CHAPTER 14 — SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

PYQ ANALYSIS: CHAPTER 14

Topic Name	MCQs Asked	2-Mark	3-Mark	4-Mark
14.2 Classification (Bands, Types)	9	0	0	0
14.3/14.4 Intrinsic & Extrinsic	6	3	1	0
14.5/14.6 p-n Junction & Biasing	3	2	3	1
14.7 Rectifier	2	0	4	3
14.8 Special Purpose Diodes (Removed)	0	0	0	0

14.1 INTRODUCTION

- **Electronic devices** are those in which a controlled flow of electrons can be obtained.
- Before 1948, these devices were mainly **vacuum tubes** (also called valves).
  - Examples: Vacuum diode (2 electrodes: anode, cathode), triode (3 electrodes: cathode, plate, grid), tetrode (4), and pentode (5).
  - In vacuum tubes, electrons are supplied by a *heated* cathode and flow through a *vacuum*.
  - The flow is controlled by changing the voltage between the electrodes.
  - They were called "valves" because electrons could only flow in one direction (cathode to anode).
  - **Drawbacks of vacuum tubes:** They are **bulky**, **consume high power**, need **high operating voltages** (~100V), have a **limited life**, and are **not very reliable**.
- Modern electronics are based on **solid-state semiconductors**, starting in the 1930s.
- These devices allow control over the number and direction of charge carriers (like electrons) within the solid material itself.
- Simple inputs like light, heat, or a small voltage can change the number of mobile charges.
- **Advantages of semiconductor devices:**
  - They are **small in size**.
  - They **consume low power**.
  - They **operate at low voltages**.
  - They have a **long life** and **high reliability**.
  - No external heating or vacuum is needed.
- Even CRT (Cathode Ray Tube) monitors, based on vacuum tube principles, are now replaced by solid-state LCD (Liquid Crystal Display) monitors.

14.2 CLASSIFICATION OF METALS, CONDUCTORS AND SEMICONDUCTORS

On the basis of conductivity (σ) or resistivity ($\rho = 1/\sigma$)

- **(i) Metals:** Possess very low resistivity (high conductivity).
  - $\rho \sim 10^{-2} - 10^{-8}\,\Omega m$
  - $\sigma \sim 10^{2} - 10^{8}\,S m^{-1}$
- **(ii) Semiconductors:** Have resistivity or conductivity intermediate to metals and insulators. (★ Board Relevant Line)
  - $\rho \sim 10^{-5} - 10^{6}\,\Omega m$
  - $\sigma \sim 10^{5} - 10^{-6}\,S m^{-1}$
- **(iii) Insulators:** Have high resistivity (low conductivity).
  - $\rho \sim 10^{11} - 10^{19}\,\Omega m$
  - $\sigma \sim 10^{-11} - 10^{-19}\,S m^{-1}$

Semiconductors can be:

- **(i) Elemental semiconductors:** Si and Ge
- **(ii) Compound semiconductors:** Examples are: (★ Board Relevant Line)
  - **Inorganic:** CdS, GaAs, CdSe, InP, etc.
  - **Organic:** anthracene, doped pthalocyanines, etc.
  - **Organic polymers:** polypyrrole, polyaniline, etc.

This chapter will focus on inorganic elemental semiconductors (Si and Ge).

On the basis of energy bands

- In an isolated atom, electrons have distinct energy levels (orbits).

- When atoms come together to form a solid, their outer orbits overlap.
- This causes the individual energy levels to split and form continuous bands of many, closely-packed energy levels. These are called **energy bands**.
- **Valence Band (VB):** The energy band which includes the energy levels of the valence electrons. At 0K, this band is completely filled in semiconductors and insulators. (★ Board Relevant Line)
- **Conduction Band (CB):** The energy band above the valence band. At 0K, this band is completely empty in semiconductors and insulators. Electrons that move into this band are free to move and are responsible for electrical conduction. (★ Board Relevant Line)
- **Energy Band Gap (E_g):** The energy gap between the top of the valence band (E_V) and the bottom of the conduction band (E_C). This gap may be large, small, or zero, and it determines the material's electrical properties. (★ Board Relevant Line)

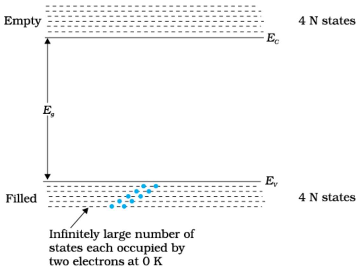

Fig 14.1: The energy band positions in a semiconductor at 0 K. The upper band, called the conduction band, consists of infinitely large number of closely spaced energy states. The lower band, called the valence band, consists of closely spaced completely filled energy states.

