Course outline
PHYS 3705: Introduction to Quantum Systems - Fall 2025

We, the people of the Faculty of Science at Carleton University, acknowledge that our campus is located on the traditional, unceded territories of the Algonquin Anishinabeg people. Miigwetch for your hospitality and stewardship of this territory and the teachings that come from it. We are grateful for this land, the air that we breathe, and the water that sustains us all as well as for the animals, plants and other living beings: these enable us to research, teach, mentor, support, study, and learn. We recognize our responsibility to our natural environment and to reconciliation with Indigenous peoples.

Instructor: Thomas Grégoire (HP 3378, thomasgregoire@cunet.carleton.ca)

Student Hours: Monday 11am-12pm and Thursday 2pm-3pm. If you are not available during those time, contact me to make an appointment.

Lectures: Tuesday-Thursday, 11:35 am - 12:55 pm. First lecture on Thursday Sept. 4 and last lecture on Thursday Dec. 4 2025.

Prerequisites: (MATH 1004 or MATH 1007) (Calculus) and (MATH 1104 or MATH 1107) (Linear Algebra).

Preclusion: This course preclude credit for PHYS 3701 (you cannot get credits for both) and will not be an acceptable pre-requisite for PHYS 4707. It is not recommended for students in a physics programs

Suggested textbook: Schumacher and Westmoreland,"Quantum Processes, Systems, & Information", Cambridge University Press ($116.99 of Amazon, $ 134.95 on Indigo)

Other references: :

- Leonard Susskind and Art Friedman, " Quantum Mechanics, the Theoretical Minimum", Basic Books
- Richard Feynman, "The Feynman Lectures on Physics", Volume III, Addison-Wesley
- Michael A. Nielsen and Isaac L. Chuang, "Quantum Computation and Quantum Information", Cambridge University Press
- Shayan Majidy, Christopher Wilson, Raymond Laflamme, 'Building Quantum Computers", Cambridge University Press

Course Modality: This course will be an in-person course only and is not suitable for remote learning. The lectures will be delivered mainly on the blackboard and will not be recorded. If a student cannot attend class for a limited period of time due to health issues, reference material will be provided.

Website: I will use Brightspace (`https://brightspace.carleton.ca/`) as the course website. I will post a tentative schedule of the semester as well as problem sets.

Content of the course and learning objectives: The goal of this course is to give a rigorous introduction to the rules of quantum mechanics to students with little physics background. Being a physics course, it will be fairly mathematical. We will use linear algebra to study 2 states ystems (qubits), with examples from quantum cryptography and communication. We will also study entanglement, the EPR paradox and Bell inequalities. We will then extend the rules to continuous observables and study 1D potentials, tunnelling, the harmonic oscillator and quantization of energy. Finally we will briefly look at physical implementations of quantum computers. I am planning to cover the following topics in the textbook:

- Wave-particle duality (1.2)
- Qubits: The photon interferometer (2.1), spin 1/2 (2.2)
- Rules of quantum mechanics: States and Observables (parts of 3.1, 3.2, 3.3, 3.4, 3.5)
- Application to quantum communication (4.1, 4.2, 4.4)
- Quantum Dynamics (5.1, 5.2)
- Entanglement (6.1, 6.5, 6.6)
- ebits (7.1, 7.2, 7.3, 7.4)
- Particle in one dimensional space (10.1, 10.2, 10.3)
- 1-D potential (15.1,15.2, 15.3, 15.4)
- Quantum circuits (18.1)
- NMR (18.3,18.4)
- Physical realization of quantum computers

The learning objectives are:

- Understand the fundamental postulates of Quantum Mechanics and how they relate to the concepts of vector space and operators.
- Be able to describe a 2 state system mathematically and predict the outcome of observation for non-commuting observables in a given state
- Understand how quantum mechanics can improve communication and cryptography
- Understand the concept of entanglement, recognize if a state is entangled or not and predict the results of observations made on parts of an entangled state
- Understand how correlations in an entangled state differ from the correlations that might be present in classical systems (Bell theorem)
- Give a qualitative description of the wave function in position space and understand the different behaviour of the wave function for different 1-D potentials: transmission, reflection, tunnelling, quantization of energy.
- Give a qualitative description of various physical realization of quantum computers.

Important Dates: Some important dates: (For the full list please consult the official calendar.)

- September 16: Last day for registration and course changes for full fall, late fall and fall/winter courses

- September 30: Last day to withdraw from full fall and fall/winter courses with full fee adjustment
- October 20-24: Fall Break. No classes
- November 15: Last day for academic withdrawal from full fall and late fall courses. Last day to request Formal Examination Accommodations for December full fall and late fall examinations and fall/winter midterm examinations from the Paul Menton Center.
- December 5: fall term ends
- December 8-20: Final examinations in full fall and late fall courses and midterm examination in fall/winter courses. Examinations are normally held all seven days of the week.

