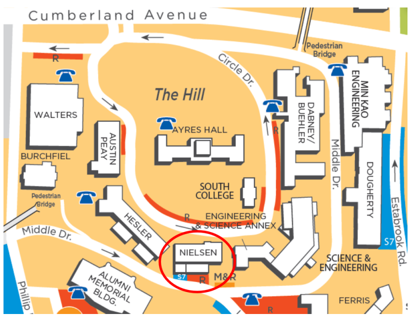
Physics 522: Quantum Physics II, Spring 2022

University of Tennessee, Knoxville

Time: TR, 1:10 PM–2:25 PM
Place: Nielsen 306
Zoom room at `https://tennessee.zoom.us/j/2840525544`



Instructor: Maxim O. Lavrentovich

Office location: Nielsen 406A
Office hours: T: 3-4 PM W: 12-1 PM
(will be held on Zoom and in person)
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website: `www.maxlavrentovich.com`
telephone: (865) 974-5947

Course description: Second course on graduate-level quantum mechanics. Hydrogen atom. Spin-orbit coupling. Perturbation theory. Semi-classical approximations. Propagators and path integration. Scattering in 3D. Identical particles. Quantizing the electromagnetic field.
Credit Hours: 3
Course Section: 001
Notes: This course requires the successful completion of Physics 521.

Overall Goals and Learning Objectives

In the second semester of this course, we cover advanced techniques in quantum mechanics that will bring us to the cutting edge of the theoretical developments in this field. After this course, you will have seen a significant fraction of the techniques and conceptual advances made possible by quantum mechanics. You will also be prepared to study relativistic quantum mechanics (quantum field theory). This semester is also more focused on the applications of the fundamental theories covered in the first semester. After taking this second semester course, you will be able to:

- describe in detail the quantum mechanics of the hydrogen atom, including relativistic effects such as the spin-orbit coupling
- use perturbation theory to calculate properties of complex quantum systems for both time-dependent and time-independent cases
- have an understanding of the classical limit of quantum mechanics and its use in approximate methods including the WKB approximation
- understand the path integral and propagators, including their many applications in not only quantum systems, but in finance, polymer physics, and other areas

- develop a formalism for understanding the quantum mechanics of 3D scattering, including the Born and partial wave approximations
- analyze systems with multiple identical particles using the method of second quantization, establishing the foundations for quantum many-body theory
- have a basic knowledge of how electrodynamics is combined with quantum mechanics and of the foundational principles of quantum field theory
- confidently approach the quantum mechanical modelling of any given system or phenomenon (the hydrogen atom, molecules, particle scattering, the Aharonov-Bohm effect, etc.), using a comprehensive set of techniques

How to Be Successful in This Course

Quantum mechanics by now is almost a century old. There have been countless books written on the topic, so there are many good sources for you to go to! It is important to learn how to develop your own understanding via *multiple* sources, including textbooks, scientific articles, online lecture notes, etc. The class lectures will also present topics in a unique way, so it will be important to *regularly attend class and take your own notes.* Recording your own notes will help reinforce the concepts in your memory. If you have to miss a lecture, please review the recorded lecture as posted on Canvas. *All lectures will be available online.* Supplemental reading material will also be provided during the course from time to time.

The majority of the learning will take place during the *completion of the homework assignments.* You should start on the assignments as early as possible, and not hesitate to ask questions about the problems. The homework should take up the majority of the work for this course outside of the classroom. You are expected to discuss with your fellow classmates, but any work you turn in should be your own. DO NOT copy solutions to problems from Internet sources. This is an act of **plagiarism** and is a serious offense as detailed in the Academic Honesty Policy.

Finally, please be sure to contact the instructor immediately about any concerns about credits earned on exams, homework, and the participation-related grade.

Materials and Textbooks

Since it is best to have some organizational principle for the topics covered, we will have a single recommended book, which is written in a modern style. The recommended book, however, does not cover path integration, so we will use segments from the other, optional books to cover this topic.

- Highly recommended textbook: *Quantum Physics* by Michel Le Bellac, Cambridge University Press; 1st Ed. ISBN: 978-1107602762. This is a nice new book on the subject that has a careful exposition. It does not cover path integration, however. I will provide different materials for this portion of the course.

