# Bachelor in Physics
## (Academic Year 2024-25)

| **Quantum Physics I** | | **Code** | 800503 | **Year** | 2nd | **Sem.** | 2nd |
|---|---|---|---|---|---|---|---|
| **Module** | General Core | **Topic** | Classical Physics | | **Character** | Obligatory | |

| | Total | Theory | Exercises |
|---|---|---|---|
| **ECTS Credits** | 6 | 3.5 | 2.5 |
| **Semester hours** | 55 | 30 | 25 |

### Learning Objectives (according to the Degree's Verification Document)

- To acquire the concept of wave function and the basics on the quantum phenomena description by the Schrödinger equation.
- To solve one and three-dimensional problems with spherical symmetry (hydrogen atom and harmonic oscillator)

### Brief description of contents

Origin and experimental basis of Quantum Physics. Mathematical formalism: states and observables. Schrödinger's equation: one and three-dimensional potentials. Harmonic oscillator and hydrogen atom.

### Prerequisites

Mathematical concepts learned in Algebra and Calculus and Mathematical Methods I. Physical concepts learned in Classical Mechanics and Electromagnetism I.

| **Coordinator** | Clara Peset Martín | | | **Dept.** | FT |
|---|---|---|---|---|---|
| | **Office** | 02.314.0 | **e-mail** | cpeset@ucm.es | |

| **Theory/Problems – Schedule and Teaching Staff** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Group** | **Lecture Room** | **Day** | **Time** | **Professor** | **Period/ Dates** | **Hours** | **T/P** | **Dept.** |
| **B** | 4A | Mo, Tu<br>Fr | 9:00 – 10:30<br>9:00 – 10:00 | Artemio González López | Full Term | 55 | T/P | FT |

T: Theory, E: Exercises

| **Office hours** | | | | |
|---|---|---|---|---|
| **Group** | **Professor** | **Schedule** | **E-mail** | **Location** |
| **B** | Artemio González López | Tu, Th 11:00-13:00<br>+ 2 hours online | artemio@fis.ucm.es | 02.0307.0 |

## Syllabus

**1. Experimental bases of quantum mechanics.** Black body radiation and Planck's hypothesis. The photoelectric effect. Compton scattering. Bohr's atomic model. De Broglie's matter waves. Wave-particle duality. The double slit experiment.

**2. The Schrödinger equation.** The wave function and its probabilistic interpretation. Schrödinger's wave equation. The continuity equation. Expectation values of dynamical variables and Ehrenfest's theorem. Self-adjoint operators and observables. Eigenfunctions and eigenvalues. The momentum representation. Wave packets. Heisenberg's uncertainty principle.

**3. One-dimensional problems.** The time-independent Schrödinger equation. Stationary states. Bound and scattering states. Potential wells and barriers. Reflection and transmission coefficients. The tunnel effect. The spectrum of a general one-dimensional potential.

**4. The formalism of quantum mechanics.** Hilbert spaces. Quantum states. Dirac's notation. Measurements and probability. Time evolution and conserved quantities. Compatible observables.

**5. The one-dimensional harmonic oscillator.** Solution by power series and Hermite polynomials. Spectrum and wave functions for bound states. Creation and annihilation operators. Algebraic solution.

**6. Three-dimensional problems.** Separation of variables in Cartesian coordinates. The infinite well and the harmonic oscillator. Central potentials. Separation of variables in spherical coordinates. Angular momentum and spherical harmonics. Radial equation. The infinite spherical well. Hydrogen-like atoms: bound state energies and wave functions. The isotropic harmonic oscillator.

## Bibliography

**Basic:**
1. C. Cohen-Tannoudji, B. Diu, F. Laloë, Quantum Mechanics, vol. 1, 2nd ed. Wiley-Blackwell, Berlin, 2019.
2. D. J. Griffiths, Introduction to Quantum Mechanics, 3rd ed. Cambridge University Press, Cambridge (UK), 2018.
3. C. Sánchez del Rio (coord.), Física Cuántica, 7ª ed. Pirámide, Madrid, 2020.
4. L. E. Schiff, Quantum Mechanics, 3rd ed. McGraw-Hill, New York, 1968.

**Complementary:**
1. F. Constantinescu and E. Magyari, Problems in Quantum Mechanics. Pergamon Press, London, 1971.
2. S. Flügge, Practical Quantum Mechanics. Springer, Berlin, 1999.
3. L. D. Landau, E. M. Lifshitz, Quantum Mechanics (Non-relativistic Theory), 3rd ed. Pergamon, Guildford (UK), 1977.
4. A. Messiah, Quantum Mechanics. Dover, New York, 1994.
5. R. Shankar, Principles of Quantum Mechanics, 2nd ed. Springer, New York, 2008.
6. S. Weinberg, Lectures on Quantum Mechanics, 2nd ed. Cambridge University Press, Cambridge (UK), 2015.
7. I. I. Goldman, V. D. Krivchenkov. Problems in Quantum Mechanics. Nueva York 1993. Ed. Dover.
8. A. Galindo, P. Pascual. Mecánica Cuántica. Madrid 1999. Eudema.

## Online Resources

Course related material and announcements will be regularly posted in UCM's "Campus Virtual".

## Methodology

Lectures will consist of theoretical explanations (including worked out examples) and problem solving sessions. The corresponding problems will be handed out to the students in advance through UCM's "Campus Virtual" at the beginning of each chapter.

The instructor will answer both theoretical and problem-related questions from the students during his office hours.

Student participation during the lectures and attendance in the office hours will be strongly encouraged.

| Evaluation Criteria | | |
|---|---|---|
| **Exams** | **Weight:** | 70% |
| The final exam will consist of a number of practical problems and/or theoretical questions similar in difficulty to those solved during the lectures. | | |
| **Other Activities** | **Weight:** | 30% |
| A written test may be taken in the middle of the course. Several times during the course, exercises from the problems' handouts will be proposed to the class to be individually solved in writing by the students during lecture hours. | | |
| **Final Mark** | | |

The "Other activities" grade will only be taken into account if the grade of the final exam (in the range 0-10) is at least 3.5. If that is the case, the final grade G will be computed according to the formula

$$G = \max(E, 0.7\,E + 0.3\,A)$$

where E and A are respectively the "Exams" and "Other activities" grades (both in the range 0-10).

The grade obtained in the "Other activities" category will be carried over to the remedial evaluation (when applicable).