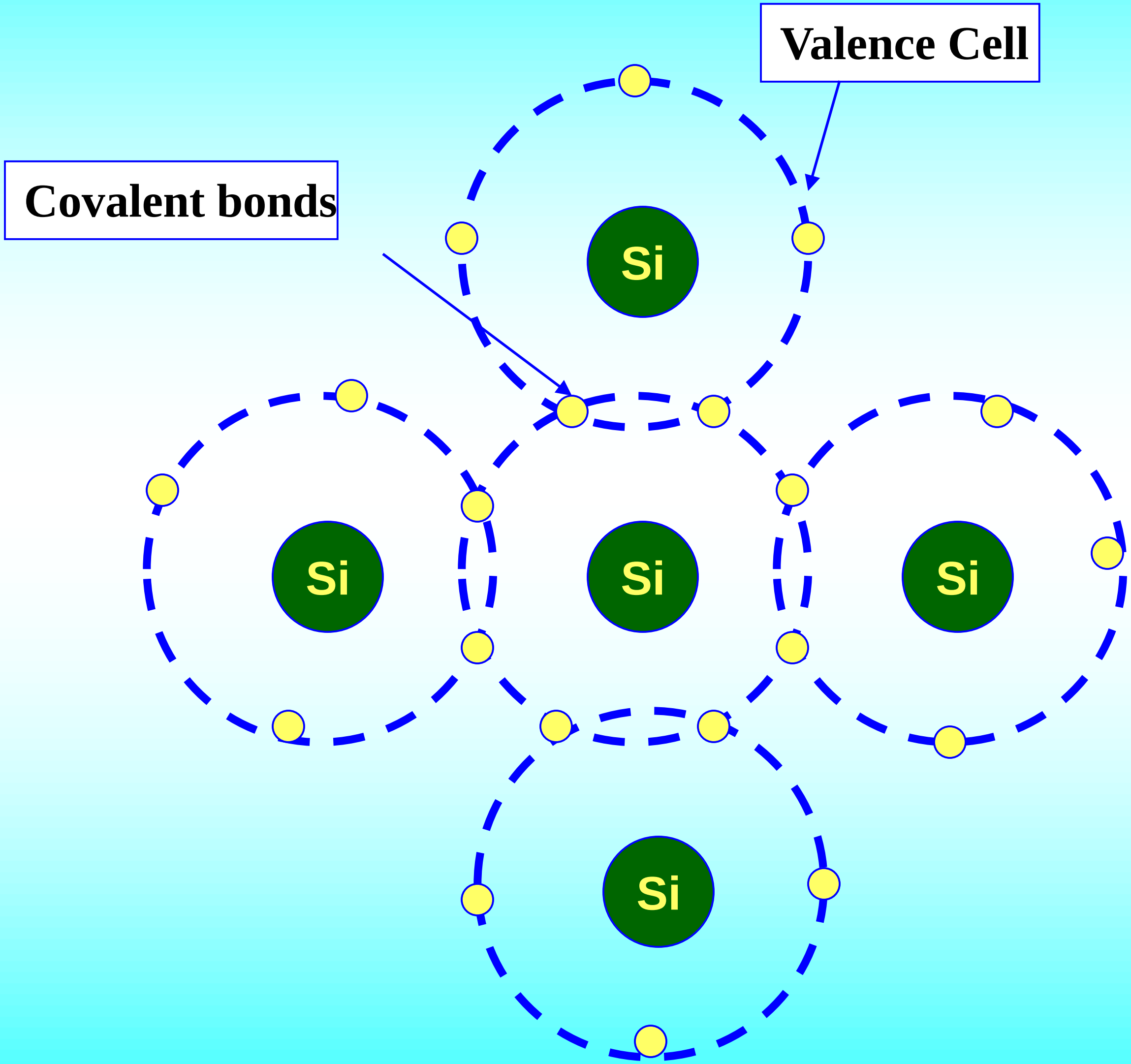
1. ***Intrinsic (Pure) Semiconductors***
2. ***Extrinsic (Impure) Semiconductors***