- **Case I: Metals**
  - The conduction band is partially filled, OR the conduction and valence bands overlap.
  - There is no energy gap ($E_g \approx 0$).
  - Electrons from the valence band can easily move into the conduction band, making a large number of electrons available for conduction. This results in high conductivity.
- **Case II: Insulators**
  - A large energy gap exists ($E_g > 3$ eV). The valence band is completely full and the conduction band is empty. Electrons cannot be excited from the VB to the CB by normal thermal energy, so no electrical conduction is possible. (★ Board Relevant Line)
- **Case III: Semiconductors**
  - A finite but small band gap exists ($E_g < 3$ eV). Because the gap is small, at room temperature some electrons from the valence band can acquire enough thermal energy to cross the gap and enter the conduction band, allowing for limited conduction. (★ Board Relevant Line)
  - For **Silicon (Si)**, $E_g \approx 1.1$ eV. For **Germanium (Ge)**, $E_g \approx 0.7$ eV. (★ Board Relevant Line)

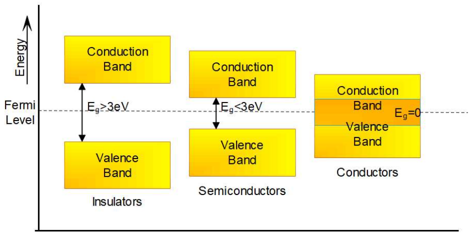

Fig 14.2: Difference between energy bands of (a) metals, (b) insulators and (c) semiconductors.

MCQs (Classification)

1. **For which of the following elements is the energy gap $Eg > 3eV$?**
   (A) Non-metal (B) Alloy (C) Metalloid
   (D) Metal

(March 2024)

2. **What type of semiconductor is Cds?**
   (A) Organic polymer (B) Organic
   (C) Inorganic (D) Elemental

(March 2024)

3. **Which of the following is an inorganic compound semiconductor?**
   (A) GaAs (B) Ge (C) Si (D) Polyaniline

(June 2024)

4. **Select the correct pair of compound semiconductors from the following.**
   (A) GaAs, CdSe (B) CdS, Si (C) InP, Ge
   (D) Si, Ge

(June 2025)

5. **At room temperature, the energy required for an electron to jump from the forbidden band in pure Si is ___ eV.**
   (A) 1.1 (B) 0.11 (C) 2.1 (D) 0.21

(July 2022) (Feb-March 2025)

6. **The energy gap (E_g) of metals is ___ the energy gap (E_g) of insulators.**
   (A) equal to (B) greater than (C) less than
   (D) greater than or equal to

(June 2025)

7. **The range of resistivities for metals is approximately ___.**

   (A) $10^{-2} - 10^{-8} \Omega m$ (B) $10^{2} - 10^{8} \Omega m$

   (C) $10^{-5} - 10^{6} \Omega m$ (D) $10^{11} - 10^{19} \Omega m$

(Feb-March 2025)

8. **Resistivity of semiconductor is approximately ___ Ωm.**

   (A) 10^{-2} to 10^{-8} (B) 10^{5} to 10^{-6} (C) 10^{11} to 10^{19}

   (D) 10^{-5} to 10^{6}

(July 2025)

9. **Carbon, silicon and germanium have four valence electrons each. These are characterised by valence and conduction bands separated by energy band gaps respectively equal to $(E_g)_C, (E_g)_{Si}$ and $(E_g)_{Ge}$. Which of the following statements is true?**

   (A) $(E_g)_{Si} < (E_g)_{Ge} < (E_g)_C$< /li>

   (B) $(E_g)_C < (E_g)_{Ge} > (E_g)_{Si}$

   (C) $(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$

   (D) $(E_g)_C = (E_g)_{Si} = (E_g)_{Ge}$

(July 2023) (Feb-March 2025) (June 2024) (NCERT Exercise 14.3)

NCERT Examples & Exercises

- **Example 14.1: C, Si and Ge have same lattice structure. Why is C insulator while Si and Ge intrinsic semiconductors?**

(NCERT Example 14.1)

14.3 INTRINSIC SEMICONDUCTOR

- A pure semiconductor (like Si or Ge) is called an **intrinsic semiconductor**.
- Si and Ge are **tetravalent** (have 4 valence electrons).
- In the crystal lattice, each atom shares one valence electron with each of its four nearest neighbours, forming four **covalent bonds**.