- Optional textbook more popular in other versions of this course: *Modern Quantum Mechanics* by J. J. Sakurai and Jim J. Napolitano, Pearson Education; 2nd Ed. ISBN: 978-0805382914. This is a shorter book which is slightly more technical than the required. It is also a little bit more old-fashioned.
- The book I used as a graduate student is: *Quantum Mechanics* by Eugen Merzbacher, John Wiley & Sons; 3rd Ed. ISBN: 978-0471887027. The book is straightforward, but also rather technical and not particularly modern.
- You are under no obligation to follow the required book! If you do not like it, feel free to use another resource. I will be able to tell you which sections to read in your book of choice. Just ask! I recommend you search around for the resource that works best for you! I will also be posting my notes on the Canvas site.

Homework Assignments

Homeworks will be assigned roughly every two weeks. The homeworks will be due on Thursdays at the start of class. *Electronic* copies must be turned in to the instructor on the due date before midnight. Homework submitted after the deadline *will not count.*
Exception: students who are typesetting their homework using LaTeX will receive an extra 48 hours to complete the assignments. They may turn their homework in electronically via e-mail (pdf and TeX formats).

Remember that these assignments will constitute the most important component of the course. Please take your time and put down as many details as possible for the problems. Partial credit will be awarded for demonstrating a correct train of thought. On certain homework assignments, extra credit opportunities will be available.

Participation via Quizzes

Participation is an important component of any classroom. I strongly encourage you to attend class and to ask questions! To help you motivated to come to class, short quizzes will be given in the beginning of some lectures. These are intended to make sure you are regularly attending the lectures and following the class material. A record of your completion of these quizzes will be kept and will serve as the participation portion of your course grade.

Exams

There will be a midterm and final exam. These exams will be open textbook and open notes. Both of the exams will be timed take-home exams where you get a 24 hour period to complete and send in the exam. The times and dates of these two exams will be announced later.

Grades

The homework is the most important component of your success in the course. The grade distribution reflects this philosophy.

Grade Distribution	
Homework	30%
Participation Quizzes	10%
Midterm Exam	30%
Final Exam	30%

Letter Grade Distribution			
$\geq$ 90.00	A	70.00 - 72.99	C
87.00 - 89.99	A−	67.00 - 69.99	C−
83.00 - 86.99	B+	63.00 - 66.99	D+
80.00 - 82.99	B	60.00 - 62.99	D
77.00 - 79.99	B−	57.00 - 59.99	D−
73.00 - 76.99	C+	$\leq$ 56.99	F

Note that in some tests and homework assignments, a scaling may be applied. The scaling will not lower your grade.

Announcements

Please check the Canvas site for the course regularly for announcements and postings!

Communication

This is an in-person class, but I will have Zoom running during each lecture. Please attend in person, unless there are difficulties. If so, please *e-mail me* and we can use the Zoom room as a backup. It is also important that you do your best with asking questions whether you are in the classroom or on Zoom. We must have class participation during the lectures. In addition, the lectures will be recorded and are available to you upon request.

To facilitate the electronic communication, we will have a class Discord where we can chat. In addition, the office hours will be held over Zoom, but you can also come to my office in person. The permanent room number is: `https://tennessee.zoom.us/j/2840525544` This is the room for both the lectures and for office hours. I will generally try to keep the Zoom room open. So, feel free to stop by!

Academic Integrity

Working together on homework assignments and discussing with classmates outside of class is encouraged! However, work you turn in should be your own. Please take the time to demonstrate your own thoughts about the solutions and derivations. This is in keeping with the university honor statement:

> An essential feature of the University of Tennessee, Knoxville is a commitment to maintaining an atmosphere of intellectual integrity and academic honesty. As a student of the university, I pledge that I will neither knowingly give nor receive

> any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity.

Accommodations

Please contact the instructor about any concerns or any need for accommodations! The official statement on accommodations is:

> Any student who feels s/he may need an accommodation based on the impact of a disability should contact Student Disability Services in Dunford Hall, at 865-974-6087, or by video relay at 865-622-6566, to coordinate reasonable academic accommodations.

Additional contact information:

Disability Services
915 Volunteer Blvd/100 Dunford Hall
Knoxville, TN 37996-4020
e-mail: `ods@utk.edu`
website: `http://ods.utk.edu/`

Tentative Schedule of Topics

Weeks	Topic	Chapters
1-2	applications of quantum mechanics: hydrogen, benzene, ammonia, NMR	5
3-5	perturbation theory, variational methods, WKB approximation, spin-orbit coupling	14
6-7	propagators, path integration, Aharonov-Bohm effect	provided reading
8-10	scattering, Born approximation, partial wave expansion, optical theorem	12
11-13	identical particles, second quantization, bosons and fermions	13
14-15	quantization of the electromagnetic field	11, provided reading