Complete notes of semiconductor electronics for class 12th

SEMICONDUCTOR ELECTRONICS – COMPLETE NOTES

Class 12 Physics | CBSE Board Examination

These notes provided by Physics classes by Nayan jha covers the important concepts, definitions, diagrams, working principles, formulas, graphs and board-examination questions from **Semiconductor Electronics**.

What is a Semiconductor?

A semiconductor is a material whose electrical conductivity lies between that of a conductor and an insulator.

In other words, semiconductors conduct electricity better than insulators but less effectively than conductors.

Examples: Silicon (Si) , Germanium (Ge)

Comparison between Conductors, Semiconductors and Insulators

Property	Conductors	Semiconductors	Insulators
Conductivity	Very high	Moderate	Very low
Resistivity	Very low	Moderate	Very high
Energy gap	Nearly zero	Small	Large
Examples	Copper, Silver	Silicon, Germanium	Glass, Rubber

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Energy Band Theory

According to energy band theory, the energy levels of electrons in a solid are grouped into continuous energy bands.

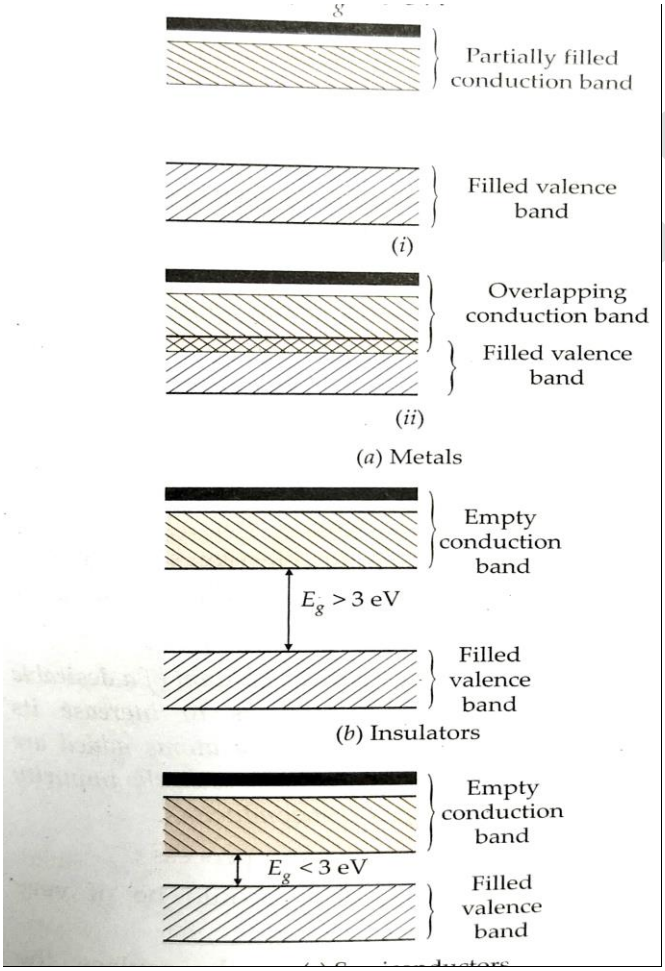
There are three important energy bands:

(i) Valence Band (VB)- The energy band occupied by valence electrons. Electrons in this band are generally bound to atoms. They do not contribute significantly to electrical conduction.

(ii) Conduction Band (CB) - The energy band in which electrons are free to move. Electrons present in this band contribute to electrical conduction.

(iii) Forbidden Energy Gap (Eg) - The energy gap between the valence band and conduction band. No allowed electron energy states exist in this gap.

Energy Band Diagrams



A. Conductor (metals)

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In conductors, the valence band and conduction band overlap or the conduction band is partially filled.

B. Semiconductor

The forbidden energy gap is small.

C. Insulator

The forbidden energy gap is large.

Energy Gap Values

Material	Energy Gap
Germanium	0.7 eV
Silicon	1.1 eV
Diamond	5.5 eV

Important: The conductivity of a semiconductor increases with an increase in temperature.This is because more electrons gain sufficient energy to move from the valence band to the conduction band.

Types of Semiconductors

Semiconductors are mainly classified into two types:

1. Intrinsic Semiconductor
2. Extrinsic Semiconductor

A. Intrinsic Semiconductor

A pure semiconductor without any impurity is called an intrinsic semiconductor.

