

*“‘Quantum mechanics’ is the description of the behavior of matter and light in all its details and, in particular, of the happenings on an atomic scale. Things on a very small scale behave like nothing that you have any direct experience about. They do not behave like waves, they do not behave like particles, they do not behave like clouds, or billiard balls, or weights on springs, or like anything that you have ever seen.” — **The Feynman Lectures on Physics Vol. III***

LOCATION AND TIME:

- **LECTURE: 8:30 AM - 9:20 AM (MWF), RCH 302**
- **TUT 1: 9:30 AM - 10:20 AM (M), DWE 3518 — TA: Luke Neal**
- **TUT 2: 10:30 AM - 11:20 AM (T), RCH 308 — TA: Scott Johnstun**
- **TUT 3: 9:30 AM - 10:20 AM (W), MC 4042 — TA: Sahand Tabatabaei**

CONTACT INFORMATION:

- Dr. Raffi Budakian
- email: rbudakian@uwaterloo.ca
- Office hours: QNC 4104 Thursday 10:00-11:30 am

TEACHING ASSISTANTS:

- **Luke Neal** lneal@uwaterloo.ca
- **Seyed Sahand Tabatabaei** ss4tabat@uwaterloo.ca
- **Scott Johnstun** sjohnstu@uwaterloo.ca

COURSE DESCRIPTION:

- Background of quantum physics. Introduction to formalism of quantum physics. Introduction to operators. Quantization, waves and particles. The uncertainty principle. The Schrödinger equation for one-dimensional problems: bound states in square wells. Harmonic oscillator; transmission through barriers.

LEARNING OBJECTIVES:

- Background: understanding why we need a quantum theory
- Learning the building blocks of a quantum theory: state vectors and operators
- Learning how to use quantum mechanics to compute probabilities for outcomes of measurements
- Learning how to use quantum physics for technological applications

MATHEMATICAL TOOLS:

- **Complex numbers**

- **Basic Probability**
- **Linear Algebra**
- **Differential Equations**
- **Fourier Integrals**
- **LEARN Website contains some primers on complex numbers, probability and linear algebra.**

RESOURCES:

- **Textbook (required):** “Quantum Mechanics” by David H. McIntyre. Link to the textbook is below.
<https://uwaterloo-store.vitalsource.com/products/quantum-mechanics-janet-tate-v9780133559026>
- **Additional Resources:** “A Modern Approach to Quantum Mechanics” by John S. Townsend, “Introduction to Quantum Mechanics” by David J. Griffiths
- **Lectures:** There will be 3 lectures per week on a MWF schedule. These lectures generally cover the same material as the textbook, however I will cover additional topics that are not covered in the textbook. I will also sometimes go deeper into particular topics. Some of this additional material is intended to provide a deeper understanding into the more foundational concepts in Quantum Mechanics. I will try to post my lectures a day before my lectures so that you may go over the material prior to the lecture. All lectures will be posted on LEARN.
- **LEARN Website:** I will use the LEARN site to communicate all information related to the course. Please check the Announcements section regularly, as well as the Calendar section for all important dates related to Assignments and Assessments.
- **Piazza:** This is a resource for collaboration among students. I will not be monitoring this site.
 - Signup link: <https://piazza.com/uwaterloo.ca/winter2023/phys234>
 - Class link: <https://piazza.com/uwaterloo.ca/winter2023/phys234/home>

COURSE OUTLINE:

Week	Date	Lecture Material
1	Jan. 9th	Introduction to Quantum Mechanics Stern-Gerlach experiments (1-4)
2	Jan. 16th	Quantum State Vectors
3	Jan. 23rd	Basis definition, Matrix Notation General Quantum Systems
4	Feb. 6th	Operators, Eigenstates and Eigenvalues Expectation values
5	Feb. 13th	Mixed State, Density Operator, Projection operators Commutators and Uncertainty
6	Feb. 19th	Reading Week
7	Feb. 27th	Time dependence, Schrodinger Equation Dynamics for time indep. Hamiltonian
8	Mar. 6th	Spin Precession, Magnetic Resonance

9	Mar. 13th	Continuous Observables in QM Wavefunctions and wave mechanics
10	Mar. 20th	Infinite Potential Well
11	Mar. 27th	Quantum Harmonic Oscillator
12	Apr. 3rd	Free Particle Eigenstates / Scattering of Unbound States

The course lecture plan and the schedule of due dates given above will be followed as closely as possible, but some changes may occur. Any changes in assignment due dates or test dates will be discussed and announced in class and posted on the course webpage. However, the grading scheme (below) will remain the same.