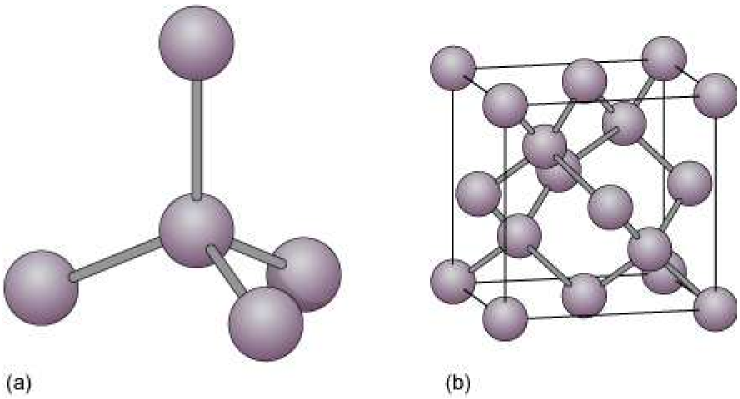

Fig 14.3: Three-dimensional diamond-like crystal structure

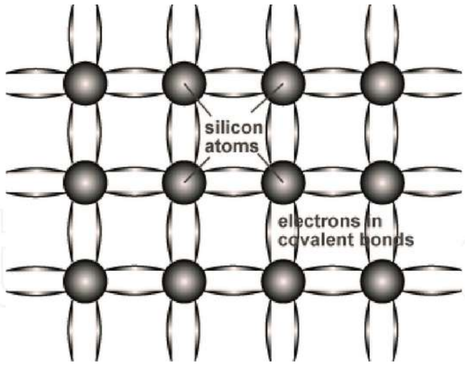

Fig 14.4: Schematic two-dimensional representation of Si or Ge structure

- At low temperatures ($T = 0$ K), all covalent bonds are intact. All electrons are in the valence band, and the conduction band is completely empty. With no free electrons for conduction, the semiconductor behaves as a perfect insulator. (★ Board Relevant Line)
- As temperature increases ($T > 0$ K), thermal energy breaks some covalent bonds.
- When a bond breaks, an electron is freed and can move into the conduction band. This is now a **free electron** (charge $-q$).
- The broken bond is left with a vacancy for an electron. This vacancy, which is a missing electron in the covalent bond, has an effective positive charge ($+q$) and is called a **hole**. The hole behaves as an apparent free particle. (★ Board Relevant Line)
- This process of creating a free electron and a hole is called **electron-hole pair generation**.

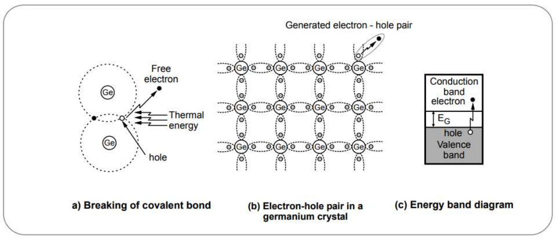

Fig. 0.4.2

Fig 14.5: (a) Schematic model of generation of hole... and conduction electron... (b) Simplified representation of possible thermal motion of a hole.

- In an intrinsic semiconductor, free electrons and holes are always created in pairs. Therefore, the number of free electrons (n_e) is always equal to the number of holes (n_h). (★ Board Relevant Line)

- $n_e = n_h = n_i$ (Important Formula)
  where n_i is the intrinsic carrier concentration.
- **Hole Movement:** A hole is a vacancy. An electron from a nearby covalent bond can jump into the hole, filling it. This makes the hole "move" to the position the electron came from.
- **Conduction:** Current in an intrinsic semiconductor is due to *both* charge carriers:
  - **Electron current (I_e):** due to free electrons in the conduction band.
  - **Hole current (I_h):** due to the movement of holes in the valence band.
- $I = I_e + I_h$
- **Recombination:** A free electron can also meet a hole, "fall" back into the valence band, and reform the covalent bond. This process, where an electron-hole pair is destroyed, is called **recombination**.
- At thermal equilibrium, the rate of generation of e-h pairs is equal to the rate of recombination.

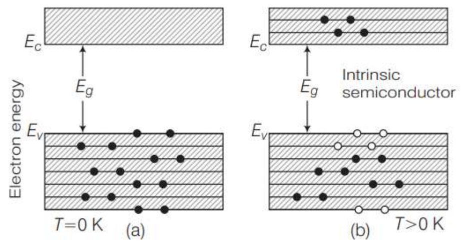

Fig 14.6: (a) An intrinsic semiconductor at $T = 0K$ behaves like insulator. (b) At $T > 0K$, four thermally generated electron-hole pairs.

MCQs (Intrinsic)

1. **If, $n_e =$ number of free electrons and $n_h =$ number of holes, then in intrinsic semiconductors ___.**

   (A) $n_e > n_h$ (B) $n_e = n_h$ (C) $n_h > n_e$

   (D) $n_e = {n_h}^2$

   (March 2022)

2. **In an intrinsic semiconductor, on increasing the temperature, the energy gap ___.**

   (A) initially increases then decreases.

   (B) decreases. (C) increases.

   (D) remains constant.

