Physics 412—Syllabus Winter 2020

Administrative Information

Instructor: Chris Goedde
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Class hours: MTuWTh 9:40–11:10, 202 Byrne Hall

Office hours: MTuWTh 11:15–12:00, or by appointment

Textbook: *PHY 412 Course Notes*
The material covered by the course notes is similar to first two chapters of *Modern Quantum Mechanics* by J. J. Sakurai.

Final Exam: Tuesday, March 17, 4:20–5:50, 202 Byrne Hall

Course Content

Physics 412 is the first half of a two-quarter sequence in quantum mechanics at the graduate level. Graduate quantum mechanics courses differ from undergraduate courses more in their perspective and the required degree of mathematical sophistication rather than in content. As a result, most of the topics we discuss in this class will probably look familiar to you:

- Vector spaces, operators, and Hilbert space
- Measurements in quantum mechanics
- The uncertainty principle
- Time evolution; the Schrödinger equation
- The free particle in one dimension
- Step potentials in one dimension
- The harmonic oscillator

The biggest change from a typical undergraduate quantum mechanics course is that we will start by discussing Hilbert space, and the fundamental object of our studies will be the state vector $|\Psi\rangle$ rather than the wave function $\psi(x)$. Of course, before too long we will discuss the wave function and its relation to the state vector.

Course Structure and Format

The design of this course is based on the best practices developed by the physics education research community. Their work has shown that the best way to learn physics best is in a course that is structured around "active learning" principles. What that means for this class is that I will *not* be presenting the material to you through a traditional lecture, but that you will prepare for each class by reading the text. Our time in class will be used for discussion and analysis of the course material and group work to help you develop your understanding of quantum mechanics. In other words, this class will be run much like a graduate seminar.

There will be one reading assignments each week, due on Tuesday, with the exception of the first week of classes. All the reading assignments will be from the course notes. These reading

assignments will be the primary way in which you will encounter new material in this class, so it is vital that you complete them on time and as thoroughly as you can. Along with each reading assignment comes an online warm-up exercise, which is due at 11 am on the day of the assigned reading. In the first part of your response I want you to do two things:

1. Summarize or rephrase the most important ideas from that reading assignment *in your own words*. Your goal for this part should be to condense the mathematical concepts and ideas down to one or two paragraphs, each containing several sentences. In other words, your answer should be *your* summary of the material.

2. Articulate any questions you have about the reading assignment. If you feel that you don't have any questions, then you should write about what you found most interesting about the reading, and why.

In addition to the above, each warm-up assignment will include one or two free-response questions related to the material in the reading. I will use your responses to the warm-up exercises to help prepare the in-class activities for the week. The warm-up exercises will all be on D2L (<http://d2l.depaul.edu>), which we will also use as a repository for handouts, homework reports, and for copies of the in-class activities.

Assignments and Grading

In this class we will use a method of assessment called standards based grading. The goal is to address the following issues with traditional assessment methods:

- Students may cram for an exam but sometimes don't retain the information.
- Students can sometimes focus more on points than on learning (especially on the homework).
- If a student doesn't understand a concept or skill at the time homework is due or an exam is given, they lose the points, even if they clearly master the concept or skill by the end of the course.
- Expectations for what students should be learning or what skills they should develop are not always clearly articulated in the course syllabus.

The basic idea behind standards based grading is that there are certain things the department thinks you should learn in this class. Those are what we'll call the "standards." Typically each chapter that we cover in the course notes will have between one or two standards associated with it. For Physics 412, there are 8 content standards, one warm-up standard, and a summary standard, for a total of 10 standards. All the standards are listed on the last page of the syllabus.

You may choose to be assessed multiple times on each standard. The first assessment for each content standard will be a half-hour in-class assessment that will cover one standard. These will generally be on Thursdays, beginning during the third week of classes (January 23), and will continue at a rate of once each week throughout the quarter. On each assessment you will be evaluated on how well you demonstrated mastery of the standard covered by that assessment.

To help you prepare for the assessments, I will assign several homework problems each week. These homework assignments are meant for you to practice, so I will not be collecting and grading them. Instead, you will write a weekly homework report, describing which homework problems you completed, and which you still have questions about. This gives me the opportunity to monitor your progress and to answer your questions.

In addition to the homework assignments, each in-class assessment will be preceded by a take-home practice assessment. As with the on-line warm-up exercises, your score on the practice assessment will be based on your effort; you will receive credit for this practice assessment whether your answers are correct or not. I will also give you a score and some comments on each practice assessment you complete, so you will have some feedback about your progress toward mastery of the standard being assessed.

As the quarter proceeds you may choose to reassess on each of the standards. Every time a standard is reassessed, the evaluation of your mastery of that standard will be updated in my grade book. That evaluation might go up and it might go down, depending on your performance on the reassessment. Your overall grade in the course will be determined by the most recent assessment of your performance on each of the standards, so your final grade will reflect any improvement (or regression) that you show in your mastery of the standards during the quarter.

