

Carleton University Physics Department
PHYS 3701 B – Elements of Quantum Mechanics (Winter 2024)
Course Outline

Instructor:

Prof. Heather Logan (she/her) (please call me “Dr. Logan” or “Professor”)

Email: logan@physics.carleton.ca

Required Textbook:

Griffiths, David J. and Schroeter, Darrell F., “Introduction to Quantum Mechanics,” Third Edition (Cambridge University Press, 2018). Available directly from Cambridge University Press and at the Carleton Bookstore.

Supplemental Textbook:

Krane, Kenneth S. “Modern Physics,” Fourth Edition (Wiley, 2020). You should have a copy of this book already from PHYS 2604.

Course web page:

The webpage for this course will be hosted in Brightspace, at <https://brightspace.carleton.ca/> (you may be redirected to log in using your MyCarletonOne name and password). Readings and homework assignments will be distributed using the Brightspace page, and there you will also find a gradebook. Homework submission will be by uploading to Brightspace. Time-sensitive announcements will also be sent out by email.

Lecture times:

Wednesdays and Fridays, 10:05–11:25 a.m., in XXXXXXXXXX. The first lecture is on Wednesday January 10 and the last one is on Wednesday April 10. There are no lectures on February 21 or 23 because that week is Winter Break. There is no lecture on March 29 because that day is a holiday.

Office hours (dedicated times for you to ask me questions about homework problems or course material):

Times and location to be announced; or email me (at least 24 hours in advance) to arrange an appointment.

Lecture, assignment, and exam format:

Lectures will be held in-person. Lecture attendance is encouraged but not required – if you get sick, please stay home. To increase accessibility I will post scans of my lecture notes to Brightspace after each lecture, though you are not obligated to read them. I will also post the textbook sections to be covered in each lecture a few days ahead of time, so that you can read them in advance of the lecture. *Homework assignments* are to be done outside of class time. The question papers will be made available on the Brightspace page. Your solutions for each assignment should be submitted by scanning or saving them to a single pdf file which you will upload to the Brightspace page. More details are below. *Two midterms and the final exam* will be held in-person. The two midterm exams will be held in our usual classroom during two of the normal lecture periods. The final exam will be held during the April final exam period at a time and location to be assigned by the university. More details are below.

If you are repeating this course:

I invite you to meet with me early in the term to discuss your study strategy and develop a plan for successful completion of the course.

Course Description

PHYS 3701 [0.5 credit]

Elements of Quantum Mechanics

Analysis of interference experiments with waves and particles; fundamental concepts of quantum mechanics, Schrödinger equation; angular momentum, atomic beams; hydrogen atom; atomic and molecular spectroscopy; Pauli principle; simple applications in the physics of elementary particles.

Prerequisite(s): PHYS 2604, MATH 2000 [1.0] (may be taken concurrently), or MATH 2004 or MATH 2008, and MATH 3705 (may be taken concurrently), or permission of the Department.

Lectures three hours a week.

The goal of this course is to introduce the sometimes surprising concepts of quantum mechanics and to develop the Schrödinger equation formalism for solving some simple quantum systems, such as the “particle in a box,” tunneling, and the hydrogen atom. The course is based on the material in Chapters 1 through 6 of the textbook by Griffiths, though I will cover it in a somewhat different order and supplement it with additional introductory material building on PHYS 2604. Topics to be covered are as follows:

1. The beginnings of quantum theory and development of wave mechanics. Photoelectric effect, Compton effect, the Bohr model of the atom, basic atomic processes. De Broglie’s particle waves, double slit experiment. Heisenberg’s uncertainty principle, waves and wave packets, the Schrödinger equation, probability interpretation, stationary states.
2. Solutions of one-dimensional systems. Particle in a one-dimensional box, harmonic oscillator and molecular vibrations. Finite square well and continuum states. Finite potential step, transmission and reflection coefficients, tunneling.
3. Further development of the quantum framework. Observables, eigenfunctions and eigenvalues, operators and expectation values. Introduction to Dirac’s bra-ket notation.
4. The wave equation in three dimensions. The three dimensional box, Schrödinger equation in spherical coordinates, rotational motion. Spherical harmonics, angular momentum operators, parity. Radial wavefunction for hydrogenic atoms, electric dipole transitions and selection rules.
5. Spin and the addition of angular momentum. Atoms in magnetic fields, Zeeman effect, Stern-Gerlach experiment and electron spin, magnetic resonance, spin-orbit coupling, fine structure and the anomalous Zeeman effect. Pauli’s exclusion principle. (if time allows)

Learning Outcomes

After successfully completing this course, you will be able to:

- Set up, solve, and interpret canonical 1- and 3-dimensional potentials in quantum mechanics; e.g. particle in a box, potential barrier, harmonic oscillator, rigid rotator, hydrogen atom;
- Apply physical principles such as single-valuedness, continuity, and finiteness to select and combine appropriate solutions of Schrödinger’s equation;
- Calculate probabilities and expectation values given a wavefunction; and
- Use the formalism of differential operators and superposition to determine whether a given wavefunction is an eigenstate of an operator, and find the corresponding eigenvalue.