   (July 2025)

14.4 EXTRINSIC SEMICONDUCTOR

- The conductivity of intrinsic semiconductors is very low and not useful for most devices.
- The process of deliberately adding a desirable impurity, in very small amounts (e.g., a few parts per million), to a pure semiconductor to increase its conductivity is called **doping**. (★ Board Relevant Line)
- The impurity atoms are called **dopants**.
- The doped semiconductor is called an **extrinsic semiconductor**.
- The dopant atom should have a size nearly the same as the semiconductor atom (Si or Ge) so it doesn't distort the crystal lattice.
- Dopants are usually from Group 13 (trivalent) or Group 15 (pentavalent).

(i) n-type semiconductor

- Formed by doping a pure tetravalent semiconductor (like Si or Ge) with a **pentavalent** (valency 5) impurity. (★ Board Relevant Line)
- **Donor Impurities:** These are pentavalent impurities like **Arsenic (As)**, **Antimony (Sb)**, or **Phosphorous (P)**. (★ Board Relevant Line)
- The pentavalent dopant atom (e.g., As) replaces a Si atom.
- Four of its five valence electrons form covalent bonds with the four neighbouring Si atoms.
- The fifth electron is very weakly bound to the As atom.
- A very small amount of energy (~0.01 eV for Ge, ~0.05 eV for Si) is enough to free this fifth electron, making it a free electron in the conduction band.
- This process does *not* create a hole in the valence band.
- Since the pentavalent atom **donates** an extra electron for conduction (without creating a hole), it is called a **donor impurity**. (★ Board Relevant Line)

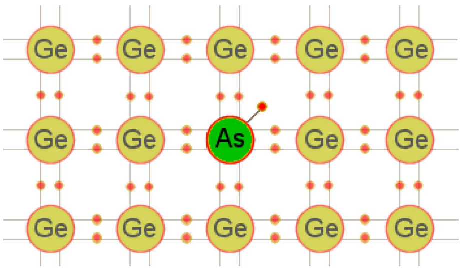

Fig 14.7: (a) Pentavalent donor atom... doped for tetravalent Si or Ge giving n-type semiconductor, and (b) Commonly used schematic representation...

- In an n-type semiconductor, the number of free electrons is much greater than the number of thermally generated holes. Thus, **electrons are the majority carriers** and **holes are the minority carriers**. (★ Board Relevant Line)

- $n_e \gg n_h$
- The energy level of the fifth electron (**donor level,** E_D) is in the forbidden gap, but very close to the conduction band. Electrons can easily move from E_D to E_C.

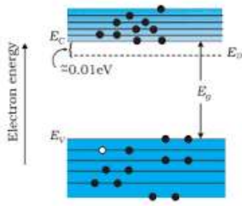

Fig 14.9(a): Energy bands of n-type semiconductor at $T > 0K$.

(ii) p-type semiconductor

- Formed by doping a pure tetravalent semiconductor (like Si or Ge) with a **trivalent** (valency 3) impurity. (★ Board Relevant Line)
- **Acceptor Impurities:** These are trivalent impurities like **Indium (In)**, **Boron (B)**, or **Aluminium (Al)**. (★ Board Relevant Line)
- The trivalent dopant atom (e.g., B) replaces a Si atom.
- Its three valence electrons form covalent bonds with three neighbouring Si atoms.
- There is one missing electron to form the fourth bond. This vacancy is a **hole**.

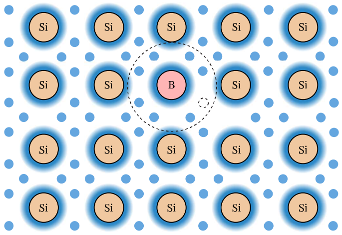

Fig 14.8: (a) Trivalent acceptor atom... doped in tetravalent Si or Ge lattice giving p-type semiconductor. (b) Commonly used schematic representation...

- An electron from a nearby Si atom can easily jump into this hole (requiring very little energy), causing the hole to move.
- Since the trivalent atom creates a hole, which can easily **accept** an electron from a neighbouring bond to complete its structure, it is called an **acceptor impurity**. (★ Board Relevant Line)
- In a p-type semiconductor, the number of holes (from doping) is much greater than the number of thermally generated electrons. Thus, **holes are the majority carriers** and **electrons are the minority carriers**. (★ Board Relevant Line)
- $n_h \gg n_e$
- The energy level of the hole (**acceptor level,** E_A) is in the forbidden gap, but very close to the valence band. Electrons can easily jump from E_V to E_A, leaving a hole in the VB.

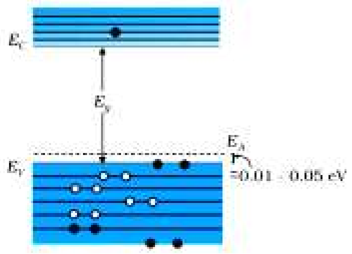

Fig 14.9(b): Energy bands of p-type semiconductor at $T > 0K$.