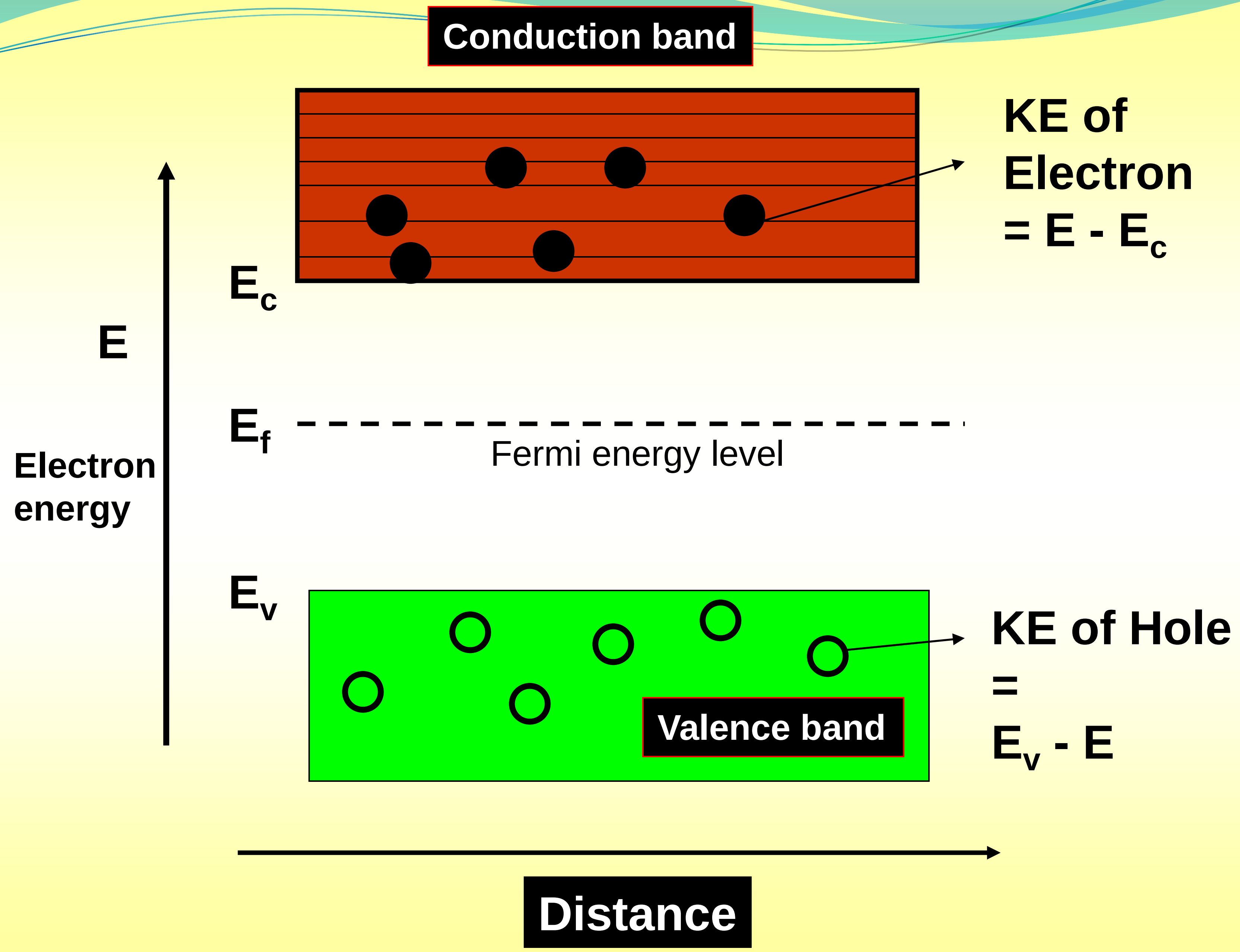
Intrinsic Semiconductor

- ***A Semiconductor which does not have any kind of impurities, behaves as an Insulator at 0k and behaves as a Conductor at higher temperature is known as Intrinsic Semiconductor or Pure Semiconductors.***

- ***Germanium and Silicon (4^{th} group elements) are the best examples of intrinsic semiconductors and they possess diamond cubic crystalline structure.***

Intrinsic Semiconductor





Conduction band
KE of Electron = E - E_c
E_c
E
E_f
Fermi energy level
Electron energy
E_v
KE of Hole = E_v - E
Valence band
Distance

Carrier Concentration in Intrinsic Semiconductor

When a suitable form of Energy is supplied to a Semiconductor then electrons take transition from Valence band to Conduction band.

Hence a free electron in Conduction band and simultaneously free hole in Valence band is formed. This phenomenon is known as Electron - Hole pair generation.

In Intrinsic Semiconductor the Number of Conduction electrons will be equal to the Number of Vacant sites or holes in the valence band.

