UNIT-02

LAQ'S

Q1) Explicate the postulates of Drude and Loventz theory? Write it'sadvantages and disadvantages?

Q2) Examine important features of Kronig and penny model?

Q3) Depict the origin of energy band in solid's which leads to the classifications of materials in conductor, semiconductor and insulators.

Q4) Enunciate Hall Effect. list out the applications of hall effect.

Q5) Discuss P-N junction diode along with its V-I characteristics.

Q6) Explain V-I Characteristics of LED.

SAQ'S

Q1) What is meant by electron gas?

Q2) Define Electron Volt's?

Q3) mention the applications of solar cell?

Q4) Write down few applications of LED.

Q5) what is Opto -Electronic device?

Q6) Discuss intrinsic and extrinsic semiconductor with a neat diagram.

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Laq's

1) **1.Explain Drude – Lorentz free electron theory. (BTL 2)**

Introduction: In 1900 Drude proposed electron gas model to explain the electrical conduction in metals. It was modified by Lorentz in 1909 and the theory is termed as Drude-Lorentz theory or classical free electron theory.

Postulates:

1. Metal crystal consist of positive metal ions whose valence electrons are free to move between ions as if they constitute an electron gas.
2. The crystal is then held together by electrostatic forces of attraction between positive charged ions and negative charged electron gas.
3. The mutual repulsion between the electron is ignored.

4. The potential field due to positive ions is completely uniform, so that electron can move from place to place in the crystal without any change in their energy.
5. They collide occasionally with the atoms, at given temperature and their velocities could be determined according to Maxwell – Boltzmann distribution. The free electrons are treated equivalent to gas molecules, and thus are assumed to obey the laws of kinetic theory of gases.

Advantages:

1.It is used to verify ohm's law

2.It is used to explain the electrical and thermal conductivities of metals

3.It is used to explain the optical properties of metals

4.It is used to explain Ductility and malleability of metals.

Failures:

1.It is failed to explain why some solids are conductors and some are insulators.

2.It is failed to explain the properties of solids which are determined by their internal structure.

3.It is failed to explain the electrical conductivity of semiconductors and insulators.

4.Photoelectric effect, Compton Effect and black body radiation cannot be explained by this theory.

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2) Examine the important features of the Kronig-Penney Model.

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1. One-Dimensional Periodic Potential

- Assumes electrons move in a **1D periodic potential** representing atoms in a crystal.
- The potential repeats with a pattern of **wells and barriers**.

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2. Piecewise Constant Potential

- $V(x) = 0$ in the well region (width a); $V(x) = V_0$ in the barrier region (width b).

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- $V(x) = 0$ in the well region (width a); $V(x) = V_0$ in the barrier region (width b).
- The periodicity is $d = a + b$.

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3. Bloch's Theorem Applies

- Due to the periodic potential:

$$\psi(x + d) = e^{ikd}\psi(x)$$

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4. Energy Bands and Gaps

- The dispersion relation:

$$\cos(kd) = f(E)$$

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5. Quantum Tunneling

- Electrons can **tunnel through barriers**, leading to wavefunction overlap across atoms and the formation of extended energy bands.

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6. Explanation of Band Structure

- Demonstrates how discrete atomic levels broaden into **energy bands** when atoms form solids.

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7. Classification of Materials

- Explains:
  - **Conductors**: overlapping or partially filled bands,
  - **Semiconductors**: small band gap,

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7. Classification of Materials

- Explains:
  - **Conductors**: overlapping or partially filled bands,
  - **Semiconductors**: small band gap,
  - **Insulators**: large band gap.

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8. Limitations

- Idealized 1D model; neglects electron-electron interactions and real crystal complexities.
- Still effective for qualitative understanding of band formation.

