Quantum Theory Course Outline

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Instructor

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Instructor

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Land Acknowledgment

Perimeter Institute is located on the Haldimand Tract which was given to the Six Nations of the Grand River and Mississaugas of the Credit First Nation by the British as compensation for their role in the American Revolutionary War of Independence and for the loss of their traditional lands in upstate New York. Of the 950,000 acres given to the Haudenosaunee, only 46,000 acres remain Six Nations land and 6,100 acres remain Mississaugas of the Credit Nation land. The Haldimand Tract is a small portion of the traditional territory of the Anishnawbe, Haudenosaunee, and Neutral peoples.

The policies of expulsion and assimilation that harmed and continue to harm Indigenous peoples directly benefited us in giving us the ability to live and work here. We have the responsibility to learn about and acknowledge these injustices so that we may begin to remedy the damages that have been done and those that are ongoing.

Course Description

This course on quantum mechanics is divided in two parts:

The aim of the first part is to present a brief over view of selected topics in quantum theory. Schrodinger, Heisenberg and Interaction picture is discussed and applied to study time evolution. Density matrix and Feynman path integral is introduced.

The second part of the course is an introduction to scalar quantum field theory. The Feynman diagram technique for perturbation theory is developed and applied to the scattering of relativistic particles. Renormalization is briefly discussed.

Course Components

The course contains

- 14 1.5-hour lectures
- 8 1.5-hour tutorials
- Question and answer session
- Office hours
- Quizzes, tutorials, and homework assignments will be posted on the PSI portal.

For timing of the various components, see the Google calendar.

Learning Outcomes

By the end of the course each student will learn

- about different approaches to quantum theory including Schrodinger, Heisenberg and Interaction picture, Density matrix and path integral formulation.
- to use canonical quantization to construct relativistic theories of spin-0 particles.
- to compute matrix elements in scalar quantum field theory using perturbation theory.

Tentative schedule of topics

- Lecture 1: A quick review of quantum mechanics using double slit experiment
- Lecture 2: Schrodinger and Heisenberg picture
- Lecture 3: Interaction picture
- Lecture 4: Density matrix formulation

- Lecture 5: Feynman's path integral (PI) formulation
- Lecture 6: Scalar fields and propagators (PI)
- Lecture 7: Particles, forces and perturbation theory
- Lecture 8: Introduction to relativistic quantum mechanics and classical field theory
- Lecture 9: Klein-Gordon theory
- Lecture 10: LSZ reduction formula
- Lecture 11: Dyson's formula, Wick's theorem, and the propagator
- Lecture 12: Feynman diagrams for correlation functions
- Lecture 13: Feynman diagrams for S-matrix elements
- Lecture 14: Renormalization

Tentative schedule of tutorials

- Tutorial 1: Double slit experiment
- Tutorial 2: Heisenberg picture
- Tutorial 3: Interaction picture & Gaussian integral
- Tutorial 4: Density matrix
- Tutorial 5: Single-particle relativistic propagator and the Casimir effect
- Tutorial 6: Complex scalar fields
- Tutorial 7: Feynman diagrams
- Tutorial 8: Renormalization

Resources

- Suggested references
  - Lecture notes on the PSI portal
  - *Modern Quantum Mechanics* by J. J. Sakurai
  - *Quantum Field Theory and the Standard Model* by Schwartz
  - *An Introduction to Quantum Field Theory* by Peskin and Schroeder
  - *Quantum Field Theory* by Srednicki
  - *Quantum Field Theory in a Nutshell* by Zee
  - Lecture notes by Tong
- Mental health resources
  - In-house therapists

  - Employee, Student and Family Assistance Program
  - Community Resources for Mental Health
  - UW Counselling Services
- Respectful Environment Code of Conduct

Course Requirements

The course is offered on a credit/no credit basis only. To receive credit for the course each student must:

- Attend and participate in all tutorials. You do not need to submit your tutorial work if you participate in the live session.
- Submit correct solutions to all homework problems. Homework solutions should be submitted electronically via the link on the course website.
- Demonstrate an understanding of key concepts and an ability to perform basic calculations in a interview.

Makeup Policy

- If you need to miss a tutorial for a valid reason, you should let the instructor know ahead of time. In this case you should submit written evidence submit written evidence of 1.5 hours of work on the tutorial to the instructor, with credit given for work that shows effort. Repeated, excessive tardiness to tutorial counts as an absence.
- You have 3 opportunities to submit each homework assignment:
  - Deadline: It is expected that most students submit a complete assignment by the deadline, and all students submit either a partial assignment or questions by the deadline. No extensions are possible for the deadline.
  - Late deadline: It is expected that all students submit a complete assignment by the late deadline. No extensions are possible for the late deadline.
  - Pass/fail deadline: The pass/fail deadline should only be used in extenuating circumstances. If you require an extension to the pass/fail deadline, you must submit the extension request form (or meet with Dan or Angela Hovdestad) at least one business day in advance.
- If your homework solution submitted by the deadline or late deadline has a major error, you will be given a chance to correct the error and resubmit your homework by the late deadline or pass/fail deadline respectively.
- If some gaps in your understanding are discovered during the interview, you will be given feedback by the instructors and a chance to redo the interview. Each student may attempt the interview up to three times.

Feedback

Students will receive feedback at the end of the course by the instructors. Students will also receive feedback on their homework assignments by the teaching assistant. In addition, students may request

oral feedback from the instructors throughout the course.

Accommodations

Accommodations for the various course components will be made according to PI's Accommodation Policy. Students can contact the instructors if accommodations are required.

Academic Integrity

All students are expected to know, understand, and follow the academic integrity policies detailed on the University of Waterloo Academic Integrity website.