

PHYS 3701 Elements of Quantum Mechanics

Instructor: Jesse Heilman

How to address me: Dr/Prof Heilman

Gender Pronouns: (he/him/his) ([learn more](#))

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Voicemail is NOT reliably checked during the pandemic]

Student Hours: TBA.

What are 'Student Hours'?

Student hours are office hours renamed, i.e., dedicated times through the week for the course instructor to meet with you. This course will be delivered with synchronous classes (see below) in which students are encouraged to ask questions. If you would like to meet separately, feel free to email me to set up a time to meet.

Office Location: Room 3314 HP

[Click here for visual directions.](#)

Class Location: 101 AT or virtually (see "Course delivery" below)

[Click here for visual directions.](#)

Class Times: Tuesday & Thursday, 11:35am – 12:55pm

Prerequisites: PHYS 2604, MATH 2000 (may be taken concurrently), or MATH 2004 or MATH 2008, and MATH 3705 (may be taken concurrently); or permission of the Department.

Website: <https://carleton.brightspace.com>

Algonquin territory acknowledgement: We acknowledge that the land on which we gather and learn is the traditional and unceded territory of the Algonquin nation. You are invited to [learn more](#), reflect on how you can support anti-racism and decolonization, and take action. <https://carleton.ca/indigenous/>

Course delivery: The course will consist of a mixture of synchronous meetings and asynchronous activities. The synchronous meetings will be held remotely during January and will move to in person as soon as the University deems it safe to do so. The possibility of holding the synchronous meetings remotely will remain from February on to provide us with flexibility in these uncertain times due to the pandemic.

- **Asynchronous activities:** Material (lecture notes, recorded lectures + audio) will be posted to Brightspace. You are expected to review and study material; keep up to date. The asynchronous activities are intended to provide flexibility to students.
- **Synchronous classes:** These will be held during the class times (Tuesday, Thursday at starting at 11:35 am Ottawa time) either in person (101 AT) or virtually (Zoom). These sessions are intended to be the primary method of course delivery. It is expected that you attend these sessions in person unless you are exceptionally

unable to. In the case you can not attend in person, it is expected that you will watch and study the recorded lectures asynchronously.

- You will be notified by email/Brightspace announcements of changes for synchronous meetings.

Welcome to this Course!

This course focuses on introducing you to the fundamental concepts of the Quantum world. The instincts and understanding that we have built up through our lived experience cease to function on very small scales so you will have to re-train the way you think to understand this exciting and strange world. When our ability to form an analogy to a common experience breaks down, we must rely on mathematics to be the common language between the macroscopic and microscopic. I hope you will enjoy learning about this new layer of reality!

The course is based on the material in Chapters 1 through 6 of the textbook, though I will cover it in a somewhat different order and supplement it with additional introductory material building on what you will have seen in PHYS 2604.

A brief and non-exhaustive list of concepts that we will cover in the course:

1. The beginnings of quantum theory. Blackbody radiation, photoelectric effect, Compton effect. The quantum picture of the atom and the Bohr model, atomic processes.
2. The development of wave mechanics. Wilson-Sommerfeld quantization rules, de Broglie's particle waves, double slit experiment, probability distributions. Heisenberg's uncertainty principle, waves and wave packets, the Schrödinger equation, probability interpretation, stationary states. Wavefunction sketching.
3. Solutions of some one-dimensional systems. Particle in a one-dimensional box, harmonic oscillator and molecular vibrations.
4. Further development of the quantum framework. Observables, eigenfunctions and eigenvalues, operators and expectation values. Dirac's bra-ket notation.
5. Solutions of more one-dimensional systems. Finite square well and continuum states. Finite potential step, transmission and reflection coefficients, tunneling.
6. The wave equation in three dimensions. The three dimensional box, Schrödinger equation in spherical coordinates, rotational motion. Spherical harmonics, angular

momentum operators, commutation relations, parity. Radial wavefunction for hydrogenic atoms, electric dipole transition amplitude and selection rules.

7. 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.

Calendar entry: 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.

