SEMICONDUCTOR

EEE 1221

ELECTRONICS

Prepared by Md. Kamrul Hasan,
EEE, CUET

Reference Book

1. Electronic Devices and Circuit Theory- Robert Boylestad

2. Electronic Devices- Thomas L Floyd.

This presentation slide only contains the overview of the related topics. Students are advised to take decent class-notes and read thoroughly from the prescribed text books.

Outlines

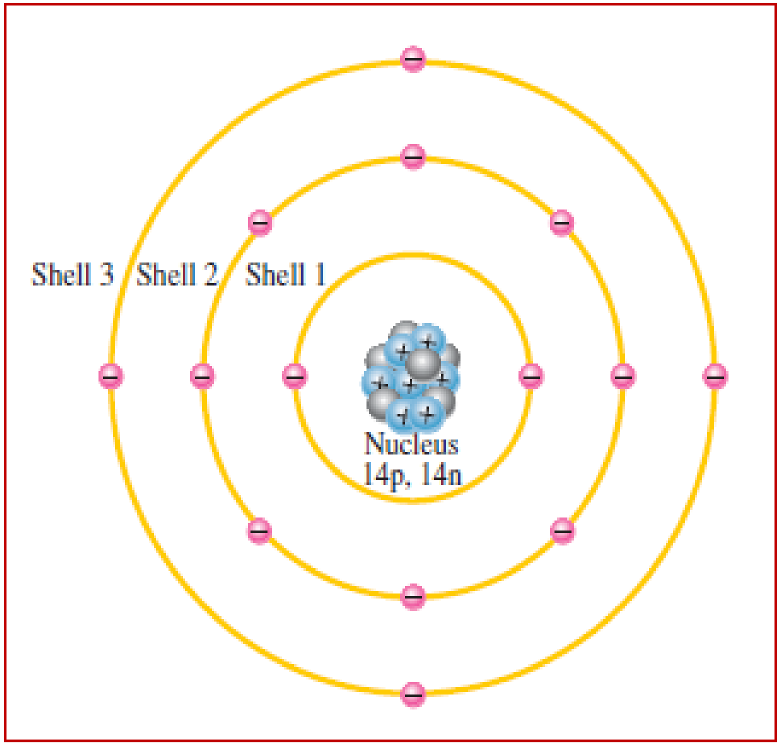
- Band Diagram and Band Gap
- Classification of Material
- Current In Semiconductor
- Doping
- N-type Semiconductor
- P-type Semiconductor
- P-N Junction Formation
- Depletion Region
- Energy Diagram of P-N Junction

Some Definition

- **Shell:**

  $N_e = 2n^2$

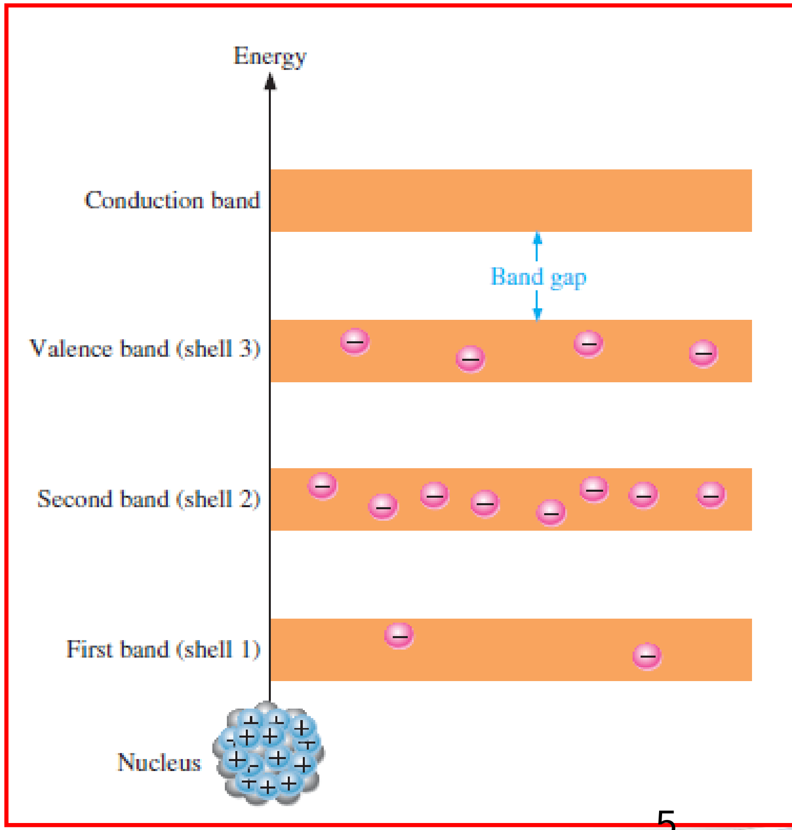
- **Valence Shell:**
- **Valence Electrons:**
- **Ionization:**
- **Free Electrons:**
- **Conduction Band:**



Band Diagram & Band Gap

The difference in energy between the valence band and the conduction band is called an ***Energy Gap*** or ***Band Gap.***

- The diagram that shows the energy distribution of different bands is **Band diagram.**



Classification of Materials

Conductor:

- Easily conducts electrical current.
- Band gap is too small
- Valence electrons can easily become free electrons.
- Most metals are good conductors.
- Cu, Ag, Au, and Al.

Insulator

- Does not conduct electrical current under normal conditions.
- Band gap is too high that electrons needs high energy.
- Valence electrons are tightly bound to the atoms.
- rubber, plastics, glass, mica, and quartz.

Semiconductor

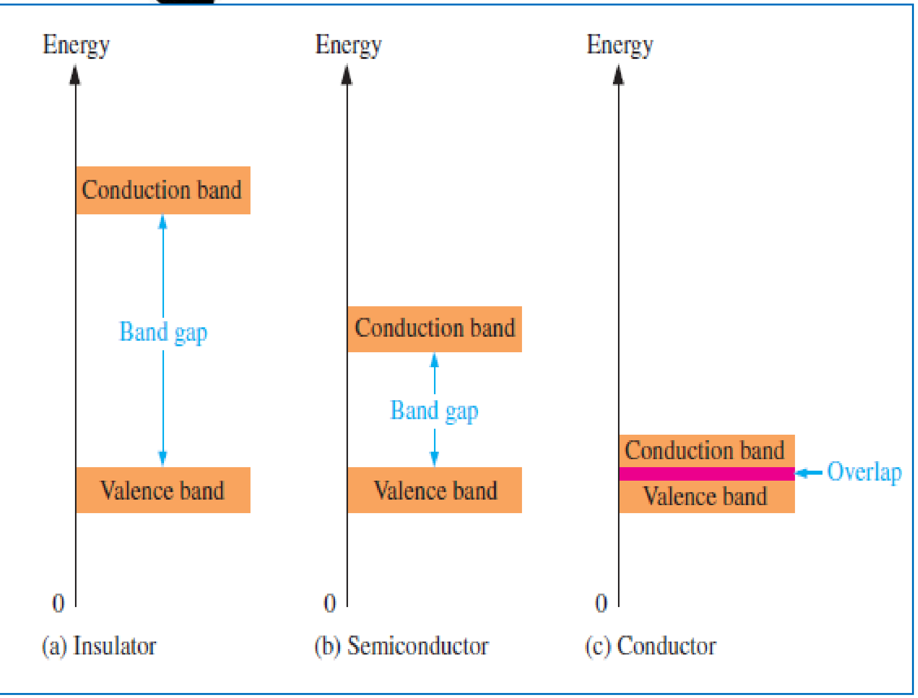
- Ability to conduct electrical current is in between conductors and insulators.
- A semiconductor in its pure (intrinsic) state is neither a good conductor nor a good insulator.
- Silicon is the most commonly used semiconductor.