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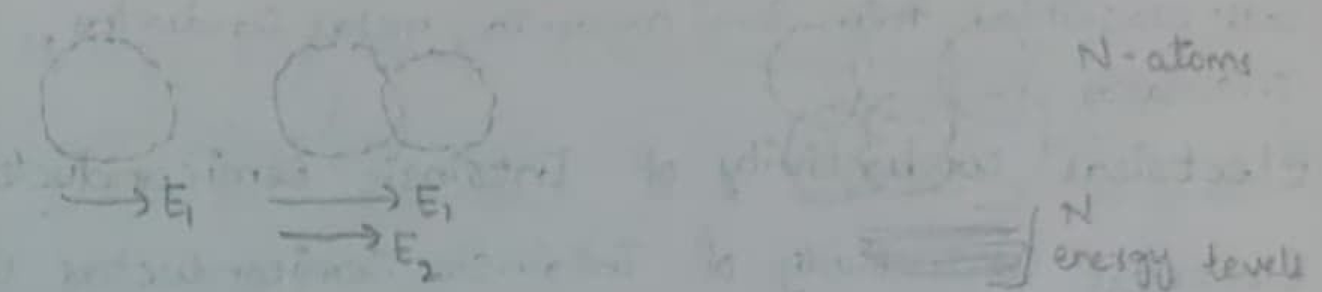
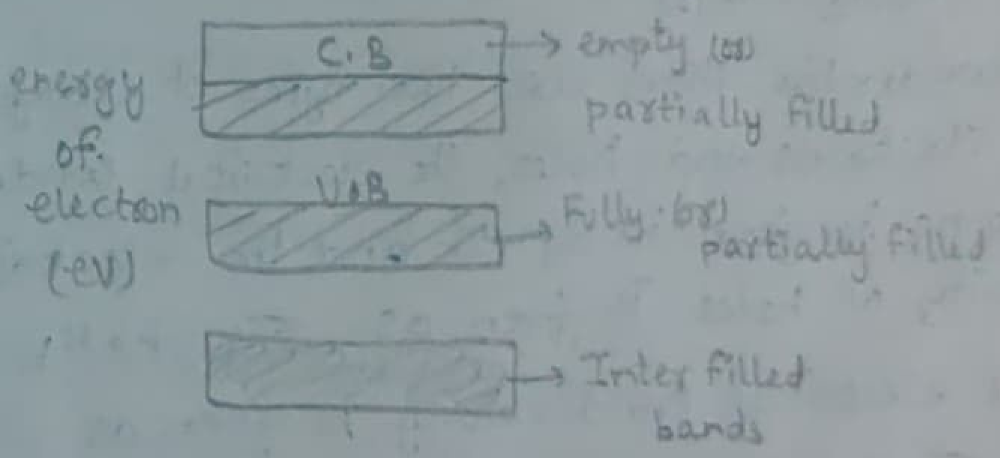
3) Origin of energy bands in solids.



Let us consider the solid which contains "N" number of atoms, due to the Closeness of the atom one electron of the atom inter-mixed with the neiboring electron of the consicutive atom. due to this intermixing of electrons more energy levels are form, as they are very close to each other they form continous band of energy. A set of closely spaced energy levels is known as energy band.

We know that the electrons present in the outermost shell is known as valance electrons.



And the energy band formed by the valance electron is said to be valance band which is partially or completely filled. The next higher band (or) permitted band is known as conduction band which is empty (or) partially filled. The Conduction band and the valance band is separated by forbidden band (or) energy gap.

forbidden band.

Based on the equilibrium spacing we can classify the solids into conductors' insulators' and semiconductors.

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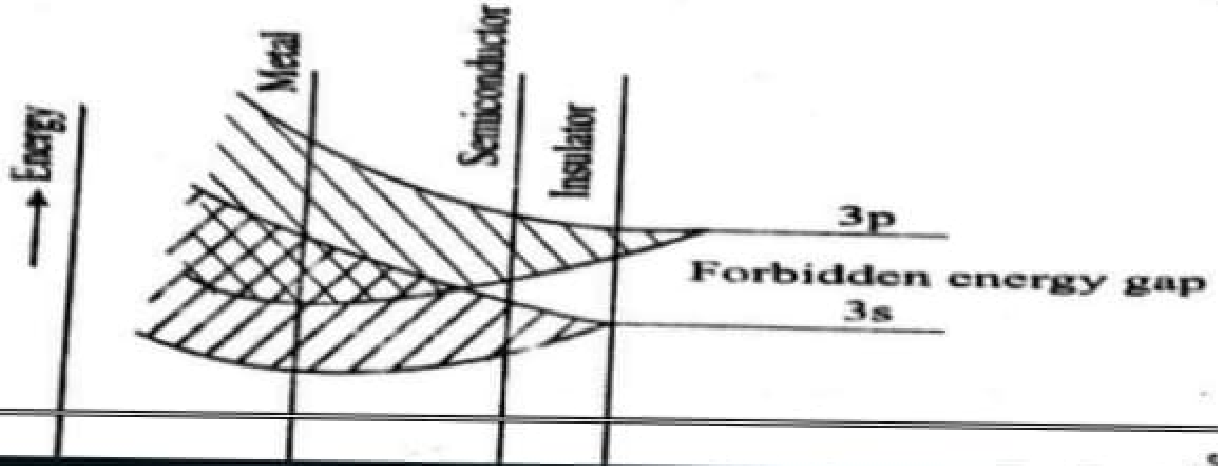

