ITMO University

Quantum Electrodynamics

Course Workload		Assessment form (examination/ graded test/ ungraded test)
ECTS	Hours	
3	108	Exam

Quantum electrodynamics (QED), or relativistic quantum field theory of electrodynamics, is considered a theory of perturbations of the quantum vacuum and allows us to describe all phenomena associated with interacting charged particles. Being both the simplest and most successful quantum field theory, QED allows us to teach students the mathematical and physical languages of quantum field theory, illustrating their application with specific examples. As a result of this course, students will learn to construct and calculate the amplitudes of interaction processes, master the Feynman diagram technique, and become familiar with the basic principles of the Standard Model.

Course structure:

1. Quantum electrodynamics

1.1. Classical field theory. Equations of motion. Noether's theorem. Momentum and energy of the field. Lorentz invariance
1.2. Quantization of a free field. Commutation relations for fields. Expansion of fields in modes (creation/annihilation operators). Hamiltonian of a free field
1.3. Normal ordering of operators. Transition to the Heisenberg picture. The field operator in the Heisenberg representation. Causality
1.4. The propagator in quantum field theory. Calculation of asymptotics outside the light cone, interpretation of the answer using the WKB theorem
1.5. The Feynman propagator, its momentum representation. Theories with interaction. Representation of interaction. T-ordering. Dyson's formula for the evolution operator. S-matrix.
1.6. Example: Yukawa-type interaction (i.e. \psi^\dagger \psi \phi). Wick's theorem. Feynman diagrams. The scalar field model \phi^4.
1.7. Relationship between correlation functions and S-matrix. Cancellation of vacuum diagrams. Gell-Mann-Low theorem.
1.8. Lorentz group and Lorentz algebra. Weyl spinors.
1.9. Clifford algebra. Spinor representation.
1.10. Dirac equation and its solutions

1.11. Spatial parity. Scalars and pseudoscalars, vectors and pseudovectors. Relationship between spin and statistics. Anticommutation relations. Quantization of the Dirac field.
1.12. Dirac field propagator. Wick's theorem for fermions.
1.13. Simplest processes with fermions, first order.
1.14. Simplest processes with fermions, second order.
1.15. Interaction of the electromagnetic field with fermions. Tree processes.
1.16. Scattering cross sections of the simplest processes.