SYLLABUS 2019/2020

Course title	**Quantum mechanics**

Semester (winter/summer)	3	ECTS	5

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Department	Institute of Physics, Pedagogical University	

Course objectives (learning outcomes)

The purpose of this course is to provide a graduate level and/or an advanced undergraduate level the introduction to quantum physics. In the first part, the experimental basis of quantum physics will be explored. Topics include: photoelectric effect, Compton scattering, photons, Franck-Hertz experiment, the Bohr atom, electron diffraction, de Broglie waves, and the wave-particle duality of matter and light. An introduction to wave mechanics and matrix mechanics will be followed in the second part: wave functions, wave packets, probability amplitudes, stationary states. In the third part, the basis of quantum mechanics and its postulates will be provided: solutions to Schrödinger's equation in one dimension (transmission and reflection at a barrier, barrier penetration, potential wells, the simple harmonic oscillator), Schrödinger's equation in three dimensions, the bracket notation of Dirac, the operator formalism, angular momentum and spin, matrix representation of quantum mechanics, the Pauli principle, the Heisenberg uncertainty principle, none-degenerate and degenerate time independent perturbation treatment, coupling of spin and angular momentum, the Zeeman effect, the hyperfine structure, charged particles in electromagnetic fields, introduction to scattering theory and the Born approximation, the hydrogen and helium atoms, the simple molecules.

The emphasis throughout the course will be on applications of general techniques to specific quantum-mechanical problems and phenomena, e.g. quantum tunnelling, quantum fluids, superconductivity. the quantum Hall effect, quantum computers, quantum dots, quantum communication.

The course also seeks to provide the background knowledge necessary to understand seminars and to read research articles related to quantum phenomena.

Prerequisites

Knowledge	Two years of general physics are required especially the modern physics. Basic understanding of calculus and linear algebra is essential for completing this course, and knowledge of differential equations and matrix/linear algebra is valuable.
Skills	Basic skills of description of physical problems.
Courses completed	Basic Physics and Mathematical methods for physics at the graduate level.

Learning effects:

	Learning effects of the course	Relation of the learning effects to the specialization
Knowledge	**W01** The student knows the first steps to quantum theory (black body radiation, photoelectric effect, Bohr's atomic model, wave-particle duality…) **W02** The student knows Schrödinger's equation, the principal, orbital and magnetic quantum number. **W03** The student knows Heisenberg's matrix mechanics, Pauli exclusion principle, Heisenberg uncertainty principle, Pauli spin matrices. **W04** The student knows Dirac equation and the prediction of antimatter, Zeeman effect, spin-orbit coupling. **W05** The student knows some applications of Quantum Physics, Schrodinger Cat. Quantum Entanglement, Einstein-Podolsky Rosen paradox. Quantum dots. Quantum fluids. Superconductivity.	K_W01 – K_W05
Skills	Learning effects of the course	Relation of the learning effects to the specialization
	U01 A student can solve some simple exercises/problems related to back body radiation, photoelectric effect, eigen energy and wave function in an hydrogen atom. **U02** The student can find the solution by him/herself of the Schrödinger's equation in 1D, 2D and 3D. **U03** The student can deal with some simple examples of Pauli exclusion principle, Heisenberg uncertainty principle, Pauli spin matrices. **U04** The student learns how to find the solution of Dirac equation and how Dirac got the idea of antimatter. The students learns about Zeeman effect, spin-orbit coupling.. **U05** The student gets to know the basics of Schrodinger Cat. Quantum Entanglement, Einstein-Podolsky Rosen paradox. Quantum dots. Quantum fluids.	K_U01 – K_U05
Social skills	Learning effects of the course	Relation of the learning effects to the specialization
	K01. A student has the creativity and the ability to conceptual thinking. **K02** A student is able to present and justify the personal point of view. **K03** A student is able to use the aquired knowledge and skills for the communication with the scientific community. **K04** A student is aimed to expand personal knowledge and skills. **K05** A student has the legal erudition.	K_K01 – K_K05

Course organization:

Course organization							
Form of classes	W (Lecture)	Group type					
		A (large group)	K (small group)	L (Lab)	S (Seminar)	P (Project)	E (Exam)
Contact hours	30	30					1

Teaching methods:

Classes will be performed in tutorial system on a weekly basis using multimedia presentation and internet.
In-class quizzes, examples and exercises are designed to probe knowledge developed through this process, with emphasis on how well students have understood the underlying physical ideas.
There is a problem set every week (homework/exercise). The main purpose of the problem sets is to help to learn quantum mechanics. It does not need to reflect a student's understanding, but trying to solve a problem certainly helps the student to do well on the exams.
Presentation/seminar: at the end of the course, each student complete an individual presentation on a topic or an application of Quantum Physics not covered in the class. The topic will be chosen in the list of suggested topics by the lecturer or chosen by the student with the lecturer’s approval. The presentation should be about 40-45 min. long. The detailed schedule for the presentation will be arranged commonly by the lecturer and the student.
Essay: the student can also choose completing a final project (instead of presentation/seminar) that will be based on an article of the student’s choice on the topics of Quantum Physics in the physical journals. The topic’s choice should obtain the lecturer’s approval in advance. The essay should be in the written form. The student should bring the essay to the scheduled final exam time and will have 20-30 minute presentation of the essay.