Extrinsic Semiconductors

- The Extrinsic Semiconductors are those in which impurities of large quantity are present. Usually, the impurities can be either 3rd group elements or 5th group elements.

- Based on the impurities present in the Extrinsic Semiconductors, they are classified into two categories.

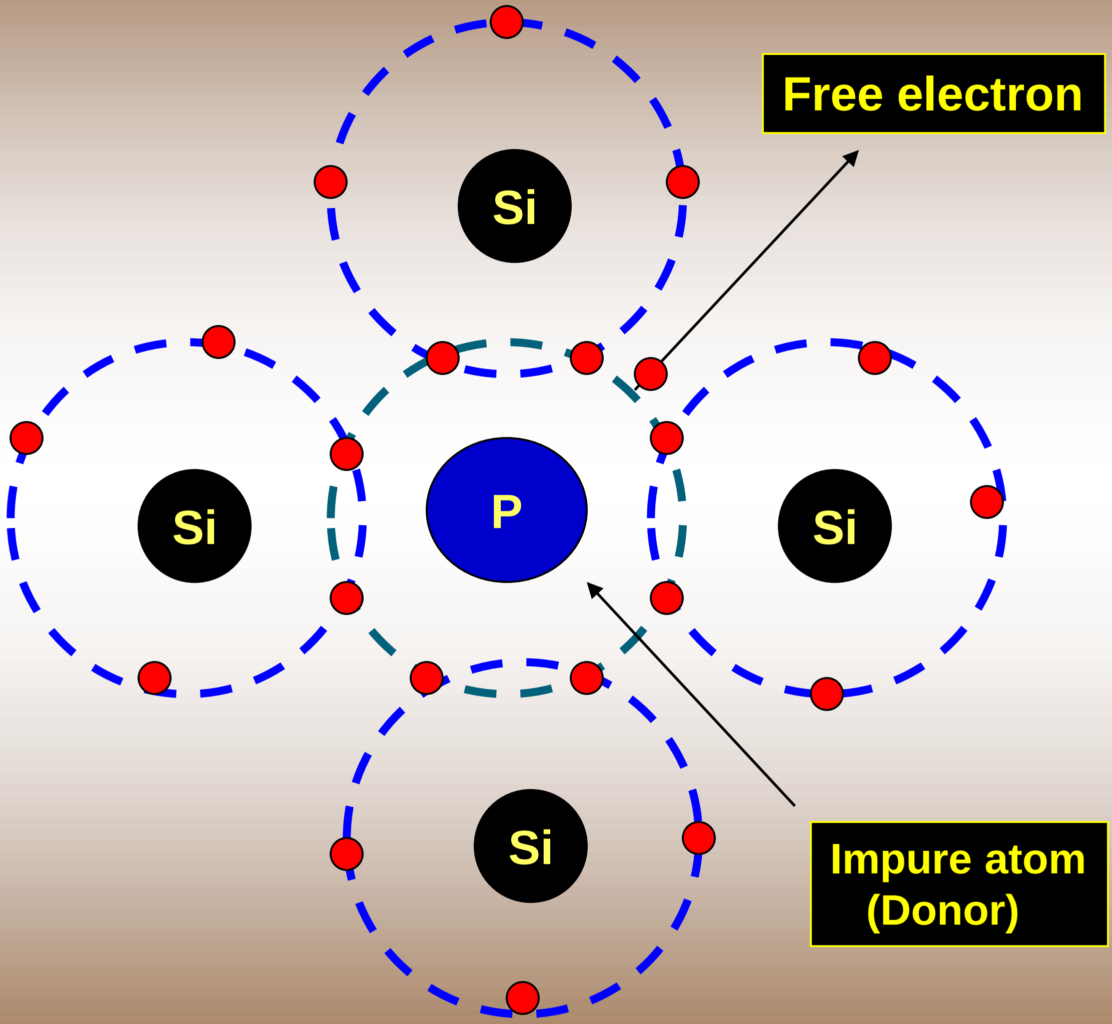
  1. **N-type** semiconductors
  2. **P-type** semiconductors

N - type Semiconductors

When any pentavalent element such as Phosphorous, Arsenic or Antimony is added to the intrinsic Semiconductor , four electrons are involved in covalent bonding with four neighboring pure Semiconductor atoms.

The fifth electron is weakly bound to the parent atom. And even for lesser thermal energy it is released Leaving the parent atom positively ionized.

