

PHYC 4151 / 5151 Quantum Physics II

Department of Physics and Atmospheric Science

Fall 2026

Dalhousie University acknowledges that we are in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq People and pays respect to the Indigenous knowledges held by the Mi'kmaq People, and to the wisdom of their Elders past and present.

The Mi'kmaq People signed Peace and Friendship Treaties with the Crown, and section 35 of the Constitution Act, 1982 recognizes and affirms Aboriginal and Treaty rights. We are all Treaty people.

Dalhousie University also acknowledges the histories, contributions, and legacies of African Nova Scotians, who have been here for over 400 years.

Lecturer

Prof. Ted Monchesky, e-mail: Theodore.Monchesky@Dal.Ca, office: Dunn Rm 239

TA

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Lectures

Tuesday & Thursday, Dunn 135, 10:05 am – 11:25 am

Tutorials

Thursday, Dunn 135, 10:05 am – 11:25 am

Note that Tutorial and Lecture times may be swapped some weeks (see the lecture schedule below, and check for updates on BrightSpace during the term)

Course Delivery

In-person

Course Description

This course builds on the concepts and theory of quantum mechanics presented in “Quantum Physics I” (PHYC 3640) by introducing additional topics of fundamental importance, including: spin, identical particles, time-independent perturbation theory, WKB approximation, time-dependent perturbation theory, and scattering theory.

Course Prerequisites

PHYC 3640.03 Quantum Physics I or equivalent

Learning Objectives

Familiarity with the physical concepts and theoretical approaches for: calculating the properties of particle spin, the treatment of multi-particle quantum systems, computing approximate eigenenergies and eigenfunctions from complicated Hamiltonians using perturbation theory, finding approximate ground state energies using the variational approach, calculating bound state energies and tunneling rates with the WKB approximation, using time-dependent perturbation theory to calculate atomic transition rates.

Course Materials

Course Notes:

- I have used AI to convert my handwritten lecture notes into a typeset document that will take the place of an assigned textbook.



Recommended reference textbooks:

I encourage you to make use of other textbooks, as each brings its own insights and perspectives that are valuable in gaining a deeper understanding of the material. Griffiths provides concise and insightful descriptions, but it is not as rigorous as other textbooks. There are many excellent textbooks. Here are some of the ones that I found useful in preparing for the course.

- D.J. Griffiths and D.F. Schroeter *Introduction to Quantum Mechanics*, 3rd Ed., (Cambridge University Press, 2018).

I expect that you will all have a copy from your previous course PHYC 3640. There are many good problems

in the book that I will assign as practice problems. I will use the 3rd Ed. of the textbook for most of the course

- R. Shankar, *Principles of Quantum Mechanics*, 2nd Ed., (Plenum Press 1999)
This is one of my favourite quantum mechanics textbooks. Shankar is known for his clear explanations of the fundamental concepts. I considered using this as a textbook for the course. Although this is a very accessible reference, its level of detail is better suited for a graduate course. This is the book that I used when I was a graduate student.
- B. Zwiebach *Mastering Quantum Mechanics Essentials, Theory, and Applications* (MIT Press, 2022)
This is an excellent textbook that is also very clear but it covers topics in greater depth than we will go, but I think that this will be an excellent reference for the course. The textbook is based on lectures notes from Zwiebach's three courses on quantum mechanics at MIT, which are freely available (see for example <https://ocw.mit.edu/courses/8-06-quantum-physics-iii-spring-2018/>).
- J. S. Townsend, *A Modern Approach to Quantum Mechanics*, 2nd Ed., (Science books, 2012)
This is a textbook that has been used in the past for PHYC 4151. I am told that students liked the book, although I prefer Griffiths. However, unlike Griffiths, Townsend does make extensive use of bra-ket notation throughout the book, which is what we will be using. This textbook is inspired in part by the Feynman Lectures and Sakurai's book, which presents spin as a way of introducing Quantum Mechanics.
- C. Cohen-Tannoudji, B. Diu, F. Laloe, *Quantum Mechanics, Vol. 1 and 2*, (Wiley Interscience, 1977).
This is encyclopedic textbook covers the same range of topics in 1516 pages as what Griffiths covers in 485 pages. This is what was assigned to me when I was a student, and it wasn't fun learning from. However, there is a lot of useful material in there and it is worth having a look at. It contains many interesting examples.
- J. J. Sakurai, *Modern Quantum Mechanics*, Revised Ed., (Addison Wesley, 1994).
This is a classic textbook at the graduate level. There is now a 3rd edition with contributions from an additional author.

