Physics 460—Syllabus Spring 2020

Administrative Information

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Textbooks: *Physics 460 Course Notes*, compiled by C. Goedde, available on D2L

Course Content

Physics 460 is the second half of a two-quarter sequence in quantum mechanics at the graduate level. This quarter will build on the foundation we built in Physics 412. We'll begin with quantum mechanics in three dimensions, looking at both angular momentum and applications such as the hydrogen atom. We'll then move on to systems with more than one particle, and finish with some modern applications of quantum mechanics, such as quantum computing, quantum cryptography, and quantum teleportation. The list of topics and their location in the course notes is given below:

- Angular momentum (Chapter 1)
- Three dimensional examples (Chapter 2)
- Composite systems (Chapter 3)
- Entangled states (Chapter 4)
- Quantum Computing (Chapter 5)
- Modern Applications of Entangled States (Chapter 6)

Assignments and Grading

There will be one reading assignment each week, due on Monday, except for the first week's reading assignment which is due Wednesday April 1, and the reading the week of Memorial Day. The reading assignments will taken primarily from the Physics 460 Course Notes, which are available on D2L. In the second half of the class we will also mix some research papers in with the course notes as part of the reading. 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 reading assignment, which is due at 7 am on the day of the assigned reading. The first question asks you to 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. The second question asks for a short (one or two paragraph) summary of the important points of the reading. In addition, each reading assignment will include one or two free-response questions related to the material in the reading.

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.
- 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 460, there are 11 standards total (9 content standards, one final standard, and one warm-up standard), listed on the last page of the syllabus.

To help you prepare for the assessments of the standards, there will be a weekly homework report and practice assessment. You will submit these electronically, preferably as a single PDF, using the appropriate link on D2L. The homework reports, reading assignments, and practice assessments all contribute to your score on the warmup standard, W–1.

Assessments of the theoretical standards will be done by video. For each standard you will submit a short (5 minute or less) video showing your work and explaining, in your own words, what you did. I will distribute the problem or problems to be solved for each standard through D2L. Due dates for the assessment videos will be provided with each assignment.

If you do not submit an assessment video by the due date you will receive an evaluation of "Unsatisfactory" for that standard. Reassessments on the theoretical and computational standards can be done for any reason. If you wish to reassess on any standard, contact me through D2L and I will assign you a new problem (or problems) appropriate to that standard; you can then submit a new video explaining your work for your reassessment.

In order to keep everyone on a proper pace to complete the course in a timely fashion, *all reassessments must be completed within three week of the due date of the original assessment for that standard*.

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

- 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.
- 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.

· 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.

· 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, take-home final exam. There will be no reassessments for this standard.

There are a total of 27 warm-up exercises for the quarter; 9 on-line reading assignments, 9 homework reports, and 9 practice assessments. For the warm-up standard, W–1, a minimum of 15 on-time responses are required for "Progressing," 19 on-time responses for "Acceptable," and 23 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. The four mastery levels listed above will be converted to a numerical score according to the rubric:

Unsatisfactory: 0 points **Progressing:** 1 point **Acceptable:** 3 points **Polished:** 4 points

There are eleven standards for the course, so a total of 44 points is possible. Final grades will be assigned as follows:

A range: 40 – 44 **B range:** 35 – 39 **C range:** 31 – 34 **D range:** 26 – 30

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 460 Standards

S–1: I can apply the fundamental properties of the angular momentum operators and use and interpret their eigenstates.

S–2: I can analyze systems with intrinsic angular momentum (spin).

S–3: I can apply and interpret wave functions in three dimensions in Cartesian coordinates.

S–4: I can analyze three dimensional systems with spherically symmetric potentials.

S–5: I can apply the rules of composite Hilbert spaces to analyze two-particle quantum systems.

S–6: I can analyze quantum systems with more than one source of angular momentum (for example, spin and orbital angular momentum).

S–7: I can make predictions about systems described by entangled states and explain the EPR paradox and Bell's theorem.

S–8: I can analyze one- and two-qubit quantum networks.

S–9: I can analyze and explain applications of entangled states such as quantum teleportation and secure communication.

W–1: I can consistently complete the reading assignments, homework reports, and practice assessments.

F–1: I can use the postulates of quantum mechanics to analyze three-dimensional systems, two-particle systems, and systems with entangled states.