Examples:

Pure Silicon, Pure Germanium

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Structure of Silicon- Silicon has atomic number 14. Its electronic configuration is 2, 8, 4. It has four valence electrons.Each silicon atom forms four covalent bonds with neighbouring silicon atoms.

Formation of Electron-Hole Pairs

At room temperature, some covalent bonds break due to thermal energy.

As a result, A free electron is produced. A vacancy is created in the covalent bond. This vacancy is called a hole.

Electron: A negatively charged particle.

Hole: The vacancy left by an electron, which behaves like a positively charged particle.

Thus, in an intrinsic semiconductor:

Number of electrons = Number of holes.

$ne=nh$

Where:

ne = electron concentration

nh = hole concentration

Important: Both electrons and holes contribute to electrical conduction.

B. Extrinsic Semiconductor

A semiconductor obtained by adding a small amount of suitable impurity to a pure semiconductor is called an extrinsic semiconductor.

The process of adding impurities is called **doping**.

Extrinsic semiconductors are of two types:

1. N-type semiconductor
2. P-type semiconductor

N-Type Semiconductor

When a pure semiconductor is doped with a pentavalent impurity, an N-type semiconductor is formed.

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Pentavalent impurities have five valence electrons.

Examples:

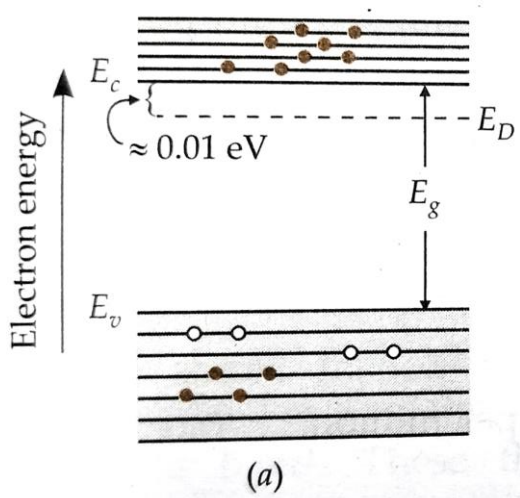
- Phosphorus (P)
- Arsenic (As)
- Antimony (Sb)

Formation of N-Type Semiconductor

When a pentavalent impurity is added to silicon:

- Four electrons form covalent bonds with neighbouring silicon atoms.
- The fifth electron becomes almost free.
- It contributes to electrical conduction.

Diagram



Important Characteristics

1. Electrons are majority charge carriers.
2. Holes are minority charge carriers.
3. Pentavalent impurity is called a donor impurity.
4. The semiconductor remains electrically neutral.

Remember:

N-type → Negative electrons are majority carriers.

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P-Type Semiconductor

When a pure semiconductor is doped with a trivalent impurity, a P-type semiconductor is formed.

Trivalent impurities have three valence electrons.

Examples:

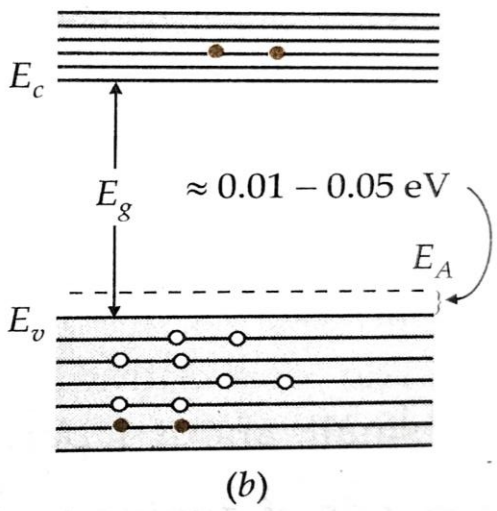
- Boron (B)
- Aluminium (Al)
- Gallium (Ga)

Formation of P-Type Semiconductor

When a trivalent impurity is added to silicon:

- Three electrons form covalent bonds.
- One covalent bond remains incomplete.
- This creates a hole.

Diagram



Important Characteristics

1. Holes are majority charge carriers.
2. Electrons are minority charge carriers.
3. Trivalent impurity is called an acceptor impurity.
4. The semiconductor remains electrically neutral.

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Remember:

P-type → Positive holes are majority carriers.

