Introduction to Quantum Mechanics (Winter 2021)

ECE 405

Lectures: Online via LEARN

CONTACT INFORMATION:

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- I will be available every Wednesday from 4-5 PM on MS teams by appointment
- Please contact me via MS teams and expect a reply within 2 business days

COURSE DESCRIPTION:

This course is intended to introduce the fundamental concepts of quantum mechanics for engineers and study modern applications of quantum mechanics including quantum computing and cryptography. Fundamental concepts include quantization of angular momentum and spin, quantum measurement and quantum interference. The fundamental concepts and formalism of quantum mechanics will be applied to compute probabilities for outcomes of measurements and determine how quantum systems evolve in time via the Schrödinger equation. Other solvable examples of the Schrödinger equation will include stationary states of a particle-in-a-box and the harmonic oscillator, which is used to approximate many realistic physical systems.

LEARNING OBJECTIVES:

- Introduction to spin
- Understand and apply the fundamental concepts and formulism of quantum mechanics
- Utilize quantum mechanics to compute probabilities for outcomes of measurements
- Quantum dynamics: how quantum systems evolve in time?
- Wavefunctions and wave mechanics to explain the structure of the microscopic world (atoms, molecules, solids)
- Modern applications in quantum mechanics including quantum computing and cryptography

RESOURCES:

- Textbook (required): "Quantum Mechanics" by David H. McIntyre
- *SPINS* software can be obtained using links from the following url: http://www.physics.oregonstate.edu/qmactivities
- LEARN Website: We will be using the LEARN website to make video lectures and tutorials available. Announcements will be made via the LEARN system as online notifications, but also as emails. Please remember to initialize the forwarding mechanism in LEARN so that all email notifications reach you even if you are not logged into the system.

COURSE OUTLINE:

- Why Quantum Mechanics?
- Introduction to spin
- Postulates of Quantum Mechanics (fundamental concepts)
- Stern-Gerlach experiments (1-4): concept of spin
- Calculating probabilities for predicting outcomes of measurements
- Operators and measurements
- Commutators and the uncertainty principle
- Quantum dynamics: how a quantum system evolves in time?
- Wavefunctions and wave mechanics
- Quantized energies: particle in a box
    - Infinite potential well
    - Finite potential well
    - Harmonic oscillator
- Modern applications in quantum mechanics
    - Quantum computing
    - Quantum communication
- Project Presentations

ECE 405: Introduction to Quantum Mechanics Course Outline (Winter 2021)

Week	Date	Lecture	Lecture	Tutorial
1	January 11-15	Introduction	Particle-Wave Duality of Matter	None
2	January 18-22	What is Spin? Stern-Gerlach experiments	Quantum State Tomography	Probability and Statistics (Spin1 software)
3	January 25-29	Quantum State Vectors	Matrix Notation	Quantum State Tomography (Spin2 software)
4	February 1-5	Operators and Measurement	Quantum Measurement: Projection	Quantum Measurement
5	February 8-12	Expectation Value & Uncertainty	Commutation and the Uncertainty Relation	Calculating Expectation Values
Reading Week	**February 13-21**	**Reading Week**		
6	February 22-26	Quantum Dynamics	Quantum Dynamics	Review
7	**March 1-5**	**Open Book Test #1 – Covers Weeks 1-5** (Pickup on Wednesday, due 24 hours later)		
8	March 8-12	Wave mechanics	Wavefunctions	Quantum Dynamics
9	March 15-19	Infinite Square Well	Finite Square Well	Wave mechanics
10	March 22-26	Quantum Cryptography	Quantum Gates	Potential Wells
11	March 29-April 2	Quantum Computing	Quantum Computing	Review
13	**April 5-9**	**Open Book Test #2 – Covers Weeks 6-11** (Pickup on Wednesday, due 24 hours later)		
14	**April 17**	**Project Presentation due**		

ASSESSMENT:

- 25% assignments, 50% open book tests, 25% project presentation, NO FINAL
- **Project Presentation:** (Teams of 4) 15 minute presentation on a modern application of quantum mechanics
- **Graded Assignment Collection**: Assignments must be submitted online via Dropbox on LEARN prior to the due date, otherwise a grade of 0% for that assignment will be given. Graded assignments will be available approximately one to two weeks after they are due.