HYSICS

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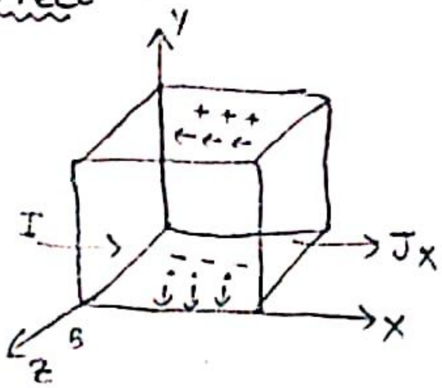
$\sigma_i = \sigma_i(0)\exp\left(\frac{-E_g}{2K_BT}\right)$

At very high temp after taking natural logarithm

$\ln\sigma_i = \ln\sigma_i(0) - \frac{E_g}{2K_BT}$

4) Hall Effect



At ~~equilibrium~~

When a semi conductor carrying current I is placed in the transverse magnetic field B, Electric field is induced and the corresponding voltage generated which is known (EH) as hall voltage and the phenomena is said to be hall effect.

Let us consider n-type semi-conductor, if v is the velocity of the electron at the upper side of the ~~sp~~ Specimen ~~specimen~~. Under the influence of lorentz force due to magnetic field B is BeV. The force which is acting on the e^- in the ~~bottom~~ part of the specimen is eE_H

At equilibrium

$BeV = eE_H$

$BV = E_H$ — ① $[\because J_x = nev]$

$V = \frac{J_x}{ne}$

$B\left(\frac{J_x}{ne}\right) = E_H \Rightarrow E_H = B \cdot J_x R_H \quad \left[\because R_H = \frac{1}{ne}\right]$

$$\boxed{R_H = \frac{E_H}{B \cdot J_x}}$$

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Applications of Hall Effect (Short Notes)

1. **Magnetic Field Measurement** – Used in magnetometers to measure magnetic field strength.
2. **Identify Charge Carrier Type** – Determines whether a material is n-type or p-type.
3. **Carrier Concentration** – Calculates number of charge carriers in a semiconductor.
4. **Carrier Mobility** – Helps determine mobility of charge carriers.
5. **Hall Sensors** – Used in position, speed, and proximity sensing (e.g., in vehicles, mobiles).
6. **Current Measurement** – Non-contact measurement of AC/DC current.
7. **Digital Switching** – Used in keyboards, tachometers, and automation.

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5)

P-N Junction Diode and Its V-I Characteristics

P-N Junction Diode:

A **P-N junction diode** is a semiconductor device formed by joining a **p-type** and an **n-type** semiconductor.

- **P-type region**: Has majority **holes.**
- **N-type region**: Has majority **electrons.**

At the junction, electrons and holes diffuse and recombine, forming a **depletion region** with an electric field that opposes further charge movement.

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Biasing of P-N Junction:

1. Forward Bias:

- P is connected to **positive** and N to **negative** terminal of a battery.
- Depletion layer becomes **narrow**.
- Current flows easily after a certain threshold voltage.

2. Reverse Bias:

- P is connected to **negative** and N to **positive**.
- Depletion layer becomes **wider**.
- Very **small current** flows due to minority carriers (reverse saturation current).

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V-I Characteristics of P-N Junction Diode:

Forward Bias Region:

- **Below threshold (cut-in) voltage**: Very small current.
  - ~0.7V for silicon, ~0.3V for germanium.
- **Above threshold**: Current increases **exponentially** with voltage.

Reverse Bias Region:

- Current is very small and nearly constant (reverse saturation current).
- **Breakdown** may occur at high reverse voltage, causing a sharp increase in current.

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Graph Description:

- **X-axis**: Voltage (V)
- **Y-axis**: Current (I)
- Forward bias: Exponential rise in current after threshold voltage.
- Reverse bias: Almost flat line (small current), sudden rise at breakdown.

Conclusion:

The P-N junction diode conducts current in **one direction** (forward bias) and blocks in the **other direction** (reverse bias), making it essential in **rectifiers**, **clippers**, and **switching circuits**.