Course website:

Brightspace

Announcements

Announcements pertaining to lectures and laboratory will be made via e-mail.

Course Assessment

	Method 1	Method 2
1st Midterm	20%	best of two quizzes 33%
2nd Midterm	20%	
Tutorials	2%	2%
Assignments	25%	25%
Exam	33%	40%
	100%	100%

Conversion of numerical grades to Final Letter Grades follows the Dalhousie Common Grade Scale, shown below.

A+ (90-100)	B+ (77-79)	C+ (65-69)	D (50-54)
A (85-89)	B (73-76)	C (60-64)	F (<50)
A- (80-84)	B- (70-72)	C- (55-59)	

Course Policies on Missed or Late Academic Requirements

Midterm: There is no make-up test for a missed midterm: method 2 will automatically be applied in this case to calculate your final grade.

Exam: If a student misses the final exam for good reason, they should contact the Lecturer as soon as possible and submit a

Problem Sets:

Assignments are approximately every week, except for the weeks of the midterms.

Late assignment will have 10% deducted per day after the due date, and no credit will be given for assignments handed in after the solutions have been provided. If you are unable to submit an assignment for good reason, you need to contact the Lecturer as soon as possible and submit a “Student Declaration of Absence form” upon return to class. For a valid excuse, an extension will be provided when possible; otherwise the assignment mark will be dropped.

Lectures, Tutorials and Reading Assignments

The following is a rough outline for the lectures and tutorials, subject to change depending of the needs of the class. You are expected to read the relevant chapters in the course notes before coming to class.

Date	Topic	Due dates and midterms
Sep 08	L1 Review of linear algebra	
Sep 09	L2 Review of Dirac notation and Hilbert spaces	
Sep 10	Tutorial 1: Dirac notation	
Sep 15	L3 Spin and two-level systems	PS1
Sep 16	L4 Matrix representation of spin	
Sep 17	Tutorial 2: Spin	
Sep 22	L5 Spin in a magnetic Field	PS2
Sep 23	L6 Addition of angular momentum	
Sep 24	L7 Orbital and spin angular momentum	
Sep 29	Tutorial 3: Addition of angular momentum	
Sep 30	<i>Truth and Reconciliation Day</i>	
Oct 01	L8 Density matrices and mixed states	
Oct 06	L9 Reduced density matrices and identical particles	PS3
Oct 07	Tutorial 4: Density matrices	
Oct 08	L10 Exchange symmetry and the Pauli principle	
Oct 13	Tutorial 5: Identical particles	
Oct 14	L11 Entanglement	
Oct 15	Tutorial 6: Entanglement problems	
Oct 20	L12 Non-degenerate perturbation theory (NDPT)	Midterm 1: Oct 20
Oct 21	Tutorial 7: Non-degenerate perturbation theory	PS4
Oct 22	L13 Perturbation theory: distorted harmonic oscillators	
Oct 27	L14 Degenerate perturbation theory	
Oct 28	Tutorial 8: Degenerate perturbation theory	PS5
Oct 29	L15 Zeeman and hyperfine interactions	
Nov 03	Tutorial 9: Zeeman and hyperfine interactions	
Nov 04	L16 WKB approximation	PS6
Nov 05	L17 WKB approximation (connection formulae)	
Nov 10	— Reading Week — Nov 9 to Nov 13	
Nov 17	L18 Two-level systems and Rabi oscillations	Midterm 2: Nov 17
Nov 18	L19 Time-dependent perturbation theory	
Nov 19	Tutorial 11: Time-dependent perturbation theory	
Nov 24	L20 Emission and absorption processes	
Nov 25	— Problem session (no formal tutorial)	PS7
Nov 26	L21 Scattering theory	
Dec 01	L22 Partial wave analysis	

Dec 02		Tutorial 12: Scattering theory	
Dec 03	L23	Green's functions and Born approximation	PS8
Dec 08	—	No lecture — Monday schedule	
Dec 09	L24	Dirac equation and relativistic quantum mechanics	PS9
Dec 11	—	EXAM PERIOD Dec 11 -- Dec 20	Final Exam: TBD

Tutorials

The tutorials involve problems that you work on in small groups. Your participation and effort during the tutorials will be graded on a scale from 0 to 2. You will be permitted to miss one week of tutorial without question. Any absence beyond this will require a “Student Declaration of Absence form”.

