Skoltech
Skolkovo Institute of Science and Technology

Course Syllabus

Course Title (in English)	Quantum Field Theory
Course Title (in Russian)	Квантовая теория поля
Lead Instructor(s)	Semenov, Andrei

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Course Description

At present time Quantum Field Theory (QFT) is the main theoretical tool used for the description of the phenomena occurring in the microworld. Examples include interactions between elementary particles, hadron structure and so on. At the same time, QFT methods are widely used in all areas of modern theoretical physics such as condensed matter physics, statistical mechanics, turbulence theory and others. Moreover, the creation of QFT has stimulated the development of many modern areas of mathematics.

The course is aimed at the study of the basic ideas and methods of QFT, as well as the discussion of its applications in various areas of modern theoretical and mathematical physics. Topics include quantization of scalar and gauge theories, path integral approach, perturbative expansions and Feynman diagrams, (1+1) dimensional exactly soluble models and some other ideas of modern science.

Course Prerequisites / Recommendations	Calculus, Complex analysis, ODE and PDE, Classical Mechanics, Classical Fields, Quantum mechanics

Аннотация

В настоящее время квантовая теория поля является основным средством описания явлений происходящих в микромире: взаимодействия элементарных частиц, строение адронов и т.п. Её методы широко используются и в других областях теоретической физики: конденсированное состояние вещества, статистическая механика, теория турбулентности и др. Помимо этого, квантовая теория поля служит важнейшим стимулом для развития множества современных математических исследований.

Будет рассказано о квантовании скалярных и калибровочный теорий, методе функционального интегрирования, построении теории возмущений и диаграммах Фейнмана, (1 + 1)-мерных точно решаемых теориях, а также о применении этих подходов в различных областях современной науки.

Course Academic Level	Master-level course suitable for PhD students
Number of ECTS credits	6

Topic	Summary of Topic	Lectures (# of hours)	Seminars (# of hours)	Labs (# of hours)
Introduction	Relativistic particle and path integrals.	1	3	0
Scalar field	Scalar field and its quantization. Operator approach.	1	3	0
S-matrix	Observables and S-matrix. Fock space interpretation.	1	3	0
Path integral	Path integral quantization of scalar fields.	1	3	0
Perturbative expansion	Perturbative expansion. Feynman diagrams, construction and evaluation. Symmetry factors.	1	3	0
Gauge fields.	Gauge fields and problem of its quantization. Physical degrees of freedom. SU(N) Yang-Mills.	1	3	0
Gauge fields via path integrals.	Gauge field quantization. Faddeev-Popov trick. Abelian and non-Abelian fields. Ghosts.	1	3	0
Fermions	Fermions. Spinors. Dirac equation& Grassmann fields.	1	3	0
Renormalization	Infinities in perturbative expansion. Renormalization. Running coupling constants.	1	3	0
Model systems and QED	Model systems. Evaluation of physical observables. QED.	1	3	0
1+1 systems	1+1 systems. Sine-gordon model. Solitons and its quasiclassical meaning. Why exact solutions exists.	1	3	0
QFT in adjacent fields.	QFT in condensed matter and statistical mechanics.	0	4	0
Nonperturbative effects	Anomalies. Nonperturbative effects. Tunnelling and decay of metastable states. Meaning of asymptotic series.	0	4	0

Assignment Type	Assignment Summary
Problem Set	Problem set about scalar fields.
Problem Set	Problem set about fermions, gauge fields and renormalization.
Final Exam	Final exam with small report.

Type of Assessment	Graded

Grade Structure

Activity Type	Activity weight, %
Problem Set	20
Problem Set	20
Final Exam	60

A:	86
B:	76
C:	66
D:	56
E:	46
F:	0
Attendance Requirements	Optional with Exceptions
Course Term (in context of Academic Year)	Term 3 Term 4

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

Masters Programs	PhD Programs
Materials Science Mathematical and Theoretical Physics Photonics and Quantum Materials	Materials Science and Engineering Mathematics and Mechanics Physics

Course Tags	Math Physics

Knowledge
Know methods of Quantum Field Theory.
Know about achievements and modern problems of Quantum Field Theory.