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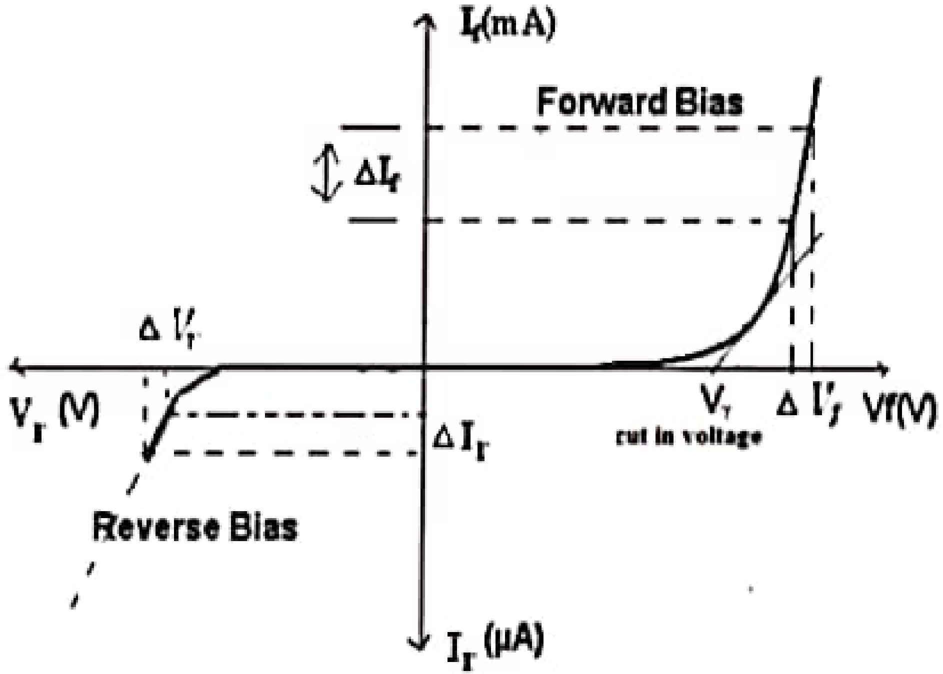

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Q6) Explain V-I Characteristics of LED

Introduction:

An **LED (Light Emitting Diode)** is a special type of **P-N junction diode** that emits **visible light** when forward biased. It is made using compound semiconductors like **Gallium Arsenide (GaAs)** or **Gallium Phosphide (GaP)**, which release energy as **photons** during electron-hole recombination.

Working Principle:

- When the LED is **forward biased**, electrons from the n-region and holes from the p-region move toward the junction.

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Working Principle:

- When the LED is **forward biased**, electrons from the n-region and holes from the p-region move toward the junction.
- Upon recombination, the energy is released in the form of **light (electroluminescence)**.
- The color (wavelength) of the emitted light depends on the **band gap** of the material used.

V-I Characteristics of LED:

The **Voltage-Current (V-I) characteristics** of an LED describe how current changes with applied voltage.

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1. **Forward Bias Region:**

- The LED does **not conduct significantly** until a **threshold (cut-in) voltage** is reached (typically **1.5V to 2.5V**, depending on the material and color).
- After this voltage, **current increases rapidly**, and **light is emitted**.
- The relationship between current and voltage becomes **exponential**.

2. **Reverse Bias Region:**

- Only a **very small leakage current** flows.
- The LED does **not emit light** in reverse bias.
- LEDs do **not tolerate high reverse voltage**—they can be **permanently damaged** (unlike Zener diodes).

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V-I Characteristics Graph (Sketch Description):

- **X-axis**: Voltage (V), **Y-axis**: Current (I)
- In **forward bias**:
  - Initially, current is almost zero.
  - After the threshold voltage, the current increases **sharply**.
  - This region shows **light emission**.
- In **reverse bias**:
  - Very little current (flat line near X-axis).
  - No conduction or light emission.