  Assignment Solutions: Solutions will be available on LEARN after the due date.

  Please Note: *No late assignments will be accepted for credit without prior consultation with the course instructor.*
- **Examinations**
  - We will have two open book tests throughout the term.

Please Note: *Student travel plans are not considered acceptable grounds for granting an alternative examination time*
http://www.registrar.uwaterloo.ca/exams/finalexams.html

- If any graded elements are missed and appropriate documentation is forthcoming (e.g. VIF for illness), the student should discuss with the instructor how to accommodate the missed element. Typically, the grade for that component will be renormalized to reflect the missing element(s).
- Students are reminded that it is their responsibility to check appropriate uWaterloo websites for details concerning various dates (e.g., final examination, drop deadlines, etc.)

COMMITMENT EXPECTATIONS:

- Students are expected to spend 3-5 hours per week on assignment problems and reading textbooks and notes outside of class and tutorials.
- Attendance at lectures is strongly recommended. The course material is conceptually challenging and students are encouraged to ask questions about the material via MS Teams.

VERIFICATION OF ILLNESS:

- Verification of Illness: In order to request accommodation due to illness, students will have to file a Verification of Illness form with the Science Undergraduate office. Based on this filing, and an explicit request from the student, the Lecturer will decide how and if an accommodation will be made.
- Science students should be aware that starting with the Winter 2013 term, the only Verification of Illness forms (VIFs) that instructors will accept for accommodation for missed assessments (labs, quizzes, midterms, final exams, etc.) will be those issued by the University of Waterloo, Health Services, when this service is open. VIFs issued by walk-in clinics will not be accepted, except when obtaining a VIF from Health Services is not possible.
- If a student is sick on a weekend, during off-hours, while out of town or receiving ongoing care from a family physician or specialist, it is acceptable to provide documentation from other health service providers. Information should include (1) date of the physician assessment, (2) dates of illness, (3) level of incapacitation and (4) whether the diagnosis was made by the physician or based on description by the student.
- Keeping the playing field level for all of our students is a priority. Students are reminded that obtaining a VIF under false pretenses is an academic offense. For tests and exams, a student found guilty of misrepresentation will receive a failing grade in the course and be suspended.
- Any questions concerning this policy can be directed to an undergraduate advisor in the Science Undergraduate Office.
    - ESC 253 (Monday: 9:30 am to 12:00 pm, and 1:00 pm to 4:15 pm; Tuesday-Friday: 8:30 am to 12:00 pm, and 1:00 pm to 4:15 pm)
    - Email: current@science.uwaterloo.ca,
    - Phone: 519-888-4567, extension 35244,
    - Web: https://uwaterloo.ca/science/current---undergraduate---students

ACADEMIC INTEGRITY:

- *Office of Academic Integrity provides relevant information for students, faculty and staff.*
    - ***Academic Integrity**: In order to maintain a culture of academic integrity,*

members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility.

- ***Grievance**: Students, who believe that a decision affecting some aspect of their university life has been unfair or unreasonable, may have grounds for initiating a grievance. Students should read Policy #70, Student Petitions and Grievances, Section 4. When in doubt, students must contact the department's/school's administrative assistant who will provide further assistance.*
- ***Discipline**: Students are expected to know what constitutes academic integrity, to avoid committing academic offenses, and to take responsibility for their actions. Students who are unsure whether an action constitutes an offense, or who need help in learning how to avoid offenses (e.g., plagiarism, cheating) or about 'rules' for group work/collaboration should seek guidance from the course instructor, academic advisor, or the Associate Dean of Science for Undergraduate Studies. For information on categories of offenses and types of penalties, students should refer to Policy #71, Student Discipline. For information on typical penalties, students should check Guidelines for the Assessment of Penalties.*
- ***Appeals**: A decision or penalty imposed under Policy 33 (Ethical Behavior), Policy #70 (Student Petitions and Grievances) or Policy #71 (Student Discipline) may be appealed, if there is a ground. Students, who believe they have a ground for an appeal, should refer to Policy #72 (Student Appeals).*

STUDENTS WITH DISABILITIES:

- *AccessAbility Services, located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If students require academic accommodations to lessen the impact of their disability, they should register with AccessAbility Services at the beginning of each academic term.*