Quantum Theory (PHYS 450) Course Syllabus

Spring 2014 v1.0

1. Introduction to Phys 450:

Welcome to Quantum Theory and the world of the utterly strange!

Quantum mechanics is unique as far as I know in the fields of physics in that *what it means* is seriously debated in the physics and philosophy communities, and this debate has led to new avenues of experimental work. Many (most?) books at this level regard delving into these issues as something to hold at arms' length, perhaps by quarantining the discussion in an epilogue.[1] My own view is that no time is better than now to understand these issues; it's fundamental to quantum. Townsend has somewhat the same point of view and so we we encounter these puzzles in their natural habitat. In any case, rest assuaged that if you want to focus on simply *how it works* you can do that as well. Much of the semester is using your considerable resources to explore some very interesting physics. I hope you enjoy this material as much as I did (and do)!

2. Seminars

Quantum Theory will be taught in seminar format. Perhaps this format is new to you all so let me explain a bit about it. The typical seminar consists of a series of 15 ± 10 minute student presentations at the boards, punctuated by discussion. You take an active role in teaching yourselves. It is your class! There is but one rule: No Keynote, PowerPoint, or similar presentations. We'll take a 15 minute break in the middle of the 3+ hours to enjoy some treats.

Your presentations will roughly follow the textbook. I'll assign presentations in the "Guides." Some of the presentations will not involve challenging material but, in addition to being absolutely clear on the material, think carefully on how is best to present the material. I encourage you to view your presentations as opportunities to explore the subject - bring in other resources, mention articles, tell us something new. If you don't like Townsend's presentation, then tell us about some other author's presentation of the material. Make use of our wonderful library! Some presentations will be challenging, perhaps by explicitly referring you to journal articles, but most will not be beyond textbook material. You will get a flavor for what I have in mind from my own (few) presentations.

As with usual problem sets it is best to look over the material early to determine whether you will need to spend extra time preparing, asking questions, and researching the topic. This is even more critical in a seminar as the success of the seminar depends on all of us. Your presentations should be - above all - *clear* and well-prepared and thoughtful. Poorly prepared presentations are not acceptable. You may use any method of presentation that is the most effective. (No sitting and pointing at a piece of paper, please.) I have noticed that it is possible, although not easy, to match the effectiveness of the blackboard. These will be "informal presentations" in that you should feel free to ask a question at any time - or even launch a discussion.

During the week *previous* to the seminar you will have a problem set to work on. These problems should help you explore and master the material. With this preparation the discussions in seminar will be interesting, thoughtful, and may very well go beyond the basic material.

I realize that this is a challenging classroom environment! But (IMHO) it is, hands down, the best environment for learning physics. One of my major goals for the semester is for you to become proficient in teaching yourself. You will take a little time getting used to it. That is fine. I've listed some useful points below to help you along. I will also send you feedback via email during the semester.

[1] When I took this course, for instance, a bunch of us organized "gorilla seminars" so we would have an opportunity to read papers on the EPR paradox and discuss them. Fortunately those days are now gone.

2.1. **The Ideal, Suggestions, and Slogans:**

3. Seminars:

My Platonic Ideal of The Seminar: The professor provides a detailed syllabus of a subject which, if followed carefully, will build a solid foundation of the subject. The students, working together with the professor, learn and present the material in class in a way which is clear to everyone. Discussion is active, intellectually challenging, non-threatening, and pushes the envelope of understanding. In preparation every member has no problem asking others about a solution, an integral, or definition whether it is in class, in the common room, or in the dining halls. In seminar any remaining questions are discussed in depth resulting in new insights which, naturally, arrive with a blinding flash of light.

Here are a few suggestions to help you along. Slogans lead the more detailed descriptions.

(1) *Start early. Work slowly and carefully.* Nothing will help you better than to start preparing for seminar early. As good as they are, these chapters are not short stories; it would be unpleasant to read the entire chapter in one sitting. Further, read with a scratch pad and writing utensil; work through the presentation of the text. Schedule in plenty of time.

(2) *Do all the problems.* Dance is not learned by only watching a video; physics is not learned by only reading. To learn the subject one must try out the stuff by talking and writing about it and working through problems. For many of us this process has two purposes. One is to gain mathematical fluency. The other is to unravel the physics in the mathematics.

(3) *Minimize frustration!'* One of the aspects of the seminar experience that took me the longest to learn was the utility of asking a question. If you encounter difficulty, carefully formulate a question (often the question answers itself in this process!), then ask someone. If this person is madly preparing a midterm or a French buttercream, or does not know the answer then try someone else. In particular, do not hesitate to ask me (Science G052, x4919, smajor). If all else fails, go on to other problems and return to the question later.

