Quantum Mechanics I

PHY C56 - Summer 2021

"The more I ponder the physical part of Schrödinger's theory, the more disgusting it appears to me."
– Heisenberg commenting on Schrödinger's *Wave Mechanics*

"If one has to stick to this damned quantum jumping, I regret ever having been involved in this thing."
– Schrödinger commenting on Heinsenberg's *Matrix Mechanics*

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Office Hours

Tuesday	1:00 pm - 2:00 pm
Thursday	1:00 pm - 2:00 pm

Course Description, Learning Outcomes, and Requirements

The course will start with a review of key ideas from linear algebra. Using the mathematical tools learned up to this point we will continue by developing the formalism of quantum mechanics in the form of Hilbert spaces and the Dirac notation; observables and the statistical interpretation; and the uncertainty principle. We will then apply this formalism to solve the problem of the hydrogen atom, to extend the classical angular momentum into quantum mechanics, and to introduce the concept of spin. Time permitting, we will study two-particle systems; fermions and bosons; and atomic structure.

By the end of the course students will be able to:

- Identify and define the formal mathematical structure of Quantum Mechanics.
- Apply the fundamental laws and principles of Quantum Mechanics to describe and solve problems related to observables with discrete and continuous spectra.
- Analyze the solutions to quantum mechanical problems within the statistical paradigm.
- Explain and illustrate how Quantum Mechanics describes the structure of the hydrogen atom, the spectra of measurements of angular momentum, and the notion of quantum mechanical spin.
- Develop and implement problem-solving strategies useful in the analysis of examples and questions related to the description, behaviour, and evolution of quantum mechanical systems.
- Identify the main ideas and core physical principles in Quantum Mechanics, and demonstrate their knowledge through deliberate time management and reflective judgement of the questions and problems in tutorial work, tests, and the final exam.
- Self-assess the level of confidence in the acquired knowledge of the core concepts and ideas in the field of Quantum Mechanics under the statistical paradigm, through the decision-making process associated with the allocation of resources during tests and the final exam.
- Review and update the mathematical toolbox of quantitative and analytical skills relevant and useful in the scientific endeavour in general, and to the study of Physics in particular.

Math Prerequisites: Algebra I (MATA23); Vector Calculus II (MATB42); Diff. Equations I (MATB44)
Physics Prerequisites: Intro. to Quantum Physics (PHYB56); Electricity and Magnetism (PHYB21)

Required Materials

- **Calculator:** A scientific, non-programmable, and non-graphing calculator is required.
- **Textbook:** ***Introduction to Quantum Mechanics*** by David J. Griffiths (Cambridge, 3rd Ed.)

The schedule provided at the end of this document indicates the chapters and sections you must read **before** the release of each lecture video. The textbook also provides the conceptual questions and detailed problems that will be the subject of the weekly problem sets and tutorial work.

- **Technical Requirements for Remote and Online Learning:**

Please review the minimum and recommended technical requirements for learning in the remote and online environment. Specifically for our course you will need a fast and reliable Internet connection. This is particularly important for all the scheduled synchronous course components, including tutorials, tests, and the final exam.

Use of a computer (laptop or desktop) instead of a mobile device (smartphone or tablet) will be critical during all electronic forms of assessment. Additionally, you should connect via wire (Ethernet) to your modem or router instead of using a wireless (WiFi) connection to ensure stability and reduce interference.

You will also be required to produce scans of handwritten work in PDF format for your tutorials, tests, and the final exam. This can be accomplished using a dedicated scanner or using the camera in your smartphone after installing a document scanner app. More details and suggestions will be provided in the course website.

Grading Scheme and Components

Component	%	Due Date
Tutorial Work	20	Ongoing (Weekly Tutorials)
Test #1	15	Week 05 (Tentative)
Test #2	20	Week 09 (Tentative)
Final Examination	45	Exam Period (August 16 - 29)

Tutorial Work (20%)
Prior to each tutorial session you will have the opportunity to review the problem set containing relevant examples and problems for that week. During the online synchronous tutorials on Bb Collaborate we will discuss the most important points in the problem sets as well as any difficulties you may have encountered in your readings.