N-type Semiconductor

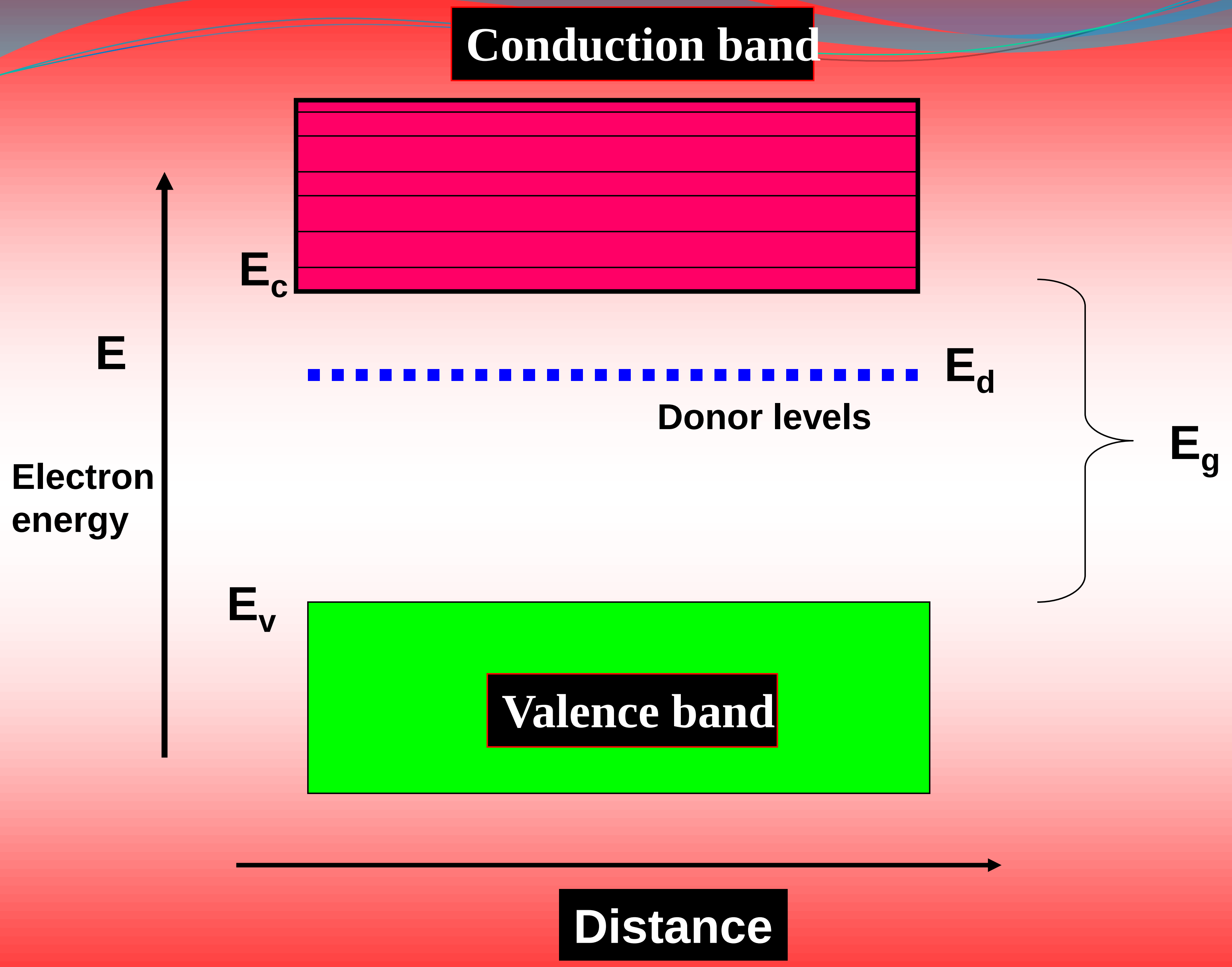


The Intrinsic Semiconductors doped with pentavalent impurities are called N-type Semiconductors.

The energy level of fifth electron is called donor level.

The donor level is close to the bottom of the conduction band most of the donor level electrons are excited in to the conduction band at room temperature and become the Majority charge carriers.

Hence in N-type Semiconductors electrons are Majority carriers and holes are Minority carriers.


Conduction band
E
Electron
energy
E_c
E_d
Donor levels
E_g
E_v
Valence band
Distance

Carrier Concentration in N-type Semiconductor

- Consider N_d is the donor Concentration i.e., the number of donor atoms per unit volume of the material and E_d is the donor energy level.