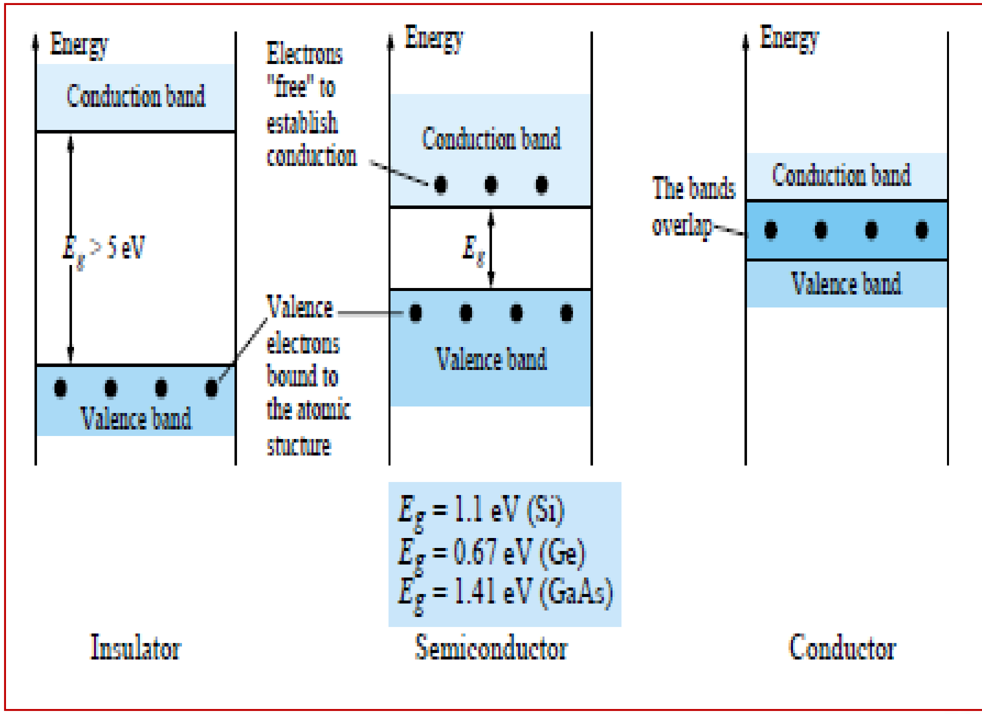
- Single-element semiconductors are Sb, As, B, Po, Te, Si and Ge.
- Compound semiconductors such as GaAs, InP, GaN, SiC are also commonly used.