(4) *Write clean and clear solutions* When writing solutions keep in mind that there is also a large difference in sketching a solution on a piece of scrap paper and writing up the solution so that a fellow student can read it easily (and that includes you!) As with much writing, keep your audience in mind. Keep your classmates in mind but also try thinking of yourself in 3 months. The logical argument of your solution should be clear on a first read.

(5) *For presentations: Be clear. To impress, exhibit novelty.* Much of what is true for solutions also applies to presentations. Clearly state the issue or problem, outline the tools needed, and proceed providing information when needed. Learn from your classmates' presentations. Feel free to skip algebraic steps once you have cleared it with the class. Show us (including me) something we don't already know, e.g. a new numerical solution or a experimental manifestation of a problem.

(6) *Preserve class notes.* The best policy is to prepare fully for seminar before we meet and write up summaries and/or complete solutions after the actual seminar. It is not easy to keep up. But your notes will be loads of help for the final, for graduate school classes, for qualifying exams, and even when you teach this course! Think of this as writing up notes from which you can relearn the subject.

(7) *Be clear about what you understand and what you don't.* It is never too early (or too late) to start being clear about what you understand and what you do not. There is a vast, amorphous plain between familiarity and understanding. Question your own understanding by trying it out on new situations. If your knowledge is not what is required, find the difference and learn from it.

(8) *Make a formula sheet* If you haven't already started, start keeping a sheet of paper with useful formulae so you can quickly answer questions such as, what is the generating function for Hermite polynominals?

We only meet 14 times during the semester, discussing about 1 chapter a week, so each seminar is critical. That being said, if you are really sick, it may be best for you to rest. Please let me know in advance if this is the case. It is also that time of year when you may have interviews and campus visits. Please let me know as soon as you know that there is a conflict.

Any absences that are not arranged ahead of time hurt the learning of your peers. Each such absence will cause you to loose one letter grade in presentations, number (1) in section 7.

3.1. **Timing and scheduling:** Because our seminar time is precious please plan on arriving, with your solutions copied, 5 minutes before the official start of seminar. We may (frequently) run a bit late. Please plan on it. If are unable to attend, please send me an email as soon as you know. Late notification hurts us all as I would not have time to reshuffle the presentations.

4. Texts:

John Townsend, *A Modern Approach to Quantum Mechanics* 2nd edition
Davies and Betts, *Quantum Mechanics* 2nd edition (optional)

5. Course info:

All materials will be available online. You can find them through the Courses tab on my homepage. The latest versions will be labeled by a version number in the top right of the first page.

6. Problem sets

We will have weekly problem sets that form the backbone of the seminar. Part of the role of seminars will be for you to fill in any gaps in your solutions. I strongly recommend that you write up final copies of your solutions after you have correct, complete solutions. I will not be grading, writing up, or distributing solutions. Please plan on leaving seminar with clean solutions, or at least, a very good idea on how to correct your solutions.

7. Grades:

There are 4 parts to the grade:

(1) Seminar participation and effectiveness (45%): Your presentations will be assessed for clarity and novelty.
(2) Mid-term: (25 %) One take-home midterm.
(3) Final (30 %): This closed-book final will be self-scheduled during finals week. More on this later.

8. A Reasonable Approximation to the Weekly Schedule

What follows is how things went in 2012, therefore it is preliminary! The meeting dates are updated for 2014.
Enjoy!

Seth Major
Science G052
x4919
smajor

Week	Date	Topic	Reading
1	26 January	Two state systems	Ch 1
2	2 February	Dirac notation & matrix mechanics	Ch 2
3	9 February	QM in 3D - angular momentum	Ch 3
4	16 February	Dynamics of 2 states systems	Ch 4
5	23 February	Addition of angular momentum	Ch 5
6	2 March	EPR Week!	Ch 5, EPR paper & more
7	9 March	1D wave mechanics revisited	**Exam** Ch 6
	14 & 30 March	*Spring break*	
8	30 March	Harmonic oscillator	Ch 7
9	6 April	3D wave mechanics	Ch 8
10	13 April	More 3D	Ch 9
11	20 April	Time independent perturbation theory	Ch 10
12	27 April	Fine structure & identical particles	Ch 11
13	4 May	Symmetry, multi-electron atoms	Ch 12
14	11 May	Time dependent perturbation theory	Ch 13 & 14