Course outline
PHYS 5701: Intermediate Quantum Mechanics with Applications - 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: Tuesday - Thursday 10am-11am. If you are not available during those time, contact me to make an appointment.

Lectures: Tuesday-Thursday, 8:35 - 9:55 pm. First lecture on Thursday Sept. 4 and last lecture on Thursday Dec. 4 2025.

Prerequisites: PHYS 4707 (Introduction to Quantum Mechanics I) and PHYS 4708 (Introduction to Quantum Mechanics II). Some of these prerequisite can be waived with consent of the instructor.

Suggested textbook: "Modern Quantum Mechanics", J.J. Sakurai and Jim Napolitano, Third edition, Cambridge University Press ($101.95 on Indigo or Amazon)

Other references: :

- "Quantum Mechanics, An experimentalist approach", Eugene D. Commins, Cambridge University Press
- R, Shankar, "Principle of Quantum Mechanics", second edition, Springer
- Schumacher and Westmoreland, "Quantum Processes, Systems, & Information", Cambridge

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 problem sets and reading.
Note: U. of O. students can obtain a MyCarletonOne account to access Brightspace. Communication about the course will be done via Brightspace, so make sure that you check the email address that is associated with your Brightspace account.

Content of the course and learning objectives: The goal of this course is to present important aspects of Quantum Mechanics in more depth, mathematical sophistication than what is typically covered in an undergraduate course and to introduce a few more advanced topics.

Material covered in undergraduate courses vary by institution and so you might be familiar with some of the topics covered in the course. I invite you to fill out the survey on the Brightspace page to give me a more accurate picture of your preparation in quantum mechanics. The course will be roughly structured as follows:

- Review of the Fundamental of Quantum Mechanics (chapter 1)
- Time evolution (chapters 2.1, 2.2)
- WKB approximation (chapter 2.5)
- Path Integrals (2.6)
- Density Matrix (3.4)
- Bell inequalities (3.10)
- Rotation and the Theory of angular momentum (3.1,3.2,3.3,3.5)
- Addition of Angular, Clebsch-Gordan coefficients and the Wigner-Eckart Theorem (3.8,3.11)
- Review of time independent perturbation theory (5.1,5.2)
- Time dependent perturbation theory (5.5,5.7,5.8)
- Scattering theory (6.1,6.3,6.4)

The learning objectives are:

- Understand the fundamental postulates of Quantum Mechanics and how they relate to the concepts of Hilbert space, operators and abstract vectors.
- Be able to manipulate kets, bra and operators to compute various quantities of interest in quantum mechanics such as probabilities, expectation values and matrix elements.
- Understand how the momentum operator, the hamiltonian operator and the angular momentum operators relate to symmetry transformations.
- Be able to add angular momentum using Clebsch-Gordan coefficients and understand how the Wigner-Eckart theorem give rise to selection rules in matrix elements.
- Understand the basic principle of scattering in quantum mechanics and be able to apply Fermi's golden rules, use the Born approximation and the partial wave expansion.

Important Dates: Some important dates: (For the full listplease 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

Carleton and U. of O use slightly different translation between letter grades and percentage grades. I will establish your final grade using the table appropriate to your University. At Carleton the correspondence is:

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

At the University of Ottawa the correspondence is:

$A+ = 90-100$	$B+ = 75-79$	$C+ = 65-69$	$D+ = 55-59$
$A = 85-89$	$B = 70-74$	$C = 60-64$	$D = 50-54$
$A- = 80-84$			$E = 40-49$
$F =$ below 40			

The passing grade for a graduate course at Carleton is B- and at the University of Ottawa is B .

Homework assignements (60 %): There will be approximately 5 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**. In general 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. Problem sets can be handed in class or electronically on the Brightspace page.

Final (40 %): The final exam will be a take home exam that will be distributed during the final exam period. You have to work on the final exam alone.

Academic integrity: Plagiarism and cheating at the graduate level are viewed as being particularly serious and the sanctions imposed are accordingly severe. Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy. Plagiarism and cheating is presenting another's ideas, arguments, words or images as your own, using unauthorized material, misrepresentation, fabricating or misrepresenting research data, unauthorized co-operation or collaboration or completing work for another student weaken the quality of the graduate degree. 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 or the exam. 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.