Reassessments will be done on an individual basis, outside of class. During the first four weeks of the quarter you may schedule up to two individual reassessments each week. From the fifth week onward, you may schedule at most one individual reassessment each week. You can schedule a reassessment in class or via email. To schedule a reassessment via email, send me a message stating what standard you would like to reassess and when you would like to meet. I am available for individual reassessments most days during the week, subject to my week-to-week availability. During the last week of the quarter we will have some optional in-class reassessments; these will not count toward your limit of one individual reassessment per week.

If you miss the initial assessment of a standard, you will receive an evaluation of "Unsatisfactory" for that standard. Of course you are free to reassess, but the reassessment will count as your individual reassessment for that week.

If you are more than 10 minutes late for an individual reassessment, or miss the reassessment entirely, you will not receive a score for the reassessment, but it will count as your individual reassessment for the week. If you need to reschedule an individual reassessment, you should do so at least 24 hours in advance.

The last day to reassess on any standard is Tuesday of finals week, March 17.

Your mastery of each standard will be assessed using the following rubric:

1. Unsatisfactory:

    - I need lots of help from my instructor (one-on-one).
    - I have low confidence on how to do the skills and need more instruction.
    - I need my textbook/notes at all times.
    - I do not understand the concept/skills.
    - I cannot correctly identify concepts and/or define vocabulary.
    - I cannot make connections among ideas or extend the information.
    - My responses lack detail necessary to demonstrate basic understanding.
    - I cannot articulate most of the main ideas involved in the standard.

2. Progressing:

    - I have a general understanding of the content/skills, but I'm also confused about some important parts.
    - I need some help from my instructor to do the skills correctly.

- I do not feel confident enough to do the skills on my own.
- I need my textbook/notes most of the time.
- I can correctly identify concepts and/or define vocabulary; however I cannot make connections among ideas and/or independently extend my own learning.
- My responses demonstrate basic understanding of some main ideas, but significant information is missing.
- My written responses contain some gaps in reasoning.

3. Acceptable:

   - I understand the important things about the content/skills.
   - I have confidence on how to do the skills on my own most of the time, but I need to continue practicing some parts that still give me problems.
   - I need my handouts and notes once in a while.
   - I am proficient at describing terms and independently connecting them with concepts.
   - I understand not just the "what," but can correctly explain the "how" and "why" of scientific processes.
   - My responses demonstrate in-depth understanding of main ideas.
   - My written responses are complete and logically ordered.

4. Polished:

   - I understand the content/skills completely and can explain them with confidence and in detail.
   - I can explain/teach the skills to another student.
   - I have high confidence on how to do the skills.
   - I can create analogies and/or find connections between different areas within the sciences or between science and other areas of study.
   - My responses demonstrate in-depth understanding of main ideas and related details.
   - My written responses are complete, logically ordered, and include narrative to explain my thinking.

The final standard, F–1, will be assessed using a traditional final exam. There will be no reassessments for this standard.

There are a total of 25 warm-up exercises for the quarter; 9 on-line reading assignments, 8 practice assessments, and 8 homework reports. For the warm-up standard, W–1, a minimum of 15 on-time responses are required for "Progressing," 18 on-time responses for "Acceptable," and 22 on-time responses for "Polished."

(Much of the above discussion of standards based grading, including the rubric, is borrowed from Professor Andy Rundquist of Hamline University.)

Your overall course grade will be determined by your mastery of the standards according to the following guidelines:

A range: At least 6 of standards S–1 through W–1 at "Polished", the rest at "Acceptable"; Standard F–1 at "Acceptable" or above.

B range: At least 4 of standards S–1 through W–1 at "Polished", the rest at "Acceptable"; Standard F–1 at "Progressing" or above.

C range: At least 6 standards at “Acceptable” or above, the rest at “Progressing” or above.

D range: At least 4 standards at “Acceptable” or above; at most 2 standards at “Unsatisfactory”.

The above guidelines represent the minimum competency necessary for each grade; students just meeting the minimum requirements for each grade should expect the lowest grade in that range, *e.g.* A−, B−, *etc.*

Physics 412 Standards

S–1: I can use a set of basis vectors to represent both states and operators.

S–2: Given a state vector $|\Psi\rangle$ and a Hermitian operator A, I can calculate the results of measurements of the observable A for a quantum ensemble in terms of the probabilities of possible results, the expectation value, and the uncertainty.

S–3: I can determine whether two operators are compatible; if they are not compatible I can use the uncertainty principle to set the appropriate limits on measurements of the corresponding physical observables.

S–4: I can interpret the density matrix for a quantum ensemble and use it to make predictions about the results of measurements.

S–5: I can use the Schrödinger equation to find the energy eigenstates and propagator for a quantum system described by a time-independent Hamiltonian.

S–6: I can use the wave function in position or momentum space to make predictions about measurements for a free particle in one dimension.

S–7: I can use the position space wave function to make predictions about measurements for a one-dimensional quantum systems with step potentials.

S–8: I can explain the relationships between the energy eigenstates of the simple harmonic oscillator and use the eigenstates to make predictions about measurements.

W–1: I can consistently complete the warm-up exercises and homework reports.

F–1: I can use the postulates of quantum mechanics to analyze physically interesting systems in one spatial dimension or described by a finite-dimensional Hilbert space.