Assessment

Your final grade will be based on the following conversion

$A+ = 90-100$	$B+ = 77-79$	$C+ = 67-69$	$D+ = 57-59$
$A = 85-89$	$B = 73-76$	$C = 63-66$	$D = 53-56$
$A- = 80-84$	$B- = 70-72$	$C- = 60-62$	$D- = 50-52$
$F =$ below 50			

Homework assignements (30 %): There will be approximately 6 problem sets during the term. You are encouraged to work on your assignments together, but the work that is handed in **must be your own**. You should not look for solutions to the problems on the internet, in particular it is strictly forbidden to use 'homework help' websites or AI tools to solve the problems. Late assignment will not be accepted without an acceptable reason. Each student is allowed one late problem set without penalty if within 3 calendar days of the due date. Problem sets should be handed in class or at my offce. The mark from the worst problem set will be dropped.

Midterms (30 %) There will be two midterms, each worth 15 %. The midterms will be during class time.

Final (40 %): There will be a formally scheduled final exam during the examination period.

Academic integrity: Students are expected to uphold the values of academic integrity, which include fairness, honesty, trust, and responsibility. Examples of actions that that compromise these values include but are not limited to plagiarism, accessing unauthorized sites for assignments or tests, unauthorized collaboration on assignments or exams, and using artificial intelligence tools such as ChatGPT when your assessment instructions say it is not permitted. Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy. Academic dishonesty in any form will not be tolerated. Students who infringe the Policy may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; a refusal of permission to continue or to register in a specific degree program; academic probation; or a grade of Failure in the course. Informations on academic integrity and the list of standard sanctions can be found here

Use of AI: : It is strictly prohibited to use AI (Large language models such as ChatGPT) while working on the problem sets. The problem sets are meant to improve your problem solving skills and deepen your understanding of the material by actively thinking and questioning it. Using AI to do the problems will defeat this purpose.

You are allowed to use AI to help you understand the material or to learn about further topics, when not working on problems. However I would encourage you instead to ask colleagues or come to office hours.

Academic policy: University rules regarding registration, withdrawal, appealing marks, and most anything else you might need to know can be found on the university's website, here: http://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/

Academic accommodation: Carleton University is committed to providing access to the educational experience in order to promote academic accessibility for all individuals. Academic accommodation refers to educational practices, systems and support mechanisms designed to accommodate diversity and difference. The purpose of accommodation is to enable students to perform the essential requirements of their academic programs. At no time does academic accommodation undermine or compromise the learning objectives that are established by the academic authorities of the University. More information can be found at: `https://students.carleton.ca/course-outline/`

Student Rights & Responsibilities Students are expected to act responsibly and engage respectfully with other students and members of the Carleton and the broader community. See the Rights and Responsibilities Policy for details regarding the expectations of non-academic behaviour of students. Those who participate with another student in the commission of an infraction of this Policy will also be held liable for their actions.

Student Concerns If a concern arises regarding this course, your first point of contact is me: Email or drop in during student hours and I will do my best to address your concern. If I am unable to address your concern, the next points of contact are the the Undergraduate Chair, the Departmental Chair and finally, the Office of the Dean.

Accommodations for Missed Work Carleton recognizes that students may be experiencing greater stress and other life factors that are not in their control. As a result, Carleton has put into place a protocol for students to apply for accommodations using a self-declaration form in the event of missed work. Note that these forms should be used for short-term concerns related to missed work; if you are experiencing chronic, ongoing challenges which necessitate a broader solution, I recommend reaching out to the Paul Menton Centre and/or the Care Support team. In case of miss work, the following policies will apply to the various component of the course:

- Homework: In case of a missed homework, the corresponding mark will be dropped from the homework average. Regular homework are an important part of the course and are needed to meet the learning objective of the course, and as such, accommodation (for legitimate reasons) can be granted for a maximum of 2 homework.
- For the final exam, accommodation must be arranged through the registrar's office.

Assitsance for students: The following resources might be useful :

- Important dates and Deadlines.
- Academic and Career Development Services.
- Centre for Student Academic Support (CSAS).
- Science Student Success Centre.
- Math Tutorial Centre.

Important Information:

- Student or professor materials created for this course (including presentations and posted notes, labs, case studies, assignments and exams) remain the intellectual property of the author(s). They are intended for personal use and may not be reproduced or redistributed without prior written consent of the author(s).
- Students must always retain a hard copy of all work that is submitted.
- Standing in a course is determined by the course instructor subject to the approval of the Faculty Dean. This means that grades submitted by the instructor may be subject to revision. No grades are final until they have been approved by the Dean.
- Carleton University is committed to protecting the privacy of those who study or work here (currently and formerly). To that end, Carleton?s Privacy Office seeks to encourage the implementation of the privacy provisions of Ontario?s Freedom of Information and Protection of Privacy Act (FIPPA) within the university.
- In accordance with FIPPA, please ensure all communication with staff/faculty is via your Carleton email account. To get your Carleton Email you will need to activate your MyCarletonOne account through Carleton Central. Once you have activated your MyCarletonOne account, log into the MyCarleton Portal.