01.07.2019

Quantum Field Theory

86-804-01

Lecturer: Prof. Eugene Kogan

Course type: Lecture

Date: 2019-2020 **semester:** B **weekly hours:** 3

Aim of course:

The purpose of the course is to teach students the basics of the Quantum Field Theory, especially the way the theory is applied in modern Condensed Matter Physics.

Details of subjects to be covered:

I. Photons and the Electromagnetic Field

A. The Electromagnetic Field in the Absence of Charges
B. The Electric Dipole Interaction
C. The Electromagnetic Field in the Presence of Charges
D. Noether Theorem

II. Lagrangian Field Theory

A. Classical Lagrangian Field Theory
B. Quantized Lagrangian Field Theory
C. Symmetries and Conservation Laws

III. The Klein-Gordon Field

A. The Real Klein-Gordon Field
B. The Complex Klein-Gordon Field
C. Covariant Commutation Relations
D. The Meson Propagator

IV. The Dirac Field

A. The Number Representation for Fermions
B. The Dirac Equation
C. Second Quantization
D. The Fermion Propagator

E. The Electromagnetic Interaction and Gauge Invariance

V. Photons: Covariant Theory

A. The Classical Fields
B. Covariant Quantization
C. The Photon Propagator

VI. The S-Matrix Expansion

A. Natural Dimensions and Units
B. The S-Matrix Expansion
C. Wick's Theorem

VII. Feynman Diagrams and Rules in QED

A. Feynman Diagrams in Configuration Space
B. Feynman Diagrams in Momentum Space
C. Feynman Rules for QED
D. Leptons

VIII|. QED Processes in Lowest Order

A. The Cross-Section
B. Spin Sums
C. Photon Polarization Sums
D. Lepton Pair Production
E. Bhabha Scattering
F. Compton Scattering
G. Bremsstrahlung

IX. Radiative Corrections

A. The Second-Order Radiative Corrections of QED
B. The Photon Self-Energy
C. The Electron Self-Energy
D. External Line Renormalization
E. The Vertex Modification
F. The anomalous magnetic moment
G. The Lamb shift
H. The Infrared Divergence

X. Regularization

A. Mathematical Preliminaries
B. Cut-Off Regularization: The Electron Mass Shift
C. Dimensional Regularization
D. Vacuum Polarization
E. The Anomalous Magnetic Moment

XI. Gauge Theories

A. The Simplest Gauge Theory: QED
B. Quantum Chromodynamics
C. Alternative Interactions?

XII. Field Theory Methods

A. Green Functions
B. Feynman Diagrams and Feynman Rules
C. Relation to S-Matrix Elements
D. The Generating Functional

XIII. Quantum Chromodynamics

A. Gluon Fields
B. Including Quarks
C. Perturbation Theory
D. Feynman Rules for QCD

Prerequisites:

The prerequisite for the course are the courses of Quantum Mechanics and Statistical Physics.

Course mandatories:

To pass exams the student will have to show his/her ability to solve the problems similar to those which were taught at the lectures and/or assigned as a home task.

Grading:

The exams will consist of 4 problems assigned to the student. Correct solution of all problems will correspond to the grades 100. There will be an additional Bonus Problem, which can bring additional points.

Bibliographia:

FRANZ MANDL and GRAHAM SHAW, Quantum Field Theory, 2nd Edition, 2010 John Wiley & Sons, Ltd.