PHYS 4705/5705 - Fall 2026

Introduction to Quantum Phenomena

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.

Course Instructor: Prof. Thomas Grégoire (He/Him)

Email: thomasgregoire@cunet.carleton.ca

Best Ways to be in Touch: email, student hours or stop by my office if my door is open.

Office: Herzberg (HP) 3378

Student Hours: TBA, HP 3378

Class Location: Check Carleton Central

Class Times: M/W, 10:05 - 11:25
First class on Thursday Sept. 9, last on Friday Dec. 11

Prerequisites: There are no official pre-requisite, but to be successful you should have MATH 1104 or MATH 1107.

Course TA: George William Kyte

Topics to be Covered and Learning Outcomes

Welcome to Physics 4705! Here is the **calendar description** for the course:
“Postulates of Quantum Mechanics, Quantum communication and cryptography, Entanglement, EPR paradox and Bell inequalities, Introduction to wave mechanics: Energy quantization and tunneling, Survey of quantum material: superconductor, topological insulators, semimetals. Survey of quantum sensing: NMR, trapped ions, superconducting qubit, atomic clocks..”

This course was introduced with the new multidisciplinary MSc program in Quantum Science and Technology. It is designed to introduce quantum mechanics to students of varied

backgrounds, with an emphasis on applications to quantum communication and quantum computations.

I am committed to fostering an environment for learning that is inclusive for everyone regardless of gender identity, gender expression, sex, sexual orientation, race, ethnicity, ability, age, class, etc. Please feel free to contact me via email or in person to let me know about any experiences you have had related to this class that have made you feel uncomfortable. I will continually strive to create inclusive learning environments and would therefore appreciate your support and feedback.I welcome emails or in-person communications to let me know your preferred name or pronoun.

Week by week topics and reading schedule

Week	Topics	Reference (chapters numbers are from Westmoreland and Schumacher)
Week 0	Intro	
Week 1	Wave-particle duality and Intro two 2-state systems	Chapter 2
Week 2	Postulate of quantum mechanics and spin 1/2	Chapter 3
Week 3	Incompatible observables and uncertainty principle,	Chapter 4
Week 4	Density matrix and Bloch sphere	Chapter 8
Week 5	Quantum communication and cryptography	Chapter 4
Week 6	Entanglement, Schmidt decomposition	Chapter 6
Week 7	EPR paradox, Bell inequalities	Chapter 6
Week 8	Superdense coding and quantum teleportation	Chapter 7
Week 9	Continuous wave function, tunneling and quantization of energy	Chapter 10
Week 10	Quantum gates and algorithms	Chapter 18
Week 11	Physical realizations of quantum computers	Majidy, Wilson, Laflamme
Week 12	Survey of quantum materials	Majidy, Wilson, Laflamme

A course-by-course schedule will be posted on Brightspace. Important dates *and deadlines can be found here: https://calendar.carleton.ca/academicyear/, including class suspension for fall, winter breaks, and statutory holidays.*

Course Level Learning Outcomes

At the end of the course, students are expected to:

- 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 realizations of quantum computers.

Assessments

Letter Grade Conversion

In accordance with the Carleton University Undergraduate Calendar Regulations, the letter grades assigned in this course will have the following percentage equivalents:

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

Grade Breakdown

This course is cross-listed at the undergraduate and graduate level. Graduate students will be required to give a presentation on a topic not covered in class.

Component	PHYS 4705	PHYS 5705
Weekly Assignments	25%	20%
In-class Evaluations	5%	5%
Midterms	30%	25%
Final Exam	40%	35%
Presentation	0%	15%

Weekly Assignments

Assignments will be distributed weekly on Brightspace and will be due one week after distribution. During the week, one problem will be added, from the list of problems worked on in class. Students are encouraged to discuss concepts and strategies related to solving the assignment problems, but the submitted work must be your own.

Use of generative AI for doing assignments is strictly forbidden. The goal of the assignments is to develop your problem solving skills and reinforce your understanding of the material. Using AI in this context will defeat the purpose.

You are asked to upload your solutions to the assignments as a single pdf file on Brightspace before the due date. The worst assignment will be dropped from the final grade.

In-class Evaluations

There will be in-class evaluations designed to encourage active learning . They will be short multiple choice questions to be answered using the Wooclap platform. You must attempt at least 50% of the questions to receive a non zero grade. Then the grade will be assigned based on the number of correct answers: 3% for less than ⅓ of correct answers, 4% for less than ⅔ but more than ⅓ correct answers, and 5% for more than ⅔ correct answers.

Midterm Exams

There will be two midterm exams during class time, both with equal weight. The midterms will cover only a portion of the material and will be similar in style to problem set questions. We will discuss the exams in more detail during class.

Final Exam

The final exam will be scheduled by Exam Services during the final examination period (Dec 12 - Dec 23) and will be 3h long. It will be summative (will cover all material seen in class) and closed book, but you will be allowed a formula sheet. More details will be given in class.

Late and Missed Work Policies

If you are forced to miss part of the course for a short period of time (5 days or less) which will lead you to not submit a graded component of the course, you should advise me promptly and submit the academic consideration form. If you need to submit this form more than twice during the term, you should consult with me

For longer term absence, you should discuss with me and submit the longer-term accommodation form.

Weekly Assignments

One late assignment during the semester will be accepted without penalty if it is submitted within 3 calendar days from the due date. Otherwise the following penalty will be applied: 10% if submitted within one day of the due date, 20% if submitted within 2 days and 30% if submitted within 3 days. No assignments will be accepted after 3 days.

Midterm Exams

If one midterm is missed for a valid reason by submitting an academic consideration form, the weight of that midterm will be applied to the other midterm. If both midterms are missed, a makeup midterm will be arranged and will carry the weight of both midterms.

Final Exam

Requests for a deferred final exam should be addressed to the Registrar's office.

Learning Material and Other Course related material

Suggest textbook: Schumacher and Westmoreland,``Quantum Processes, Systems, & Information", Cambridge University Press ($140.95 of Amazon, $ 149.95 on Indigo).

Other reading:

- 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
- John Preskill's notes for Physics 219 at Caltech.

Academic Accommodations and Regulations

Carleton is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes, including information about the Academic Consideration Policy for Students in Medical and Other Extenuating Circumstances, are outlined on the Academic Accommodations website (Course Outline Information - Current Students).

Statement on Generative Artificial Intelligence

Generative AI can be used to deepen and expand your understanding of the material by asking general questions about the material.

However, it cannot be used in any way when completing assignments or lab reports, besides basic grammar and spell check (e.g. Grammarly, Microsoft Word Editor). As mentioned above, assignments are training exercises given to build your problem solving skills and deepen your understanding of the material. Those are core learning objectives of the course and using AI undermines this training by substituting for a lot of the thought process that is required to solve a problem on your own.

Statement on 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 Generative Artificial Intelligence (GenAI) tools when course assessment instructions indicate such use is not permitted.

Misconduct in scholarly activity will not be tolerated and will result in consequences as outlined in Carleton University's Academic Integrity Policy. A list of standard sanctions in the Faculty of Science can be found here.

Additional details about this process can be found on the Faculty of Science Academic Integrity website.

Students are expected to familiarize themselves with and abide by Carleton University's Academic Integrity Policy.

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 (in this order):

- In general the undergraduate Chair, which this year is also me
- The department Chair, Kevin Graham

- The Office of the Dean of Science

Note: You can also bring your concerns to Ombuds services.