UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Quantum Physics for Technological Applications

2627-2-E3004Q009

Aims

The course aims to provide an understanding of the fundamental principles of quantum mechanics and their use in the description of systems and processes relevant to quantum technologies. The course will introduce the formalism of states and observables, quantum dynamics, the role of measurement and information, entanglement, mixed states, and open systems. It will also develop the tools needed to analyze particles in potentials, spin, oscillators, many-body systems, stationary states, and perturbations, connecting the theoretical formalism to relevant physical phenomena and applications.

Contents

The course introduces the fundamental concepts of quantum mechanics, starting from bits, qubits, and wave-particle duality, and moving on to the formalism of states, observables, and measurement. It covers quantum dynamics, entanglement, mixed states, and open systems, together with applications to particles, spin, oscillators, and many-particle systems. The final part addresses stationary states, potentials, and perturbation theory.

Detailed program

The course introduces the foundations of quantum mechanics with an approach focused on systems, processes, and information. The main topics include:

- classical information, bits, qubits, and wave-particle duality;
- quantum states, observables, measurements, and Hilbert spaces;
- distinguishability, uncertainty, communication, and quantum cryptography;
- quantum dynamics, unitary evolution, and the Schrödinger equation;

- composite systems, entanglement, Bell’s theorem, and applications of entanglement;
- density operators, mixed states, open systems, and elements of dissipative dynamics;
- particles in space, wave packets, free particles, and confined states;
- spin, angular momentum, harmonic oscillators, and coherent states;
- many-particle systems, identical particles, and occupation numbers;
- stationary states in one-dimensional and three-dimensional potentials;
- the variational method and perturbation theory.

Prerequisites

Basic knowledge of linear algebra is required, in particular vectors, matrices, eigenvalues and eigenvectors, together with elements of mathematical analysis, including derivatives, integrals, elementary differential equations, and complex numbers. A preliminary knowledge of the principles of classical mechanics is also useful.

Teaching form

Lectures will be delivered in a hybrid format, combining classroom lectures with asynchronous video lectures made available on the e-learning platform. The lectures will cover the main topics of the course, while problem-solving activities will be used to illustrate and consolidate the application of the concepts introduced. During classroom sessions, interactive tools will be used to encourage student participation and engagement. Teamwork activities may also be proposed to support collaborative learning.

Textbook and teaching resource

The reference textbook is *Quantum Processes, Systems, and Information* by B. Schumacher and M. D. Westmoreland. Additional teaching materials, including lecture notes, lecture slides, asynchronous video lectures, and supplementary exercises, will be made available on the course e-learning platform.

Semester

First semester: from 28 September 2026 to 29 January 2027.

Assessment method

Assessment will consist of a written test, including multiple-choice questions and problems or open-ended questions, followed by an oral examination. The written test will assess the understanding of the fundamental concepts, the mastery of the formalism, and the ability to apply theoretical tools to problem-solving. The oral examination will further explore the student’s understanding of the course topics and their ability to present them clearly and rigorously.

Office hours

By appointment with the instructor, also online.

Sustainable Development Goals