Silicon

Gallium arsenide

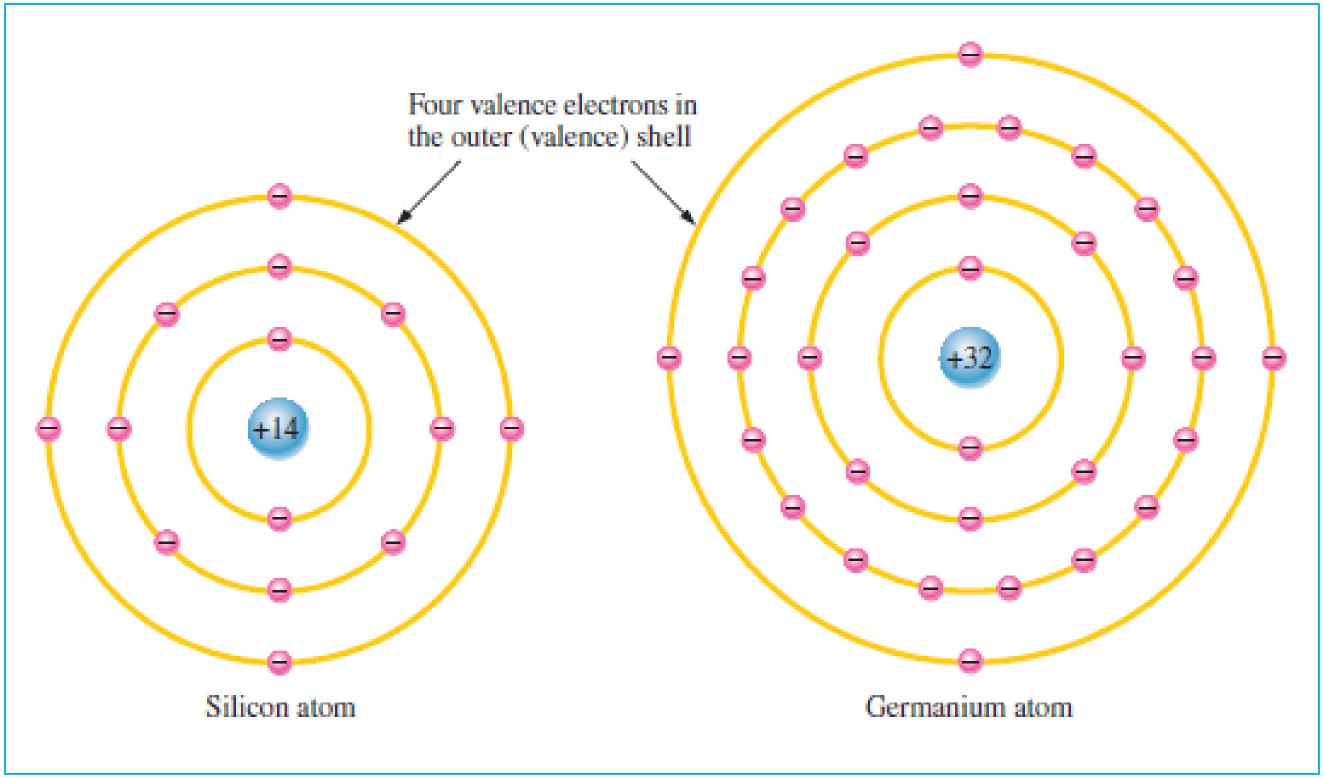
Band Diagram of Different Material



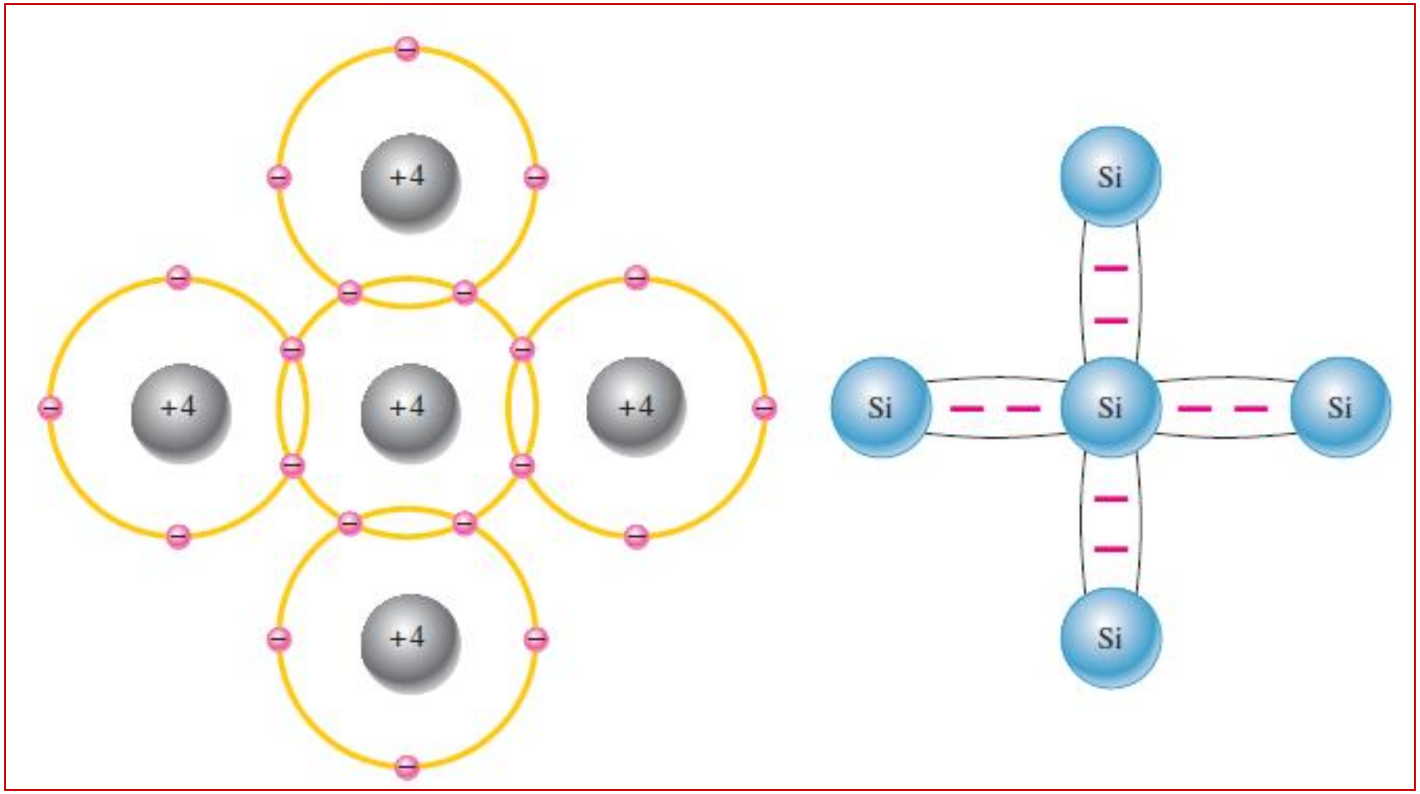


Si and Ge

- Why is Si most commonly used semiconductor?



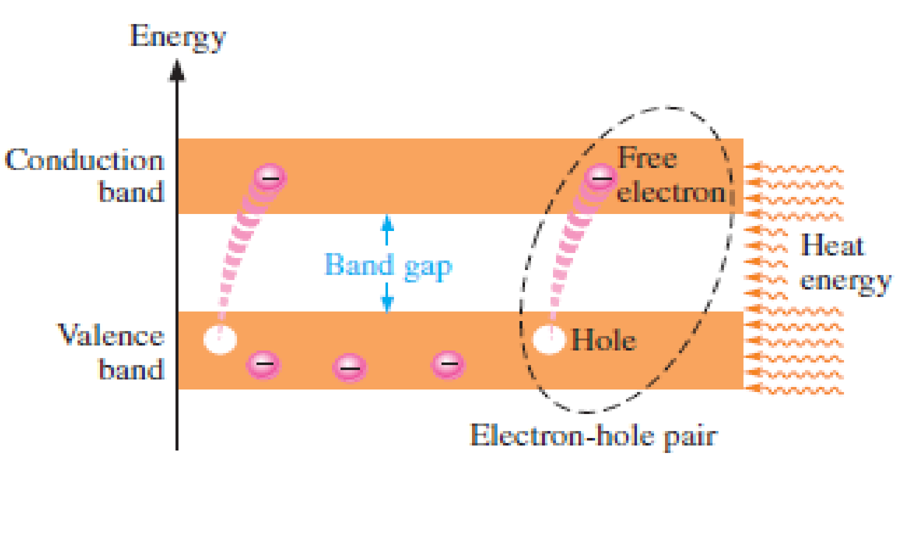
Covelent Bond in Si-crystal



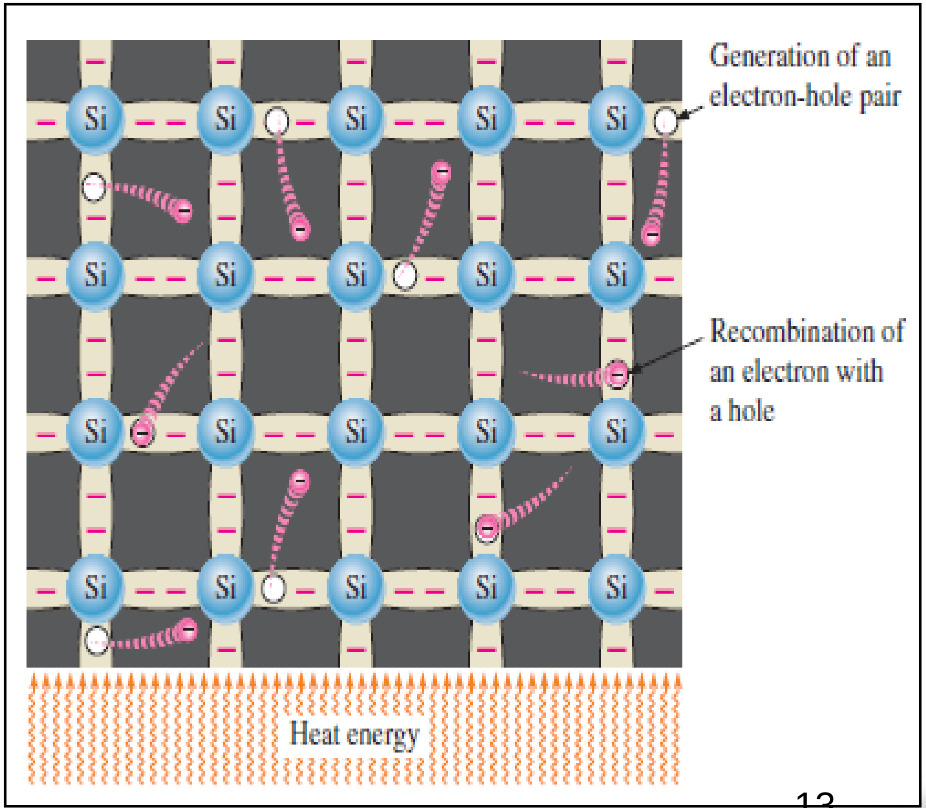
Bonding diagram of Si Crystal

Conduction Electron & Hole

- Free electron is the conduction electron.
- Vacancy of electron is called hole.

