
🔹 UNIT – II : QUANTUM MECHANICS

(Advanced Engineering Physics – R25, JNTUH)

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1. de-Broglie Hypothesis and Its Significance (10 Marks)

Introduction

Classical physics treats matter as particles and light as waves. However, experiments like electron diffraction proved that **matter also exhibits wave nature**. To explain this, **Louis de-Broglie** proposed his hypothesis.

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de-Broglie Hypothesis

According to de-Broglie, **every moving particle is associated with a wave**, called a matter wave.

The wavelength of the matter wave is given by:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Where:

- (h) = Planck's constant
- (p) = momentum
- (m) = mass of particle
- (v) = velocity

Experimental Verification

The wave nature of electrons was confirmed by **Davisson–Germer experiment**, where electron diffraction was observed.

Significance

- Explains wave–particle duality
- Foundation for quantum mechanics
- Important in electron microscopes

Conclusion

The de-Broglie hypothesis unified particle and wave concepts and laid the foundation for modern quantum theory.

Keywords

Matter waves, wave–particle duality, de-Broglie wavelength.

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2. Heisenberg Uncertainty Principle (10 Marks)

Introduction

In classical mechanics, position and momentum can be measured exactly. Quantum mechanics shows this is not possible for microscopic particles.

Statement

It is impossible to measure **both position and momentum of a particle simultaneously with absolute accuracy**.

Mathematically:

$$
\Delta x \cdot \Delta p \ge \frac{h}{4\pi}
$$

Physical Meaning

- More accuracy in position → less accuracy in momentum
- Valid only for microscopic particles

Significance

- Rejects classical determinism
- Explains atomic stability
- Justifies probabilistic nature of quantum mechanics

Conclusion

The uncertainty principle highlights the fundamental limits of measurement in the quantum world.

Keywords

Uncertainty, momentum, position, probability.

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3. Schrödinger Time-Independent Wave Equation (10 Marks)

Introduction

Schrödinger wave equation is the basic equation of quantum mechanics that describes the behavior of particles using wave functions.

Time-Independent Schrödinger Equation

$$-\frac{h^2}{8\pi^2 m}\frac{d^2\psi}{dx^2} + V\psi = E\psi$$

Where:

- ψ = wave function
- V = potential energy
- E = total energy

Physical Significance of ψ

- ψ^2 gives probability density
- Does not give exact position

Importance

- Predicts allowed energy states
- Explains atomic structure

Conclusion

Schrödinger equation provides a complete description of quantum systems.

Keywords

Wave function, probability, energy eigenvalues.

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4. Particle in a One-Dimensional Box (10 Marks)

Introduction

A particle confined in a rigid box of length (L) is a simple quantum system used to explain energy quantization.

Assumptions

- Infinite potential walls
- Particle is free inside the box
- Potential energy inside box = 0

Energy Eigenvalues

$$E_n = \frac{n^2 h^2}{8mL^2}$$

Where ($n = 1,2,3,\dots$)

Key Results

- Energy is quantized
- Zero-point energy exists
- Energy levels increase with (n^2)

Conclusion

The particle-in-a-box model clearly demonstrates quantization of energy.

Keywords

Quantization, zero-point energy, eigenvalues.

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5. Energy Bands and Band Gap in Solids (10 Marks)

Introduction

In solids, interaction between atoms leads to the formation of **energy bands** instead of discrete energy levels.

Types of Bands

1. **Valence Band** – occupied by electrons
2. **Conduction Band** – free electrons
3. **Band Gap** – energy difference between bands

Classification of Solids

- **Conductors** – no band gap
- **Semiconductors** – small band gap
- **Insulators** – large band gap

Importance

- Explains electrical conductivity
- Basis of semiconductor devices

Conclusion

Energy band theory explains the electrical behavior of solids effectively.

Keywords

Valence band, conduction band, band gap, semiconductors.

✅ UNIT–II FINAL CONCLUSION

Quantum mechanics provides a complete understanding of microscopic particles, explaining wave behavior, uncertainty, quantized energy, and electronic properties of solids.