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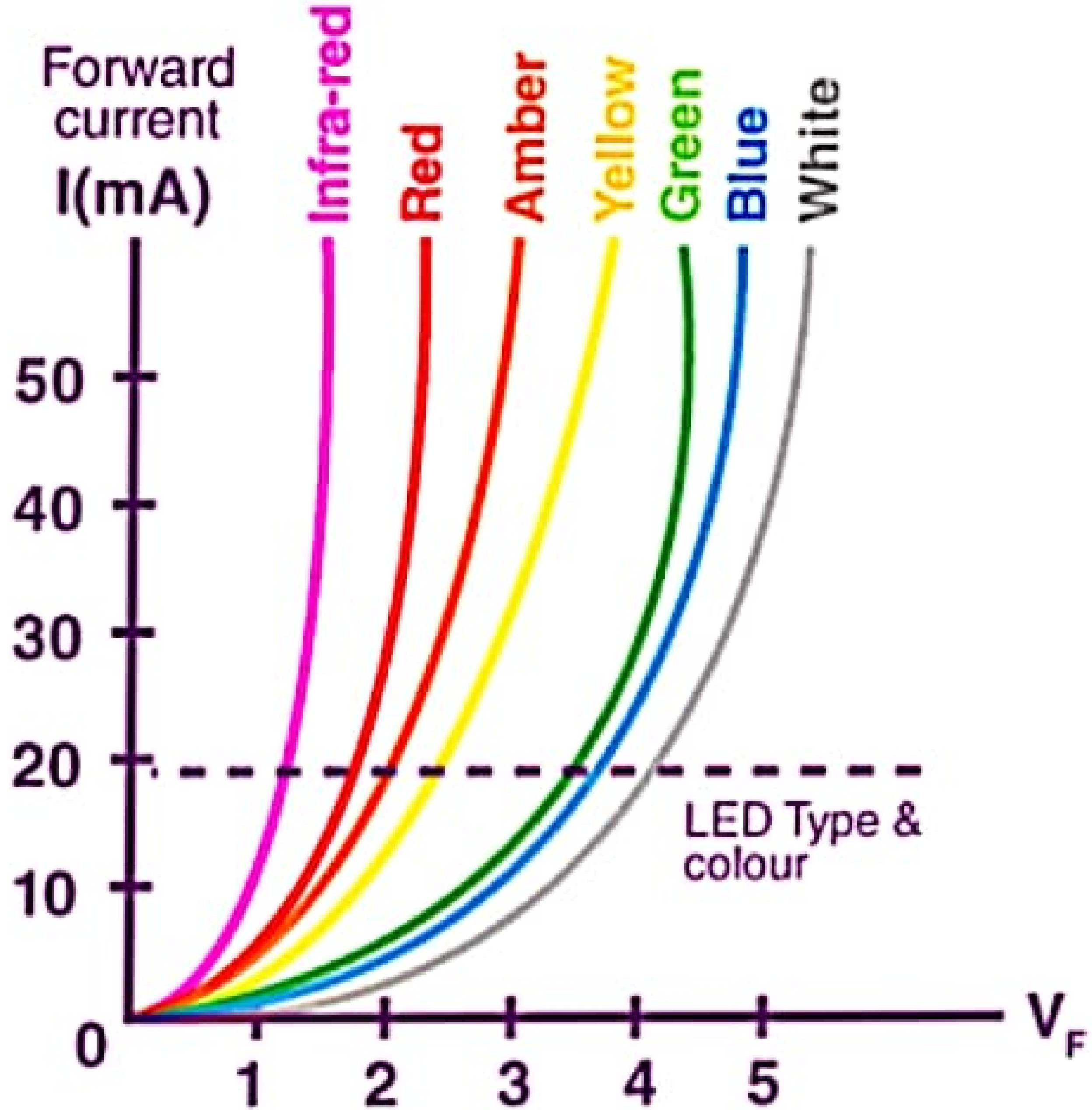

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Q1) What is meant by Electron Gas?

Electron gas refers to the **free electrons** inside a metal or semiconductor that behave like a **gas of charged particles**. These electrons are **delocalized** and move randomly within the material, similar to gas molecules, and are responsible for **electrical conductivity**.

Q2) Define Electron Volt (eV):

An **electron volt (eV)** is the amount of **kinetic energy gained** by an electron when it is accelerated through a potential difference of **1 volt**.

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ joules}$$

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Q3) Applications of Solar Cell:

1. **Calculators and Watches** – Small-scale power source
2. **Street Lighting and Traffic Signals**
3. **Remote area power supply** (rural villages, islands)
4. **Spacecraft and Satellites**
5. **Solar-powered water pumps** and chargers

Q4) Applications of LED:

1. **Indicator lights** in electronic devices
2. **Display panels** (TVs, monitors)
3. **Lighting systems** (bulbs, lamps)
4. **Traffic signals and signboards**
5. **Optical communication** systems

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5. **Optical communication** systems

Q5) What is an Opto-Electronic Device?

