146 Philosophy of Physics: Quantum Mechanics

Christian Wüthrich Winter 2013

Class schedule:	TuTh 11:00am-12:20pm, WLH 2115
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This course offers an elementary introduction to some foundational problems in quantum mechanics. An excellent description of the basic problem treated in this course can be gleaned from the back cover of Jeffrey Barrett's *The Quantum Mechanics of Minds and Worlds*: "The standard theory of quantum mechanics is one of the most successful physical theories ever, predicting the behavior of the basic constituents of all physical things; no other theory has ever made such accurate empirical predictions. However, if one tries to understand the theory as a complete and accurate framework for the description of behavior of all physical interactions, it becomes evident that the theory is ambiguous, even logically inconsistent."

The core of the theory's ambiguity is captured by the so-called *measurement problem* (aka Schrödinger's cat paradox), which will be a central concern in this class. We will try to understand what exactly the problem is and study several proposed ways of solving it. Another focus of the course will be what physicists recently voted the most beautiful physics experiment of all times as it illustrates one of the most puzzling features of quantum mechanics, its non-locality, and the related Einstein-Podolsky-Rosen (EPR) paradox.

Accessibility. I intend the course to be self-contained. Early in the course, we will go through much of the technicalities necessary to understand foundational questions in quantum mechanics. In particular, I will assume you can follow the formalism developed in chapter 2 of David Albert's textbook, plus whatever little extra I do in lecture. What that means is that you'll need to understand the very basic linear algebra introduced by Albert (most of which is really not that hard). That said, some of the articles we will read use calculus, algebra, and probability theory. So if papers with the occasional derivative, integral and velocity in it cause you panic, then perhaps this course is not for you.

Prerequisites: Upper-division standing or permission of instructor.

Required texts

- David Z Albert, *Quantum Mechanics and Experience*, Harvard University Press (1992). This book is available at the Price Center Bookstore.
- There are links from the course web page to all other articles, except those that will be made available through e-reserves.

Course requirements and evaluation

The grade for this course will be determined by the total points a student earns from the three types of evaluation indicated below. I grade to the curve, i.e., the top 25-30% of the students in this class (including all who take it for a letter grade or a P/NP, but not including the withdrawals W) will get a grade in the A range (A+, A, A-), the next 25-35% a grade in the B range (B+, B, B-), the next 25-30% a grade in the C range (C+, C, C-), and the remaining 5-25% a D or an F. This is the minimum I guarantee; if the class has worked very well and no one deserves a D or an F, I will adjust the curve upwards, accordingly.

1. *Quizzes* (30 points): There will be **six short quizzes** during the quarter, each worth 5 points. They will be announced only in class one meeting before they will be held. No make-up quizzes will be given.

2. *Midterm paper* (30 points) [`http://www.turnitin.com`]: There will be a **take-home midterm paper** due on 14 February 2013 at the end of class. I shall hand out a list of paper topics fairly early in the course. For each day your paper is late, five points will be deducted from your point total, although no negative point totals will be given.

3. *Final exam* (40 points): There will be a **final exam** on 21 March, 11:30am to 2:29pm, in a location to be announced. This exam will consist of short identifications, one-paragraph-answer questions testing your comprehension of important arguments, as well as a question asking for an essay-length answer for which you must synthesize material. You are not allowed to use any books or notes or the like, i.e. the exam is 'closed books'. The final exam is cumulative, i.e. it covers all the material of the entire course.

The midterm paper must be submitted *both as hard copy as well as through* `http://www.turnitin.com` *by the due date* in order to earn credit. You must enroll at `http://www.turnitin.com` by creating a new profile. You will need the following course information:

Class ID: 5851075
Enrollment Password: phil146wi13

Note the difference between lower case 'l' and the numeral '1'. If you have any problems with using `http://www.turnitin.com`, you can contact the Instructional Web Development Center of Academic Computing Services at 858-822-3315 or iwdc@ucsd.edu.

The fine print

Students agree that by taking this course all required papers will be subject to submission for textual similarity review to Turnitin.com for the detection of plagiarism. All submitted papers will be included as source documents in the Turnitin.com reference database solely for the purpose of detecting plagiarism of such papers. Use of the Turnitin.com service is subject to the terms of use agreement posted on the Turnitin.com site.