Difference Between N-Type and P-Type Semiconductors

N-Type	P-Type
Doped with pentavalent impurity	Doped with trivalent impurity
Electrons are majority carriers	Holes are majority carriers
Holes are minority carriers	Electrons are minority carriers
Donor impurity	Acceptor impurity
Examples: P, As, Sb	Examples: B, Al, Ga

P-N Junction Diode

A P-N junction is formed when a P-type semiconductor is joined with an N-type semiconductor in a single crystal.

A semiconductor diode is a two-terminal electronic device formed using a P-N junction.

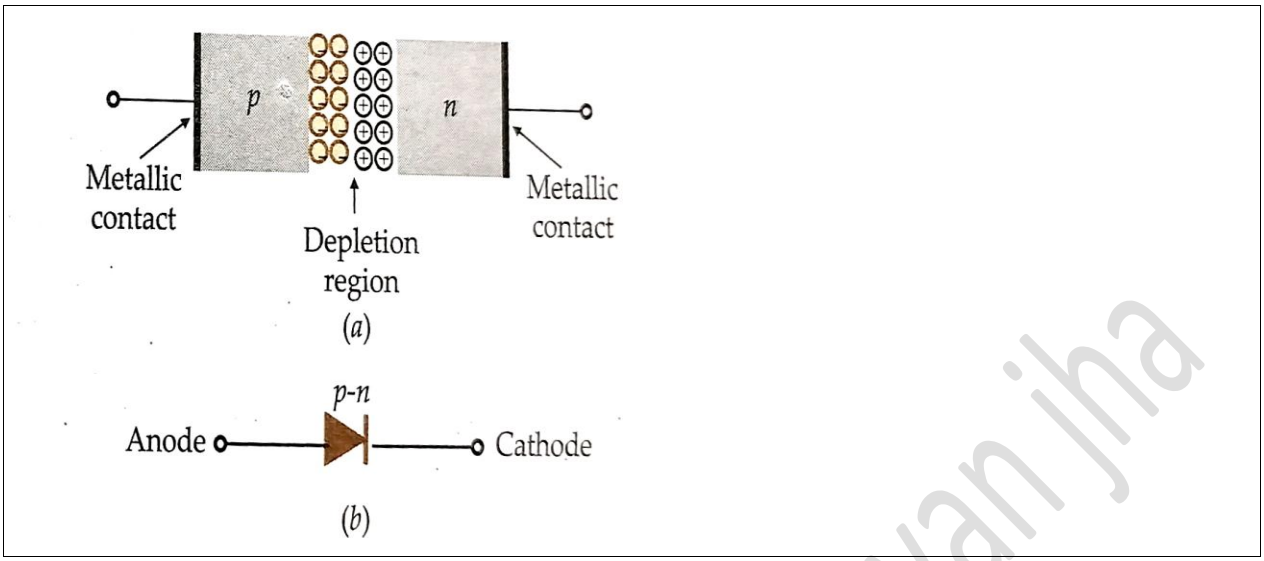
It allows current to flow easily in one direction under suitable biasing conditions.

Formation of depletion layers--

When P-type and N-type semiconductors are joined, Electrons diffuse from the N-region to the P-region And,holes diffuse from the P-region to the N-region, Electrons and holes recombine near the junction.This creates a region depleted of mobile charge carriers, This region is called the **depletion region or depletion layer**.

Diagram of P-N Junction

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so,Then we can define the region around the P-N junction that contains no mobile charge carriers (electrons and holes) is called the depletion region, It contains immobile ions: Negative acceptor ions on the P-side. Positive donor ions on the N-side.

Important Points

1. It is formed due to diffusion and recombination.
2. It has very few mobile charge carriers.
3. It produces an electric field.
4. It creates a potential barrier.

Potential Barrier

The potential difference developed across the depletion region is called the potential barrier.

It opposes the further diffusion of majority charge carriers across the junction.

Typical values at room temperature:

Semiconductor	Potential Barrier
Germanium	0.3 V

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Semiconductor	Potential Barrier
Silicon	0.7 V

Important: The potential barrier is an internal potential difference across the junction.

Biasing of P-N Junction Diode

Biasing means applying an external voltage across a P-N junction diode.