- **Overall Charge Neutrality:** Even when doped, the crystal as a whole remains electrically neutral. The positive charge of the donor ions (in n-type) balances the charge of the extra free electrons. The negative charge of the acceptor ions (in p-type) balances the charge of the extra holes.
- **Mass Action Law:** In any semiconductor (intrinsic or extrinsic) at thermal equilibrium, the product of electron and hole concentrations is constant and equal to the square of the intrinsic carrier concentration (n_i^2). (★ Board Relevant Line)
- $n_e n_h = n_i^2$ (Important Formula)
- Doping increases one type of carrier (e.g., n_e) and, by recombination, *decreases* the other type (n_h) to keep the product $n_e n_h$ constant.

MCQs (Extrinsic/Doping)

1. **The doping of a minute quantity of antimony to a silicon crystal makes it ___.**

   (A) a good insulator

   (B) a P-type semiconductor

   (C) an N-type semiconductor

   (D) a good conductor

   (July 2025)

2. **Suppose a pure Si crystal has 5×10^{28} atoms m^{-3}. It is doped by 1ppm concentration of As. The electron number density will be ___. (Given $n_i = 1.5 \times 10^{16} m^{-3}$)**

   (A) $5 \times 10^{28} m^{-3}$ (B) $5 \times 10^{16} m^{-3}$

   (C) $4.5 \times 10^{9} m^{-3}$ (D) $5 \times 10^{22} m^{-3}$

   (Feb-March 2025) (NCERT Example 14.2) (May 2021) (March 2024) (June 2025) (July 2025)

3. **Which of the following statements is true for a p-type semiconductor?**

   (A) Holes are the majority carriers and trivalent atoms are the dopants.

   (B) Electrons are the minority carriers and pentavalent atoms are the dopants.

(C) Holes are the minority carriers and pentavalent atoms are the dopants.

(D) Electrons are the majority carriers and trivalent atoms are the dopants.

(March 2024) (NCERT Exercise 14.2)

4. **Which of the following statements is true for an n-type silicon?**

(A) Electrons are majority carriers and trivalent atoms are the dopant.

(B) Holes are majority carriers and trivalent atoms are the dopant.

(C) Electrons are minority carriers and pentavalent atoms are the dopant.

(D) Holes are minority carriers and pentavalent atoms are the dopant.

(June 2024) (NCERT Exercise 14.1)

Subjective PYQs (Extrinsic/Doping)

2-Mark Questions

- **Write a note on P-type semiconductors.**

(March 2018) (Feb-March 2025)

- **Write the difference between P-type and N-type semiconductors. (Four points)**

(March 2023) (June 2025) (July 2025)

- **Suppose a pure Si crystal has** 5×10^{28} **atoms** m^{-3}**. It is doped by 1 ppm concentration of pentavalent As. Calculate the number of electrons and holes. Given that** $(n_i = 1.5 \times 10^{16} m^{-3})$**.**

(March 2024) (NCERT Example 14.2) (May 2021) (Feb-March 2025) (June 2025) (July 2025)

3-Mark Questions

- **Suppose a pure Si crystal has** 5×10^{28} **atoms** m^{-3}**. It is doped by 1 ppm concentration of pentavalent As. Calculate the number of electrons and holes. Given that** $(n_i = 1.5 \times 10^{16} m^{-3})$**.**

(May 2021) (June 2025) (July 2025) (NCERT Example 14.2) (March 2024) (Feb-March 2025)

14.5 P-N JUNCTION

- A **p-n junction** is the basic building block of devices like diodes and transistors. It is formed when a p-type and n-type semiconductor are joined together on a single crystal wafer.

14.5.1 p-n junction formation

- Two important processes occur: **diffusion** and **drift**.
- **1. Diffusion:** Due to the concentration difference (gradient) between the two sides of the junction, majority carriers diffuse across it. (★ Board Relevant Line)
  - Initially, there is a high concentration of holes on the p-side and electrons on the n-side.
  - Holes diffuse from p-side to n-side ($p \to n$).
  - Electrons diffuse from n-side to p-side ($n \to p$).
  - This motion of charge creates a **diffusion current**.
- **2. Formation of Depletion Region:** When majority carriers diffuse, they leave behind immobile ionised dopant atoms (positive donor ions on the n-side, negative acceptor ions on the p-side). This region near the junction, which is depleted of mobile charge carriers, is called the **depletion region** or **space-charge region**. (★ Board Relevant Line)
  - Its thickness is on the order of one-tenth of a micrometre.

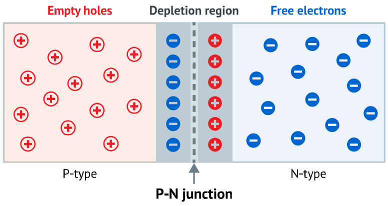

Fig 14.10: p-n junction formation process, showing diffusion and drift.