- At very low temperatures all donor levels are filled with electrons.

- With increase of temperature more and more donor atoms get ionized and the density of electrons in the conduction band increases.

Variation of Fermi level with temperature

To start with ,with increase of temperature E_f increases slightly.

As the temperature is increased more and more donor atoms are ionized.

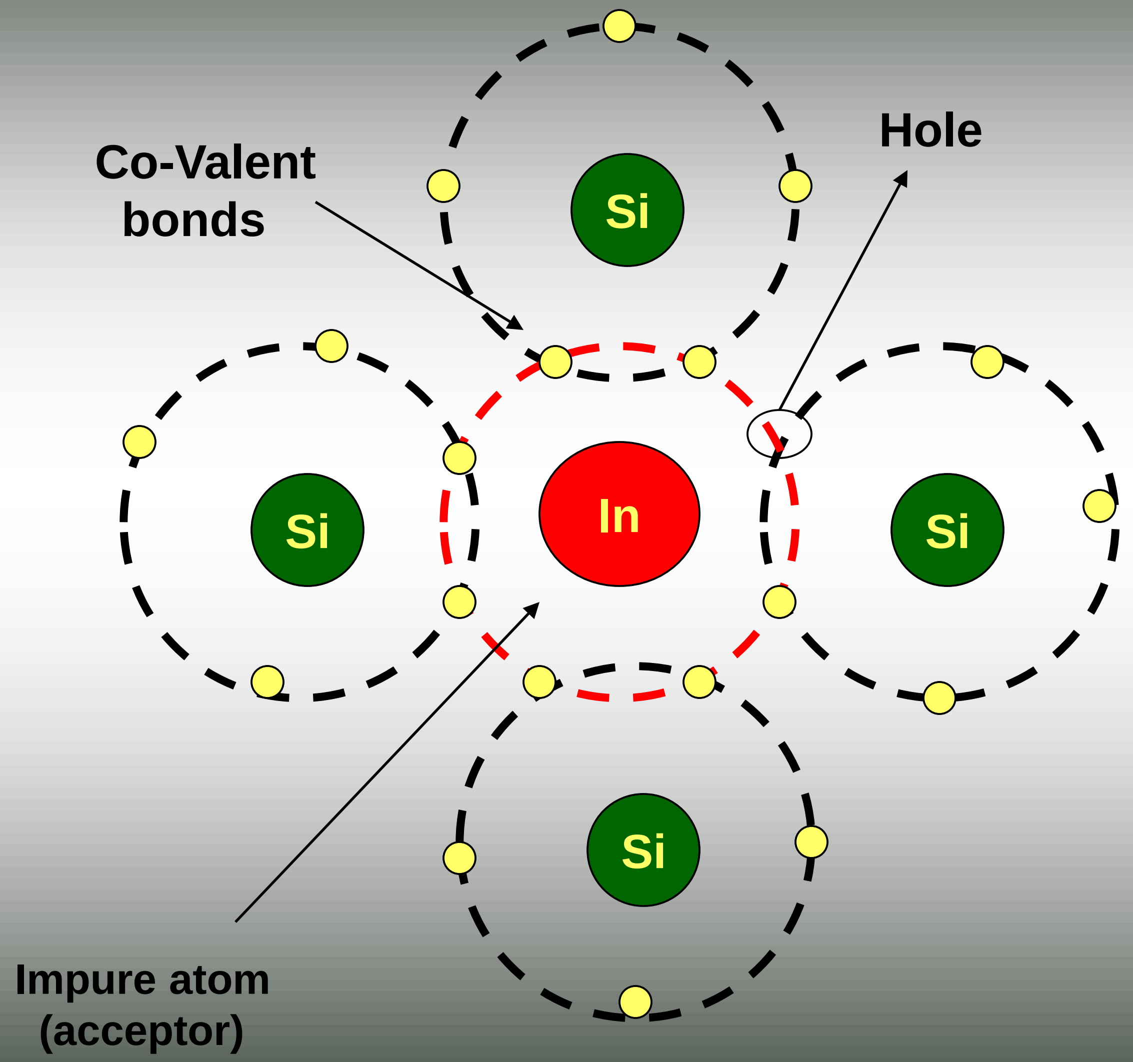
Further increase in temperature results in generation of Electron - hole pairs due to breading of covalent bonds and the material tends to behave in intrinsic manner.

