The Hebrew University of Jerusalem

Syllabus

Advanced Quantum Theory 1 - 77800

Last update 18-10-2020

HU Credits: 4

Degree/Cycle: 2nd degree (Master)

Responsible Department: Physics

Academic year: 0

Semester: 1st Semester

Teaching Languages: English and Hebrew

Campus: E. Safra

Course/Module Coordinator: Prof. Nadav Katz

Coordinator Email: nadav.katz@mail.huji.ac.il

Coordinator Office Hours: By appointment

Teaching Staff:

Prof Nadav Katz,
Mr. Noam Chai

Course/Module description:
The course deals with a number of more advanced topics in quantum mechanics. Emphasis is put on description and analysis of systems with many degrees of freedom.

Course/Module aims:
Developing quantum formalism for elementary particles with different spin and statistics and the methods to quantify the basic phenomena related to the interaction of such particles. Applying the formalism to describe phases of matter and phase transitions. Developing a quantum theory of the electromagnetic field and its interaction with matter. Introduction to field theory and relativistic quantum mechanics.

Learning outcomes - On successful completion of this module, students should be able to:
1. know how yo treat time-dependent quantum problems.
2. To know the basics of scattering theory and to apply it to problems.
3. To be familiar with second quantization and to use it to solve problems of interacting particles.
4. To know the basics of classical field theory.
5. To know the basics of the quantum theory of the electromagnetic field and to use it to solve problems.
6. To know the Dirac equation and its main consequences.

Attendance requirements(%):
0

Teaching arrangement and method of instruction: Lecture, Exercise

Course/Module Content:
Time-dependent problems:
The sudden approximation, the adiabatic approximation, Berry's phase, the Born-Oppenheimer approximation (Landau-Zenner transitions, decay of a state, the Wigner-Weiskopf approximation).

Scattering theory:
The Lippmann-Schwinger equation, scattering of plane waves and wave packets,

optical theorem, the Born approximation, Rutherford scattering (partial waves analysis, phase shifts, s-wave scattering, bound states and the analytical properties of the S-matrix, resonances, the Breit-Wigner formula)

Second quantization:
The possible quantum statistics, anyons, Fock space, operators in second quantization

Introduction to field theory:
The continuum limit, Euler-Lagrange equations, examples of field theories, symmetries and Noether's theorem, the Hamiltonian formalism, canonical quantization

Functional path integrals:
Bosonic coherent states, path integral representation of the partition function and correlation functions

Bose-Einstein condensation and superfluidity:
Phenomenology and treatment using path integrals, spontaneous symmetry breaking, saddle-point analysis, Goldstone modes, The Mermin-Wagner theorem, Landau criterion, Bogoliubov theory

Spin systems:
The XXZ chain, the Jordan-Wigner transformation

Quantization of the electromagnetic field: Gauge freedom and quantization in the Coulomb gauge, interaction with matter, dipole transitions, selection rules

The Dirac equation:
Derivation, the non-relativistic limit, plane-wave solutions, negative-energy states and the Dirac sea

Required Reading:
None

Additional Reading Material:
Nazarov and Danon - Advanced Quantum Mechanics

Sakurai - Modern Quantum Mechanics

Sakurai - Advanced Quantum Mechanics

Negele and Orland - Quantum Many-Particle Systems

Lifshitz and Pitaevskii - Statistical Physics - Part 2

Baym - Lectures on Quantum Mechanics

Course/Module evaluation:

End of year written/oral examination 70 %
Presentation 0 %
Participation in Tutorials 0 %
Project work 0 %
Assignments 10 %
Reports 0 %
Research project 0 %
Quizzes 20 %
Other 0 %

Additional information:

The midterm quiz is a supporting grade (20%)