Faculty of Health, Science and Technology
Physics

Syllabus

Advanced Quantum Mechanics

Course Code:	FYAD04
Course Title:	Advanced Quantum Mechanics *Avancerad kvantmekanik*
Credits:	7.5
Degree Level:	Master's level
Progressive Specialisation:	Second cycle, has only first-cycle course/s as entry requirements (A1N)

Major Field of Study:
FYA (Physics)
TKA (Engineering Physics)

Course Approval
The syllabus was approved by the Faculty of Health, Science and Technology 2014-10-29, and is valid from the Autumn semester 2015 at Karlstad University.

Prerequisites
Completed courses in physics totalling 52.5 ECTS credits and 37.5 ECTS credits in mathematics plus the course Quantum Physics I attended, or equivalent. Upper secondary school level Swedish 3 or B/Swedish as a second language 3 or B, and English 6 or A, or equivalent.

Learning Outcomes
Upon completion of the course, students should be able to:

- give an in-depth account of the bra-ket-formalism, the time development of quantum mechanical systems, the measuring process, the Schrödinger and Heisenberg pictures, the propagator and gauge transformations,
- solve the Schrödinger equation and compute the expectation values of various operators for the harmonic oscillator with the help of step operators,
- describe density matrices and use them in performing basic quantum mechanical calculations for the most relevant types of statistical ensembles,
- present and reflect on some central questions concerning the interpretation of quantum mechanics, and give an account of Bell's inequalities and their role in this interpretation,
- give an in-depth account of various issues concerning angular momentum, like the addition of angular momenta, the oscillator model and tensor operators,
- apply permutation symmetry in the analysis of quantum systems with identical particles,
- give a detailed description of parity and of space and time inversion, as well as of continuous symmetries and their connection with conservation laws,
- give an account of and analyse the interaction of quantum systems with electromagnetic radiation and with external electric and magnetic fields,

- apply the most important approximation methods to both time-independent and time-dependent quantum mechanical problems and give an account of their respective areas of applicability,
- give an account of the quantum mechanical description of scattering processers, including the Born approximation and the eikonal approximation,
- give an outline of the Dirac equation and its solutions for systems with a central potential.

Content
This course deepens student knowledge of and proficiency in modern quantum physics, which plays a central role in physics and chemistry, and to some extent in modern biology. The course provides practical knowledge of quantum theory, thus enhancing the understanding of the complicated properties of matter required for both application and for continued studies at advanced level.

Instruction is in the form of seminar presentations, lectures and problem solving sessions.

The course comprises the following topics:
- The basic concepts and ideas of quantum mechanics: Hilbert space, the bra-ket-formalism, operators, matrix representation, observables, the measuring process, the uncertainty relation, the position and momentum space representations, density matrices, Bell's inequalities.
- Quantum dynamics: time development, Schrödinger and Heisenberg pictures, step operators for the harmonic oscillator, the propagator, gauge transformations.
- Theory of angular momentum: step operators, spin, addition of angular momenta, the oscillator model, tensor operators.
- Symmetries in quantum mechanics: parity, translations, space and time inversion.
- Approximation methods for time-independent and time-dependent potentials, interaction picture.
- Scattering theory.
- Permutation symmetry, identical particles.
- Introduction to relativistic quantum mechanics, the Dirac equation.
- Short introduction to second quantization and to the quantization of electromagnetic fields.

Reading List
See separate document.

Examination
Assessment is based on hand-in assignments, assessment of oral seminar presentations and an oral exam.

Grades
One of the grades U (Fail), 3 (Pass), 4 (Some Distinction), or 5 (Distinction) is awarded to engineering program students. One of the grades U (Fail), G (Pass) or VG (Distinction) is awarded to any other students.

Quality Assurance
Follow-up relating to learning conditions and goal-fulfilment takes place both during and upon completion of the course in order to ensure continuous improvement. Course evaluation is partly based on student views and experiences obtained in accordance with current regulations and partly on other data and documentation. Students will be informed of the result of the evaluation and of any measures to be taken.

Course Certificate
A course certificate will be provided upon request.

Additional information
Students who enrolled before 1 July 2007 will complete their studies in accordance with the requirements of the earlier admission.
Upon completion students may request degree and course certificates to be issued under the current ordinance if they meet its requirements.

The local regulations for studies at the Bachelor's and Master's levels at Karlstad University stipulate the obligations and rights of students and staff.

The course is an elective course for the Master of Science in Engineering and the Degree Programme in Engineering Physics.