Engineering Physics Module–3 Notes Introduction to Solids

MODULE–3 TOPICS

• Free Electron Theory of Metals
• Fermi Level in Intrinsic & Extrinsic Semiconductors
• Density of States
• Bloch's Theorem
• Kronig-Penney Model
• Origin of Energy Bands
• PN Junction Diode
• Zener Diode
• Solar Cell
• Hall Effect

1. FREE ELECTRON THEORY OF METALS

Free electron theory explains electrical and thermal conductivity of metals using free electrons.

Assumptions:
• Metals contain large number of free electrons.
• Electrons move randomly inside metal.
• Positive ions remain fixed.

Advantages:
• Explains electrical conductivity.
• Explains thermal conductivity.

Limitations:
• Cannot explain semiconductors properly.
• Cannot explain magnetic properties.

2. FERMI LEVEL

Fermi level is the highest occupied energy level at absolute zero temperature.

(a) Intrinsic Semiconductor

• Pure semiconductor.
• Fermi level lies at center of forbidden energy gap.

(b) Extrinsic Semiconductor

Impurity added semiconductor.

Types:
• N-type semiconductor
• P-type semiconductor

In N-type semiconductor, Fermi level moves closer to conduction band.

In P-type semiconductor, Fermi level moves closer to valence band.

3. DENSITY OF STATES (DOS)

Density of states represents number of energy states available per unit energy range.

Importance:
• Helps determine electrical properties.
• Important in semiconductor physics.

4. BLOCH’S THEOREM

Bloch’s theorem states that electron wave function in periodic crystal lattice behaves as Bloch wave.

Bloch Function:

$\psi(x) = u(x)e^{ikx}$

Where:
u(x) = periodic function

Applications:
• Explains motion of electrons in crystals.
• Explains energy bands.

5. KRONIG-PENNEY MODEL

Kronig-Penney model explains formation of energy bands in solids using periodic potential.

Main Features:
• Allowed energy bands are formed.
• Forbidden energy gaps exist between bands.

Applications:
• Explains band structure of solids.
• Explains conductors and semiconductors.

6. ORIGIN OF ENERGY BANDS

When atoms come close together in solids, discrete energy levels split into bands.

Types of Bands:
• Valence Band
• Conduction Band
• Forbidden Energy Gap

Types of Materials:
• Conductors
• Semiconductors
• Insulators

7. P-N JUNCTION DIODE

A PN junction diode is formed by joining P-type and N-type semiconductors.

Biasing:
• Forward Bias
• Reverse Bias

V-I Characteristics:
• Current increases rapidly in forward bias.
• Small current flows in reverse bias.

Applications:
• Rectifiers
• Switching circuits

8. ZENER DIODE

Zener diode is a heavily doped PN junction diode designed to operate in reverse breakdown region.

Characteristics:
• Maintains constant voltage.
• Operates in reverse bias.

Applications:
• Voltage regulation
• Voltage stabilization

9. SOLAR CELL

Solar cell converts solar energy into electrical energy using photovoltaic effect.

Construction:
• PN junction semiconductor
• Transparent cover

Working:
Sunlight generates electron-hole pairs producing electric current.

Applications:
• Satellites
• Solar power systems
• Calculators

10. HALL EFFECT

Hall effect is the production of transverse voltage across conductor when magnetic field is applied perpendicular to current.

Hall Voltage:

VH = BI / net

Where:
B = magnetic field
I = current
n = carrier concentration

Applications:
• Measurement of magnetic field
• Semiconductor identification
• Hall sensors

MOST IMPORTANT 14 MARK QUESTIONS

1. Explain free electron theory of metals.

2. Explain Fermi level in intrinsic and extrinsic semiconductors.

3. Explain density of states and Bloch’s theorem.

4. Explain Kronig-Penney model and origin of energy bands.

5. Explain V-I characteristics of PN junction diode.

6. Explain Zener diode and its applications.

7. Explain construction and working of solar cell.

8. Explain Hall effect and derive Hall voltage expression.

IMPORTANT 7 MARK QUESTIONS

1. Define Fermi level.

2. Explain energy bands.

3. Explain N-type semiconductor.

4. Explain P-type semiconductor.

5. Explain reverse bias and forward bias.

6. Explain Hall coefficient.

7. Explain applications of solar cell.

IMPORTANT NUMERICALS

1. Hall voltage calculation.

2. Hall coefficient numerical.

3. Carrier concentration problems.

4. Zener diode voltage regulation numerical.

EXAM TIPS

• Draw neat V-I characteristic graphs.
• Learn semiconductor diagrams properly.
• Practice Hall effect numericals.
• Revise energy band theory carefully.
• Focus on applications of devices.