Engineering Physics Module–1 Notes Wave Nature of Particles and Schrodinger Equation

MODULE–1 TOPICS

• Introduction to Quantum Mechanics
• Wave Nature of Particles
• Operators
• Time-dependent Schrodinger Equation
• Time-independent Schrodinger Equation
• Particle in One Dimensional Box
• Born Interpretation
• Free Particle Wave Function
• Wave Packets
• Group Velocity and Phase Velocity Relation
• Uncertainty Principle

1. INTRODUCTION TO QUANTUM MECHANICS

Quantum mechanics is the branch of physics that studies the behavior of microscopic particles such as electrons, protons and atoms.

Classical physics cannot explain microscopic phenomena properly, therefore quantum mechanics was developed.

Applications of Quantum Mechanics:
• Semiconductor devices
• Lasers
• Electron microscopes
• Nanotechnology
• Quantum computers

2. WAVE NATURE OF PARTICLES

According to Louis de Broglie, every moving particle behaves like a wave.

This concept is called wave-particle duality.

de Broglie Wavelength Equation:

$\lambda = h / p$

Where:
λ = wavelength
h = Planck's constant
p = momentum

For a particle:

$\lambda = h / mv$

Where:
m = mass of particle
v = velocity of particle

Importance:
• Explains electron diffraction
• Basis of quantum mechanics

3. OPERATORS IN QUANTUM MECHANICS

Operators are mathematical tools used to obtain physical quantities from wave functions.

Examples of Operators:

1. Position Operator:
x■ = x

2. Momentum Operator:
p■ = -i■ (d/dx)

3. Energy Operator:
Ê = i■ (d/dt)

Where:
■ = h/2π

4. SCHRODINGER WAVE EQUATION

Schrodinger equation describes behavior of quantum particles.

(a) Time-dependent Schrodinger Equation

i■ (∂ψ/∂t) = ■ψ

Where:
ψ = wave function
■ = Hamiltonian operator

(b) Time-independent Schrodinger Equation

■ψ = Eψ

This equation is used for particles with constant energy.

Importance:
• Determines energy of particles
• Explains atomic structure

5. PARTICLE IN ONE DIMENSIONAL BOX

A particle is confined inside a box of length L where potential energy inside box is zero and outside box is infinite.

Assumptions:
• Particle moves freely inside box.
• Particle cannot escape outside box.

Energy of Particle:

$E_n = n^2h^2 / 8mL^2$

Where:
n = quantum number
m = mass of particle
L = length of box

Important Points:
• Energy is quantized.
• Ground state energy is non-zero.

Applications:
• Quantum wells

• Nanotechnology

6. BORN INTERPRETATION

According to Born interpretation, square of wave function gives probability density of particle.

Probability density:

$|\psi|^2$

Meaning:
Higher value of $|\psi|^2$ means greater probability of finding particle at that position.

7. FREE PARTICLE WAVE FUNCTION

A free particle moves without external force.

Wave function of free particle:

$\psi(x,t) = Ae^{i(kx-\omega t)}$

Where:
A = amplitude
k = wave number
ω = angular frequency

8. WAVE PACKETS

Wave packet is a group of waves having different wavelengths combined together.

Importance:
• Represents localized particle
• Explains uncertainty principle

9. GROUP VELOCITY AND PHASE VELOCITY

Phase Velocity:

$v_p = \omega / k$

Group Velocity:

$v_g = d\omega / dk$

Relation between vg and vp:

$v_g = 2v_p$ (for non-relativistic particles)

10. HEISENBERG UNCERTAINTY PRINCIPLE

It is impossible to determine exact position and momentum of a particle simultaneously.

Mathematical Expression:

$\Delta x \, \Delta p \geq h / 4\pi$

Where:
Δx = uncertainty in position
Δp = uncertainty in momentum

Importance:
• Fundamental principle of quantum mechanics

• Explains atomic stability

Applications:
• Electron microscopes
• Quantum physics research

MOST IMPORTANT 14 MARK QUESTIONS

1. Explain wave nature of particles and de Broglie hypothesis.

2. Explain Schrodinger wave equation.

3. Derive time-independent Schrodinger equation.

4. Explain particle in one dimensional box.

5. Explain Born interpretation of wave function.

6. Explain free particle wave function and wave packets.

7. Explain uncertainty principle with applications.

8. Explain relation between group velocity and phase velocity.

IMPORTANT 7 MARK QUESTIONS

1. Define quantum mechanics.

2. Explain operators in quantum mechanics.

3. Explain de Broglie wavelength.

4. Explain Born interpretation.

5. Explain uncertainty principle.

EXAM TIPS

• Learn all derivations carefully.
• Practice Schrodinger equations properly.
• Remember important formulas.
• Draw particle in box diagram neatly.
• Learn numerical problems on de Broglie wavelength and uncertainty principle.