There are two types of biasing:

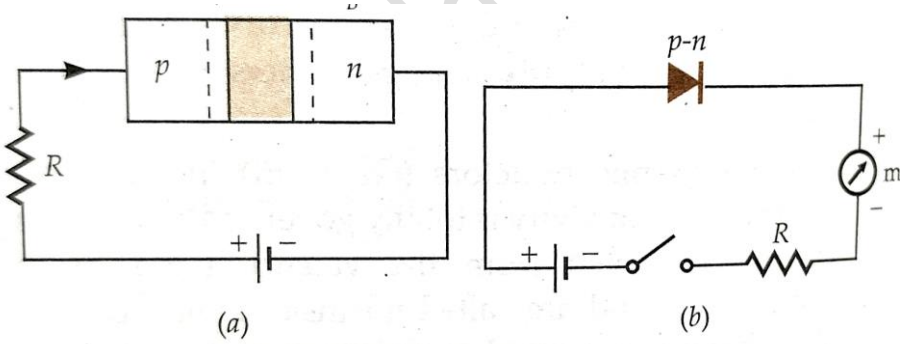
1. Forward Biasing
2. Reverse Biasing

A. Forward Biasing

A P-N junction is said to be forward biased when:

- P-side is connected to the positive terminal of the battery.
- N-side is connected to the negative terminal of the battery.

Circuit Diagram



Working

1. The external voltage opposes the potential barrier.
2. The width of the depletion region decreases.
3. The potential barrier decreases.
4. Majority charge carriers cross the junction.
5. A large current flows through the diode.

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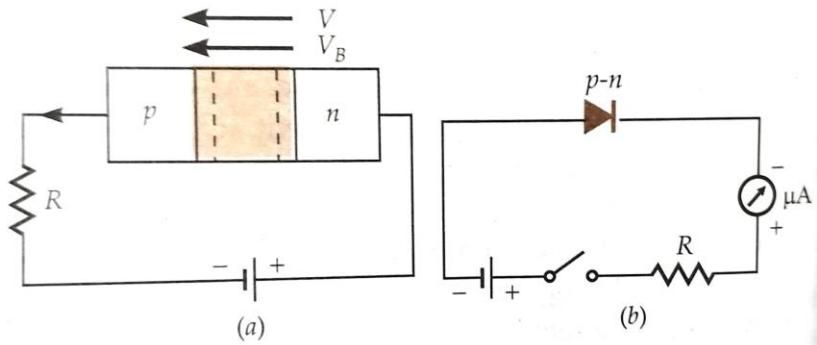
Conclusion: A forward-biased diode offers low resistance.

B. Reverse Biasing

A P-N junction is said to be reverse biased when:

- P-side is connected to the negative terminal.
- N-side is connected to the positive terminal.

Circuit Diagram



Working

1. The external voltage supports the potential barrier.
2. The depletion region becomes wider.
3. The potential barrier increases.
4. Majority charge carriers cannot easily cross the junction.
5. A very small reverse current flows due to minority charge carriers.

Conclusion: A reverse-biased diode offers very high resistance.

Difference Between Forward and Reverse Biasing

Forward Bias	Reverse Bias
P connected to positive terminal	P connected to negative terminal
N connected to negative terminal	N connected to positive terminal
Depletion layer decreases	Depletion layer increases
Barrier decreases	Barrier increases
Large current flows	Very small current flows

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Forward Bias	Reverse Bias
Low resistance	High resistance

V-I Characteristics of P-N Junction Diode

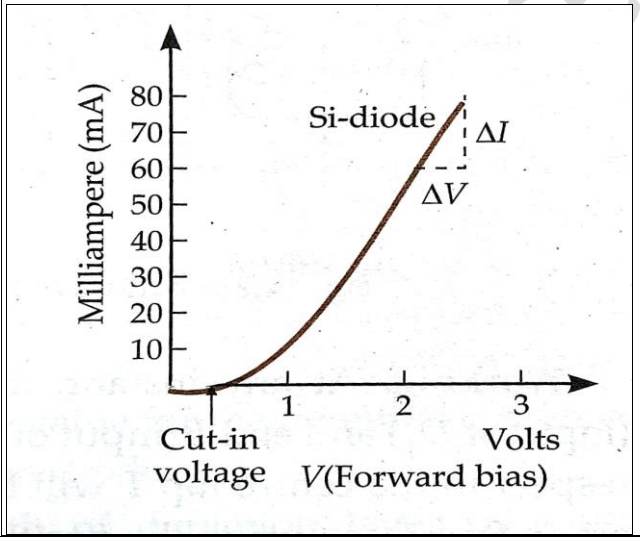
The relationship between the voltage applied across a diode and the current flowing through it is called its V-I characteristics.