TUTORIALS:

- **Attendance to tutorial sections is mandatory.**
- Tutorial work will be problem solving, performed in small groups guided by a TA.
- Attendance will be recorded and marks (20%) will be awarded for attendance and participation in the tutorial.
- There are no tutorials the first week of class. Tutorials begin Jan. 16.

ASSIGNMENTS:

- There are 7 assignments throughout the term. Check the Calendar section of LEARN for more information.
- All assignments will be turned in through Crowdmark.
 - o <https://app.crowdmark.com/courses/phys-234-winter-2023>
- Graded assignments will be available 1 week after they have been handed in.
- Assignment solutions will be available on LEARN.
- **Please Note:** *No late assignments will be accepted for credit without **prior** consultation with the course instructor.*

QUIZZES:

- There will be 2 one hour in-class quizzes throughout the term. The dates are stated in the Calendar section of LEARN.

ASSESSMENT:

- **Final Course Grades** will be assigned according to the following combination of marks:
20% Tutorials, 20% Assignments, 30% Quizzes, 30% Final

COMMITMENT EXPECTATIONS:

- Students are expected to spend 3-5 hrs per week on assignment problems and reading textbooks and notes outside of class.

VERIFICATION OF ILLNESS:

Please visit: <https://uwaterloo.ca/science/undergraduate/student-support/academic-policies-and-procedures/accommodation-illness-or-extenuating-circumstances>

regarding the University policy regarding accommodation for illness or extenuating circumstances.

A VIF will be required for any missed assignment or exam.

- **COVID-19 cases:**
 - Please do not come to class if you are experiencing COVID-19 symptoms or are required to isolate.
 - In the event of absence due to influenza-like illness or required self-isolation, you will need to submit an Illness Self-declaration form. Students can find the [Illness Self-declaration form in the Personal Information section of Quest](#). A doctor's note for accommodation is not required. For further assistance, please contact the [COVID-19 Support and Advice line](#) to report their illness.
 - If in-person instruction is canceled for some period of time due to COVID-19, then the lectures will be moved online. If a quiz coincides with the time that classes are not held in person, then the quiz will be administered via Corwdmark. This policy also applies to the final exam.

ACADEMIC INTEGRITY:

- Information about academic integrity, student discipline, grievances and appeals (the following statements are to be included in all Science outlines)
 - **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. The [Office of Academic Integrity](#) provides relevant information for students, faculty and staff. Students are expected to know what constitutes academic integrity, to avoid committing academic offences, and to take responsibility for their actions. Completion of the [Orientation to Academic Integrity Tutorial](#) is encouraged and familiarity with [Policy #71](#), (Student Discipline) is expected. Students who are unsure whether an action constitutes an offence, or need help in learning how to avoid offences (e.g., plagiarism, cheating) or understand 'rules' for group work/collaboration should seek guidance from their course instructor, academic advisor, or the Associate Dean of Science for Undergraduate Studies. For information on typical Policy 71 penalties, students should check [Guidelines for the Assessment of Penalties](#).*
 - **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 departmental/school administrative assistant who will provide further assistance.*
 - **Appeals:** *A decision or penalty imposed under Policy 33 (Ethical Behavior), grievances under Policy #70 (Student Petitions and Grievances) or Policy #71 (Student Discipline) may be appealed, if there is a ground. Petitions may not be appealed. 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 1401, 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.

EDI STATEMENT:

- *In this course, you should expect to be treated fairly and with respect by everyone on the instructional team and all your peers. You should expect an equal opportunity to learn. You are also expected to behave fairly and respectfully toward everyone else and avoid behaviours that make it harder for others to be comfortable. Everyone in this course has equally earned their place. Please help to create a welcoming and inclusive environment by, for example, refraining from discussing a person's appearance or making assumptions based on gender, race, ethnicity, sexual orientation, disability, or other personal characteristics. If you have a concern about how you are being treated, some of the people you can contact include (in order of escalating seriousness): your instructor, the current Chair of the Department of Physics and Astronomy, the University of Waterloo's Sexual Violence Prevention and Response Office at svpro@uwaterloo.ca or the police on- or off-campus.*