PHYS-426 **Quantum physics IV**

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Cursus	Sem.	Type
Ing.-phys	MA2, MA4	Opt.
Physicien	MA2, MA4	Opt.
Quantum Science and Engineering	MA2, MA4	Opt.

Language of teaching	English
Credits	6
Session	Summer
Semester	Spring
Exam	Written
Workload	180h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

Introduction to the path integral formulation of quantum mechanics. Gauge invariance. Derivation of the perturbation expansion of Green's functions in terms of Feynman diagrams. Several applications will be presented, including non-perturbative effects, such as tunneling and instanton

Content

I. The Path Integral Approach to Quantum Mechanics
1. The Feynman Path Integral in Quantum Mechanics
2. Thermal Density Matrix and Imaginary-time Path Integral
3. Propagator of the Quantum Harmonic Oscillator

II. Interaction with an external electromagnetic field and gauge invariance in quantum mechanics
1. Gauge invariance in Quantum Mechanics
2. Particle in a uniform magnetic field: magnetic translation operators and Landau levels
3. The Aharonov-Bohm effect. Magnetic monopoles and charge quantization
4. The Berry phase

III. Correlation functions, Feynman diagrams, and functional methods
1. Matrix elements, correlation functions, and Wick's theorem
2. Feynman diagrams in Quantum Mechanics
3. Variational principle and mean-field theory

IV. The Semiclassical Approximation and Instantons
1. The semiclassical spectrum
2. The semiclassical propagator
3. Instantons in Quantum Mechanics

Keywords

Path integral formalism. Green's function. Determinants. Feynman diagram. Feynman rules. Perturbation theory. Non-perturbative effects. Tunnelling. Instantons, Gauge Invariance, imaginary time, thermal density matrix, Landau levels; Aharonov-Bohm effect, Berry phase; correlation functions, Wick's theorem, Feynman diagrams, variational principle, mean-field theory; semiclassical approximation; Bohr-Sommerfeld quantization, magnetic monopoles, Van Vleck-Pauli-Morette propagator.

Learning Prerequisites

Required courses

Analytical Mechanics
Physics III (Electromagnetism)

Statistical physics
Mathematical methods (for SPH)
Quantum Physics I, II

Recommended courses

Quantum Physics III

Important concepts to start the course

Solid knowledge and practice of calculus (complex variable) and linear algebra

Learning Outcomes

By the end of the course, the student must be able to:

- Formulate a quantum mechanical problem in terms of a Path integral
- Compute gaussian path integral as determinants
- Express physical quantities in terms of the Green function
- Translate a Feynman diagram into a mathematical expression
- Compute a Feynman diagram
- Compute tunneling rates in simple quantum potentials
- Formulate the quantum theory of a particle interacting with an external electromagnetic field

Transversal skills

- Use a work methodology appropriate to the task.
- Set objectives and design an action plan to reach those objectives.

Teaching methods

Ex cathedra and exercises

Expected student activities

Participation in lectures. Solving problem sets during exercise hours. Critical study of the material.

Assessment methods

Written exam

Supervision

Office hours	Yes
Assistant.e.s	Yes
Forum	Yes

Resources

Bibliography

"Quantum Mechanics and Path Integrals" , R.P. Feynman and A.R. Hibbs, McGraw-Hill, 1965.
"Path Integrals in Quantum Mechanics, Statistics and Polymer Physics", Hagen Kleinert, World Scientific, 1995.
"Path Integrals in Quantum Mechanics", Jean Zinn-Justin, Oxford Graduate Texts, 2010.

Ressources en bibliothèque

- Find the references at the Library

Notes/Handbook

Moodle Link

- https://go.epfl.ch/PHYS-426