Quantum Mechanics II: PHYS 314
Spring 2020

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Contact details

Course Instructor Prof. Chris Monahan. My pronouns are he/his/him. Email is the best way to contact me.

Contact email cjmonahan@wm.edu.

Course webpage is cjmonahan.net/qm314_2020.

Office hours By zoom on Tuesdays 09:30–10:50am. Please email me if you cannot make that time.

College dates Add/Drop deadline is Friday February 5 and the withdrawal deadline is Monday March 29. Spring Break days are: Friday February 12, Thursday March 4, Wednesday March 17, Tuesday April 6, Wednesday April 7, and Monday April 26. No work will be due on, or the day after, these Spring Break days.

Grader Haoyue Jiang [email hjiang06@email.wm.edu–for grading questions only].

Be aware This syllabus is subject to change during the semester. I will announce changes in class, but you are responsible for keeping up to date with the latest version on the course webpage.

Course overview

Class schedule This course will be delivered in a hybrid format. I will post overview lecture videos each Monday and we will have synchronous discussion sessions during the scheduled class time of **09:30 to 10:50 am** on Thursdays. For the first two weeks, from the week of January 25 until the week of February 8, the course will be entirely remote. Our in-person discussion sessions will start on Thursday, February 11 and take place in Small Hall 111. Masks are required during our in-person classes, and you are expected to maintain physical distancing throughout the course.

Prerequisites Modern Physics (PHYS 201) and Classical Mechanics (PHYS 208) are prerequisites for this course, as is a strong command of the material from the first semester of quantum mechanics (PHYS 313). We will make extensive use of Calculus (so you should have taken MATH 111, 112, and 213 (or 212)), as well as some aspects of Linear Algebra and Ordinary Differential Equations. We will introduce and review the necessary topics from the these latter two. However, students who have taken, or are taking, MATH 211, MATH 302, or PHYS 301 will find that those courses are useful.

Lectures I will be posting short video summaries of the main topics. I will post these on the webpage. I will also post my lecture notes.

Office hours Office hours are currently scheduled for our Tuesday class time, 09:30 to 10:50 am, or by arrangement. In both cases, office hours will be via Zoom.

Assessments There will be Problem Set assignments, two take-home midterm tests, and a final (take-home) exam. The grades will be calculated based on either

- Problem Sets : 40%
- In-class Tests : 25%
- Final Exam : 35%

or

- Problem Sets : 40%
- Final Exam : 60%

For each student, the final grade will be calculated using both equations, and the result with the larger numerical grade will be the one used to determine the letter grade.

This procedure allows those students that had difficulty with one or more of the in-class tests to have the chance to make up for it with a good performance on the final exam; after all–what is relevant is how much physics you have learned at the end of the course!

Problem sets Problem Sets will be posted on the webpage on **Thursday before class** and are due by the start of class the following Thursday (that is, at 09:30 am). **I will drop the lowest grade on your weekly Problem Set**. Problem Sets are due by email to me. The first one is Problem Set 1, which will be posted on **Thursday February 4** and due on **Thursday February 11** before class.

If possible, please try to use an app, such as "PDFelement" or "Image to PDF Converter" (which should both be free, I believe) to convert your images to PDF files before submitting your Problem Set. Please include your name in the title of your pdf file and on (at least) the first page of your solution itself–this really helps both me and the grader a lot, because receiving twenty unnamed PDF files on a Thursday morning makes grading much harder!

Midterm tests The midterms will be take-home exams. I will post the first on Monday March 1 and it will be due on Wednesday March 3 (the next day is a Spring Break Day), and I will post the second on Monday March 29 and it will be due on Thursday April 1. No late submissions will be allowed, unless by prior arrangement. You may not work together on the midterm exams.

Final exam The final exam will also be a take-home exam. The final exam will be due 12 midday on Monday May 17. You may not work together on the final exams.

Recommended textbook Recommended textbook and other resources This course spans a wide range of the topics in Quantum Mechanics, and no one textbook covers everything. Much of the material will be drawn from *Introduction to Quantum Mechanics: 3rd edition*, by David J. Griffiths and Darrell F. Schroeter, Cambridge University Press (ISBN: 9781107189638). This is a brand-new (third) edition of this book, but is the same textbook as required for Quantum Mechanics I (PHYS 313).

In addition to this textbook and my own notes, you may find the lecture notes by David Tong on *Topics in Quantum Mechanics* useful. There are many other resources online.

Course description

How do we describe our Universe at very small length scales? How do we explain why hydrogen looks the way it does, or, for that matter, why the elements line up in the periodic table so neatly? The answer, of course, is QUANTUM ~~MAGIC~~ MECHANICS!