After the end of each tutorial session a set of problems and questions derived from the discussions will be made available. Each student will then be required to submit their individually-completed work on these problems and questions.

In order to submit the answers to these problems and questions you will be required to digitize the completed work either through the use of a scanner or by converting photos taken with a mobile device into acceptable PDF files. We strongly recommend the use of a document scanner app when using a mobile device.

Note that it is your responsibility to explore the available document scanner app options for your specific model and operating system. Your individual work will be graded for credit and your final grade is calculated as the average of the **best 10** results.

Test #1 (15%)
This **2.5-hour** long test will be scheduled during **Week 05**. Content includes all lecture discussions, textbook readings, and problem sets up to and including the material assigned and discussed in Week 04.

Test #2 (20%)
This **2.5-hour** long test will be scheduled during **Week 09**. Content includes all lecture discussions, textbook readings, and problem sets up to and including the material assigned and discussed in Week 08.

Final Examination (45%)
The **4-hour** long final examination will be scheduled during the exam period of **August 16 - 29**. Content for the final examination includes all the topics discussed in the assigned textbook readings, lecture videos, problem sets, and tutorial work.

Format and Allowed Aids - Tests & Final Examination
Both tests and the final examination will include conceptual questions in multiple-choice or short-answer format, and detailed problems. In order to submit work for the detailed problems you will be required to digitize completed work either through the use of a scanner or by converting photos taken with a mobile device into acceptable PDF files. We strongly recommend the use of a document scanner app when using a mobile device. It is your responsibility to explore the available document scanner app options for your specific model and operating system.

The only aids allowed for the tests and the final examination are your non-programmable and non-graphing scientific calculator, and a hand-written, double-sided, and letter-sized aid sheet that may not include explicit problem solutions. Photocopies or computer printouts are not allowed.

Class Policies

Academic Integrity and Respect for the Academic Endeavor
Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensuring that a degree from the University of Toronto is a strong signal of each student's individual academic achievement. As a result, the University treats cases of cheating and plagiarism very seriously. The University of Toronto's *Code of Behaviour on Academic Matters:*

https://governingcouncil.utoronto.ca/media/15068/view

outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences include, but are not limited to:

- In papers and assignments: Using someone else's ideas or words without appropriate acknowledgment; submitting your own work in more than one course without the permission of the instructor; making up sources or facts; obtaining or providing unauthorized assistance on any assignment; using someone else's clicker or multiple clickers for participation grades.
- On tests and exams: Using or possessing unauthorized aids; looking at someone else's answers during an exam or test; misrepresenting your identity.
- In academic work: Falsifying institutional documents or grades; falsifying or altering any documentation required by the University, including (but not limited to) doctor's notes.

All suspected cases of academic dishonesty will be investigated following procedures outlined in the *Code of Behaviour on Academic Matters*. If you have questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, you are expected to seek out additional information on academic integrity from your instructor or from other institutional resources (see https://www.utsc.utoronto.ca/vpdean/academic-integrity).

Copyright Notice
The lectures of this course will be recorded on video and will be available to students in the course for remote viewing. Course videos and all additional course materials, including all assignments and various assessment instruments, belong to your instructor, the University, and/or other sources depending on the specific facts of each situation, and are protected by copyright. Do not download, copy, or share any course materials or videos without the explicit permission of the instructor.

Email Communications
If you want to ask a question via email, please first check the various threads in the PeppeR section of the course website. Quite likely, you are not the only person with that same question, and if that question has already been asked, you will find the answer there. If the question has not been asked, go ahead and post it yourself instead of sending it by email. This way you will also help other students facing the same issue. These discussions are monitored regularly by the course instructor and your peers, making it the best way of communicating for various queries of a diverse nature.

However, if these electronic forums are not the best place for your specific concern, make sure you send your email from an official **utoronto.ca** address (e.g., your UTmail+ account), as all other addresses will be filtered out automatically. For a quicker response time include the code **PHYC56** in the subject line of your message. I reply to emails within a period of 24 hours and I rarely reply to emails during weekends.