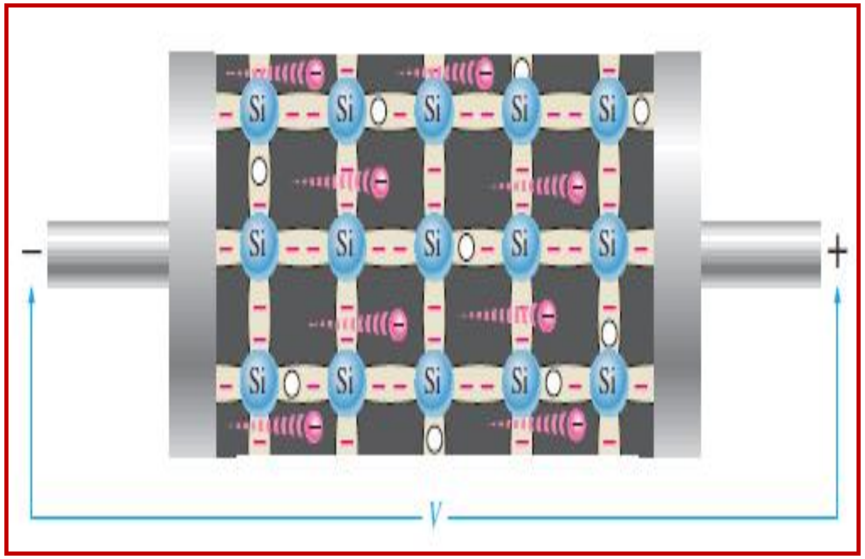


(a) Energy diagram



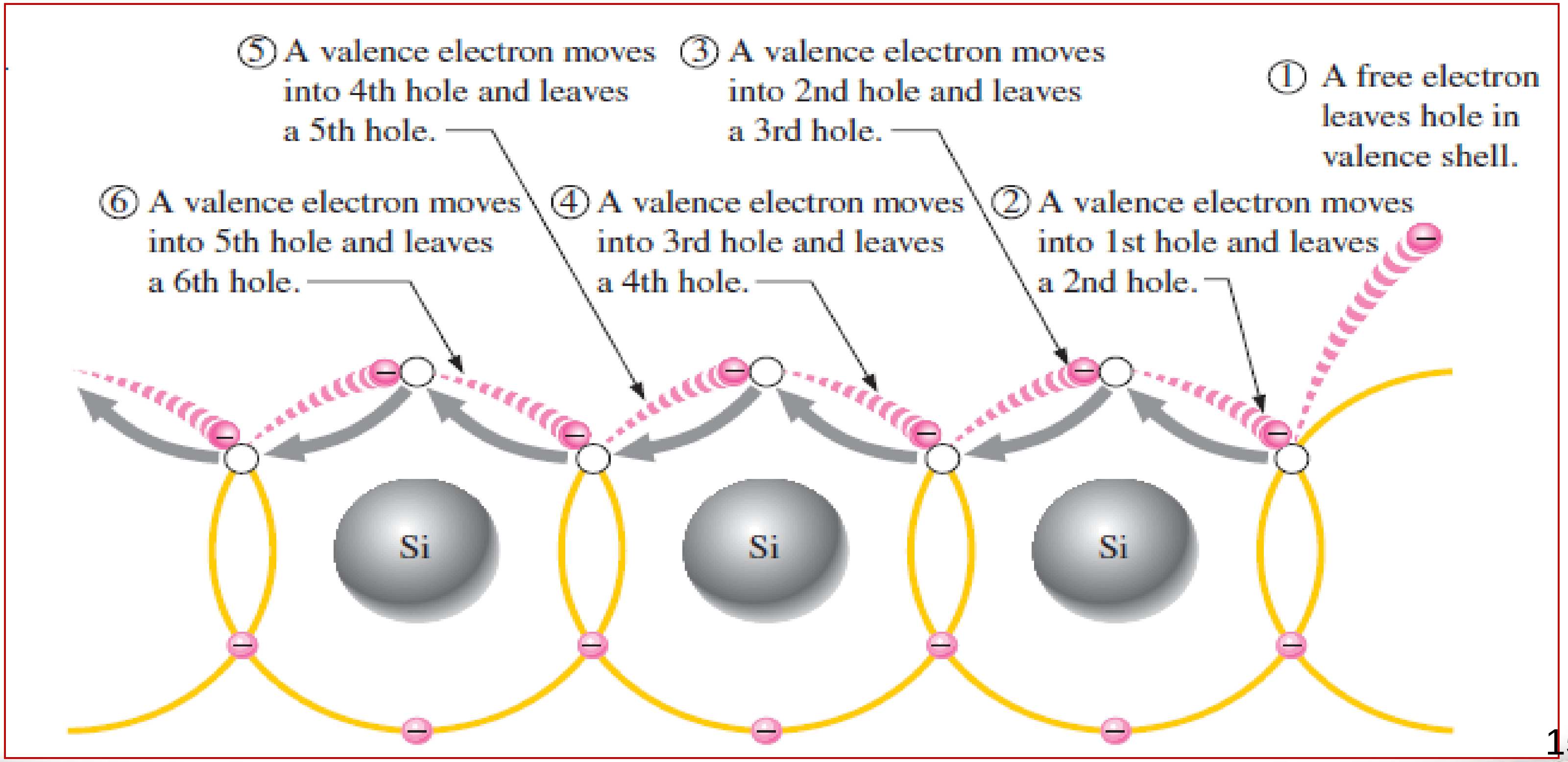
Electron Current

- If a voltage is applied, current in the conduction band produced by the free electrons called **Electron Current.**



Hole Current

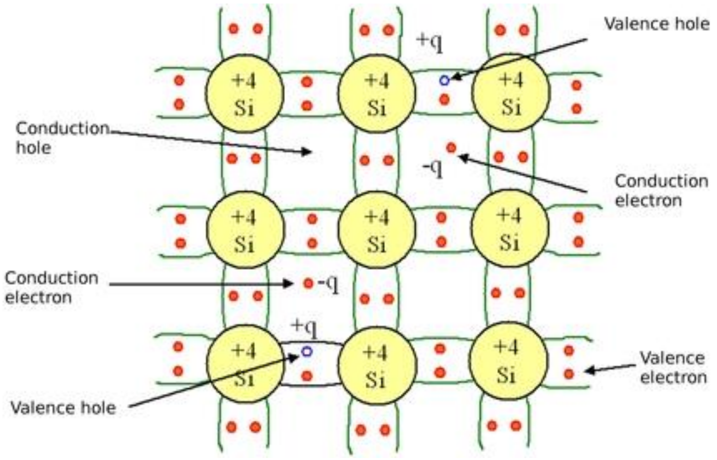
- Current in the valence band is produced by valence electrons, it is called **hole current** .