Opto-electronic devices are electronic components that either **produce light** or **respond to light** by converting electrical energy to optical energy (or vice versa).

Examples: LED, Photodiode, Solar Cell, Laser Diode.

Q6) Discuss Intrinsic and Extrinsic Semiconductors with a Neat Diagram

Intrinsic Semiconductor:

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Intrinsic Semiconductor:

- Pure semiconductor with **no impurities**.
- Conductivity is low.
- **Electrons and holes** are generated in equal numbers by thermal energy.
- **Example**: Pure silicon or germanium.

Extrinsic Semiconductor:

- Doped with **impurities** to increase conductivity.
- Two types:
  - **N-type**: Added donor atoms → More **electrons**
  - **P-type**: Added acceptor atoms → More **holes**

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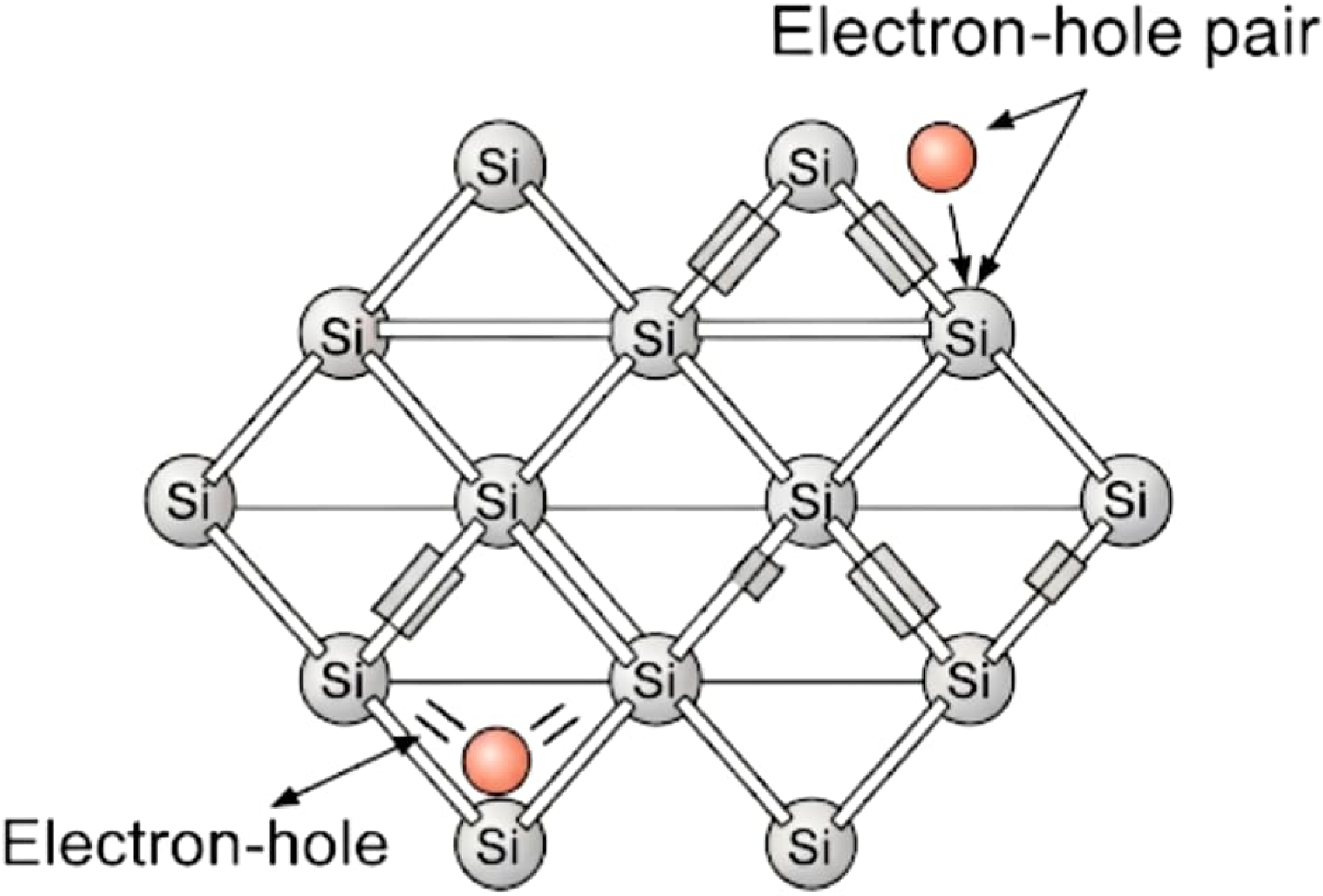
Intrisic Semisulutor