Inclusive teaching statement: Science is for everyone. 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. All students in the class, the instructor, and any guests should be treated with respect during all interactions. It is my hope that our class will support diversity of experience, thought, and perspective. 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. Please see the Faculty of Science Equity, Diversity, and Inclusion (EDI) statement:

<https://science.carleton.ca/about/edi/>

Community Guidelines

The following values are fundamental to academic integrity and are adapted from the International Center for Academic Integrity*. In our course, we will seek to behave with these values in mind:

	As students, we will...	As a teaching team, we will...
Honesty	<ul style="list-style-type: none"> Honestly demonstrate our knowledge and abilities on assignments and exams Communicate openly without using deception, including citing appropriate sources 	<ul style="list-style-type: none"> Give you honest feedback on your demonstration of knowledge and abilities on assignments and exams Communicate openly and honestly about the expectations and standards of the course through the syllabus, and with respect to assignments and exams
Responsibility	<ul style="list-style-type: none"> Complete assignments on time and in full preparation for class Show up to class on time, and be mentally/physically present Participate fully and contribute to team learning and activities 	<ul style="list-style-type: none"> Give you timely feedback on your assignments and exams Show up to class on time, and be mentally & physically present Create relevant assessments and class activities
Respect	<ul style="list-style-type: none"> Speak openly with one another, while respecting diverse viewpoints and perspectives Provide sufficient space for others to voice their ideas 	<ul style="list-style-type: none"> Respect your perspectives even while we challenge you to think more deeply and critically Help facilitate respectful exchange of ideas
Fairness	<ul style="list-style-type: none"> Contribute fully and equally to collaborative work, so that we are not freeloading off others Not seek unfair advantage over fellow students in the course 	<ul style="list-style-type: none"> Create fair assignments and exams, and grade them in a fair, and timely manner Treat all students equitably
Trust	<ul style="list-style-type: none"> Not engage in personal affairs while on class time Be open and transparent about what we are doing in class Not distribute course materials to others without authorization 	<ul style="list-style-type: none"> Be available to all students when we say we will be Follow through on our promises Not modify the expectations or standards without communicating with everyone in the course
Courage	<ul style="list-style-type: none"> Say or do something when we see actions that undermine any of the above values Accept a lower or failing grade or other consequences of upholding and protecting the above values 	<ul style="list-style-type: none"> Say or do something when we see actions that undermine any of the above values Accept the consequences (e.g., lower teaching evaluations) of upholding and protecting the above values

² This class statement of values is adapted from Tricia Bertram Gallant, Ph.D.

Learning Materials

Texts: There will be one official text for this course. It can be bought directly from Cambridge University Press, from Amazon, or through the Carleton Bookstore:

Introduction to Quantum Mechanics Third Edition
D. Griffiths and D. Schroeter
Cambridge University Press – 2018

Technology Checklist for Remote Meetings:

- An internet-enabled computer (laptop/desktop), preferably with webcam and headset with microphone.
- Zoom software installed on computer (can also install on phone as backup!)
- Access to reliable internet

Note: If there are issues with equipment, please email me as soon as possible. Options for purchase include inexpensive options for technology (Best Buy refurbished products, Kijiji); single workspaces for student use on campus (pending pandemic restrictions).

Assessment in this Course

Research about learning strongly suggests that the most important factor in learning is doing the work of reading, writing, recalling, practicing, synthesizing, and analyzing. Learning happens best when people actively engage material on a consistent basis, and that is why we have high standards in this course. We are confident that, with appropriate effort, you **all** can meet those standards.

We also make an effort to reduce unintentional bias in grading by, for example and when possible, grading assignments one question at a time (grading all of question 1 before grading any of question 2), grading anonymously, and using rubrics.

All marks will be posted on Brightspace. If you think there is an error in the Brightspace gradebook, contact me immediately as it will be used as the official record for your marks.

Grade Breakdown

COMPONENT	GRADE VALUE
ASSIGNMENTS	45%
MID-TERM EXAM	20%
FINAL EXAM	35%

Assignments

Homework will be assigned every week. Assignments will be posted as a downloadable pdf in Brightspace, and your solutions must be scanned to a single pdf file and uploaded into Brightspace by the assignment's due date. Late assignments will not be accepted except for legitimate reasons such as illness. It is your responsibility to notify me if you will be unable to upload the assignment by the deadline. In computing your final grade, I will drop your lowest assignment mark.