Absences
In order to ensure fairness in the assessment of all students, there will be no makeup options for any term work. In the case of a **valid** and **documented** problem that supports a missed assignment the grade will be calculated on the basis of all other submitted work. In the case of a **valid** and **documented** problem that supports an absence to the first test, the second test will have its weight increased accordingly. In the case of a **valid** and **documented** problem that supports an absence to the second test, the final examination will have its weight increased accordingly.

If your absence is the result of a health-related problem you must use the official form available at the Registrar's Office website under Verification of Illness or Injury. However, if your illness fits the criteria described in the COVID-19 Absence Declaration in ACORN website, please follow the alternate steps described therein.

Course Support

Access*Ability*
Students with diverse learning styles and needs are welcome in this course. In particular, if you have a disability/health consideration that may require accommodations, please feel free to approach me and/or the Access*Ability* Services Office as soon as possible. I will work with you and Access*Ability* Services to ensure you can achieve your learning goals in this course. Enquiries are confidential. The UTSC Access*Ability* Services staff (located in AA142) are available by appointment to assess specific needs, provide referrals and arrange appropriate accommodations. Contact by phone (416) 287-7560 or email at ability@utsc.utoronto.ca

PeppeR on Quercus
The course website supports electronic forums useful for questions and discussions on course content, conceptual and detailed problems, textbook readings, as well as any issues relating to administrative aspects of the course such as deadlines and scheduling.

It is recommended that you check the threads on a regular basis to keep on top of current issues. You can subscribe to the various threads in order to receive email notifications when new posts are available.

Lecture Videos
Lecture videos will be available weekly on Tuesday afternoon and will expire the following week on Friday, approximately 10 days after being released. Prior to watching the lecture videos you must read the assigned textbook materials.

Class Schedule

This schedule is ***tentative*** and might change during the term in order to accommodate for variations in the lectures in response to student performance and understanding of the various topics.

Please note that it is your responsibility to read the assigned sections **before** watching each lecture video. The lecture videos will **not** be a direct repetition of the basic material found in the textbook.

In the lecture videos we will concentrate on important and difficult aspects of the theory and concepts from your textbook readings. A minimum understanding of the basic concepts from the assigned readings will be the assumed starting point for each lecture video. As a result, failing to complete the textbook readings before watching each lecture video will significantly affect your ability to understand the material presented.

Week # Date	**Lecture Video**	**Tutorial Discussion**
Week 01 May 11	**Vectors and Matrices** Appendix A: Sections 1 - 3	**Eigenvectors & Eigenvalues** Appendix A: Sections 4 - 6
Week 02 May 18	**Hilbert Space and Observables** Chapter 3: Sections 1 - 2	**Problem Set #01**
Week 03 May 25	**Eigenfunctions and Operators** Chapter 3: Sections 3 - 4	**Problem Set #02**
Week 04 June 01	**The Uncertainty Principle** Chapter 3: Section 5	**Problem Set #03**
Week 05 June 08	**Vectors and Operators / Harmonic Oscillator** Chapter 3: Section 6 / Chapter 2: Section 3	**Problem Set #04**
Week 06 June 15	**The Schrödinger Equation in 3D** Chapter 4: Section 1	**Problem Set #05**
Week RW June 22	**Reading Week** **Reading Week**	**Problem Set #06**
Week 07 June 29	**The Hydrogen Atom** Chapter 4: Section 2	**Problem Set #07**
Week 08 July 06	**Angular Momentum** Chapter 4: Section 3	**Problem Set #08**
Week 09 July 13	**Spin - Part I** Chapter 4: Section 4	**Problem Set #09**
Week 10 July 20	**Spin - Part II** Chapter 4: Section 4	**Problem Set #10**
Week 11 July 27	**Identical Particles** Chapter 5: Section 1	**Problem Set #11**
Week 12 August 03	**The WKB Approximation** Chapter 9: Sections 1 - 2	**Problem Set #12**