Types

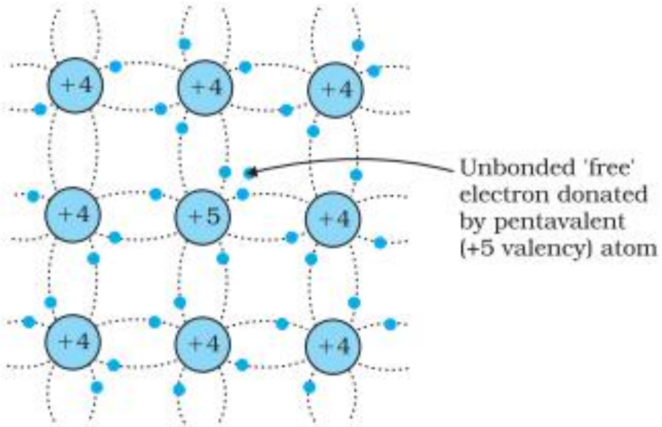
Intrinsic

- Free of impurities



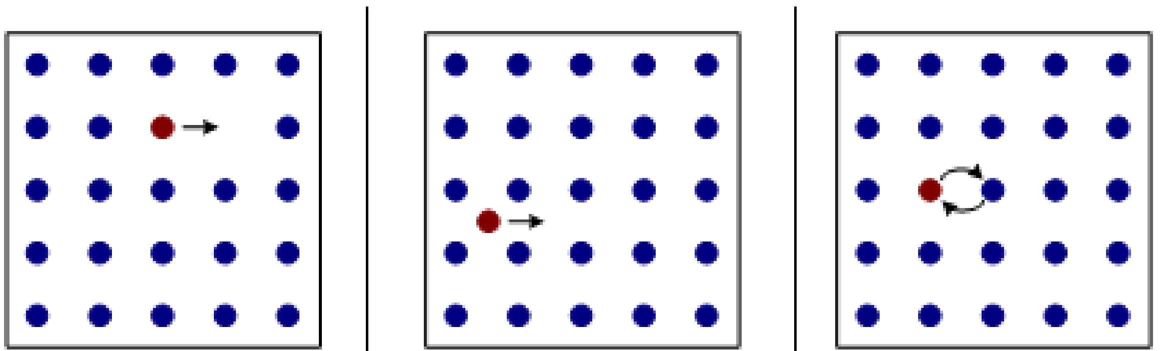
Extrinsic

- Addition of impurities



Doping

- A process of controlled addition of certain amount of specific impurities to a pure semiconductor.
- Increases electricity conductivity.



Dopants ● fill empty places in the lattice

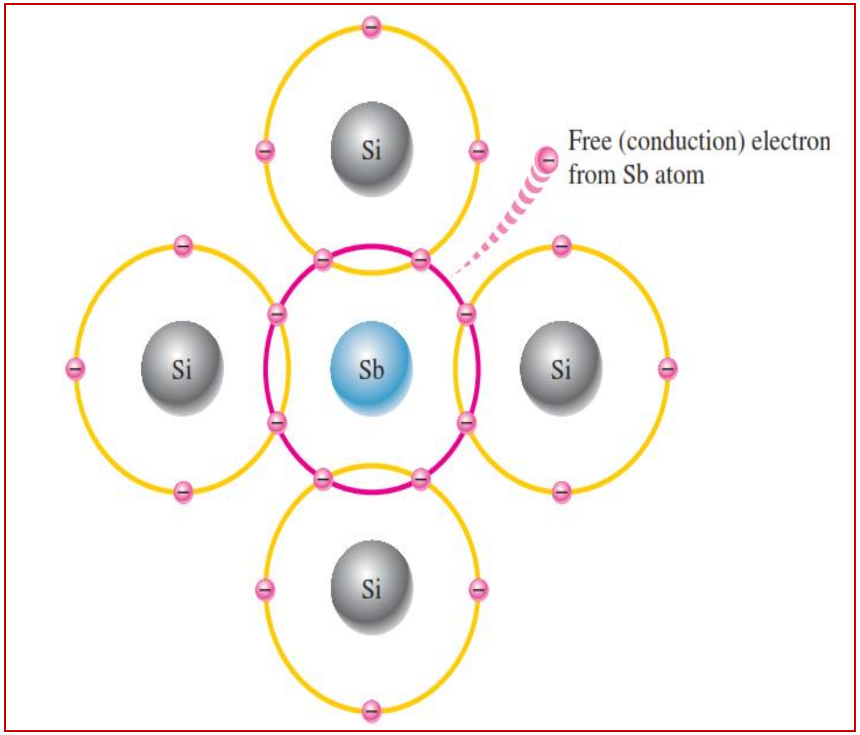
Dopants move in-between atoms

Dopants exchange places with silicon atoms

N-type Semiconductor

- N-Type semiconductor is created by adding pentavalent impurities like P, As, Sb or Bi called donor atom.

- The four valance electrons forms covalent bond with silicon leaving one electron free.



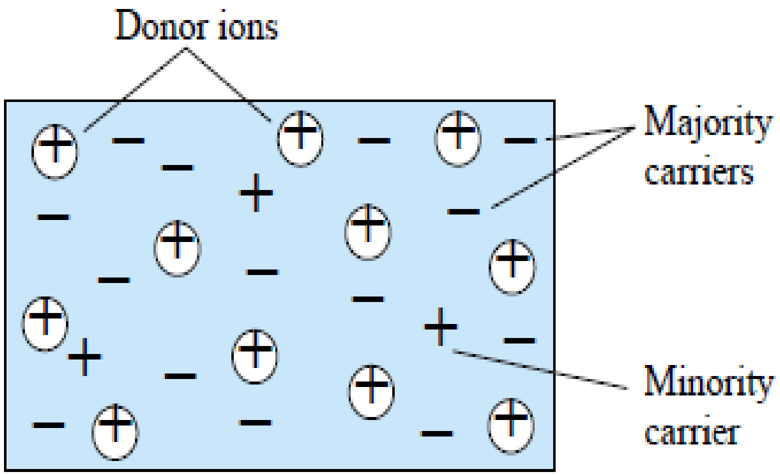
N-type Semiconductor

Majority Carriers:

Most of the current carriers are electrons, so electrons are called the ***majority carriers*** in ***n-type*** *material.*

