

Quantum Mechanics (H)

Course Code: **Hours:** 80 **Credits:** 4.00 **Attribute:** Professional Compulsory

Instructor: Yanting Wang

Purpose and Aim:

Quantum mechanics is the basic theory of the laws of motion in the material world, which is the foundation and pillar of modern physics. Since its establishment, for more than 100 years, quantum mechanics has been accurately tested by a large number of experiments and has been able to explain a wide range of natural phenomena with unprecedented success. It is not only deeply involved in various fields of physics, but also widely used in chemistry, life science, computer science, and other fields.

Quantum Mechanics is not only an important professional basic course for undergraduate students in physics, but also an indispensable basic knowledge and basic training for physicists who engage in modern physics research. Through the study of this course, students will master the basic principles of quantum mechanics and the basic methods of solving related problems with quantum mechanics.

Prerequisites

General Physics, Advanced Mathematics, Classical Mechanics, Linear Algebra

Contents and Objective

Contents

Chapter I. What is Quantum Mechanics?

1. Ultraviolet Catastrophe: the necessity of developing quantum mechanics
2. Wave-Particle Duality: De Broglie wave and uncertainty principle
3. Basic Rule: time-independent Schrödinger equation
4. Example: one-dimensional classical and quantum harmonic oscillators
5. Basic Properties: principle of superposition of states, localized and delocalized quantum particles, Boson and Fermion

Chapter II. Fundamental Concepts

1. Kets, Bras, Operators, and Matrix Representations
2. Measurements, Observables, and Uncertainty relations
3. Position, Momentum, and Wave Functions

Chapter III. Quantum Dynamics

1. Time Evolution and Schrödinger Equation
2. Elementary Solutions to Schrödinger's Wave Equation

3. The Schrödinger Versus Heisenberg Picture
4. Propagators and Feynman Path Integrals
5. Potentials and Gauge Transformations

Chapter IV. Theory of Angular Momentum

1. Rotations and Angular Momentum
2. Density Operators and Pure Versus Mixed Ensembles
3. Spin and Orbital Angular Momentum
4. Schrödinger's Equation for Central Potentials
5. Spin Correlation Measurements and Bell's Inequality
6. Tensor Operators

Chapter V. Symmetry in Quantum Mechanics

1. Symmetries, Conservation Laws, and Degeneracies
2. Discrete Symmetries, Parity, or Space Inversion
3. Lattice Translation as a Discrete Symmetry
4. Time-Reversal Discrete Symmetry

Chapter VI. Approximation Methods

1. Perturbation Theory: Time-independent and time-dependent, non-degenerate and degenerate
2. Hydrogen-Like Atoms: fine structure and the Zeeman effect
3. Variational Methods: finding solution by minimization
4. Time-Dependent Potentials: the interaction picture
5. Population of States: interactions with the classical radiation field, energy shift and decay width

Chapter VII. Scattering Theory

1. Time-Dependent Perturbation of Scattering
2. The Scattering Amplitude, Phase Shifts, and Partial Waves
3. The Born and Eikonal Approximations
4. Symmetry in Scattering

Chapter VIII. Identical Particles

1. Permutation Symmetry and Symmetrization Postulate
2. Two-Electron and Helium Systems

3. Multiparticle States
4. Quantization of the Electromagnetic Field

Chapter VIII. Relativistic Quantum Mechanics

1. Paths to Relativistic Quantum Mechanics
2. The Dirac Equation
3. Symmetries of the Dirac Equation
4. Solving with a Central Potential
5. Relativistic Quantum Field Theory

Objective:

1. Knowing the basic idea of quantization and mastering the basic principles of quantum mechanics.
2. Being able to use the Schrödinger equation to solve simple problems of microscopic systems and mastering the basic approximation methods of quantum mechanics.
3. Enabling students to understand the particularity of the contradictions in the microscopic world and the laws of motion of microscopic particles, and to preliminarily grasp the principles and basic methods of quantum mechanics, so as to lay a necessary foundation for further study and research.

Both midterm and final exams are closed-book. Partition of the overall grade: midterm exam (30%), final exam (30%), and daily performance (40%).

Distribution of Class Hours

Chapter	Lecture	Exercise
1	4	
2	8	2
3	10	2
4	8	
5	8	2
6	10	
7	8	2
8	6	
9	8	2

Course Philosophy

Through the course study, students will be trained to pursue the truth, explore the scientific spirit, learn to understand and analyze problems, find ways to solve problems, master the methods of scientific research, and form correct scientific views and values. For

instance, the instructor will introduce the history of the establishment of quantum mechanics, let students understand the brainstorming of various new ideas and experiences formed in the process of people's cognition of the microscopic world, explain the Copenhagen School of quantum theory and the theory of many worlds, analyze their advantages and disadvantages, and help students establish a correct understanding of the nature. In addition, it stimulates students' interest in exploring scientific problems, and guides students to learn how to recognize problems, analyze problems, and finally solve problems.

Textbook

J. J. Sakurai and Jim Napolitano, **Modern Quantum Mechanics**, 2nd edition, Temple University, Philadelphia, 2020.

About the Instructor

Professor Yanting Wang is a physicist working at the Institute of Theoretical Physics, Chinese Academy of Sciences, conducting scientific research in the area of theoretical soft matter physics and biophysics. He also holds a joint position in the School of Physical Sciences at the University of Chinese Academy of Sciences with abundant teaching experiences in statistical physics and computer simulation.