Assessment methods:

	E – learning	Didactic games	Classes in schools	Field classes	Laboratory tasks	Individual project	Group project	Discussion participation	Student’s presentation	Written assignment (essay)	Oral exam	Written exam	Other
W01								x	x		x	x	
W02								x	x		x	x	
W03								x	x		x	x	
W04								x	x		x	x	
W05								x	x		x	x	
U01						x	x	x	x		x	x	
U02						x	x	x	x		x	x	
U03						x	x	x	x		x	x	
U04						x	x	x	x		x	x	
U05						x	x	x	x		x	x	
K01							x	x	x		x	x	
K02							x	x	x		x	x	
K03							x	x	x		x	x	
K04							x	x	x		x	x	
K05							x	x			x	x	

Assessment criteria:

Assessment criteria	There will be 2 in-class quizzes/tests and a final presentation and/or final written report (essay). The quizzes are open-book and open-note quizzes. The students will also be evaluated on whether they have developed a capacity to extract useful content from research literature. This will be demonstrated by their individual presentation and/or by their essay. The final grade for the course will be based on the class participation, the performance on weekly homework, quizzes and on the examinations (presentation/essay). The contributions to the final grade are as follows:

Activity	**Percent of Total Grade**
Class participation	20%
Homework (Problems sets)	30%
Quiz 1	10%
Quiz 2	10%
Individual presentation / Essay	30%

The grading scale will be:

%	**marks**	**eq. Polish mark**
91 -100	A including A-	bardzo dobry (5.0)
81-90	B including +/-	dobry plus (4.5)
66-80	C including +/-	dobry (4.0)
51-65	D including +/-	dostateczny i +dostateczny (3.0/3.5)
< 50	F	niedostateczny (2.0)

Comments	The students would learn a lot from talking to and working with each other. Thus we encourage the students not only to make his/her own attempt on every problem, but also discuss the problems with each another and collaborate on understanding the problems more fully. However, the homework (solutions for the problem sets, presentation, essay) must reflect one's own work. They must not be transcriptions or reproductions of other people's work. Plagiarism is a serious offense and is easy to recognize. Problem sets and assay must be submitted on the written form, not electronically. The presentation/seminar must be prepared as the multimedia presentation.

Course content (topic list)

1. The first steps to quantum theory: Max Planck and black body radiation
2. The quantization of light: Photons. Photoelectric effect.
3. Bohr's model. Hydrogen spectral lines.
4. Double slit experiment with electrons and photons. Wave-particle duality of matter and light. De Broglie waves.
5. Electron as a wave. Schrödinger's equation. Probability amplitudes. Stationary states.
6. Solutions to Schrödinger's equation in one dimension: free particle, infinite and finite square wells, harmonic oscillator.
7. Schrödinger's equation in three dimensions. Cartesian and spherical coordinates.
8. Hydrogen atom. The principal, orbital and magnetic quantum number.
9. Matrix mechanics. Hilbert space. Heisenberg's matrix mechanics. Dirac's bracket notation.
10. The Pauli exclusion principle. The Heisenberg uncertainty principle.
11. Angular momentum in quantum mechanics: orbital and spin. Pauli spin matrices. Electron magnetic moment. Larmor precession.
12. Dirac equation. The prediction of antimatter.

13. Zeeman effect. Spin-orbit coupling. The fine and hyperfine structure of the hydrogen and helium atom.
14. Some applications of Quantum Physics: Kronig-Penny model, nearly free-electron approximations and tight binding model.
15. Schrodinger Cat. Quantum Entanglement, Einstein-Podolsky Rosen paradox. Quantum dots. Quantum fluids. Superconductivity.

Compulsory Reading

D.J. Griffiths, *Introduction to Quantum Mechanics.* second edition. Pearson Prentice Hall (2005). ISBN: 9780131118928
P.A.M. Dirac, *The Principles of Quantum Mechanics*. Clarendon Press (2011). ISBN: 9780198520115.
R.P. Feynman, R.B. Leighton, M. Sands, *The Feynman Lectures on Physics including* Feynman's Tips on Physics. The Definitive and Extended Edition (2nd edition, 2005). ISBN: 978-0465023820

Recommended reading

R.L. Liboff, Introductory Quantum Mechanics, 4th ed., 2002. Addison Wesley (2002). ISBN: 9780805387148.
R.M. Eisberg, R. Resnick. *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*. Wiley&Sons, 1985. ISBN: 9780471873730.
D.Z. Albert, *Quantum Mechanics and Experience*. Harvard University Press, 1994. ISBN: 9780674741133.
D.F. Styer, *Notes on The Physics of Quantum Mechanics*, 2011. Download from http://www.oberlin.edu/physics/dstyer/QM/PhysicsQM.pdf
Hyper Physics website: http://hyperphysics.phy-astr.gsu.edu/hbase/quacon.html
Notes/presentations from the lecturer will be also provided.

Estimation of the total working time of students:

Contact hours	Lectures	60
	Seminars	
	Other (consultation, meetings)	10
Students' work hours (without the lecturer)	Reading books and preparation for the lectures	20
	Preparation to the seminar	
	Preparation of an individual presentation	10
	Preparation to the exam	25
Total works' hours		125
ECTS credits 1 ECTS = 25 h		5