

Introduction to Quantum Physics for Electrical Engineering (E901176)

Course size *(nominal values; actual values may depend on programme)*

Credits 4.0 **Study time 120 h**

Course offerings in academic year 2025-2026

A (semester 1) English Gent

Lecturers in academic year 2025-2026

Van Der Sande, Guy VUB lecturer-in-charge

Offered in the following programmes in 2025-2026

Bridging Programme Master of Science in Photonics Engineering	4	A
Master of Science in Photonics Engineering	4	A

Teaching languages

English

Keywords

Position of the course

This course's objectives are : 1. To give the students the necessary insights and skills required to understand the physics behind the electronic and optoelectronic properties of solid state materials in general and of semiconductor structures in particular. 2. To introduce the basics, mathematics and the notation specific to quantum physics. At the end of the course the student should be able to grasp some of the basic concept that are present in scientific literature 3. To prepare the students for courses concerning electronic components, lasers, optical materials, (opto-)electronic systems, non-linear and quantum optics etc. 4. By working in small groups (2-4 persons), the students will implement the necessary algorithms to solve arbitrary 1D quantum mechanical problems and apply to specific examples. Each group will present their findings through presentation in class

This course is taught at the VUB, as part of the interuniversity master's programme Master of Science in Photonics Engineering.

Contents

The course is structured into twelve chapters. 1. Historical review on the early quantum struggle 2. Description of a system in Quantum Physics 3. Time independent Schrödinger's equation. 4. The infinite deep potential well 5. Formalism and the postulates of QM 6. The Wave packet 7. The Tunneling Effect 8. Identical Particles 9. Quantum Statistical Mechanics 10. Ideal Gases of Quantum Particles 11. The Kronig-Penning model 12. The Fermi-Golden Rule This course will be lectured in English. As course material, the student have access to a set of slides that explain the concepts and derivations in fine detail.

Initial competences

The students should be acquainted with the basics of physical optics (interference, superposition, light as an electromagnetic field , intensity) and a good knowledge of algebra (vector spaces, Hilbert spaces, linear operators on these spaces). But all these concepts and tools will be brushed up in the beginning of the course.

Final competences

- At the end of the course the students should be able to address all the following questions and solve problems related to these matters.
- Explain the basic postulates of quantum physics, explain their background and

- briefly give examples from the course that illustrate their importance.
- 2 Deduce the Heisenberg's Uncertainty principle. Give examples in the course where Heisenberg's principle plays a crucial role.
 - 3 What is time dependent Schrödinger's equation? Discuss the difference between Schrödinger's equation and a electromagnetic wave equation. Show that Schrödinger's equation is equivalent with a conservation law for the density of probability to find a particle in a specific position.
 - 4 Describe the time-independent Schrödinger's equation. Explain the notion of stationary states. How does a linear combination of stationary states evolve with time?
 - 5 Determine the energy spectrum and stationary states of one particle with mass m in an one dimensional infinite potential well. Discuss. Do you know realistic examples of such systems?
 - 6 Determine the energy spectrum and stationary states of one particle with mass m in a three dimensional infinite potential well. You can start from the results obtained in question 6. What is a density of states?
 - 7 What is the tunneling? Determine the transmission coefficient for a particle with mass m coming from minus infinity with energy E and encountering a 1D potential barrier of height V and width a . Discuss the tunnel and diffraction regime. Give examples of applications of tunneling.
 - 8 What is a wave packet? Discuss the quantum equivalent of the propagation of a free particle whose momentum is not known with infinite precision. Give the example of a Sinc wave packet. What is the difference between phase velocity and group velocity?
 - 9 Explain how a system with two or more identical particles can be described. Explain the notion of the Pauli Exclusion principle and the exchange force.
 - 10 Deduce the Maxwell-Boltzmann, Fermi-dirac and Bose-Einstein distribution. Explain how they can be applied.
 - 11 Describe an ideal 3D gas of quantum particles. Describe the density of states, the physical interpretation of the Lagrange multiplicators. Calculate the Fermi-energy of a 3D ideal gas of fermions.
 - 12 Deduce the Fermi Golden Rule. Explain the difference between stimulated and spontaneous emission.
 - 13 Prove the Bloch's theorem and show that envelope equation of the state satisfies again a Schrödinger's equation.
 - 14 Solve the Kronig-Penney model for crystalline materials. Explain band-diagrammes, conductance electrons, holes, doping of semiconductor material

Conditions for credit contract

This course unit cannot be taken via a credit contract

Conditions for exam contract

This course unit cannot be taken via an exam contract

Teaching methods

Group work, Seminar

Study material

None

References

- David J. Griffiths "Introduction To Quantum Mechanics", Pearson Prentice Hall, New York, USA – Available at the central VUB library 530.145 G GRIF 2005 • David A.B. Miller, "Quantum Mechanics for Scientists and Engineers", Cambridge University Press, 2008 – Not yet available at the central VUB library • Amnon Yariv, "Theory and applications of Quantum Mechanics", Wiley, New York, USA – Available at the central VUB library 530.145 G YARI 82 • Claude Cohen-Tannoudji, Bernard Diu, Franck Laloë, "Mecanique Quantique", Université de Paris, France, 1973 – Available at the central VUB library 530.145 G COHE 73

Course content-related study coaching

Assessment moments

end-of-term and continuous assessment

Examination methods in case of periodic assessment during the first examination period

Oral assessment

Examination methods in case of periodic assessment during the second examination period

Oral assessment

Examination methods in case of permanent assessment

Skills test

Possibilities of retake in case of permanent assessment

examination during the second examination period is not possible

Extra information on the examination methods

The evaluation has two parts •Theory-exam (2/3 of the score): One main question out of a pool of 10 Principal Questions (50% of the theory exam) with:
4 minutes of preparation, no writing, open book 40 minutes of preparation on paper
Presentation of the problem and the solution at a blackboard. The intention is that the student can present the reasoning behind the theory in a clear manner. A series of "culture questions" (50% van de theory exam), which are number of shorter questions concerning the full extent of the material.

- Project (1/3 of the score) – 3 exercise sessions (of 2h) and a project driven approach

Calculation of the examination mark