

## B.SC. (HONOURS) PHYSICS

### DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 18: ADVANCED QUANTUM MECHANICS - II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Quantum Mechanics-II DSE 18	4	3	1	0	Quantum Mechanics (DSC 14), and Advanced Quantum Mechanics-I (DSE 13)

#### Course Objectives

This course aims to:

- Introduce and develop approximation methods for solving quantum systems where exact solutions are not possible, including both time-independent and time-dependent approaches.
- Strengthen understanding of the interaction picture and its role in quantum dynamics.
- Equip students with the tools of scattering theory, including formal techniques like the Lippmann–Schwinger equation, Green’s functions, and the Born approximation.
- Provide a conceptual and mathematical foundation for advanced topics in quantum physics such as quantum field theory, quantum optics, and condensed matter physics.

#### Learning Outcomes

At the end of this course, students will be able to

- Apply key approximation methods including time-independent perturbation theory, and the variational method to compute approximate energy levels and wavefunctions in stationary quantum systems.
- Analyze quantum systems under time-dependent perturbations using the interaction picture, derive transition probabilities, and apply Fermi’s Golden Rule to systems with a continuum of final states.
- Formulate and solve quantum scattering problems using ket formalism, Lippmann–Schwinger equations, and the Born approximation.
- Perform partial wave analysis and interpret scattering processes through phase shifts, S-matrix properties, and the optical theorem.

**SYLLABUS OF DSE 18**  
**THEORY COMPONENT**  
**(Credits: 3; Hours: 45)**

**Unit I**

**(14 Hours)**

**Approximation Methods for Stationary Systems**

Time-independent perturbation theory up to second order perturbation for non-degenerate case with applications to perturbed potential wells, linear harmonic oscillator with perturbed force constant ( $k \rightarrow (1 + \epsilon)k$ ), charged harmonic oscillator in a weak electric field. First order perturbation for anharmonic oscillator with cubic and quartic terms.

Degenerate systems with application to spin-orbit coupling and fine structure of hydrogenic atom, Zeeman effect (weak and strong field).

Variational method and its applications to ground state of simple harmonic oscillator and Helium atom, electron interaction energy and extension of variational method to excited states.

**Unit II**

**(14 Hours)**

**Approximation Methods for time-dependent perturbations**

Interaction picture. Time-dependent perturbation theory (up to first order perturbation). Transition probabilities, transition to a continuum of final states, Fermi's Golden Rule. Application to constant and harmonic perturbations. Sudden and adiabatic approximations

**Unit III**

**(17 Hours)**

**Scattering:** Wave packet description of scattering, scattering amplitude, differential and total cross section. Lippmann-Schwinger Equations, Formal treatment of scattering by Green's function method. Born approximation and applications to central potentials. Definition and properties of S-Matrix.

**Partial wave analysis:** Asymptotic behaviour of partial waves, Phase shifts and angular momentum decomposition, Optical theorem and conservation of probability.

**References**

**Essential Readings**

1. *Introduction to Quantum Mechanics*, D.J. Griffith, Pearson Education (2005).
2. *Modern Quantum Mechanics*, J. J. Sakurai and Jim Napolitano, Cambridge University Press (2021).
3. *Quantum Mechanics*, Eugene Merzbacher, John Wiley and Sons, Inc (2004).
4. *Quantum Mechanics: Theory and Applications*, Ajoy Ghatak and S. Lokanathan, Laxmi Publications (2019).
5. *Quantum Mechanics*, B. H. Bransden and C. J. Joachain, Prentice Hall (2000).

**Additional Readings**

11. *Principles of Quantum Mechanics*, R. Shankar, Springer (2008).
12. *Introduction to Quantum Mechanics*, Volume-I and II, C. Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Wiley-VCH (2020).
13. *Introduction to Quantum Mechanics*, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications (1966).

14. *Quantum Mechanics*, Leonard I. Schiff, Tata McGraw Hill (2010).
15. *Quantum Mechanics*, Walter Greiner, Springer (2001).
16. *Quantum Mechanics*, Albert Messiah, Dover Publications Inc. (2014)
17. *Scattering Theory of Waves and Particles*, R. G. Newton, Springer-Verlag Berlin and Heidelberg GmbH & Co. (2014)

### **Advisory**

The course is essential for several courses offered in the one-year M.Sc. program and is also included in the syllabi of various competitive examinations, including CSIR-NET, JEST, and GATE.

Colleges are advised to offer this as a Discipline Specific Elective (DSE). Students who intend to pursue postgraduate studies or appear for competitive exams are strongly encouraged to choose this course as a DSE.