There are two types:

1. Forward characteristics
2. Reverse characteristics

Forward Characteristics – It is the graphical relation between forward current and forward potential when diode is forward biased

It is given as .



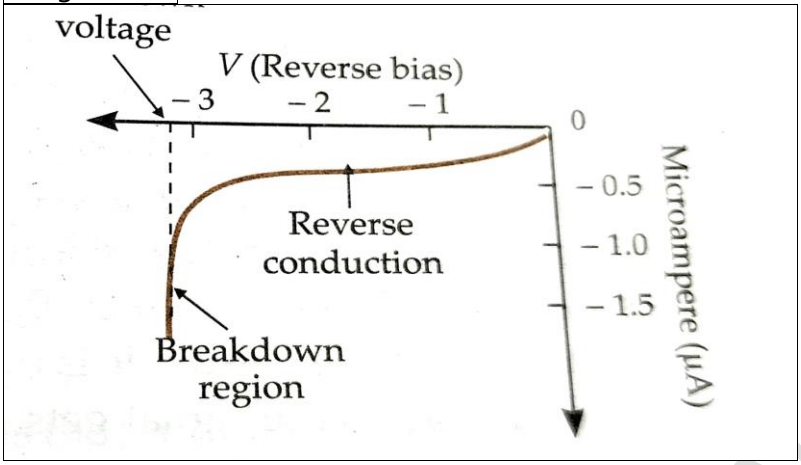
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- Initially, current is very small.
- After the knee voltage, current increases rapidly.
- Knee voltage is approximately 0.7 V for silicon and 0.3 V for germanium.

Reverse Characteristics-

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It is the graphical relation between reverse current and reverse potential when diode is reverse biased

It is given as .



- A very small reverse saturation current flows.
- When reverse voltage reaches the breakdown voltage, current increases sharply.

Diode as a Rectifier

A rectifier is an electronic device that converts alternating current (AC) into direct current (DC).

A P-N junction diode is commonly used as a rectifier.

There are two important types:

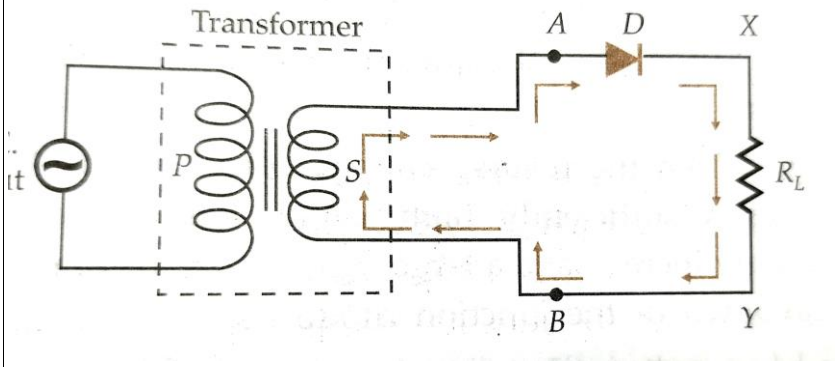
1. Half-Wave Rectifier
2. Full-Wave Rectifier

A. Half-Wave Rectifier

A half-wave rectifier converts only one half-cycle of AC into pulsating DC.

Circuit Diagram

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Working

During positive half-cycle:

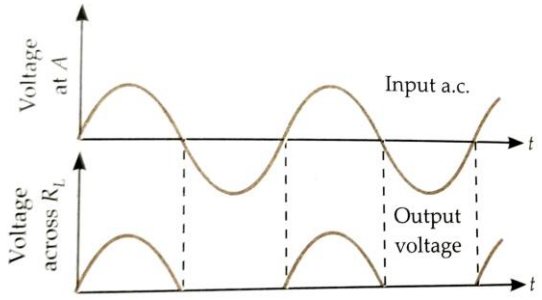
The diode becomes forward biased.

- Current flows through the load.
- Output voltage is obtained.

During negative half-cycle:

- The diode becomes reverse biased.
- Current does not flow through the load.
- Output voltage becomes zero.

