Elements of Quantum Mechanics

PHYS 3701

Course Outline

Fall 2023

Course description and prerequisites

This course is an introduction to the basic ideas and methods of non-relativistic quantum mechanics. It will introduce students to the Schrödinger equation and its basic properties and interpretations. Elementary solutions of the Schrödinger equation for 1-dimensional motion will be derived and analyzed. The uncertainty principle will be discussed. The Schrödinger, Equation in three dimensions will be introduced, and the angular momentum of quantum particles analyzed, including spin angular momentum. Solutions of the 3-dimensional Schrödinger equation for simple potentials will be derived and analyzed. Selected applications to atomic, molecular, and nuclear physics will be discussed.

Prerequisites: 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, **September 06 to December 08, 2023**.

Instructor and course information

- **Section Type:** IN-PERSON
- **Time:** Tuesday and Thursday 10:05 - 11:25
- **Instructor:** Dr. Wafia Bensalem
  Office: Herzberg 3313
  e-mail: wafiabensalem@cunet.carleton.ca
- **Office Hours:** Thursday from 3 pm to 5 pm or by appointment
- **Website: https://brightspace.carleton.ca**

Textbook

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

Course philosophy and objectives

We are learning physics to understand our universe and to perceive it in a comprehensible, enjoyable, and fascinating way. Physics is based on critical thinking and helps you become an expert problem solver, develop a critical mind, in addition to analytical, communication and mathematical skills.

No one learns physics by simply reading about it or listening to someone talk about it. You learn physics by making the **effort** to understand the course material, by **doing work** outside of class, **thinking** about and **interacting** with the course material and by **solving problems** using the principles learned.

This course focuses on introducing you to the fundamental concepts of Quantum Mechanics which completely changed our view of the world around us. The quantum realm is very strange and unpredictable in the classical sense and refutes the idea of an abstract universe perceived by the senses. Objects can occupy two spaces at the same time and can live double lives as waves and particles; and information seems to travel faster than the speed of light! The strangeness of the quantum world is legendary! The intuitions we have developed through our lived experiences 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 worlds.*

You will be introduced to the main concepts of non-relativistic quantum mechanics, and you will develop an understanding of the underlying foundations and build both **conceptual** and **quantitative/mathematical** skills necessary to understand quantum mechanics.

Course Organization

This course is delivered in person, in form of lectures. The main ideas will be summarized on slides and posted on Brightspace, and details and calculations will be explained using the blackboard ('chalk-and-talk').

You are encouraged to ask questions, discuss ideas, and engage with the material during the lectures.

It is essential that you read the textbook sections, ideally before the corresponding material is covered in the lectures.

These lectures are intended to be the primary method of course delivery and it is highly recommended that you attend these sessions.

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Important Dates

https://calendar.carleton.ca/academicyear

https://carleton.ca/registrar/registration/dates/

Tentative schedule

Week	Date	Subject	Textbook chapter sections
1	Sept 7	- Course details - Introduction: The beginnings of quantum physics	
2	Sept 12	- Mathematical tools	3.1, 3.6 and Appendix A
	Sept 14		
3	Sept 19	- Schrodinger eq - Interpretation / probability - Normalization - Momentum - Uncertainty principle	1.1 - 1.6
	Sept 21	- Stationary States - Infinite square well	2.1, 2.2
4	Sept 26	Harmonic oscillator	2.3
	Sept 28		
5	Oct 3	- Free particle - The Delta-Function Potential	2.4, 2.5
	Oct 5	Finite square well	2.6
6	Oct 10	- Observables / Operators / expectation values - Uncertainty principle	3.2-3.5
	Oct 12		
7	**Oct 17**	**Midterm Exam**	
	Oct 19	Catchup / Problems	
October 23-27, 2023: Fall break, no classes.			
8	Oct 31	3D Schrodinger eq	4.1
	Nov 2	Angular Momentum	4.3
9	Nov 7	Spin – Electron in a magnetic field	4.4
	Nov 9	Addition of angular momenta	
10	Nov 14	Electromagnetic interactions	4.5
	Nov 16		
11	Nov 21	Hydrogen atom	4.2
	Nov 23		
12	Nov 28	Multiparticle systems	5.1-5.3
	Nov 30		
13	Dec 5	Problems	
	Dec 7	Review	