- **3. Drift and Barrier Potential:**
  - The layer of fixed positive ions (n-side) and negative ions (p-side) creates an internal electric field (E) directed from the n-side to the p-side.
  - This field causes a **drift current**, which is opposite to the diffusion current. It pushes minority carriers *across* the junction (electrons from $p \to n$, holes from $n \to p$).
  - The diffusion process continues until the drift current becomes equal and opposite to the diffusion current. At this point (equilibrium), there is no net current.
  - The potential difference created by the layer of positive and negative ions in the depletion region is called the **barrier potential** or **built-**

in potential (V_0). This potential barrier opposes the further diffusion of majority carriers. (★ Board Relevant Line)

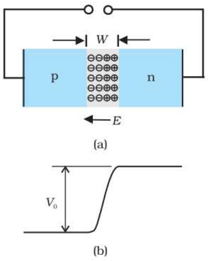

Fig 14.11: (a) Diode under equilibrium $(V = 0)$, (b) Barrier potential V_0 under no bias.

MCQs (p-n Junction)

1. **In an unbiased p-n junction, holes diffuse from the p-region to n-region because**

   (A) free electrons in the n-region attract them.

   (B) they move across the junction by the potential difference.

   (C) hole concentration in p-region is more as compared to n-region.

   (D) All the above.

(June 2025) (June 2024) (NCERT Exercise 14.4)

NCERT Examples & Exercises

- **Example 14.3: Can we take one slab of p-type semiconductor and physically join it to another n-type semiconductor to get p-n junction?**

(NCERT Example 14.3)

14.6 SEMICONDUCTOR DIODE

- A **semiconductor diode** is a p-n junction with metallic contacts provided at the ends. It is a two-terminal device.
- The arrow in the symbol shows the direction of conventional current (flow of positive charge) when the diode is forward biased.

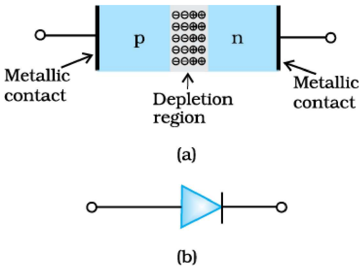

Fig 14.12: (a) A semiconductor diode, (b) Symbol for p-n junction diode.

14.6.1 p-n junction diode under forward bias

- A diode is **forward biased** when an external voltage V is applied such that the p-side is connected to the positive terminal of the battery and the n-side is connected to the negative terminal. This applied voltage opposes the barrier potential. (★ Board Relevant Line)

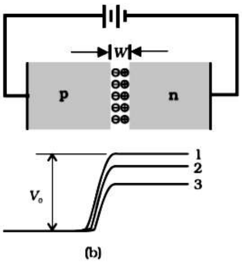

Fig 14.13: (a) p-n junction diode under forward bias. (b) Barrier potential is reduced.

- The external voltage V opposes the barrier potential V_0. The effective barrier height is **reduced** to $(V_0 - V)$, and the depletion layer width **decreases**. (★ Board Relevant Line)
- If V is large enough, many majority carriers (holes from p, electrons from n) can cross the junction.
- The reduced barrier allows majority carriers to diffuse across the junction in large numbers. Holes from the p-side cross to the n-side, and electrons from the n-side cross to the p-side. This process is called **minority carrier injection**. (★ Board Relevant Line)
- This injection and subsequent diffusion of carriers results in a large **diffusion current** flowing from p to n. The forward current is large, typically in **milliamperes (mA)**. (★ Board Relevant Line)

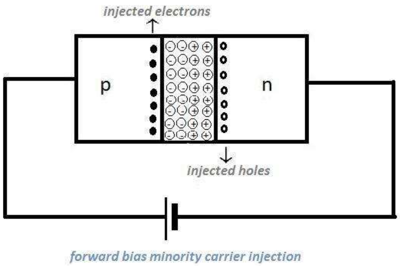

Fig 14.14: Forward bias minority carrier injection.

14.6.2 p-n junction diode under reverse bias

- A diode is **reverse biased** when the p-side is connected to the negative terminal of the battery and the n-side is connected to the positive terminal. This applied voltage *supports* the barrier potential. (★ Board Relevant Line)

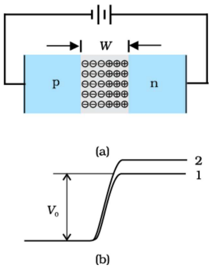

Fig 14.15: (a) Diode under reverse bias. (b) Barrier potential is increased.

- The external voltage V adds to the barrier potential V_0. The effective barrier height **increases** to $(V_0 + V)$, and the depletion layer width **increases**. (★ Board Relevant Line)
- The high barrier stops the flow (diffusion) of majority carriers.
- However, the strong electric field easily sweeps the minority carriers across the junction (electrons from $p \to n$, holes from $n \to p$).
- This creates a small **drift current**, called the **reverse saturation current**.
- This current is very small (in **microamperes, µA**) as it depends only on the concentration of thermally generated minority carriers. It is called the **reverse saturation current** and is nearly independent of the reverse voltage (up to the breakdown voltage). (★ Board Relevant Line)
- **Breakdown Voltage (V_{br}):** If the reverse voltage is made very high, the current suddenly increases sharply. This is called reverse breakdown, and it can destroy the diode if the current isn't limited.

