Introduction to Quantum Physics
PHY B56 - Fall 2021

"I think I can safely say that nobody understands quantum mechanics"
– Richard Feynman

"If you are not confused by quantum physics then you haven't really understood it"
– Niehls Bohr

Instructor: Johann Bayer **Email:** jbayer@utsc.utoronto.ca **Course Website:** q.utoronto.ca

Office Hours

Tuesday	1:00 pm - 2:00 pm
Thursday	10:00 am - 11:00 am
Thursday	1:00 pm - 2:00 pm

Course Description, Learning Outcomes, and Requisites

We will start the course with a brief introduction to the experimental basis of Quantum Mechanics and the properties of the wave function. Schrödinger's equation will then be studied with some applications in one dimension. Further topics will include square potential wells, the quantum harmonic oscillator, uncertainty principles, delta potential, scattering, and tunneling.

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

- Identify and define the basic vocabulary used in Quantum Physics.
- Recognize the experimental evidence that led to the revision of Classical Physics.
- Illustrate conceptually and with experimental examples, the main differences between the quantum and classical paradigms.
- Apply the basic ideas of Quantum Mechanics to the study and analysis of one-dimensional models.
- Develop and implement problem-solving strategies useful in the analysis of examples and questions related to the description, behaviour, and evolution of systems under the one-dimensional Schrödinger equation.
- 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, 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.

Corequisite: Techniques of the Calculus of Several Variables I (MATB41)
Pre-Requisites: Introduction to Physics IIA (PHYA21); Calculus II (MATA36/MATA37)

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, reading quizzes, and tutorial work.

- **Textbook:** ***Quantum Mechanics*** by Robert Scherrer (Pearson, 1st Ed.)

Handouts on the **Origins of Quantum Mechanics** and **Complex Numbers** will be provided.

- **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. Since you will 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

Component	%	Due Date
Reading Quizzes	5	Ongoing (Pre-Lecture)
Tutorial Work	20	Ongoing (Weekly Tutorials)
Test #1	15	Week 5 (Tentative)
Test #2	20	Week 9 (Tentative)
Final Examination	40	Exam Period (December 09 - 21)

Grade Components

Reading Quizzes (5%)
Each week on the course website you will be asked a set of questions from the assigned readings for the upcoming week. You will have until **11:55 am** on **Tuesday** to submit your answers. Each quiz is worth **5 points**, and your final grade is the total sum of all quizzes up to a maximum of **50 points**. Use the **Class Schedule** found at the end of this document to prepare for the lecture videos and reading quizzes.

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 Zoom 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 out of **10 points**, and your final grade is the average of the **best 10** results.

Test #1 (15%)
This **2.5-hour** long test will be scheduled during **Week 5**. Content includes all lecture discussions, textbook readings, and problem sets up to and including the material assigned and discussed in Week 4.

Test #2 (20%)
This **2.5-hour** long test will be scheduled during **Week 9**. Content includes all lecture discussions, textbook readings, and problem sets up to and including the material assigned and discussed in Week 8.

Final Examination (40%)
The **4-hour** long final examination will be scheduled during the exam period of **December 09 - 21**. 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 and 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

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 **PHYB56** 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.

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.

Absences
In order to ensure fairness in the assessment of all students, there will be no default 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.

Exceptional circumstances requiring a makeup test would be reviewed on a case-by-case basis. Any resulting makeup tests will be scheduled as oral examinations to be conducted via Zoom.

All valid and documented absences must be declared through **both** the Absence Declaration in ACORN **and** the DPES Self-declaration Absence Form, and the onus is fully on the student to contact promptly the course instructor. Additionally, absences that are the result of a non-COVID health-related problem must be documented with a completed Verification of Illness or Injury form. Please note that you might be required to provide additional supporting documentaiton to your instructor.

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).

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

Lecture Videos

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

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.

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 and completing the respective reading quiz.

The lecture videos will **not** be a direct repetition of the basic material found in the textbook. Instead, 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 Sep. 07-08	**Light and Matter Waves** **Scherrer** Ch.1: 1, 3, 4	**Course Organization**
Week 02 Sep. 14-15	**Bohr's Atom and Blackbody Radiation** **Scherrer** Ch.1: 5, 2, 6	**Problem Set #01**
Week 03 Sep. 21-22	**Schrödinger's Equation** **Griffiths** Ch.1: 1 - 4	**Problem Set #02**
Week 04 Sep. 28-29	**Wave Functions and Uncertainty** **Griffiths** Ch.1: 5 - 6	**Problem Set #03**
Week 05 Oct. 05-06	**Stationary States** **Griffiths** Ch.2: 1	**Problem Set #04**
Week RW Oct. 12-13	**Reading Week** **Reading Week**	**Problem Set #05**
Week 06 Oct. 19-20	**The Particle in a Box** **Griffiths** Ch.2: 2	**Problem Set #06**
Week 07 Oct. 26-27	**The Free Particle and Momentum** **Griffiths** Ch.2: 4	**Problem Set #07**
Week 08 Nov. 02-03	**Delta Potential and Scattering** **Griffiths** Ch.2: 5	**Problem Set #08**
Week 09 Nov. 09-10	**The Finite Square Well** **Griffiths** Ch.2: 6	**Problem Set #09**
Week 10 Nov. 16-17	**Quantum Harmonic Oscillator I** **Griffiths** Ch.2: 3	**Problem Set #10**
Week 11 Nov. 23-24	**Quantum Harmonic Oscillator II** **Griffiths** Ch.2: 3	**Problem Set #11**
Week 12 Nov. 30 - Dec. 01	**The WKB Approximation** **Griffiths** Ch.9: 1 - 2	**Problem Set #12**