Working through problems is an essential part of developing a deep understanding of quantum mechanics and is the best way to prepare for the exams. This material is quite mathematical and is partially meant to provide a foundation for the mathematical aspects of physics that will come in future classes. Students are encouraged to work together to understand the problems; however, the work handed in must be your own original work. Solutions showing significant overlap may have the mark divided by the number of people who provide that solution. The assigned homework problems are protected by copyright and posting them to third-party sites is forbidden and considered an academic offence. Likewise, finding solutions to equivalent problems online is forbidden and considered an academic offence.

Students who are having significant difficulties with the material are encouraged to come to my student hours for individualized help.

Mid-Term Exam

There will be one 80-minute midterm exam during the class time (11:35am–12:55pm) on Tuesday March 1. The midterm will be closed-book and closed-notes and a formula sheet will be provided (to be posted on Brightspace in advance). In the event of a midterm exam deferral for legitimate reasons, please inform me within 24 hours of the regularly scheduled midterm to arrange a time to write the deferred exam.

Final Examination

The final exam will be held during the final exam period in. It will be 3 hours long. The final exam will be closed-book and closed-notes and a formula sheet will be provided (to be posted on Brightspace in advance).

In the event that a deferred exam is necessary for a student, that exam will replace only the final exam component of the course mark and will be granted only if adequate term work has been completed. Inadequate term work constitutes earning less than 15 of the 65 possible term marks.

To pass the course:

1. your overall course mark must be at least 50%, and
2. your average on the exam component of the course must be at least 50%.
 - Exam average $\equiv (0.20 \times \text{Midterm} + 0.35 \times \text{Final}) / (0.20 + 0.35)$

Special Information Regarding COVID-19

All members of the Carleton community are required to follow COVID-19 prevention measures and all mandatory public health requirements (e.g., wearing a mask, physical distancing, hand hygiene, respiratory and cough etiquette) and mandatory self-screening prior to coming to campus daily.

If you feel ill or exhibit COVID-19 symptoms while on campus or in class, please leave campus immediately, self-isolate, and complete the mandatory symptom reporting tool. For purposes of contact tracing, attendance will be taken in all classes and labs. Participants can check in using posted QR codes through the cuScreen platform where provided. Students who do not have a smartphone will be required to complete a paper process as indicated on the COVID-19 website.

All members of the Carleton community are required to follow guidelines regarding safe movement and seating on campus (e.g., directional arrows, designated entrances and exits, designated seats that maintain physical distancing). In order to avoid congestion, allow all previous occupants to fully vacate a classroom before entering. No food or drinks are permitted in any classrooms or labs.

For the most recent information about Carleton's COVID-19 response and required measures, please see the University's COVID-19 webpage and review the Frequently Asked Questions (FAQs). Should you have additional questions after reviewing, please contact covidinfo@carleton.ca.

Please note that failure to comply with University policies and mandatory public health requirements, and endangering the safety of others are considered misconduct under the Student Rights and Responsibilities Policy. Failure to comply with Carleton's COVID-19 procedures may lead to supplementary action involving Campus Safety and/or Student Affairs.

Note about COVID-19 & Mental Health: The global pandemic has led to extra stress and uncertainty for everyone, and while we may all be experiencing the same storm, this does not mean that we are all in the same boat! If you are struggling, please do not hesitate to reach out. I can direct you to resources that might help. Remember that Carleton also offers an array of mental health and well-being resources, which can be found [here](#).

Children & zoom class sessions: You are welcome to have children with you during video sessions as I fully understand that childcare situations may be complicated for many of us at this time. Do your best to participate and engage, but also please get in touch with me if you have any questions or concerns.

University Policies

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	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 = <50			

WDN = Withdrawn from the course

ABS = Student absent from final exam

DEF = Deferred

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

Academic Accommodations, Regulations, Plagiarism, Etc.

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/>

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:

<https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/>

Academic Accommodations for Students with Disabilities

If you have a documented disability requiring academic accommodations in this course, please contact the Paul Menton Centre for Students with Disabilities (PMC) at 613-520-6608 or pmc@carleton.ca for a formal evaluation or contact your PMC coordinator to send your instructor your Letter of Accommodation at the beginning of the term. You must also contact the PMC no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet

with your instructor as soon as possible to ensure accommodation arrangements are made. For more details, visit the [Paul Menton Centre website](#).

Addressing Human Rights Concerns

The University and all members of the University 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 (including pregnancy), or sexual orientation, please contact the [Department of Equity and Inclusive Communities](#) at equity@carleton.ca.

