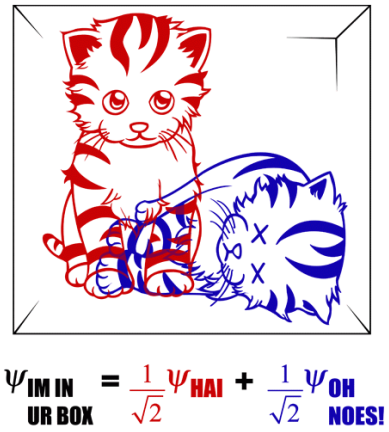
# PHYS 4701/6701: Quantum Mechanics I
# Syllabus

University of Georgia, Spring 2022
MWF Period 4 (11:30 AM-12:20 PM)

"Those who are not shocked when they first come across quantum theory cannot possibly have understood it."
— Niels Bohr




## Introduction

Quantum mechanics is one of the pillars of modern physics. It is the foundation for chemistry, condensed matter physics, atomic and molecular physics, nuclear and particle physics, and even optics. Quantum mechanics can be thought of as a generalization of Newtonian mechanics to systems where the wave-like properties of matter cannot be ignored. It has proven to be an enormously successful and practical physical theory.

From the beginning, quantum mechanics has been the source of difficult and often philosophical questions about the nature of reality, the role of measurement, and the interpretation of calculations. The mathematical foundations of quantum theory are still not fully established. As far as we know, the quantum principles apply universally, and yet the transition between "clearly" quantum and "clearly" classical systems is murky. You will probably find the central ideas in quantum mechanics to be abstract, unintuitive, or weird. But you will also find that won't stop you from successfully mastering the techniques of quantum mechanics.

## Course Description

This course is the first half of an upper-level sequence on modern quantum mechanics. The first semester focuses on understanding the fundamental principles and mathematical tools of quantum mechanics, and applying them to a variety of important "model" systems.

We won't have enough time in one semester to cover several important topics in quantum mechanics, such as three-dimensional systems, the hydrogen atom, perturbation theory, the variational method, identical particles, etc. For that, you'll want to take the second semester!

## Basic Information


**Instructor:** Professor Steven P. Lewis
307A Physics Building
Phone: 706-372-0971
Email: splewis@uga.edu


**Office Hours:** To be determined once student schedules have been handed in.

**Clinic (Optional):** If there is sufficient interest, an *optional* problem-solving clinic will be held weekly outside of class; day, time, and location to be announced.

**Official Textbook:** *Quantum Mechanics: A Paradigms Approach, 1st Edition*, by David H. McIntyre, with Corinne A. Minogue and Janet Tate, (Pearson, 2012).

**Optional Textbooks:** *Introduction to Quantum Mechanics, 3rd Edition*, by David J. Griffiths and Darrell F. Schroeter, (Cambridge, 2018).

*The Feynman Lectures on Physics, Vol. 3*, by Richard P. Feynman, Robert B. Leighton, and Matthew Sands, (Cal Tech, 1963). A free electronic version is available at http://feynmanlectures.caltech.edu/info/.

**Website:** Homework, handouts, grades, and other information will be distributed via eLearning Commons (elc.uga.edu).

**Prerequisites:** PHYS 3700 (Modern Physics); PHYS 3900 (Mathematical Methods of Physics); and PHYS 4101/6101 (Theoretical Mechanics I).

**Email:** You are expected to check your email *daily* for course announcements.

## Learning Goals

By the end of this course, you should be able to ...

- fully analyze and understand the general two-state quantum system;
- represent operators and quantum states in a given basis;
- solve eigenvalue problems to construct a basis and diagonalize a matrix, and understand the physical meaning of the results;
- reconstruct a plausible quantum state from eigenstates, given the results of a repeated measurement of an observable on a quantum state,;
- compute the commutation relationships among operators and understand their connection to simultaneous measurements and shared eigenvectors;
- calculate the expectation value and uncertainty of an observable given a quantum state;
- use the Schrödinger Equation to solve for the time evolution of quantum systems;
- explain the relationship between quantization and bound states;
- apply both position-space and momentum-space representations when analyzing systems, particularly for constructing wave packets;
- explain the qualitative behavior of your solution to any problem;
- evaluate the reasonableness of any solution through such methods as dimensional analysis, limiting cases, order of magnitude estimates, and verifying boundary conditions.