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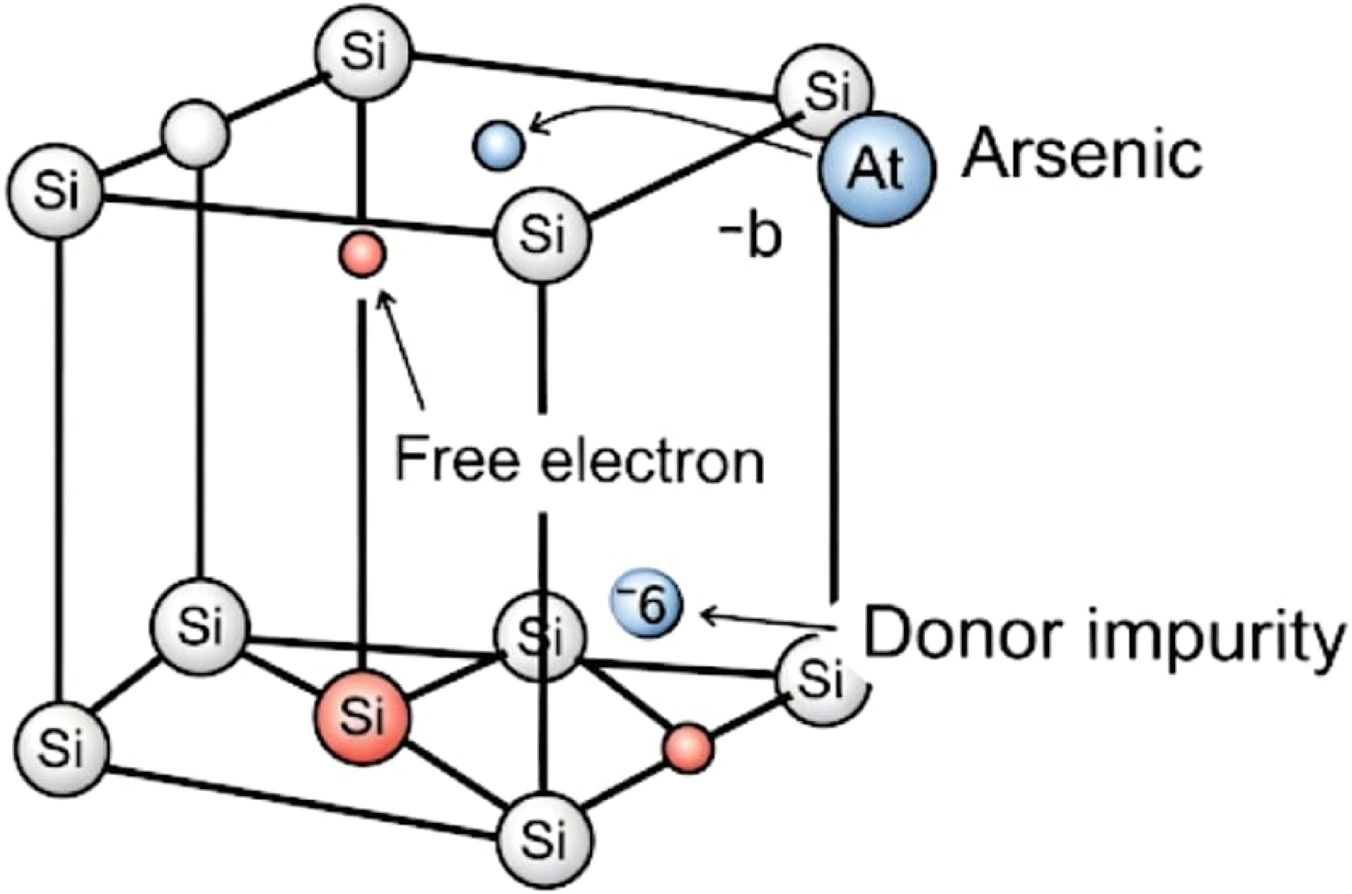
N-type semciisulstor



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