Input and Output Waveforms



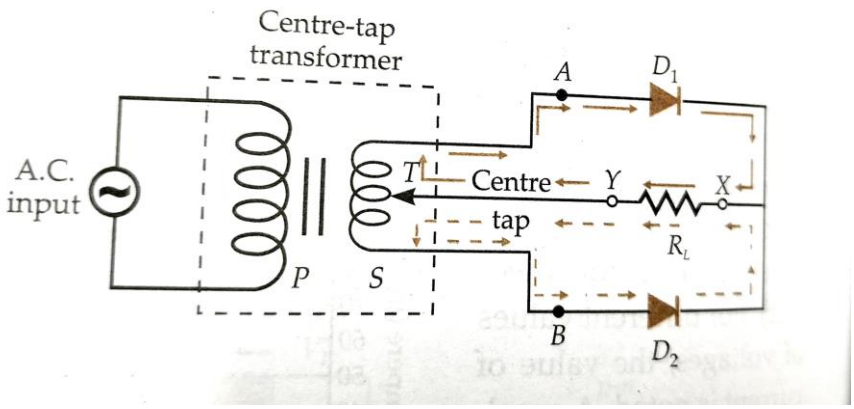
The output is pulsating DC.

B. Full-Wave Rectifier

A full-wave rectifier converts both half-cycles of AC into pulsating DC.

It commonly uses two diodes with a centre-tapped transformer or four diodes in a bridge arrangement.

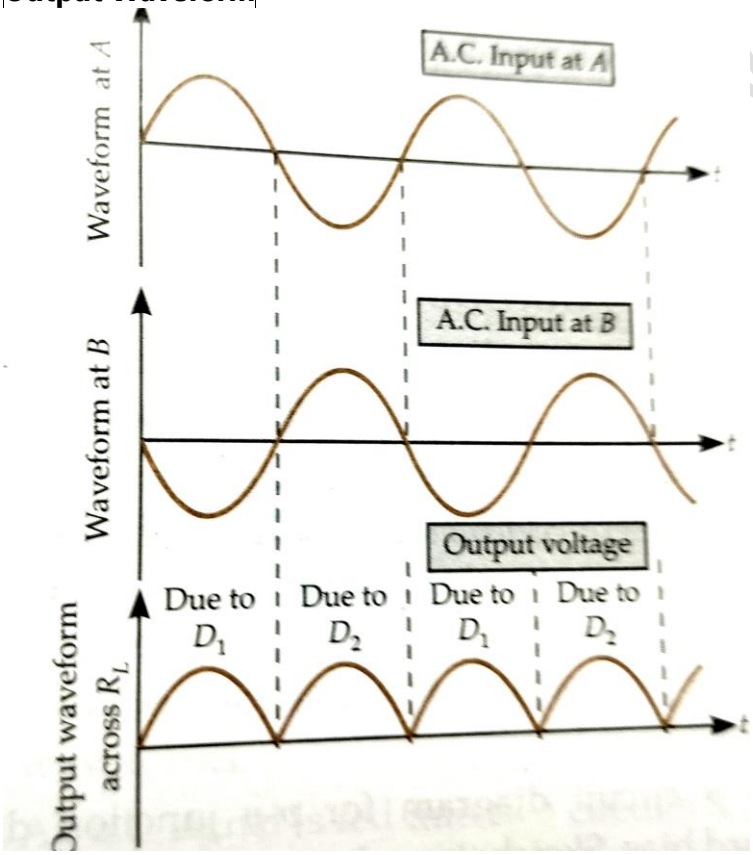
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Working

- During the positive half-cycle, one diode or diode pair conducts.
- During the negative half-cycle, the other diode or diode pair conducts.
- Current through the load flows in the same direction during both half-cycles.

Output Waveform



Difference Between Half-Wave and Full-Wave Rectifier

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Half-Wave Rectifier	Full-Wave Rectifier
Uses one half-cycle	Uses both half-cycles
One diode is sufficient	Two or four diodes are used
Lower efficiency	Higher efficiency
More ripple	Less ripple
Output frequency = f	Output frequency = 2f

Important Semiconductor Devices

Some important semiconductor devices are:

1. Diode
2. LED
3. Photodiode
4. Solar Cell
5. Zener Diode
6. Transistor

The exact devices included in your board examination depend on the prescribed syllabus.

A. LED (Light Emitting Diode)

An LED is a semiconductor device that emits light when it is forward biased.

Working:

When an LED is forward biased, electrons and holes recombine near the junction and release energy in the form of light.

Applications:

- Indicator lights
- Digital displays
- Lighting systems

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B. Photodiode

A photodiode is a semiconductor device that converts light energy into electrical current.

