PHYC 4151 Quantum Physics II

Department of Physics and Atmospheric Science

Fall 2022

Dalhousie University is located in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq. We are all Treaty people.

We acknowledge the histories, contributions, and legacies of the African Nova Scotian people and communities who have been here for over 400 years.

Instructor

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TA

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Lectures

Monday and Wednesday, Dunn 221C, 10:05 to 11:25

Tutorials

Thursday, Dunn 221C, 3:35 to 4:25

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, variational approach, 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, and calculating bound state energies and tunneling rates with the WKB approximation.

Course Materials

Required textbook:

- D.J. Griffiths and D.F. Schroeter *Introduction to Quantum Mechanics*, 3nd Ed., (Cambridge University Press, 2018).
  I expect that you will all have a copy from your previous course PHYC 3640. We will cover most of the remainder of the textbook with the exception of Chap 6 and Chap. 12. There are many good problems in the book.

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.

- 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	17%	best of two quizzes 22%
2nd Midterm	17%	
Tutorials	2%	2%
Assignments	30%	30%
Exam	33%	45%
	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
Late assignments 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. For a justified missed midterm tests or exam a "Student Declaration of Absence form" must be submitted. There is no make-up test for a missed midterm: method 2 will automatically be applied in this case to calculate your final grade. If the final exam is missed for good reason, a make-up exam will be given.

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 and will be due on Thursday at the start of the tutorial.

Midterms
1st Midterm: evening of Friday Oct. 14

2nd Midterm: evening of Friday Nov. 17

Lectures and Reading Assignments

The following is a rough outline for the lectures, subject to change depending of the needs of the class. You are expected to read the relevant chapters in the textbook before coming to class. Lecture notes will be posted on Brightspace.

Date		Lecture	Chapters
Sep 7	**1**	Review of linear algebra	Appendix A
Sep 12	**2**	Spin	4.4
Sep 14	**3**	Matrix representation of spin	4.4
Sep 19	**4**	Addition of angular momentum	4.4.3
Sep 21	**5**	Adding orbital and spin angular momentum	4.4.3
Sep 26	**6**	Identical particles	5.1.1 - 5.1.2
Sep 28	**7**	Identical particles with spin	5.1.3 - 5.1.4
Oct 3	**8**	Time independent perturbation theory	7.1
Oct 5	**9**	Time independent perturbation theory (con't)	7.1
Oct 10		***Thanksgiving***	
Oct 12	**10**	Degenerate perturbation theory	7.2
Oct 17	**11**	Hydrogen fine structure	7.3.1
Oct 19	**12**	Hydrogen fine structure	7.3.2
Oct 24	**13**	Zeeman and hyperfine interaction	7.4 - 7.5
Oct 26	**14**	Variational method	8.1 - 8.2
Oct 31	**15**	WKB approximation	9.1 - 9.2
Nov 2	**16**	WKB approximation (connection formulae)	9.3
Nov 7		***Reading Week***	
Nov 14	**17**	Scattering	10.1
Nov 16	**18**	Scattering (scattering phase shifts)	10.2 - 10.3
Nov 21	**19**	Scattering (Born approximation)	10.4
Nov 23	**20**	Time dependent perturbation theory	11.1
Nov 28	**21**	Emission and absorption	11.2
Nov 30	**22**	Spontaneous emission	11.3
Dec 5	**23**	Fermi's Golden Rule	11.4
Dec 7	**24**	Adiabatic approximation	11.5

University Policies and Statements

This course is governed by the academic rules and regulations set forth in the University Calendar and by Senate

Academic Integrity

At Dalhousie University, we are guided in all of our work by the values of academic integrity: honesty, trust, fairness, responsibility and respect (The Center for Academic Integrity, Duke University, 1999). As a student, you are required to demonstrate these values in all of 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.
Information: https://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Advising and Access Services Centre is Dalhousie's centre of expertise for student accessibility and accommodation. The advising team works with students who request accommodation as a result of a disability, religious obligation, or any barrier related to any other characteristic protected under Human Rights legislation (Canada and Nova Scotia).
Information: https://www.dal.ca/campus_life/academic-support/accessibility.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.
Code: https://www.dal.ca/dept/university_secretariat/policies/student-life/code-of-student-conduct.html

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
Statement: http://www.dal.ca/cultureofrespect.html

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 (1321 Edward St) (elders@dal.ca).
Information: https://www.dal.ca/campus_life/communities/indigenous.html

Important Dates in the Academic Year (including add/drop dates)
https://academiccalendar.dal.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog&catalogid=117&chapterid=-1&topicgroupid=31821&loaduseredits=False

University Grading Practices

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

Student Resources and Support

Advising

General Advising https://www.dal.ca/campus_life/academic-support/advising.html

Science Program Advisors: https://www.dal.ca/faculty/science/current-students/undergrad-students/degree-planning.html

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

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

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

Academic supports

Library: https://libraries.dal.ca/

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

Studying for Success: https://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html

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

Fair Dealing Guidelines https://libraries.dal.ca/services/copyright-office/fair-dealing.html

Other supports and services

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

Student Advocacy: https://dsu.ca/dsas

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

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

Dalhousie COVID-19 information and updates: https://www.dal.ca/covid-19-information-and-updates.html