Religious Obligations

Please contact me with any requests for academic accommodation during the first two weeks of class, 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 \(PDF, 2.1 MB\)](#).

Survivors of Sexual Violence

As a community, Carleton University 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 as per 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/>

Accommodations for Missed Work

Carleton recognizes that these are unprecedented times during the COVID-19 pandemic, and 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. The form can be found at: <https://carleton.ca/registrar/wp-content/uploads/self-declaration.pdf>

For Pregnancy

Please contact me with any requests for academic accommodation during the first two weeks of class, 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 \(PDF, 2.1 MB\)](#).

Accommodation for Student Activities

Carleton University recognizes the substantial benefits, both to the individual student and for 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. Please contact me with any requests for academic accommodation during the first two weeks of class, 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 \(PDF, 25KB\)](#).

Academic Integrity

Academic misconduct undermines the values of honesty, trust, respect, fairness, and responsibility that we expect in this class. Carleton University provides supports such as academic integrity workshops to ensure, as far as possible, that all students understand the norms and standards of academic integrity that we expect you to uphold. Your teaching team has a responsibility to ensure that their application of the Academic Integrity Policy upholds the university's collective commitments to fairness, equity, and integrity. (adapted from Carleton University's Academic Integrity Policy, 2021).

Examples of actions that do not adhere to Carleton's Academic Integrity Policy include:

- Plagiarism
- Accessing unauthorized sites for assignments or tests
- Unauthorized collaboration on assignment and exams

Sanctions for not abiding by Carleton's Academic Integrity Policy

A student who has not adhered to Carleton's Academic Integrity Policy may be subject to one of several sanctions:

1. If you take full responsibility for your actions, and it is the first time you have violated the policy, you will receive zero on the assessment. If you are found to have violated the policy but do not take responsibility, an additional grade deduction will be applied (e.g. an A- will become a B+)
2. Subsequent violations of the policy may result in more severe sanctions such as failing the course, suspension from all studies and/or expulsion.

Process of an Academic Misconduct Investigation

Step 1: The instructor believes misconduct has occurred and submits documentation to the Dean of the Faculty of Science.

Step 2: The Dean reviews documentation and can proceed with or dismiss the allegation.

Step 3: If sufficient evidence, the student receives an allegation statement by email. Ombuds services is copied on the email.

Step 4: The student provides a written response to the evidence provided.

Step 5: Either party may request a meeting between student, dean, and the ombudsperson.

Step 6: Dean informs the student of the 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](#). Students are expected to familiarize themselves with and follow the Carleton University [Student Academic Integrity Policy](#). The Policy is strictly enforced and is binding on all students.

Plagiarism

Plagiarism is the passing off of someone else's work as your own and is a serious academic offence. For the details of what constitutes plagiarism, refer the [Faculty of Science Academic Integrity website](#). To further understand Academic Integrity, consider attending the [Learning and Support Academic Integrity Workshop](#).

What are the Penalties for Plagiarism?

A student found to have plagiarized an assignment may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; and/or a reprimand; a refusal of permission to continue or to register in a specific degree program; academic probation; award of an FNS, Fail, or an ABS.

What are the Procedures?

1. All allegations of plagiarism are reported to the Dean of Faculty of Science. Documentation is prepared by instructors and/or departmental chairs.
2. The Dean writes to the student and the University Ombudsperson about the alleged plagiarism.
3. The Dean reviews the allegation. If it is not resolved at this level then it is referred to a tribunal appointed by the Senate.

Students are expected to familiarize themselves with and follow the Carleton University [Student Academic Integrity Policy](#). The Policy is strictly enforced and is binding on all students.

Course Copyright

Classroom teaching and learning activities, including lectures, discussions, presentations, etc., by both instructors and students, are copyright protected and remain the intellectual property of their respective author(s). All course materials, including PowerPoint presentations, outlines, and other materials, are also protected by copyright and remain the intellectual property of their respective author(s).

Students registered in the course may take notes and make copies of course materials for their own educational use only. Students are not permitted to reproduce or distribute lecture notes and course materials publicly for commercial or non-commercial purposes without express written consent from the copyright holder(s).

Assistance for Students

Academic and Career Development Services: <http://carleton.ca/sacds/>

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

Peer Assisted Study Sessions (PASS): <https://carleton.ca/csas/group-support/pass/>

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

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