Assignments, exams, and grade distribution

Homework assignments (25%; lowest assignment mark will be dropped):

Homework will be assigned approximately every week, with due dates generally on Fridays. (The complete schedule will be provided in Brightspace.) The questions for each assignment will be posted in Brightspace, and your solutions must be scanned or saved to a single pdf file and uploaded into Brightspace by the assignment's due date.

Working the assigned problems is the most important thing you can do to develop a deep understanding of the course material, and is the best way to prepare for the exams. You are encouraged to discuss the problems with me and with other students in the course; however, **the work you hand in must be your own original work.** Use of online homework-help sites or chat-bots, or searching for or viewing solutions to equivalent problems online, is strictly forbidden and will not prepare you well for the exams. If you are having difficulties with the material, please talk to me for individualized help.

Late assignments will not be accepted without permission – once the due date passes, Brightspace will simply not let you upload your assignment. Requests for extensions due to illness or other emergencies should be sent to me by email and must include (1) an estimate of when you will be able to submit the work and (2) a completed illness/emergency **self-declaration form**, which can be downloaded from <https://carleton.ca/registrar/wp-content/uploads/self-declaration.pdf> . I am pretty easy-going about extensions, so don't be afraid to contact me about this if you need to.

Two midterm exams (20% each):

There will be two in-person 80-minute midterm exams in the regular classroom during the regular lecture time (10:05–11:25am) on **Wednesday February 14** and **Wednesday March 20**. The midterms will be closed-book and closed-notes; a detailed formula sheet will be provided (I will post a draft of the formula sheet on Brightspace in advance so you can see what will be on it). If you have to miss either of the midterm exams due to illness or some other emergency, please let me know by email as soon as possible (attaching a completed self-declaration form, see above) so that I can arrange a time for you to write a deferred midterm. I plan to have the first midterm exam marked and returned to you well before the last day to withdraw from a course, which is March 15.

Final exam (35%):

The final exam will be 3 hours long and will be held in-person **during the final exam period, April 13–25** (Exam Services has said that they will publish the final exam schedule on February 16, though they are usually a few days late). The final exam will be closed-book and closed-notes and a detailed formula sheet will be provided (I will post this in Brightspace in advance). Deferrals of final exams (due to illness) are handled centrally by Exam Services; for more information and a link to the deferral application web-form, see <https://carleton.ca/registrar/deferral/> . (Doctor's notes are not required, but you will need to submit a self-declaration form. The deadline for deferrals is 3 working days after the exam date.)

Academic accommodations and human rights

Carleton University is committed to promoting 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. For more information: <https://students.carleton.ca/course-outline/> .

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

Human rights and non-discrimination:

Carleton University and all members of the Carleton community share responsibility for ensuring that the University's educational, work, and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex, pregnancy, or sexual orientation, please contact the Department of Equity and Inclusive Communities (<https://carleton.ca/equity>) at equity@carleton.ca.

If you feel comfortable doing so, you can also contact me to address any concerns related to the course or classroom environment. I am a member of the Carleton Physics Department's Equity, Diversity, and Inclusion committee.

Academic accommodations for students with disabilities/Disabled students:

If you have a documented disability requiring academic accommodations in this course, please consult the Paul Menton Centre for Students with Disabilities (PMC)'s new centralized accommodation-handling web portal called Ventus at <https://ventus.carleton.ca/student/> . PMC can also be reached at 613-520-6608 or pmc@carleton.ca. **You have to log into Ventus each semester to select which courses you want your accommodations to apply to.** This has to be done no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After setting up your accommodations in Ventus, let me know by email as soon as possible to ensure that I do the administrative stuff on my end (e.g., send exam papers to the McIntyre Exam Centre). For more details, visit the Paul Menton Centre website (<https://carleton.ca/pmc>).

