

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
<b>Hours</b>	<b>4 weekly</b>
Courses	2 weekly
Exercises	2 weekly
<b>Number of positions</b>	

**Summary**

Introduction to the path integral formulation of quantum mechanics. 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 instantons.

**Content****1. Path Integral formalism**

- Introduction
- Propagators and Green's functions.
- Quantum mechanics in imaginary time and statistical mechanics.

**2. Perturbation theory**

- Green's functions: definition and general properties
- Functional methods
- Perturbation theory by Feynman diagrams

**3. Semiclassical approximation**

- The semiclassical limit

**4. Non perturbative effects**

- Reflection and tunneling through a barrier
- Instantons

**5. Interaction with external magnetic field**

- Gauge invariance in quantum mechanics
- Aharonov-Bohm effect
- Dirac's magnetic monopole and charge quantization.

**Keywords**

Path integral formalism. Green's function. Determinants. Feynman diagram. Feynman rules. Perturbation theory. Non-perturbative effects. Tunnelling. Instantons. Gauge-invariance.

## Learning Prerequisites

### Recommended courses

Quantum physics I and II

### 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
Assistants	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

- [Path Integrals in Quantum Mechanics / Zinn-Justin](#)
- [Path integrals in quantum mechanics, statistics, polymer physics, and financial markets / Kleiner](#)

- [Quantum Mechanics and Path Integrals / Feynman & Hibbs](#)

### Notes/Handbook

### Moodle Link

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