Minority Carriers:

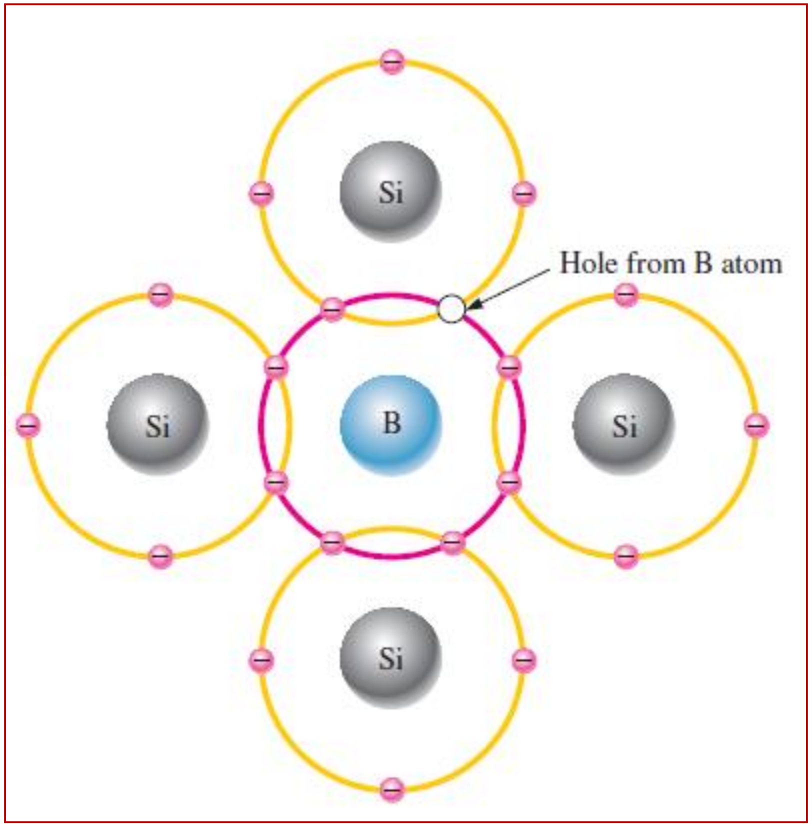
A few holes that are created when electron-hole pairs are thermally generated. Holes in an ***n-type*** *material are called* ***minority carriers.***



n-type

P-type Semiconductor

- A p-type Semiconductor is formed by adding a trivalent impurities (B, Ga, In) to a pure semiconductor resulting in many holes.



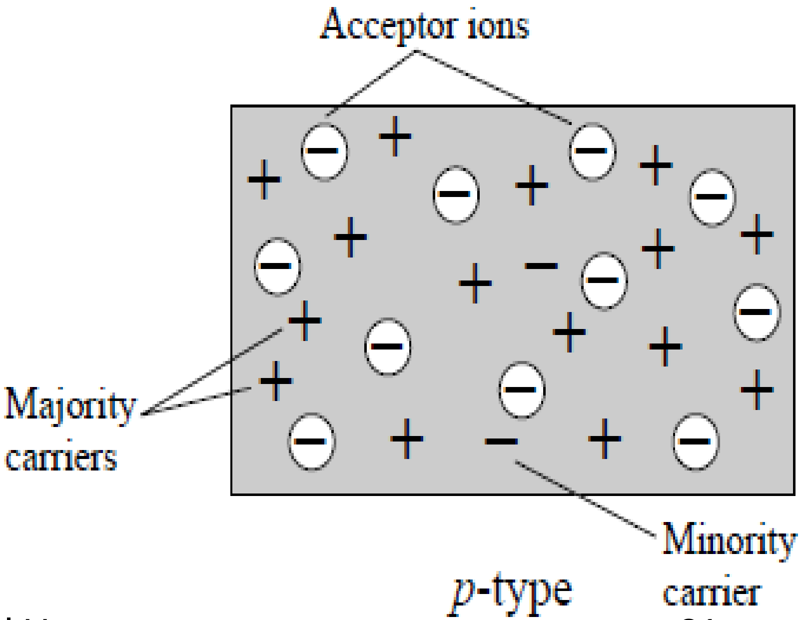
P-type Semiconductor

Majority Carriers:

Since most of the current carriers are holes in p-type semiconductor. The ***holes*** are the ***majority carriers*** in p-type material.

Minority Carriers:

Few conduction-band electrons that are created when electron-hole pairs are thermally generated. This ***electrons*** are the ***minority carriers***.

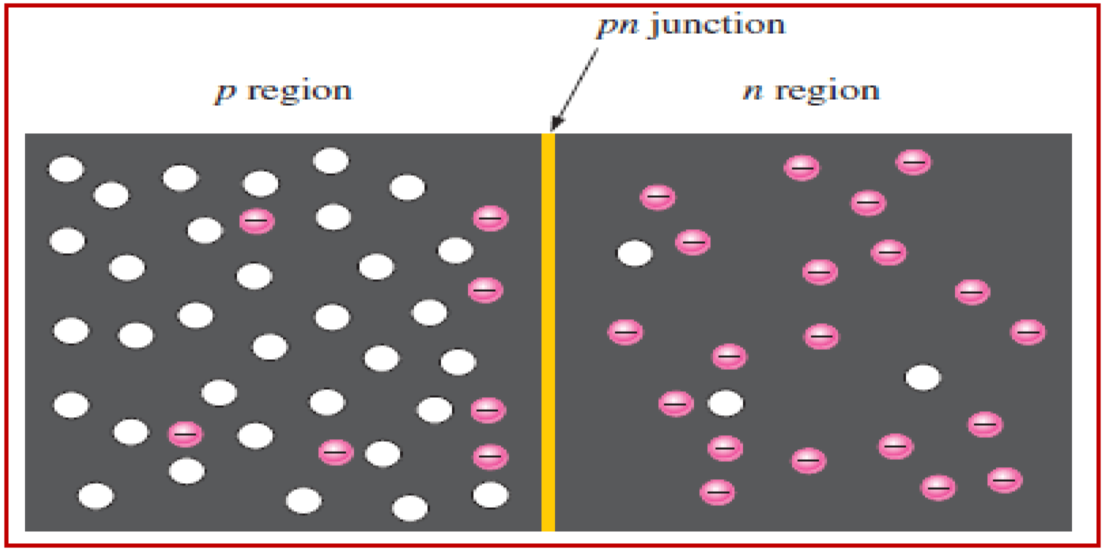


Note

- The number of **protons** and the number of **electrons** are equal throughout the material (p-type & n-type individually), there is **no net charge** in the material (p-type & n-type individually) and so both material is individually ***neutral***.

P-N Junction

- If a piece of intrinsic silicon is doped so that part is n-type and the other part is p-type, a p-n junction forms at the boundary between the two regions.



