UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Meccanica Quantistica

2425-1-F4001Q121

Aims

Introduction to the principles of Quantum Mechanics

Contents

- **Fundamentals of quantum physics**: states, operator and postulates of quantum physics
- **Quantum properties**: operators, indetermination principle, basics of quantum information
- **Canonical quantisation and quantum mechanics**: momentum and position operators, Noether's theorem
- **Time evolution**: Schroedinger equation, Shroedinger and Heisenberg representations
- **One-dimensional quantum mechanics**: free particle, wave packet, potential well, potential step, potential barrier, harmonic oscillator
- **Multi-dimensional quantum systems**: tensor product spaces, separable potentials, two-body problem
- **Angular momentum**: Lie groups and Lie algebras; rotation group, angular momentum, spin, composition of spin and angular momenta
- **Three-dimensional problems**: radial Schroedinger equation, Coulomb potential and the hydrogen atom
- **Perturbation theory**
- **Action in quantum mechanics**: path integral and Feynman approach

Detailed program

Once the course is completed, the student will have acquired the following **knowledge**:

- They will know how to identify experiments incompatible with classical physics and justify the need for a

quantum theory to resolve them.
- They will be able to summarize the basic concepts of quantum physics in terms of operators and states.
- They will be able to state, in their own words, the postulates of quantum physics.
- They will be able to state the uncertainty principle and provide examples of compatible and incompatible observables based on their commutation properties.
- They will be able to characterize the information contained in a quantum state using the density matrix formalism.
- They will be able to state Noether's theorem and apply it to quantum systems.
- They will know how to introduce position and momentum operators and discuss their properties.
- They will be able to introduce the operator that controls the time evolution of a quantum system and formulate the Schroedinger equation for the wave function.
- They will be able to discuss solutions in terms of eigenstates and eigenvalues of simple one-dimensional problems such as the potential well, potential step, potential barrier, and harmonic oscillator.
- They will know how to generalize the quantization of mechanical systems to quantum systems in more than one dimension.
- They will be able to provide a physical realization of the mathematical concept of a symmetry group representation using the example of the rotation group and angular momentum.
- They will be able to illustrate how to solve three-dimensional problems such as the hydrogen atom.
- They will be able to discuss approximation methods to solve the Schrödinger equation.
- They will know how to introduce the concept of action in quantum mechanics and derive the Schroedinger equation from the path integral.

Once the course is completed, the student will have acquired the following **skills**:

- They will be able to determine the amount of information contained in a quantum system and how it changes following a measurement.
- They will know how to apply the language of quantum physics to classical mechanics based on physical considerations related to the realization of symmetries in mechanical systems.
- They will be able to solve simple one-dimensional problems analogous to the prototypes discussed in class.
- They will be able to estimate the shape of a particle's wave function based on the properties of the potential.
- They will be able to apply the technique of variable separation to solve problems in more than one dimension.
- They will know how to combine spins and angular momenta.
- They will know how to apply approximation techniques such as time-independent perturbation theory to solve simple problems.

Once the course is completed, the student will have acquired the following **competencies**:

- They will understand the conceptual scope of quantum physics and the necessity for a radical rethinking of what is expected from a physical theory.
- They will have gained familiarity with the universal language used in the formulation of modern physics.
- They will have acquired a set of mathematical techniques and tools useful for various applications in theoretical physics, providing a solid foundation for more advanced courses such as quantum field theory or condensed matter physics.

Prerequisites

Basic knowledge of classical physics, analysis and algebra at the level of the Bachelor's programme in Mathematics

Teaching form

Lecture. Active participation will be encouraged through the discussion of examples and problems during the lessons, according to the principles of active learning and participatory learning.

Textbook and teaching resource

Main textbook

- S. Forte, L. Rottoli, "Fisica Quantistica", Zanichelli

Additional textbooks

- J. Dimock, "Quantum Mechanics and Quantum Field Theory", Cambridge
- J.J. Sakurai, J. Napolitano, "Modern Quantum Mechanics (2nd Edition)", Addison-Wesley
- Benjamin Schumacher, Michael Westmoreland, "Quantum Processes Systems, and Information", Cambridge University Press
- A. Berera e L. Del Debbio, "Quantum Mechanics", Cambridge U.P.
- J. Binney e D. Skinner, "The Physics of Quantum Mechanics", Oxford U.P.
- M. Maggiore, "A modern introduction to quantum field theory", Oxford U.P. (group theory reference)

Semester

First term

Assessment method

Oral exam based on the discussion of topics covered in class and exercises completed during the course. The starting point of the exam will be an assigned exercise to be solved at home and presented at the exam.

The exam covers the entire course program, including exercises and in-depth topics discussed during the lessons, which are an integral part of the course.

Office hours

On student request, at agreed time via email appointment

Sustainable Development Goals

QUALITY EDUCATION