Adam Mickiewicz University in Poznań

Doctoral School of Exact Sciences AMU

Introduction to Modern Quantum Physics

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Field of science	Physical Science
Teaching method	Lectures
Language	English
Numbers of hours	20
Aims of the course	This course is designed to introduce students to key themes in contemporary physics, with a particular focus on the rapidly evolving field of quantum technologies across different generations. It provides a broad yet rigorous overview of cutting-edge research areas, highlights fundamental open questions at the forefront of the discipline, and explores a range of practical applications—from foundational concepts to emerging innovations.
Course contents	Week 1: Quantum Physics Principles: Superpositions, Indeterminism, Non-Realism, Nonlocality, and Entanglement Week 2: Quantum Optics: Light-Matter Interactions. Week 3: Atomic Physics. Week 4: Low-Dimensional Systems and Artificial Atoms. Week 5: Nuclear Physics. Week 6: Quantum Technologies 1.0. Week 7: Quantum Technologies in Medicine. Week 8: Quantum Technologies 2.0. Week 9: Quantum Computing. Week 10: The Standard Model and Beyond.
Prerequisites and co-requisites	**Knowledge, Skills, and Competencies:** Students are expected to have a solid understanding of the fundamental concepts and methods of quantum mechanics. While prior exposure to quantum optics and quantum information is beneficial, it is not required, as the course is largely self-contained in these areas and will develop the necessary concepts from first principles.

Learning outcomes

On completion of the course PhD candidates will be able to:

Knowledge - Student:		**Assessment mode**
To provide foundational knowledge of modern quantum physics, with a focus on quantum technologies, in accordance with the defined course curriculum.	E_W01, E_W02, E_W03, E_W07, E_W08	"Open book" exam and/or report
Skills - Student:		
To develop students' ability to solve basic quantum problems using the acquired knowledge, as well as their skills in performing numerical simulations.	E_U01, E_U02, E_U04, E_U05, E_U06, E_U07, E_U08	Project/Report

Social competences - Student:		
Fostering in students the skills of self-learning and teamwork.	E_K01 E_K02 E_K05	Report/Project/Oral Exam
Encouraging students to critically evaluate their knowledge and content received, and to consult their knowledge and problems with experts, while trying to maintain independent and critical thinking.	E_K01 E_K02 E_K04 E_K05	Report/Project/Oral Exam

Literature	[1] "Modern Physics" by Paul A. Tipler & Ralph A. Llewellyn (Freeman, New York, 2012); Polish Edition: "Fizyka Współczesna" (PWN, Warszawa, 2011) [2] "Physics for Scientists and Engineers: A Strategic Approach with Modern Physics" (especially "Part 8: Quantum Physics") by Randall Knight (Pearson, 2023). [3] "Modern Physics" by Kenneth Krane (Wiley, 2020). [4] "Modern Physics for Scientists and Engineers" by John Taylor, Chris Zafiratos, & Michael A. Dubson (Pearson, 2003) [5] "Exploring the Quantum: Atoms, Cavities, and Photons" by S. Haroche & J.M. Raimond (Oxford University Press, 2000).
Additional information	**Assessment and Grading Criteria** Students may choose one of the following two paths to complete the course: **Option A: Report + Oral Exam (Default Option)** The final grade will be calculated as the arithmetic average of the scores from the written report and the oral exam: Final Score = (Report Points + Oral Exam Points) / 2 Important: To pass the course, both components must independently receive a score higher than 2.0. **A.1 Written Report with Integrated Numerical Simulations** Length: 15,000–17,000 characters Content: Based on one topic selected from a list of provided research papers Evaluation criteria: Clarity and structure of presentation Logical coherence and consistency Technical quality and computational complexity of the simulations (project) Depth of understanding of the chosen topic Style and presentation quality Score: Between 2.0 and 5.0 points

	A.2 Oral Exam Structure: 2 questions from general knowledge topics covered in the course ("Open book" exam) 1 research-oriented problem tailored to the student's PhD project 1 question related to the student's report Scoring: Each question is graded from 2 to 5 points. Final oral exam score: Arithmetic average of the four question scores. **Option B: Comprehensive Oral Exam Only** Instead of submitting a written report, students may opt for an extended oral exam, covering: 3 questions from the general knowledge topics 1 research-oriented problem tailored to the student's PhD project 1 in-depth question on a pre-selected topic from the research paper list (no written report required) This alternative exam will assess the same competencies as Option A, with appropriately adjusted expectations for depth and clarity in oral responses. Final grading follows the same scale. **Grade Conversion Scale** Very Good (bdb; 5.0): 4.5 – 5.0 points Good Plus (+db; 4.5): 4.0 – 4.5 points Good (db; 4.0): 3.5 – 4.0 points Satisfactory Plus (+dst; 3.5): 3.0 – 3.5 points Satisfactory (dst; 3.0): 2.5 – 3.0 points Unsatisfactory (ndst; 2.0): Below 2.5 points