It is generally operated in reverse bias.

Working:

When light falls on the depletion region, electron-hole pairs are generated.

As a result, reverse current increases.

Applications:

- Light sensors
- Optical communication
- Automatic lighting systems

C. Solar Cell

A solar cell is a semiconductor device that converts solar energy directly into electrical energy.

It works on the photovoltaic effect.

Working:

1. Sunlight falls on the P-N junction.
2. Electron-hole pairs are generated.
3. The electric field of the depletion region separates these charge carriers.
4. An emf is produced across the terminals.

Applications:

- Solar panels
- Satellites
- Solar-powered calculators

Important Definitions for CBSE Board Examination

These definitions are important for short-answer questions.

1. Semiconductor: A material whose electrical conductivity lies between that of a conductor and an insulator.

2. Doping: The process of adding a small quantity of impurity to a pure semiconductor to increase its conductivity.

3. Intrinsic Semiconductor: A pure semiconductor without any impurity.

4. Extrinsic Semiconductor: A semiconductor whose conductivity is increased by adding suitable impurities.

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5. Majority Charge Carriers: The charge carriers present in greater concentration in a semiconductor.

6. Minority Charge Carriers: The charge carriers present in smaller concentration in a semiconductor.

7. Depletion Region: The region around a P-N junction that is depleted of mobile charge carriers.

8. Potential Barrier: The potential difference developed across the depletion region that opposes further diffusion of majority charge carriers.

9. Forward Biasing: Connecting the P-side of a diode to the positive terminal and the N-side to the negative terminal of a battery.

10. Reverse Biasing: Connecting the P-side to the negative terminal and the N-side to the positive terminal of a battery.

11. Rectifier: An electronic device that converts alternating current into direct current.

Most Important CBSE Board Examination Questions

A. Very Short Answer Questions (1 Mark)

1. What is a semiconductor?
2. Define doping.
3. What is an intrinsic semiconductor?
4. What is an extrinsic semiconductor?
5. Name two pentavalent impurities.
6. Name two trivalent impurities.
7. What are majority charge carriers in an N-type semiconductor?
8. What are majority charge carriers in a P-type semiconductor?
9. What is a depletion region?
10. What is the approximate barrier potential of a silicon diode?

B. Short Answer Questions (2–3 Marks)

1. Differentiate between intrinsic and extrinsic semiconductors.
2. Explain the formation of N-type semiconductors with a diagram.
3. Explain the formation of P-type semiconductors with a diagram.

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4. Differentiate between P-type and N-type semiconductors.
5. Explain the formation of the depletion region.
6. What is potential barrier? Explain its formation.
7. Explain forward biasing and reverse biasing of a P-N junction.
8. Draw and explain the V-I characteristics of a P-N junction diode.
9. Why does the conductivity of a semiconductor increase with temperature?
10. Why is a photodiode operated in reverse bias?

C. Long Answer Questions (3–5 Marks)

1. Explain the formation of a P-N junction diode with a suitable diagram.
2. Explain forward and reverse biasing of a P-N junction diode with circuit diagrams.
3. Draw and explain the V-I characteristics of a semiconductor diode.
4. Explain the working of a half-wave rectifier with a circuit diagram and waveforms.
5. Explain the working of a full-wave rectifier with a circuit diagram and waveforms.
6. Explain the energy band theory of conductors, semiconductors and insulators with diagrams.

Important Conceptual Questions with Answers

Q1. Why does the conductivity of a semiconductor increase with an increase in temperature?

Answer: As temperature increases, more electrons gain thermal energy and move from the valence band to the conduction band. This increases the number of electron-hole pairs, resulting in increased conductivity.

Q2. Why is silicon preferred over germanium in semiconductor devices?

Answer:

- Silicon has a higher energy gap.
- It has lower leakage current at room temperature.
- It can operate at comparatively higher temperatures.

Q3. Why is a diode called a unidirectional device?

Answer: A diode allows current to flow easily in forward bias but offers very high resistance in reverse bias. Therefore, it conducts mainly in one direction.

Q4. Why is a P-N junction diode not a perfect conductor in forward bias?

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Answer: Even in forward bias, the diode offers some resistance due to the semiconductor material and junction properties.

Q5. Why is a photodiode operated in reverse bias?

Answer: Reverse bias provides a wider depletion region and allows the photocurrent produced by incident light to be detected effectively.

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