Skoltech
Skolkovo Institute of Science and Technology

Course Syllabus

Course Title (in English)	Research seminar Quantum Mechanics
Course Title (in Russian)	Научно- исследовательский семинар "Квантовая механика"
Lead Instructor(s)	Losyakov, Vladimir Semenov, Andrey

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Course Description

Advanced course in quantum mechanics, in which the basic principles quantum theory is supplemented and applied to the study of specific physical systems. Modern methods of research of quantum systems are proposed - the construction of integrable potentials, the integral along trajectories, and the concepts of density matrix and effective action are introduced. The course involves a transition to the consideration of free field theories, their canonical quantization, and discussion of differences
quantum mechanics from quantum field theory.
The purpose of the course is to consolidate the basic principles and methods of quantum theory, study the transition from quantum mechanics to quantum field theory. The course introduces the basic concepts necessary for studying the courses of the program "Mathematical physics".
The course is designed as a solution to specific problems in quantum theory (see the course content).
The course involves significant independent work on solving problems.
I would like the results of the course to coincide with the goals.

Course Prerequisites / Recommendations	Course "Introduction to quantum theory"or completed course "Quantum mechanics" in a good University's undergraduate program.

Аннотация

Продвинутый курс квантовой механики, в котором основные принципы
квантовой теории дополняются и применяются для изучения конкретных физических
систем. Предлагаются современные методы исследования квантовых систем - построение интегрируемых потенциалов, интеграл по траекториям, вводятся концепции матрицы плотности и эффективного действия. Курс предполагает переход к рассмотрению свободных полевых теорий, их каноническому квантованию, обсуждению отличия квантовой механики от квантовой теории поля.

Course Academic Level	PhD-level
Number of ECTS credits	6

Topic	Summary of Topic	Lectures (# of hours)	Seminars (# of hours)	Labs (# of hours)
Introduction.	Basic principles of quantum theory.	2	4	
Quantum mechanics in external fields.	The motion of an electron in external electromagnetic fields. Pauli's Equation. Quantization of an electron in a uniform and constant magnetic field. The Landau Levels. A hydrogen atom in the outer field. Perturbation theory.	1	6	
Integrable potentials of one-dimensional quantum mechanics.	Soliton potentials, their construction and properties. Communication with integrated systems.	1	6	
Motion of a particle in a periodic potential.	Band structure.	1	5	
Systems of identical particles.	Bosons and fermions. The Fock space for fermions and bosons.	1	5	
Quantum system in the environment.	The concept of the density matrix, its calculation using path integral. The Feynman-Katz Formula.	1	5	
Dynamics of quantum theory and the functional integral method.	Effective action. Quasiclassical approximation. The friction model of Caldeira-Leggett.	2	6	
Quantization of the field.	Quantization of the free electromagnetic field as a gauge theory. Radiation of absolutely black body.	2	6	

Assignment Type	Assignment Summary
Homework Assignments	Solving problems by topic 1,2,3
Homework Assignments	Solving problems by topic 4,5,6
Homework Assignments	Solving problems on topics 7,8 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

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

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 1 Term 2
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	Mathematics and Mechanics

Course Tags	Math Physics

Required Textbooks	ISBN-13 (or ISBN-10)
П. Дирак, Принципы квантовой механики, 1979, М., Наука	
Р. Фейнман, Статистическая механика, 1978, М., Мир	

Recommended Textbooks	ISBN-13 (or ISBN-10)
П.В.Елютин, В.Д.Кривченков, Квантовая механика с задачами.	

Knowledge
Knowledge of the principles of quantum theory for solving problems.

Skill
Application of modern mathematical methods for solving the tasks.

Experience
Creating mental images for solving problems of quantum theory.

Select Assignment 1 Type	Homework Assignments
Input Example(s) of Assignment 1 (preferable)	

	1.To find the variance the square of coordinates is real one dimensional generator (frequency - $omega$, mass m) in the state with the energy is definitely $ 3hbaromega / 2$. 2.Find the average kinetic energy of an electron in the Coulomb field of attraction in the 2p-state with the minimum projection of the moment of momentum on the selected axis. 3.Two neutrons can only move along a straight line and they interact with each other as follows: $U(q_1,q_2)=momega^2 (q_1-q_2)^2/4$ (here $q_{1,2}$ - coordinates of neutrons on a straight line, $omega$ - characteristic potential, m - the mass of the neutron). The system is placed in a uniform magnetic field $vec{B}$. What is the main magnetic field the state of this system is singlet? 4.Find the splitting of the first excited level of hydrogen in a linear magnetic field approximation. 5. The electron is located near an ideal metal surface. The surface is impervious to the electron. The electron is in the ground state. What is the distance from this surface at which this electron can be detected?
Assessment Criteria for Assignment 1	The score is set according to the percentage of correct decisions.
Select Assignment 2 Type	Homework Assignments
Input Example(s) of Assignment 2 (preferable)	Investigate the fine structure of the hydrogen atom.
Assessment Criteria for Assignment 2	The score is set according to the percentage of correct decisions.
Select Assignment 3 Type	Homework Assignments
Input Example(s) of Assignment 3 (preferable)	Prepare and solve a quantum mechanics problem of your choice.
Assessment Criteria for Assignment 3	The score is set according to the percentage of correct decisions.