Regardless of documentation, if your learning experience could be improved by me adjusting the way I do things in this course, please don't hesitate to let me know and I will do what I can to address it.

Religious obligations:

Please contact me during the first two weeks of class with any requests for religious accommodations, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (<https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf> (2.1 MB pdf)).

For survivors of sexual violence:

Carleton is committed to maintaining a positive learning, working, and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations in accordance with Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: <https://carleton.ca/sexual-violence-support/>

For pregnancy:

Please contact me during the first two weeks of class with any requests for academic accommodation, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (<https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf> (2.1 MB pdf)).

For extracurricular student activities:

Carleton recognizes the substantial benefits, both to the individual student and to the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level (this also includes things like student conferences and research). Please contact me during the first two weeks of class with any requests for academic accommodation, or as soon as possible after the need for accommodation is known to exist. For more details, see the Senate Policy on Accommodation for Student Activities (<https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf> (25 kB pdf)).

Note about mental health:

Stress affects each person in a unique way. If you need extra help with course material or have missed something, don't panic—email me and we can set a time to talk. Carleton also offers a variety of mental health and well-being resources, which can be found at <https://wellness.carleton.ca>.

Some resources for peer support, academic help, and skill development:

Carleton Undergraduate Physics Society: <https://physsoc.physics.carleton.ca/>

Carleton Science Student Society: <https://www.sciencesociety.ca/>

Science Student Success Centre: <https://sssc.carleton.ca/>

Math Tutorial Centre: <https://carleton.ca/math/math-tutorial-centre/>

Academic Support Services: <https://students.carleton.ca/academics/>

Writing Services: <http://www.carleton.ca/csas/writing-services/>

Carleton's letter grade scheme

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

A+ = 90–100 B+ = 77–79.99 C+ = 67–69.99 D+ = 57–59.99 F = below 50

A = 85–89.99 B = 73–76.99 C = 63–66.99 D = 53–56.99

A– = 80–84.99 B– = 70–72.99 C– = 60–62.99 D– = 50–52.99

WDN = Withdrawn from the course (**deadline to withdraw is March 15**)

ABS = Student absent from final exam

DEF = Deferred

FND = (Failed, no Deferred) = student could not pass even with 100% on final exam

Academic integrity and how to avoid cheating (this is important)

Examples of actions that violate Carleton's Academic Integrity Policy include:

- Plagiarism (e.g., passing off the words, equations, problem-solving strategies, or thoughts of another entity—human or AI¹—as your own, without citing the source);
- Accessing unauthorized sites for assignments or tests (e.g., posting the assigned questions on Chegg, searching the internet for solutions to similar problems, or using chat-bots in any way);
- Unauthorized collaboration on assignments or exams (e.g., communicating with another student during an exam).

For details of what constitutes plagiarism, please see the Faculty of Science Academic Integrity website (<https://science.carleton.ca/academic-integrity/>). Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy (<https://carleton.ca/registrar/academic-integrity/>). The Policy is strictly enforced and is binding on all students. To further understand Academic Integrity, consider attending the Learning Support Academic Integrity Workshop (<https://carleton.ca/csas/learning-support/learning-support-workshops/>).

Standard penalties for violating Carleton's Academic Integrity Policy:

- **First offence:** a grade of zero on the work(s) associated with the misconduct, and a deduction of up to three (3) grade points from the final course grade (e.g. a grade of B could be reduced to a C).
- **Any subsequent offence:** sanctions range from a final grade of F in the course, to suspension from studies for up to 3 semesters, to expulsion from the University.

Note: These sanctions are provided here as guidelines only; more severe sanctions may be applied as appropriate (e.g., in the case of cheating on an examination).

Process of an Academic Misconduct Investigation:

Step 1: Instructor believes misconduct has occurred, and forwards all relevant details to the Office of the Dean of Science.

Step 2: Student is notified that a review of their work is pending.

Step 3: Dean of the Faculty of Science reviews the documentation.

Step 4: Student receives an Allegation Letter by email, documenting the claims and evidence.

Step 5: Student provides a written statement responding to the evidence provided. Either party may request a meeting between student and Dean (and ombuds) to discuss further.

Step 6: Dean considers all statements and evidence and renders a decision.

Appeal: Student has the right to appeal the decision.

Additional details about this process can be found on the Faculty of Science Academic Integrity website (<https://science.carleton.ca/academic-integrity/>).

¹This phrasing is not meant to imply that a Large Language Model or other Artificial Intelligence has thoughts, or is doing anything beyond producing a mindless remix of existing human work.