## Grading Policy

**Grade components:** At the end of the semester, I will compute a "semester average" from your performance on exams and homework, weighted as follows:

- Cumulative final exam: 36%
- First regular exam: 24%
- Second regular exam: 24%
- Homework average: 16%

**Letter grades:** Ranges for letter grades will be *no worse for you* than the following:

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|---|---|---|---|---|---|---|---|
| A+ | [Nonexistent] | B+ | = [83-85) | C+ | = [73-75) | D± | [Nonexistent] |
| A | = [87-100] | B | = [77-83) | C | = [67-73) | D | = [50-65) |
| A− | = [85-87) | B− | = [75-77) | C− | = [65-67) | F | = [0-50) |

Here a square bracket means the end point is included in the range, and a round bracket (i.e., a parenthesis) means the end point is not included in the range. Actual grade ranges may end up having lower cutoffs, depending on the overall level of performance.

**Final exam grade boost:** The comprehensive final exam is your opportunity to demonstrate that you have broadly and coherently mastered the course material. This is, after all, the main goal of the course. Therefore, I will give a grade boost for getting a higher grade on the final than for the semester as a whole, provided you haven't neglected the course during the semester. Here's how the boost works. At the end of the semester, I will calculate two letter grades for each student: one based on the formula given above ("formula-based grade") and one based *only* on the final exam ("final-exam grade"). If you meet ***all four*** of the following criteria, then the course grade I assign you will be one grade step higher than your formula-based grade (*e.g.*, B+ → A−); otherwise, your course grade will be your formula-based grade. The criteria for the grade boost are:

(a) you have not missed *any* regular exams,
(b) your average grade on regular exams is at the passing level (C− or better),
(c) your homework average is also at the passing level, and
(d) your final exam score *exceeds* your overall score.

**Regrade requests:** Any requests for a regrade of an assignment or an exam must be made *no later than one week after the item is returned*. Any regrade requests made after this one- week window will be declined without further review. Keep in mind that a regrade may end up raising *or* lowering your score. Correction of arithmetic errors made in totaling up points does not count as a regrade and is not subject to the above time limitations.

**Borderline grades:** Like any other measurement, grades possess a degree of uncertainty. Therefore, factors such as improvement *may* help borderline grades. (Lobbying, however, will not!) There is no extra credit in this course, so please don't ask.

**Withdrawals/Incompletes:** The *Undergraduate Bulletin* and the website of the Office of the Registrar describe University policies regarding withdrawals and incompletes. Make sure you are

familiar with them. This semester's withdrawal deadline is **Thursday, March 24**. Any student showing serious neglect for this course (*e.g.*, routinely failing to turn in homework, rarely attending class, etc.) may be asked to withdraw. Any student missing 3 consecutive classes or failing to turn in 2 consecutive homework assignments, without adequate prior explanation, will be considered eligible for an instructor-initiated withdrawal from the course.

If you are considering withdrawing from the course, you are advised to discuss your choice with me beforehand. In many cases, students are doing better in the course than they think.

A grade of Incomplete is intended for a student who has completed a substantial part of the course, but, *for non-academic reasons beyond their control*, was unable to complete all of the course. An Incomplete is not appropriate for a student who has missed a large portion of the course assessments, regardless of the reason. Nor is an Incomplete appropriate for a student who is unhappy with their performance in the course and wants to avoid getting a low grade. In both of these cases, withdrawal from the course is the appropriate action.

## Exams

**Number and rules:** There will be two regular midterm exams and a *cumulative* final exam. They will all be closed-book and closed-notes. You may use a calculator on exams *for arithmetic only*, not algebra, calculus, graphing, or information storage; all programs and memory registers must be cleared. Unless told otherwise, you must show work on each exam problem in order to receive full credit. Partial credit is awarded (based on your work) for incomplete or incorrect answers, so it is usually in your best interest to attempt every problem.