You must observe the University's Policy on Integrity of Scholarship, which can be found at `http://students.ucsd.edu/academics/academic-integrity/policy.html`.

Make-up exams (for both midterm and final) will only be given under the most severe circumstances. The student who wishes to write a make-up exam must inform me (by phone or email) ahead of the time of when the exam is due (midterm) or takes place (final). In order to qualify for a make-up exam, appropriate evidence of the most severe circumstances must be produced by the student. I will determine, in consultation with the student, what qualifies as appropriate evidence.

Tentative schedule

Readings: for each session, the listed readings must be read in advance; the readings with an asterisk are background reading which will not be examined in either the quizzes or the final exam. SEP stands for *Stanford Encyclopedia of Philosophy*, a free online resource edited by Ed Zalta.

Date	Topic and readings
8 Jan	**Introduction: early history of quantum mechanics**
10 Jan	**Early history of quantum mechanics continued** Barrett, *The Quantum Mechanics of Minds and Worlds*, Ch. 1, pp. 1-11
15 Jan	**Superposition** Albert, Ch. 1 Albert, Ch. 2, pp. 17-43
17 Jan	**The mathematical formalism and the standard way of thinking about it** Albert, Ch. 2, pp. 43-60 Barrett, *The Quantum Mechanics of Minds and Worlds*, Appendix A, pp. 249-252
22 Jan	**Standard quantum mechanics continued** Barrett, *The Quantum Mechanics of Minds and Worlds*, Ch. 2, pp. 18-41
24 Jan	**Wrapping up the standard theory** *SEP entry on quantum mechanics, `http://plato.stanford.edu/entries/qm/`
29 Jan	**The Bohr-Einstein debate** Niels Bohr, 'Discussion with Einstein on epistemological problems in atomic physics'
31 Jan	**The Einstein-Podolsky-Rosen paradox** Einstein, Podolsky, Rosen, 'Can quantum-mechanical description of physical reality...' *Arthur Fine, *The Shaky Game*, Ch. 3, pp. 26-39.
5 Feb	**Bell's theorem** Bell, 'Bertlmann's socks and the nature of reality' *Mermin, 'Is the moon there when nobody looks? Reality and the quantum theory'
7 Feb	**Nonlocality** Albert, Ch. 3 Maudlin, *Quantum Non-Locality and Relativity*, Ch. 1, pp. 6-24
12 Feb	**Copenhagen and complementarity** Bohr, 'On the notion of causality and complementarity', *dialectica* 2 (1948) *Fuchs and Peres, 'Quantum theory needs no 'interpretation' ', *Physics Today* *SEP on the Copenhagen int., `http://plato.stanford.edu/entries/qm-copenhagen/`

Date	Topic and readings
14 Feb	**Finally: The measurement problem** Albert, Ch. 4 Maudlin, 'Three measurement problems', *Topoi* *Barrett, *The Quantum Mechanics of Minds and Worlds*, pp. 14-17 and 54-55 *Saunders, 'What is the problem of measurement?', *Harvard Rev Phil*
19 Feb	**Collapse** Albert, Ch. 5 *SEP on collapse theories, `http://plato.stanford.edu/entries/qm-collapse/`
21 Feb	**Dynamics by itself** Albert, Ch. 6
26 Feb	**Everett and many worlds** SEP on Everett, `http://plato.stanford.edu/entries/qm-everett/` Byrne, 'The many worlds of Hugh Everett', *Scientific American*
28 Feb	**Bohm and hidden variables** Albert, Ch. 7
5 Mar	**Bohm again** *SEP on Bohmian mechanics, `http://plato.stanford.edu/entries/qm-bohm/`
7 Mar	**A philosopher looks at quantum mechanics (twice)** Putnam, 'A philosopher looks at quantum mechanics' (1965) Putnam, 'A philosopher looks at quantum mechanics (again)' (2005)
12 Mar	**Determinism** Earman, 'Defining determinism' (1985) Wüthrich, 'Can the world be shown to be indeterministic after all?' (2011, selections) *SEP on causal determinism, `http://plato.stanford.edu/entries/determinism-causal/`
14 Mar	**Catching up and wrapping up**
21 Mar	**Final exam**, 11:30am-2:29pm, location TBA