Course Title (in English)	Introduction to Quantum Theory
Course Title (in Russian)	Введение в квантовую теорию
Lead Instructor(s)	Gavrylenko, Pavlo Losyakov, Vladimir

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Course Description

One of the most striking breakthrough of the XX century is the creation of the entirely new area of physics named quantum physics. It emerged that the whole world around us obeys the laws of quantum mechanics, while the laws of classical physics that we are familiar with (such as, for example, Newton's equations) describe only macroscopic objects and can be obtained in limiting case. After that a lot of phenomena in different areas of physics found their explanation. Also quantum mechanics had a very significant impact on the development of mathematics and mathematical physics. Today quantum mechanics is one of the keystone parts of theoretical and mathematical physics.

Course Prerequisites / Recommendations	Basic math courses, Complex analysis, Probability theory, Classical mechanics

Аннотация

На примере электромагнитной волны вводятся основные постулаты квантовой теории (пространство состояний, наблюдаемые, вопрос об измерениях и динамика), ее структура и математический аппарат. Обсуждается взаимоотношение классической и квантовой теорий. Пользуясь введенными понятиями изучаются важнейшие примеры квантовых систем - гармонический осциллятор, частица в кулоновском (ньютоновском) поле, свободная релятивистская частица. Курс предполагает существенную самостоятельную работу по решению задач.
Цель курса: формирование образов и внутренней структуры квантовой теории, а также навыков перевода с физического языка к строгим понятиям математического аппарата квантовой теории.
Предоставление студентам возможности дальнейшего совершенствования полученных знаний и навыков в курсах программы "математическая физика"

Course Academic Level	Master-level
Number of ECTS credits	6

Topic	Summary of Topic	Lectures (# of hours)	Seminars (# of hours)	Labs (# of hours)
Introduction	Classical theory on the example of an electromagnetic wave. An electromagnetic wave is a set of harmonic oscillators. Hamiltonian approach.	1	4	
Uncertainty relation.	Gedanken experiments with light. The passage of light through the polarizer and photoelectric effect. Conclusion: our world is not classical. Uncertainty relation.	1	4	
The state space.	States of the physical system in quantum theory. Own state. Superposition principle. Probability of transition from one state to another (transition amplitude). The state space is the Hilbert space.	1	4	
Observable values.	Observable in quantum theory are operators on Hilbert space. The action of the operator on eigenstates. The requirement of self-adjoint of the operator. The measurement of observable as a problem of eigenvalues. Determination of the mean and variance of the observable value.	1	4	
The canonical commutation relations.	The ratio of uncertainty and simultaneous measurability of physical quantities. The canonical commutation relations. Canonical quantization in quantum theory. A complete set of observables.	1	4	
Schrodinger equation.	Dynamics in quantum theory. Schrodinger equation. Hamiltonian as the observed that determines the dynamics in the quantum theory. The eigenvalue and eigenstates problem of the Hamiltonian as a problem solving the problem of the dynamics of an arbitrary state in quantum mechanics.	1	4	
Quantization of the harmonic oscillator.	Quantization of the harmonic oscillator. Operators of birth and destruction. Energy spectrum and eigenstates.	1	6	

Coherent states.	Coherent state. Coherent States as minimizing the uncertainty relation. Dynamics of coherent state. The decomposition unit for the coherent States. The ultimate transition to classical theory.	1	6	
Continuous spectrum.	Measurement of position and momentum. Spectral theorem.	1	4	
Quantum theory of a particle in the Central potential.	Measurement of the moment of impulse. Hydrogen atom.	1	6	
Dirac equation.	The relativistic theory of Dirac. Spin. Physical failure of a single-particle quantum theory: the need for a quantum field theory.	1	4	

Assignment Type	Assignment Summary
Homework Assignments	Solving problems by topic 1 - 7.
Homework Assignments	Solving problems by topic 7 - 10.
Homework Assignments	Solving problems on topics 9 -11 and preparing a question of choice for the exam.

Type of Assessment	Graded

Grade Structure

Activity Type	Activity weight, %
Homework Assignments	30
Homework Assignments	30
Homework Assignments	30
Final Exam	10

A:	86
B:	76
C:	66
D:	56
E:	46
F:	0

Maximum Number of Students

	Maximum Number of Students
Overall:	12
Per Group (for seminars and labs):	12

Course Stream	Science, Technology and Engineering (STE)
Course Term (in context of Academic Year)	Term 3 Term 4
Course Delivery Frequency	Every year

Students of Which Programs do You Recommend to Consider this Course as an Elective?

Masters Programs	PhD Programs
Mathematical and Theoretical Physics Photonics and Quantum Materials	

Course Tags	Math Physics

Required Textbooks	ISBN-13 (or ISBN-10)
The Principle of Quantum Mechanics. Paul Dirac, Clarendon Press, 1981	9780198520115

Recommended Textbooks	ISBN-13 (or ISBN-10)
Лекции по квантовой механике для студентов-математиков. Л.Д. Фаддеев, О.А. Якубовский, 1980	

Papers	DOI or URL
P. A. M. Dirac. Generalized Hamiltonian Dynamics.	Proc. R. Soc. Lond. A. 1958. T. 246. C. 326-332