**Formula sheets:** I will provide you with a formula sheet on each exam, and will post a copy to eLC before the exam. Its purpose is to focus your studying on understanding rather than memorization. If you need an equation that's not on the sheet, don't memorize it; learn how to derive it from the equations that *are* given.

**Timing:** Regular exams will be two hours long and will be held in the evening (or some other suitable time) in order to give you extra time to complete them. The specific dates and times have not yet been determined. I will give further information on each exam before the exam date. Solutions will be posted to eLC after each exam has been graded.

**Missed exams:** If you need to miss an exam for a *legitimate and documentable* reason, you must contact me before the exam if at all possible, or else as soon as possible after the exam. Arrangements for dealing with missed exams will be made *only* for cases involving legiti- mate, documentable reasons and *only* if you notify me in a timely fashion. Do not presume that your situation or documentation merits an excused absence; that determination is not your prerogative. Instead ask me. *Unexcused exam absences will result in a grade of zero.*

**Final exam schedule:** Monday, May 9, 12:00-3:00 PM.

## Homework

**Logistics**: There will be 8-10 problem sets. Each will be due at the time and date given on the assignment sheet, unless otherwise stated. The pace of the class and changes to the schedule may necessitate changes to the due dates, which will be announced in class (and probably by email and on eLC). You will submit each problem set as a PDF document to the appropriate assignment drop box on eLC. If you write your problem set on paper (as most of you undoubtedly will), you will need to scan the pages and save them to a PDF. Several smartphone apps are available for this purpose (e.g., CamScanner, Adobe Scan). Detailed homework solutions will be posted to eLC after the homework is due.

**Citing sources**: On the last page of your homework write-up, list all classmates you worked with and cite any sources you used other than the course textbook, the course eLC site, or me. (e.g., Wolfram Alpha, Dr. Stancil, Wikipedia, etc.). If you have gotten this far, draw a picture of a bunny on the upper left corner of your Agreements sheet before scanning and submitting it. Read on.

**Grading:** Problem sets will be graded by a graduate student assigned as the grader for this course (I will grade exams) and returned to you in a timely fashion. Be sure to write legibly and explain your work in sufficient detail so that the grader can follow it easily. Rule of thumb: If the person grading can't understand it, then it's wrong. Disputes about the grading should be directed to me, and I will act as the final arbiter. Homework problems will be graded not only for correctness of the end result, but also on process.

**Dropping lowest score:** If you complete the online student evaluation for this course during the official period at the end of the semester when the evaluations website is up, then I will drop your lowest homework score when calculating your homework average for semester grades. If you do not complete the evaluation, then all homework scores will be included in your homework average. This policy serves two functions: (a) it gives you an incentive to submit a course evaluation, and (b) it compensates for unavoidable circumstances that may prevent you from a submitting homework assignment (*e.g.*, illness, scheduled event, paper due in another class, emergency, etc.).

**Late problem sets:** If you have a good reason for wanting an extension, ask me for it (in advance!), and I will probably give it, provided you don't abuse the privilege. *However, late problem sets will not be accepted or excused without prior approval*.

**Teamwork vs. plagiarism:** Teamwork can be a very good way of learning; so I encourage you to interact with your classmates on homework. However, do not mistake teamwork for plagiarism. It is unacceptable, for example, to divvy up the problems and then swap solutions. The work you hand in *must be your own*, not copied, reworded, or paraphrased from someone else's work. I will choose problems from a variety of sources, including my own imagination. It is likely that solutions for many of the assigned problems can be found on the internet or other sources. I know this, and now you do too. It is *unacceptable* for you to solve homework problems by "mining" for existing solutions. Nor is it acceptable to consult existing solutions for hints. Both of these constitute forms of plagiarism. Remember, the only way you will learn the subject is by sweating through problems on your own and/or with your study team.

**Final comment:** Working physics problems is *by far* the best way to learn physics, so it is important that you make every effort to do an honest and thorough job.