Assignment Schedule

Assignment	Available	Due Date
1	Sept 19	Sept 26
2	Sept 26	Oct 03
3	Oct 03	Oct 10
4	Oct 31	Nov 07
5	Nov 07	Nov 14
6	Nov 14	Nov 21
7	Nov 21	Nov 28
8	Nov 28	Dec 05

Course Evaluation

- There will be 8 **assignments** scheduled as in the schedule provided above. The assignments will be posted as pdf files on Brightspace. Your **solutions must be posted as pdf files** to Brightspace; they can be scanned versions of hand-written solutions. **Assignments must be handed in by the indicated due date or they will not be graded and receive a mark of zero.**
  The lowest assignment grade will not be included in the overall assignment grade calculation.
- The **midterm exam** will occur on October 19th during the class time. It will be closed-book and closed-notes and a formula sheet will be provided (to be posted on Brightspace in advance). The midterm exam is not optional and must be attempted to successfully pass the course.
- The **final exam** will occur during the final exam period as scheduled by the university. It will be 3 hours long, closed-book and closed-notes. A formula sheet will be provided (to be posted on Brightspace in advance). The final exam is not optional and must be attempted to successfully pass the course.

All marks will be posted on Brightspace. Contact the instructor immediately if you think there is an error in the Brightspace gradebook.

Assessment	Grade value
Assignments (best 7 of 8)	**45%**
Midterm exam	**20%**
Final exam	**35%**

To pass the course:

1. Your overall course mark must be at least 50%.
2. Your average on the exam component of the course must be at least 50%.
   Exam average ≡ (0.20 ×Midterm + 0.35 ×Final) ÷ (0.20 + 0.35)

University policies

Letter Grades

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 Regulations

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

Academic Accommodations for Students with Disabilities

The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation.
If you are already registered with the PMC, contact your PMC coordinator to send your *Letter of Accommodation* at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (*if applicable*).
https://carleton.ca/pmc/

Academic Accommodations for Religious Obligations

You should make a formal, written request to the instructor during the first two weeks of class, or as soon as possible - after the need for accommodation is known to exist-, but no later than two weeks before the compulsory event.

Students who have questions or want to confirm accommodation eligibility of a religious event or practice may refer to the Equity Services website for a list of holy days and Carleton's Academic Accommodation policies or may contact an Equity Services Advisor in the Equity Services Department for assistance: https://carleton.ca/equity/

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, please contact the Department of Equity and Inclusive Communities | Carleton University at equity@carleton.ca.

Pregnancy
Pregnant students requiring academic accommodations are encouraged to contact an Equity Advisor in Equity Services to complete a letter of accommodation. The student must then make an appointment to discuss her needs with the instructor at least two weeks prior to the first academic event in which it is anticipated the accommodation will be required.

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:
carleton.ca/sexual-violence-support.

Accommodations 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 your instructor 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 policy.
You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at: carleton.ca/equity/.

Accommodations for Missed Work
Carleton recognizes 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

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, the potential penalties and the procedures refer to the section on Instructional Offences in the Undergraduate Calendar.

What are the Penalties for Plagiarism?

Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy (see https://carleton.ca/registrar/academic-integrity/). The Policy is strictly enforced and is binding on all students. Plagiarism and cheating – presenting another's ideas, arguments, words or images as your own, using unauthorized material, misrepresentation, fabricating or misrepresenting research data, unauthorized co-operation or collaboration or completing work for another student – weaken the quality of the undergraduate degree. Academic dishonesty in any form will not be tolerated. Students who infringe the Policy may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; a refusal of permission to continue or to register in a specific degree program; academic probation; or a grade of Failure in the course.

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/