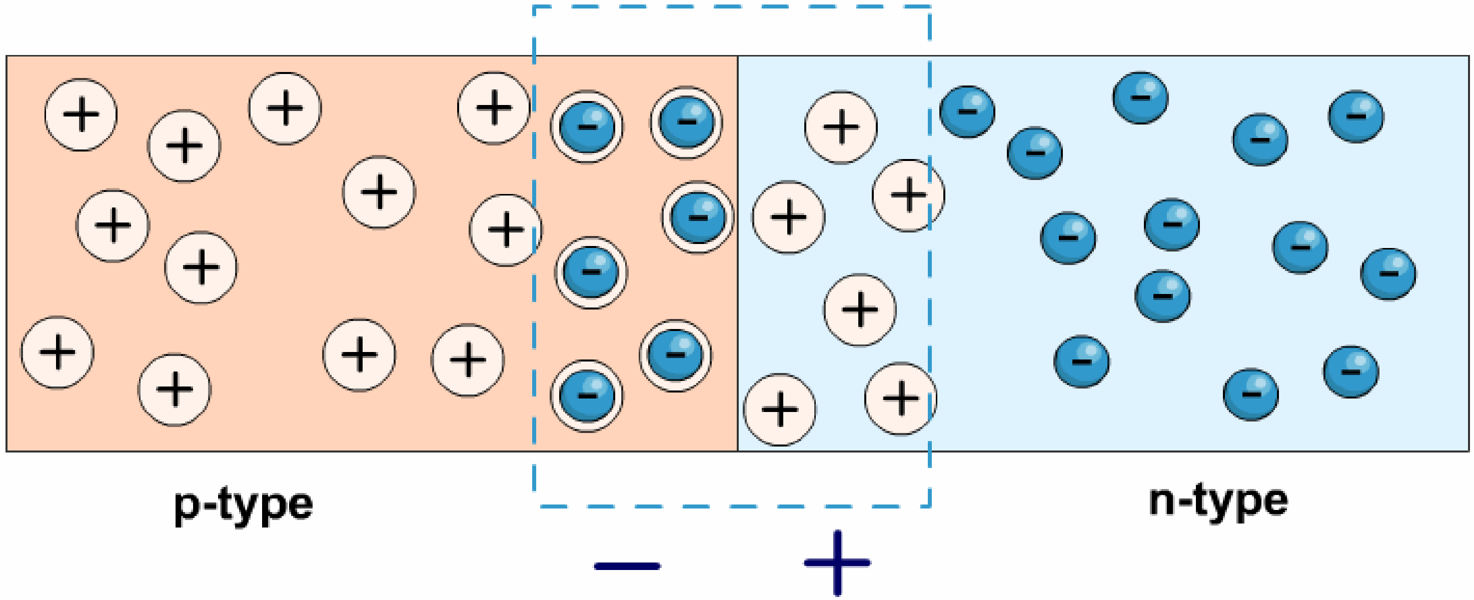
Depletion Region

When the pn junction is formed, the n-region loses free electrons as they diffuse across the junction leaving behind positive charge.

As the electrons move across the junction, the p-region loses holes which makes negative charge near the junction.

These two layers of positive and negative charges form the depletion region,

Depletion Region



-Semiconductors n-type and p-type are brought together

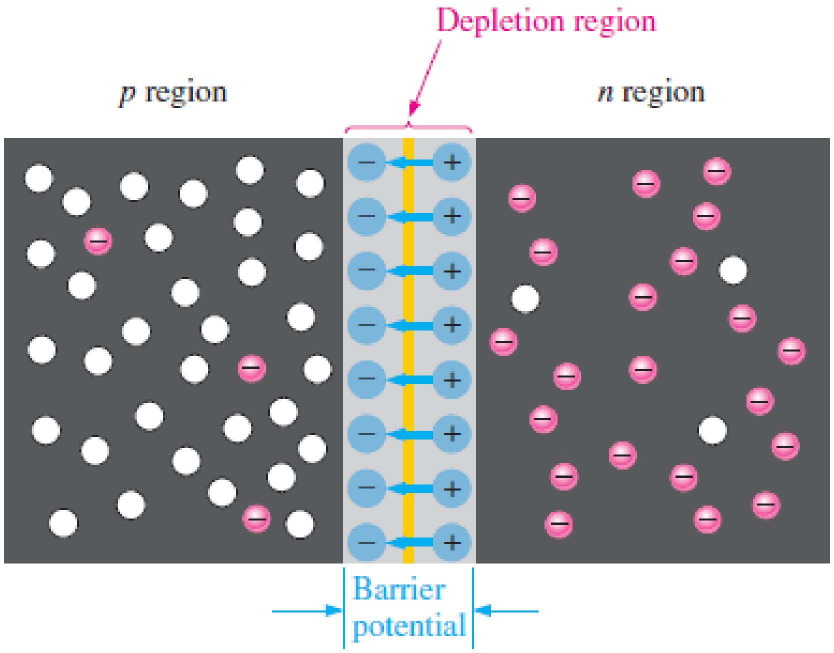
-Electrons and holes migrate across the junction

-The depletion layer is formed

-A p.d. is set up across the depletion layer

Depletion Region

- Diffusion stops when the total negative charge in the depletion region repels any further diffusion of electrons into the p-region.



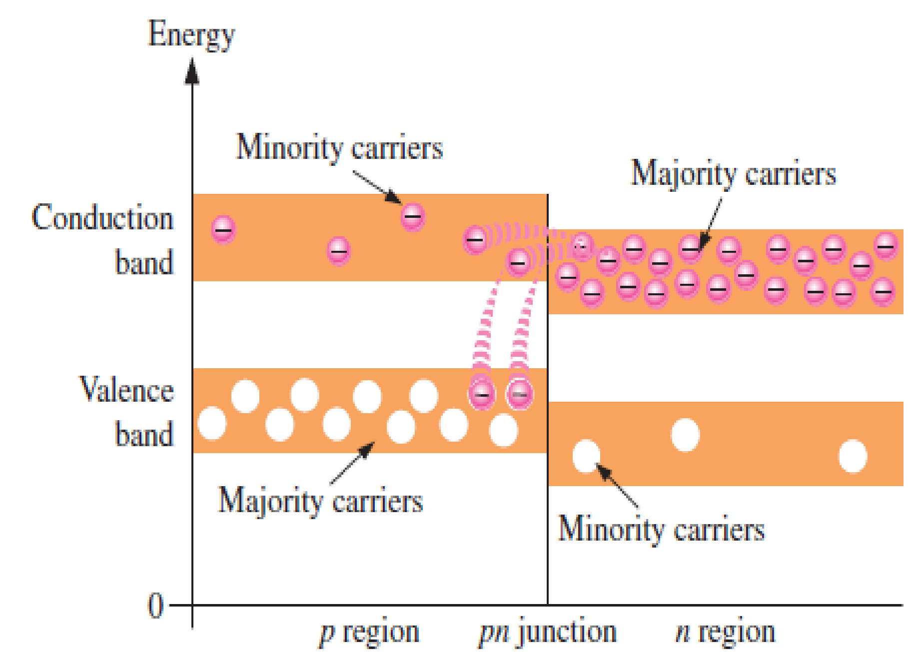
Barrier Potential

- There are many positive and many negative charges on opposite sides in the depletion region.
- The forces between the opposite charges form an electric field.
- This electric field works as a barrier.
- A voltage is needed to remove the barrier of the force and to move the electrons through the electric field.