## Graduate/Honors Credit

**Who:** Graduate students in this course are enrolled in PHYS 6701. Undergraduates in the Honors Program wishing to receive honors credit for this course must transfer into PHYS 6701. (See your undergraduate major advisor.)

**What:** Students enrolled in PHYS 6701 will have an additional term project. I will communicate the details of this term project at a later time in a separate document.

**Effect on grade:** Your preliminary semester letter grade will be determined according to the section "Grading Policy" above and then (possibly) adjusted based on your performance on the term project. The purpose of the term project is to warrant graduate (or honors) credit for this course, distinguishing it from 4701. It is *not* designed to give 6701 students an opportunity for extra credit (or extra penalty) that the 4701 students don't have. Therefore, in most cases a satisfactorily completed term project will not change your final letter grade from the preliminary letter grade. However, a truly outstanding term project will be rewarded with a one-step increase in your letter grade (*e.g.*, B becomes B+, B+ becomes A−, A becomes A with a special gift from me). Similarly, a very poor term project will be penalized with a one-step decrease in your letter grade (*e.g.*, A− becomes B+, B+ becomes B, etc.). Finally, if you fail to submit the term project by the deadline, then your final grade will be two steps lower than your preliminary grade (*e.g.*, A− becomes B, B+ becomes B−, etc.). Specification of what "truly outstanding", "very poor", and "deadline" mean for the term project will be addressed in the document describing it.

## Academic Honesty

The University of Georgia has a comprehensive policy on academic honesty known as *A Culture of Honesty*. This policy not only describes required and prohibited conduct, as pertains to academic honesty, but also provides a detailed procedure for resolving matters of alleged academic dishonesty, including a description of consequences for honesty violations. The complete policy can be found online at http://www.uga.edu/honesty/. All students are responsible for knowing, understanding, and abiding by this policy. If you have any questions about the appropriateness of your work in this course, you are obligated to ask me for clarification.

I take issues of academic honesty *very seriously*, and it is my responsibility to uphold the University's policy. This means, among other things, that I will not hesitate to report my suspicions of dishonesty (*e.g.*, plagiarism, unauthorized assistance, etc.) to the Office of Instruction. This extends not only to exams but also to homework and (for PHYS 6701 students) term projects.

## Disability Accommodations

I will make every reasonable effort to accommodate students with documented disabilities. Any student requesting accommodations must provide documentation from the Disability Resource Center in a timely fashion.

## Student Distress and Mental Health

If your course performance is significantly affected by issues beyond your control, I urge you both to let me know and to seek assistance promptly from Student Care and Outreach:

https://sco.uga.edu or 706-542-7774

They will help you navigate any difficult circumstances you may be facing by connecting you with the appropriate resources or services. It is always easier to address exceptional circumstances when you raise these concerns as early as possible. Waiting until the end of the semester to take action may limit my ability to provide you with appropriate support.

UGA has several resources for a student seeking mental health services or crisis support:

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| https://www.uhs.uga.edu/bewelluga/bewelluga | (mental health) |
| https://www.uhs.uga.edu/info/emergencies | (crisis support) |

If you need help managing stress anxiety, relationships, etc., please visit BeWellUGA (see URL above) for a list of FREE workshops, classes, mentoring, and health coaching led by licensed clinicians and health educators in the University Health Center. Additional resources can be accessed through the UGA App.

## Course Topics and Schedule

The following schedule of topics is approximate and subject to change.

- Stern-Gerlach Experiments (Ch 1)
- Operators and Measurement (Ch 2)
- Schrödinger Time Evolution (Ch 3)
- Quantized Energies: Particle in a Box (Ch 5)
- Harmonic Oscillator (Ch 9)
- Unbound States (Ch 6)

I anticipate that the first regular exam will cover Chapters 1-3, and the second regular exam will cover Chapters 5 and 9 (and maybe 6). Again, this plan is subject to change. The final exam will cover the entire course comprehensively.

## Disclaimer

Unexpected circumstances and concurrent course assessment may require changes to the rules and information contained in this syllabus. If so, such changes will be done as fairly as possible, and you will be kept informed of the changes and their causes.