Course Policies related to Academic Integrity

You are encouraged to work on problem sets together, but the assignment that you hand in **must** be in your own words, and the calculations **must** be your own. When you complete your assignments, make sure that you explain your thought process. Putting your thoughts into words is a very useful way of learning the material more deeply. The problem sets will be approximately every week.

The assignment that you submit reflect your understanding and problem-solving skills and represent the most important part of your learning experience. The use of artificial intelligence (AI), including large language models (LLM) such as ChatGPT to solve assignment problems is **not permitted**, as this short-circuits this learning process. You should be able to reproduce and explain every step in your assignments and be prepared to explain your reasoning in detail.

However, LLMs can be a useful coach for learning physics and to ask questions about concepts that you are struggling with, which is permitted. However, there are a number of things that you should consider before using one:

- A recent report on *cognitive offloading* by Kosmyna *et al.* at MIT¹ find that users who habitually use AI to perform tasks that require critical thinking gradually accrue a *cognitive deficit*. Take-away message: make sure that you are engaging with the AI critically, questioning its answer and probing what is given you with follow-up question.
- The quality of the answers you get vary considerably between models and how you use them. Generally Claude and ChatGPT's latest models outperform the competition in modelling and simulations in physics (<https://juliahub.com/blog/frontier-models-physical-ai-evaluation>), although these models require a paid subscription. You all have access to Microsoft Co-Pilot through Dalhousie, but I have not tested this extensively for our course material. However, it was able to answer the few Quantum Physics II problems that I gave it correctly.
- Even the latest AI models make mistakes. You should be questioning anything it gives you and push back on anything that you are unsure of. Check anything important against a reputable source, such as a known textbook.

Even better is to discuss your questions with your classmates, TA and/or your professor. *If you do use an AI tool as a learning coach, note in your assignment where you used it e.g., 'I asked ChatGPT to explain the divergence theorem,' or 'I used Claude to check my integral'.* This helps us understand your learning process and gives credit where due.

Midterms

Tentative dates

1st Midterm: Tuesday Oct. 20, 6:00 pm – 8:00 pm

2nd Midterm: Monday Nov. 17, 6:00 pm – 8:00 pm

¹ <https://www.media.mit.edu/publications/your-brain-on-chatgpt/>

University Policies and Statements

Recognition of Mi'kmaq Territory

Dalhousie University would like to acknowledge that the University is on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit or e-mail the Indigenous Student Centre at 1321 Edward St or elders@dal.ca. Additional information regarding the Indigenous Student Centre can be found at: https://www.dal.ca/campus_life/communities/indigenous.html

Internationalization

At Dalhousie, 'thinking and acting globally' enhances the quality and impact of education, supporting learning that is "interdisciplinary, cross-cultural, global in reach, and orientated toward solving problems that extend across national borders." Additional internationalization information can be found at: <https://www.dal.ca/about-dal/internationalization.html>

Academic Integrity

At Dalhousie University, we are guided in all our work by the values of academic integrity: honesty, trust, fairness, responsibility, and respect. As a student, you are required to demonstrate these values in all the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity. Additional academic integrity information can be found at: https://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Student Accessibility Centre is Dalhousie's centre of expertise for matters related to student accessibility and accommodation. If there are aspects of the design, instruction, and/or experiences within this course (online or in-person) that result in barriers to your inclusion, please contact the Student Accessibility Centre (https://www.dal.ca/campus_life/academic-support/accessibility.html) for all courses offered by Dalhousie with the exception of Truro. For courses offered by the Faculty of Agriculture, please contact the Student Success Centre in Truro (<https://www.dal.ca/about-dal/agricultural-campus/student-success-centre.html>)

Conduct in the Classroom – Culture of Respect

Substantial and constructive dialogue on challenging issues is an important part of academic inquiry and exchange. It requires willingness to listen and tolerance of opposing points of view. Consideration of individual differences and alternative viewpoints is required of all class members, towards each other, towards instructors, and towards guest speakers. While expressions of differing perspectives are welcome and encouraged, the words and language used should remain within acceptable bounds of civility and respect.