V-I Characteristics of a p-n junction diode

- This is a graph of current (I) vs. applied voltage (V).

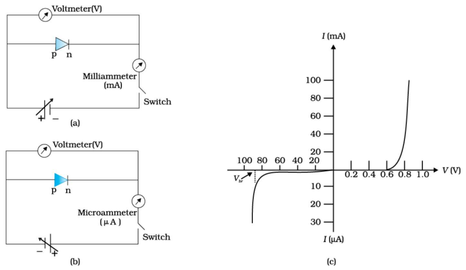

Fig 14.16: Experimental circuit arrangement for studying V-I characteristics of a p-n junction diode (a) in forward bias, (b) in reverse bias. (c) Typical V-I characteristics of a silicon diode.

- **Forward Bias Region (Quadrant I):**
- In forward bias, the current is very small (almost zero) until the applied voltage is large enough to overcome the barrier potential. This voltage is called the **threshold voltage** or **cut-in voltage**. (★ Board Relevant Line)
- Cut-in Voltage: ~ 0.2 V for **Ge**, ~ 0.7 V for **Si**. (★ Board Relevant Line)
- Above this voltage, the current increases exponentially. The diode has very low resistance.
- **Reverse Bias Region (Quadrant III):**
- The current is very small (µA) and almost constant. This is the reverse saturation current.
- The diode has very high resistance.
- At the breakdown voltage (V_{br}), the current increases dramatically.
- This shows the diode is a one-way device: it easily allows current in forward bias but blocks it in reverse bias. This property is used for rectification.
- **Dynamic Resistance (r_d):** The resistance offered by the diode to a changing AC signal.
- $r_d = \frac{\Delta V}{\Delta I}$ (Important Formula)

MCQs (Diode/Bias)

1. **When a p-n junction is forward biased, it**

   (A) increases the height of the potential barrier.

   (B) reduces the majority carrier current to zero.

   (C) decreases the height of the potential barrier.

   (D) None of the above.

   (March 2023) (March 2022) (Feb-March 2025) (March 2024)
   (NCERT Exercise 14.5)

2. **A diode with infinite reverse bias resistance is connected in the circuit shown. The values of I_1 and I_2 will be ___ respectively.**

   (A) 0.0A; 0.0A (B) 10.0A; 0.0 A (C) 0.2A; 0.0A

   (D) 0.0A; 0.2 A

   (March 2024)

Subjective PYQs (Diode/Bias)

2-Mark Questions

- **Draw the circuit diagram for obtaining the forward bias characteristic curve of a P-N junction diode and explain it.**

  (March 2017)

- **Discuss the p-n junction diode under forward bias.**

  (June 2024)

3-Mark Questions

- **To study the $v - I$ characteristics of a $p - n$ junction diode, draw a) the forward bias circuit b) the reverse bias circuit. Also, draw the typical $v - I$ characteristics of a silicon diode.**

  (July 2022)

- **When is a p-n junction diode said to be forward biased? Draw its V-I characteristic curve and explain forward biasing.**

  (July 2023)

- **Draw the experimental setup circuit for**

studying the reverse bias V-I characteristic of a P-N junction diode and explain the reverse bias characteristic.

(July 2025)

4-Mark Questions

- **State the points of difference between forward bias and reverse bias of a p-n junction diode. (Four points each)**

(Feb-March 2025)

NCERT Examples & Exercises

- **Example 14.4: The V-I characteristic of a silicon diode is shown in the Fig. 14.17. Calculate the resistance of the diode at (a) $I_D = 15$ mA and (b) $V_D = -10\,V$.**

(NCERT Example 14.4)

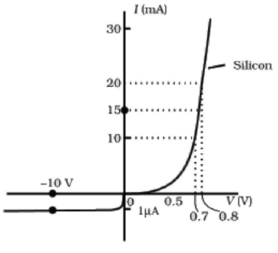

Fig 14.17

14.7 APPLICATION OF JUNCTION DIODE AS A RECTIFIER

- **Rectification** is the process of converting alternating voltage (ac), which periodically reverses direction, into a unidirectional (dc) voltage. (★ Board Relevant Line)
- The circuit used for this is called a **rectifier**.