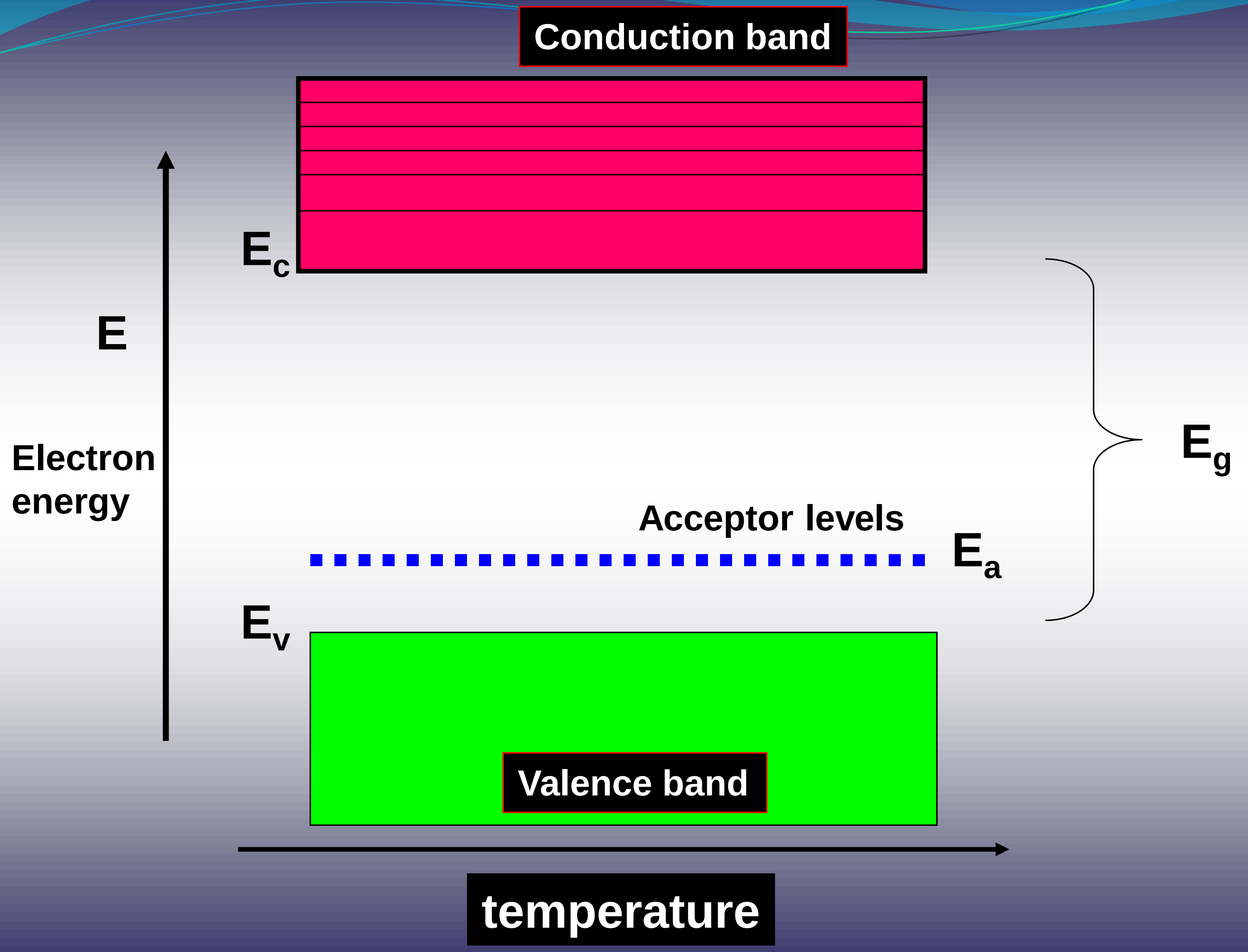
The Fermi level gradually moves towards the intrinsic Fermi level E_i.

P-type semiconductors

- When a trivalent elements such as **Al, Ga or Indium** have three electrons in their outer most orbits , added to the intrinsic semiconductor all the three electrons of Indium are engaged in covalent bonding with the three neighboring Si atoms.
- Indium needs one more electron to complete its bond. this electron maybe supplied by Silicon , there by creating a vacant electron site or hole on the semiconductor atom.
- Indium accepts one extra electron, the energy level of this impurity atom is called **acceptor level** and this acceptor level lies just above the valence band.
- These type of trivalent impurities are called **acceptor impurities** and the semiconductors doped the acceptor impurities are called **P-type semiconductors**.