Diversity and Inclusion – Culture of Respect

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness (Strategic Priority 5.2). Additional diversity and inclusion information can be found at: <http://www.dal.ca/cultureofrespect.html>

Student Code of Conduct

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner - perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. The full Code of Student Conduct can be found at: https://www.dal.ca/dept/university_secretariat/policies/student-life/code-of-student-conduct.html

Fair Dealing Policy

The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie. Additional information regarding the Fair Dealing Policy can be found at: https://www.dal.ca/dept/university_secretariat/policies/academic/fair-dealing-policy-.html

Originality Checking Software

The course instructor may use Dalhousie's approved originality checking software and Google to check the originality of any work submitted for credit, in accordance with the Student Submission of Assignments and Use of Originality Checking Software Policy. Students are free, without penalty of grade, to choose an alternative method of attesting to the authenticity of their work and must inform the instructor no later than the last day to add/drop classes of their intent to choose an alternate method. Additional information regarding Originality Checking Software can be found at:

https://www.dal.ca/dept/university_secretariat/policies/academic/student-submission-of-assignments-and-use-of-originality-checking-software-policy-.html

Student Use of Course Materials

Course materials are designed for use as part of this course at Dalhousie University and are the property of the instructor unless otherwise stated. Third party copyrighted materials (such as books, journal articles, music, videos, etc.) have either been licensed for use in this course or fall under an exception or limitation in Canadian Copyright law. Copying this course material for distribution (e.g. uploading to a commercial third-party website) may lead to a violation of Copyright law.

Student Resources and Support

University Policies and Programs

Important Dates in the Academic Year (including add/drop dates): http://www.dal.ca/academics/important_dates.html

Classroom Recording Protocol: https://www.dal.ca/dept/university_secretariat/policies/academic/classroom-recording-protocol.html

Dalhousie Grading Practices Policies: https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html

Grade Appeal Process: https://www.dal.ca/campus_life/academic-support/grades-and-student-records/appealing-a-grade.html

Sexualized Violence Policy: https://www.dal.ca/dept/university_secretariat/policies/health-and-safety/sexualized-violence-policy.html

Scent-Free Program: <https://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html>

Learning and Support Resources

General Academic Support – Advising (Halifax): https://www.dal.ca/campus_life/academic-support/advising.html

General Academic Support – Advising (Truro): <https://www.dal.ca/about-dal/agricultural-campus/ssc/academic-support/advising.html>

Student Health & Wellness Centre: https://www.dal.ca/campus_life/health-and-wellness.html

On Track (helps you transition into university, and supports you through your first year at Dalhousie and beyond): https://www.dal.ca/campus_life/academic-support/On-track.html

Indigenous Student Centre: https://www.dal.ca/campus_life/communities/indigenous.html

Indigenous Connection: <https://www.dal.ca/about-dal/indigenous-connection.html>

Elders-in-Residence (The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit the office in the Indigenous Student Centre or contact the program at elders@dal.ca or 902-494-6803: <https://cdn.dal.ca/content/dam/dalhousie/pdf/academics/UG/indigenous-studies/Elder-Protocol-July2018.pdf>

Black Student Advising Centre: https://www.dal.ca/campus_life/communities/black-student-advising.html

International Centre: https://www.dal.ca/campus_life/international-centre.html

South House Sexual and Gender Resource Centre: <https://southhousehalifax.ca/about/>

LGBTQ2SIA+ Collaborative: <https://www.dal.ca/dept/vpei/edia/education/community-specific-spaces/LGBTQ2SIA-collaborative.html>

Dalhousie Libraries: <http://libraries.dal.ca/>

Copyright Office: <https://libraries.dal.ca/services/copyright-office.html>

Dalhousie Student Advocacy Services: <https://www.dsu.ca/dsas?rq=student%20advocacy>

Dalhousie Ombudsperson: https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html

Human Rights and Equity Services: <https://www.dal.ca/dept/hres.html>

Writing Centre: https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html

Study Skills/Tutoring: http://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html

Faculty of Science Advising Support: <https://www.dal.ca/faculty/science/current-students/undergrad-students/degree-planning.html>