Energy Diagram of PN Junction

At Instant of Junction Formation:

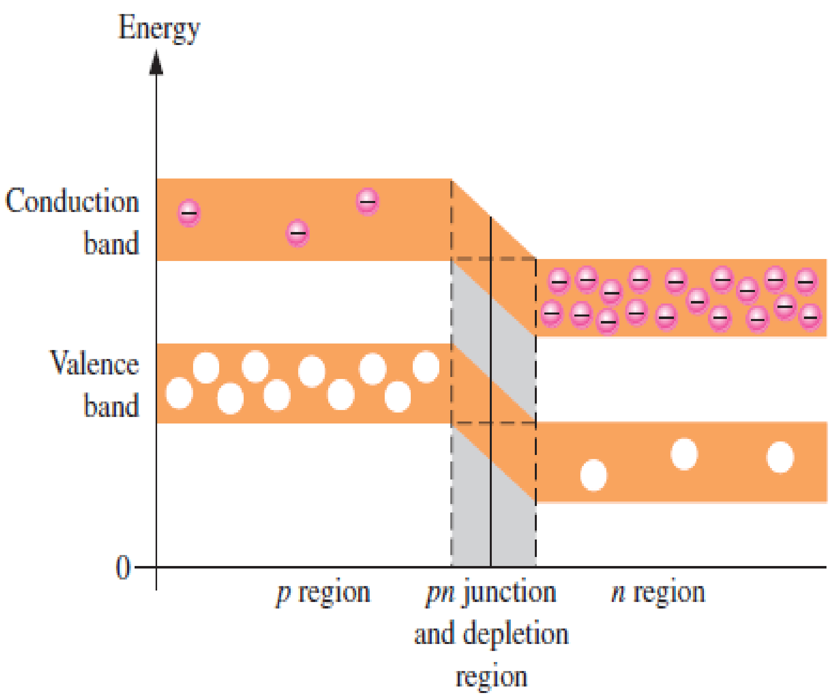
- After crossing the junction, the electrons quickly lose energy and fall into the holes in the *p-region valence band.*

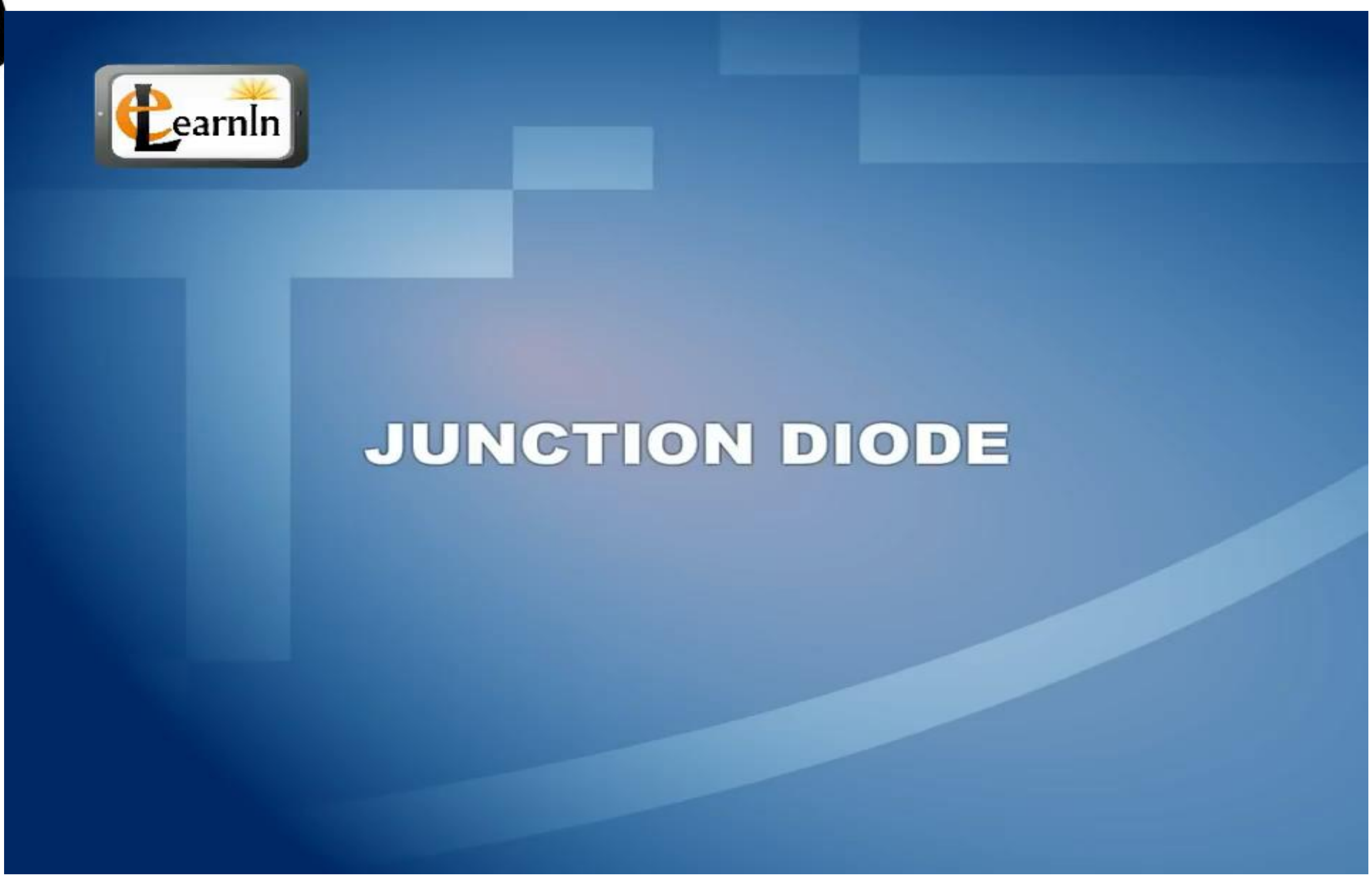


Energy Diagram of PN Junction

At Equilibrium:

- At this point, the junction is at equilibrium; and the depletion region is complete because diffusion has ceased.





https://www.youtube.com/watch?v=4SlfaocMfdA

For More

- https://www.electronicshub.org/pn-junction-tutorial/
- http://hyperphysics.phy-astr.gsu.edu/hbase/Solids/pnjun.html
- https://www.physics-and-radio-electronics.com/electronic-devices-and-circuits/semiconductor-diodes/p-n-junction-introduction.html
- https://www.halbleiter.org/en/fundamentals/the-p-n-junction/

Thank You!