We will start to unravel some of this quantum magic by building on the first semester of quantum mechanics (PHYS 313) and introducing new techniques for systems for which we do not have exact solutions (that is, basically everything). This includes the detailed structure of hydrogen energy levels, helium atoms and nuclei, collections of identical particles, quantum scattering effects, and systems that evolve with time. We will briefly introduce concepts that appear throughout modern theoretical physics, such as the deep relationship of symmetries and conserved quantities, and a sneak peek at quantum field theory, the mathematical framework that brings together quantum mechanics with special relativity, which explains all fundamental particles in the observable Universe.

By the end of the course, you will be able to:

- Describe the three pictures of quantum mechanics, and apply the path integral approach to one-dimensional systems.
- Define the relation between symmetries and conserved quantities and apply this relationship to spacetime symmetries.
- Relate spin to particle properties and apply this relationship to the collective behaviour of quantum mechanical systems, such as simple solids.
- Identify how relativistic quantum mechanics breaks down.
- Write down the Dirac equation and discuss its key features.
- Distinguish classical and quantum mechanical scattering.
- Calculate scattering amplitudes and phase shifts for one-dimensional systems, incorporating partial wave analysis.
- Connect quantum mechanical scattering methods to modern particle physics.
- Describe several approximate approaches to quantum mechanical systems, including the variational method, time-independent, and time-dependent perturbation theory.
- Assess the relative merits of approximate methods for different quantum mechanical systems.
- Use variational methods to solve simple atomic systems.
- Apply time-independent perturbation theory to second order to simple quantum mechanical systems, including to Hydrogen fine structure.
- Define and apply Fermi's golden rule.

We will cover:

1. Review of Quantum Mechanics II.
2. Path integrals in quantum mechanics.
3. Symmetries and conservation laws.
4. Spin and statistics.
5. Relativistic quantum mechanics.
6. Scattering.
7. Variational methods.
8. Time-independent perturbation theory.
9. Fine and hyperfine structure of hydrogen.

10. Time-dependent perturbation theory.

Accommodations and Student Accessibility Services

William and Mary accommodates students with disabilities in accordance with federal laws and university policy. Any student who feels they may need an accommodation based on the impact of a learning, psychiatric, physical, or chronic health diagnosis should contact Student Accessibility Services staff at 757-221-2512 or at sas@wm.edu to determine if accommodations are warranted and to obtain an official letter of accommodation. For more information, please see the Student Accommodation Services website.

Course policies

The following policies are founded on two tenets:

1. You are responsible for your own learning.
2. You have agreed to abide by the Honor Code.

Some aspects or details of these policies are open for revision during the semester, if we, as a class, feel that they are not working. These two tenets, however, are not.

Honor Code

As students at William and Mary you have agreed to abide by the Honor Code. You are responsible for your behaviour in class and are expected to uphold the Honor Code.

Responsibility for learning

You are responsible for your own understanding of the course material. We may all learn in different ways, and I aim to foster an environment that allows us all to learn effectively. Taking responsibility for your own learning guides the following policies.

Working together You are welcome to work together for homeworks if you so choose, but you must write up your own solutions. Collaboration helps develop and cement understanding of the material, and is an important skill for your future careers. Your homework, however, should represent your own understanding and we must strike a balance between working collaboratively and copying someone else's work. I cannot emphasise this enough: **Copying solutions will not help you understand quantum mechanics**. Moreover, copying is cheating and a form of plagiarism. An example of appropriate collaboration is working together to sketch out the main steps in a derivation or in the solution to a problem, then going away to write up your solutions in detail separately. An example of cheating is taking someone else's solutions the night before the deadline and copying them line by line. You may not work together on midterms or on the final exam.

Attendance Attendance does not form part of the grade for this class. After all, you are responsible for your own understanding of the course material. Attending class will, however, significantly improve your enjoyment of the course and will likely improve your satisfaction with both your own understanding and your grade.

Late work, extensions I can make occasional accommodations for late homework if you inform me in advance. Reasons are appreciated, but not necessary, because sometimes you may not wish to share your reasons with me, for, you know, personal reasons. As with all these policies, I expect you to treat this responsibly. Sudden emergencies and unexpected life events will obviously be accommodated appropriately.

Laptops and mobile devices You are welcome to bring laptops and mobile devices to class and are responsible for their appropriate use. Please note, however, that there is significant evidence (see, for example, **here**, **here**, and **here**) that using your device for tasks that are not related to in-class activities will (significantly) impinge on your understanding of quantum mechanics and perhaps even your grade.

Typewriters Typewriters are not permitted in the classroom.

Student resources

Useful resources (links in online PDF):

- The Dean of Students and the Student Success office.
- Student Accessibility Services
- Writing Resource Center
- Equity program
- LGBTQ resources
- Neurodiversity Initiative
- Health and Wellness, mental health resources and the Counseling Center
- The Haven
- Lifeline

- Options for reporting Discrimination, Harassment, Retaliation and Sexual Misconduct.

The full policy of the College on Discrimination, Harassment and Retaliation is here.