P-type Semiconductor





Conduction band
E
Electron
energy
E_c
E_g
Acceptor levels
E_a
E_v
Valence band
temperature

- **Even at relatively low temperatures, these acceptor atoms get ionized taking electrons from valence band and thus giving rise to holes in valence band for conduction.**

- **Due to ionization of acceptor atoms only holes and no electrons are created.**

- **Thus holes are more in number than electrons and hence holes are majority carriers and electros are minority carriers in P-type semiconductors.**

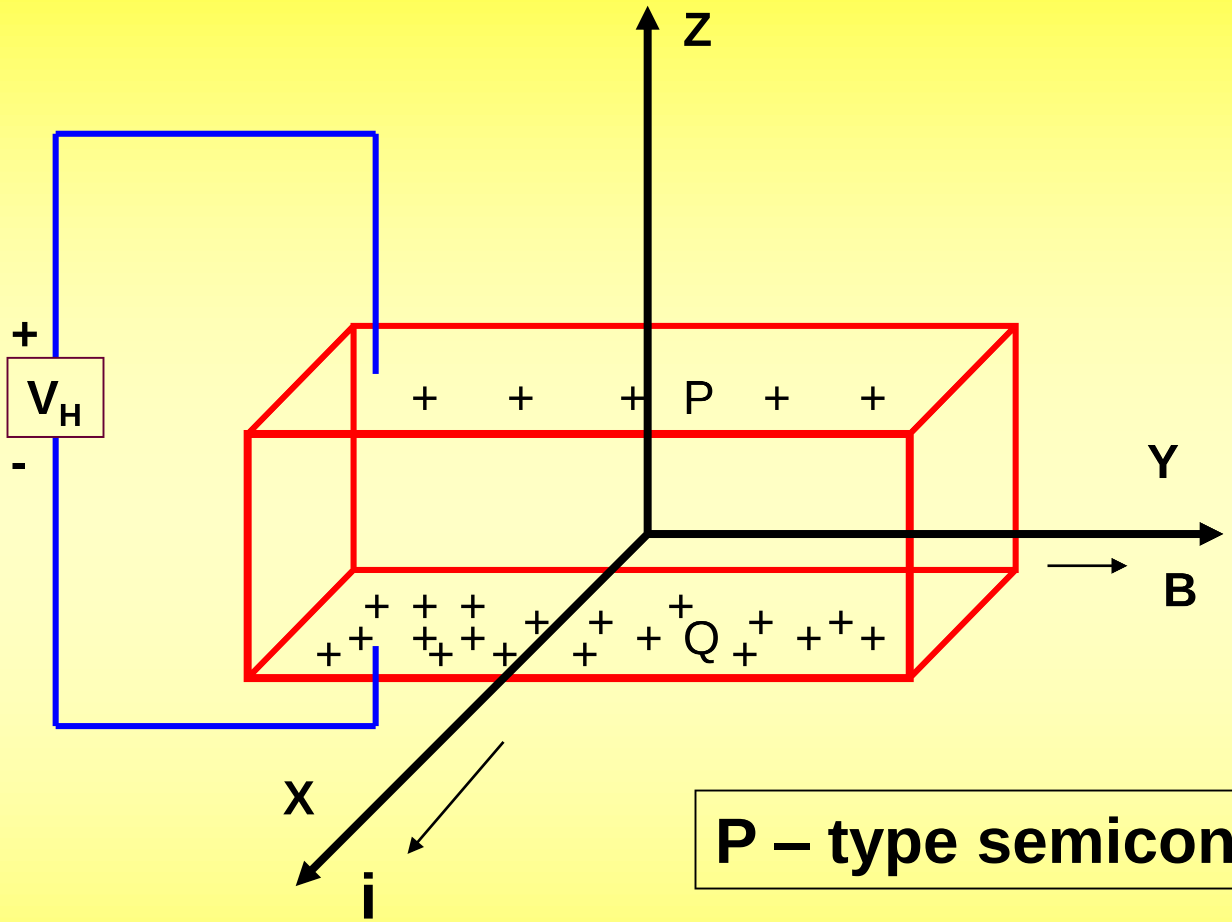
Hall effect

When a **magnetic field** is applied perpendicular to a current carrying conductor or semiconductor, **voltage** is developed across the specimen in a direction perpendicular to both the current and the magnetic field. This phenomenon is called the **Hall effect** and voltage so developed is called the **Hall voltage**.