Half-Wave Rectifier

- Uses a single diode in series with a load resistor (R_L).
- An ac voltage is supplied (usually via a transformer).
- **Working:**
  - During the **positive half-cycle** of the ac input, the diode is **forward biased**. It acts like a closed switch and conducts current. A voltage appears across R_L.
  - During the **negative half-cycle**, the diode is **reverse biased**. It acts like an open switch and does not conduct. The current and output voltage are zero.
- The output voltage is a series of positive pulses. Since only one-half of the input ac wave is present in the output, it is called a half-wave rectifier.
- The output waveform consists of one positive pulse for each full cycle of the input ac. Therefore, the output frequency is the same as the input ac frequency. (e.g., If $f_{in} = 50$ Hz, then $f_{out} = 50$ Hz). (★ Board Relevant Line)

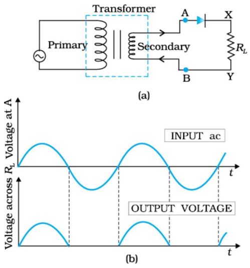

Fig 14.18: (a) Half-wave rectifier circuit, (b) Input ac voltage and output voltage waveforms from the rectifier circuit.

Full-Wave Rectifier

- This circuit rectifies both halves of the ac cycle.
- One common type uses two diodes (D_1, D_2) and a **centre-tap transformer**.
- The p-sides of the diodes connect to the two ends (A and B) of the transformer secondary.
- The n-sides are joined, and the output load R_L is connected between this common point and the centre tap.
- **Working:**
  - During the **positive half-cycle**: End A is positive, B is negative. D_1 is forward biased and conducts. D_2 is reverse biased and does not. Current flows through R_L.
  - During the **negative half-cycle**: End A is negative, B is positive. D_1 is reverse biased. D_2 is forward biased and conducts. Current flows through R_L *in the same direction as before*.
- An output pulse is obtained for *both* half-cycles. This is more efficient.
- The output waveform consists of two positive pulses for each full cycle of the input ac (one for the positive half-cycle, one for the negative). Therefore, the output frequency is double the input ac frequency. (e.g., If $f_{in} = 50$ Hz, then $f_{out} = 100$ Hz). (★ Board Relevant Line)

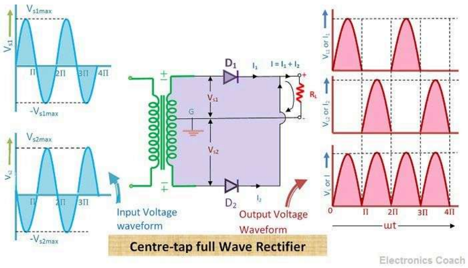

Fig 14.19: (a) A Full-wave rectifier circuit; (b) Input wave forms... (c) Output waveform...

Filter Circuits

- The output from a rectifier is **pulsating dc** (it is unidirectional but not steady).
- To get smooth, steady dc, a **filter circuit** is used.
- The simplest filter is a large **capacitor** connected in parallel with the load resistor R_L.
- **Working:** The capacitor charges up to the peak voltage of the rectified pulse. When the pulse voltage drops, the capacitor slowly discharges through R_L, holding the voltage up.
- This process smooths out the "ripples" and produces a much steadier dc voltage.

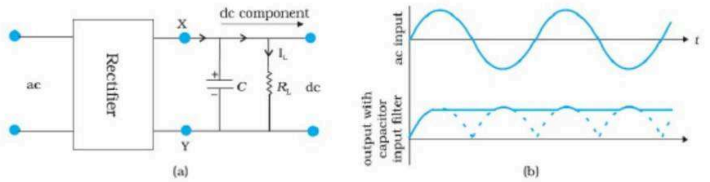

Fig 14.20: (a) A full-wave rectifier with capacitor filter. (b) Input and output waveforms.

MCQs (Rectifiers & Filters)

1. **The purpose of an RC filter circuit in a rectifier is ___.**

   (A) To filter AC ripples and get pure DC.

   (B) To convert AC to DC.

   (C) To increase the frequency of the output voltage.

   (D) To amplify the output voltage.

   (June 2025)

2. **In full wave rectification, if input frequency is 60 Hz then output frequency is ___.**

   (A) 30 Hz (B) 60 Hz (C) 120 Hz (D) 90 Hz

   (July 2025) **(NCERT Exercise 14.6)**

Subjective PYQs (Rectifiers)

3-Mark Questions

- **What is rectification? Explain the working of a half-wave rectifier with a circuit diagram and show its input and output voltage waveforms.**

  (March 2017) **(May 2021)** **(March 2023)** **(June 2025)** **(Feb-March 2025)**

- **Draw a neat circuit diagram of a full-wave rectifier and briefly explain its working principle. Draw the input and output voltage waveforms.**

  (March/April 2022) **(June 2024)**

4-Mark Questions

- **Draw the circuit diagram for half-wave and full-wave rectifiers and explain their working.**

  (March 2018)

- **Draw the circuit diagram of a full-wave rectifier and explain its working (show waveforms).**

  (March 2019) **(March 2024)**