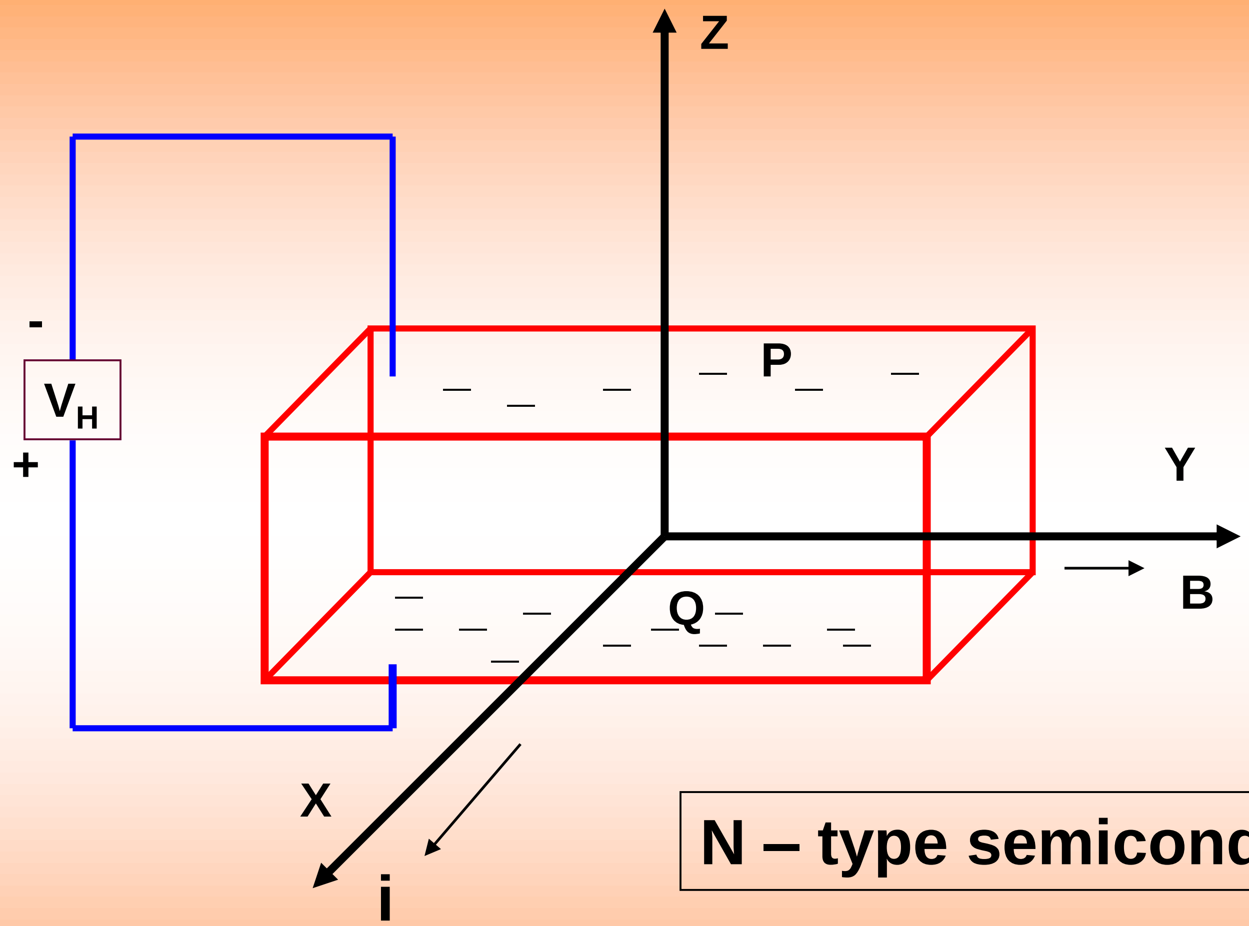
Let us consider, a thin rectangular slab carrying current (i) in the x-direction.

If we place it in a magnetic field B which is in the y-direction.

Potential difference Vpq will develop between the faces p and q which are perpendicular to the z-direction.



P – type semiconductor



N – type semiconductor

Applications

- Displays:
  - (OLED) Organic Light Emitting Diodes
- RFID :
  - Organic Nano-Radio Frequency Identification Devices
- Solar cells