Topics in Phil. of Physics: Puzzles of the Quantum (PHIL 20648)
Monday/Wednesday, 2:00–3:15 pm, Pasquerilla Center 107

Instructor: Jeremy Steeger
Email: jsteeger@nd.edu
Office: Malloy 103
Office Hours: Wednesday 11:00 AM to 1:00 PM / Thursday 2:00 to 4:00 PM in Malloy Hall, First Floor Alcove
Class Blog: TBD

This syllabus is subject to change.
Last updated: October 30, 2018

Course Description: Quantum theory is one of the must successful scientific theories we have. Its predictive success is astonishing. Suppose your friend guesses the distance from New York to Los Angeles and turns out to be correct to within a *hand's width*; that's how accurately quantum mechanics predicts the maximum wavelength of light that will dislodge electrons from helium atoms. But as successful as quantum theory is, it is also one of the most puzzling theories we have: to try to make sense of it, physicists have talked of many worlds hidden from our own, and of cats in 'superpositions' of being alive and dead. This course focuses on three puzzles of the quantum. First, we will discuss *ontology*: we will investigate what sorts of descriptions of the world are consistent with quantum theory. Second, we will discuss *logic*: we will debate whether there can be more than one logic that's correct and whether quantum theory pushes us to revise our logical notions. Third, we will discuss *probability*: we will ask how we ought to interpret the probabilities that quantum theory assigns to measurement events. What is the world like, how should we reason about it, and what are probabilities? These questions, fascinating in their own right, are also essential to understanding and improving our scientific inquiries.
Prerequisite(s): A 10000-level or higher philosophy course, a 10000-level physics course.
Credit Hours: 3

Required Texts:

- Sakurai, J. J., and Jim Napolitano. 2010. *Modern Quantum Mechanics.* Reading: Addison-Wesley Publishing Company.
- Rédei, Miklós. 1998. *Quantum Logic in Algebraic Approach.* Dordrecht: Kluwer Academic Publishers.

Course Objectives:
At the completion of this course, students will:

1. Be familiar with the basics of quantum mechanics.
2. Be knowledgeable about the major views in three key debates: the ontology of quantum mechanics, logical pluralism and quantum logic, and the nature of quantum probability.

Requirements:

- Participation and Problem Sets (33%)
  - *Problem Sets.* There will be two problem sets. You are encouraged to work together in groups; each group is expected to submit one copy of the problem set.
  - *Class discussions and blog comments.* You are expected to contribute to breakout discussions. (Use the blog posts to prepare!)
  - *Debates.* There will be three more formal *debates* for blocks 3, 4, and 5; the class will be divided into two teams, each defending one of two opposing positions. Debates consist of:
    - **Opening comments.** One-third of your team is expected to make opening comments defending your position. (Roughly 7 minutes each.)
    - **Questions.** One-third of your team is expected to come up with questions to challenge the opposing side. (Roughly one question per person.)
    - **Responses.** One-third of your team is expected to respond to questions from the opposing team. (Collaboration between the teams is encouraged!)
- Two Essay Assignments (33%)
  - There will be two short, 5–7 page essay assignments for this class.
  - For each essay, you will choose a sub-topic from a "block" to engage with more directly. For the first essay, you must choose a topic from Block 3; for the second, you must choose a topic from Block 4 or 5.
  - There will be suggested prompts for each essay, but you are not required to choose from these. However: if you wish to propose your own topic, you must meet with me to discuss it within the week that the prompts are posted.
  - You may choose *one* essay to revise and resubmit. If you take advantage of this option, you will be given the higher of the two grades received.
- Final Paper (33%)
  - You will complete one longer, 8–9 page essay assignment whose topic you will choose (but that fits within one of the three blocks: ontology, logic, probability).

Course Policies:

- **General**
  - You are required to have done the assigned readings and submitted responses to the blog prior to each class meeting (see below for the list of readings).
- **Academic Integrity**
  - It is your responsibility to familiarize yourself with the Academic Honor Code (http://fys.nd.edu/current-students/honor-code/).

Course Outline:
The weekly coverage is subject to change. When in doubt, consult the latest version of this syllabus (the version on the blog).

Week	Content
Week 1	*Jan. 16* Introduction: Historical Overview
	Block 1: Tools of the Trade
Week 2	*Jan. 21* The Theory and Its Interpretation Required readings: – Ruetsche, Laura. 2011. *Interpreting Quantum Theories.* Oxford: Oxford University Press. Chapter 1. – Sakurai, Sections 1.1 to 1.3. *Jan. 23* Basic QM: Fundamental Concepts Required reading: – Sakurai, Sections 1.4 to 1.5.
Week 3	*Jan. 28* Basic QM: Dynamics Required reading: – Sakurai, Sections 1.6 to 1.7, 2.1. *Jan. 30* The Logic of QM: The Spectral Theorem **Problem Set 1 due.** Required reading: – Rédei, Chapter 2.
Week 4	*Feb. 4* The Logic of QM: A Propositional Language Required reading: – Rédei, Chapter 5. *Feb. 6* The Logic of QM: Unsharp Measurements Required reading: – Busch, Paul, Marian Grabowski, and Pekka J. Lahti. 1996. *Operational Quantum Physics.* Section 11.3.3, "Measurements."

	Block 2: The Central Puzzles
Week 5	*Feb. 11* Puzzle 1: Nonlocality Required reading: – Maudlin, Tim. 2011. "Bell's Theorem: The Price of Locality." In *Quantum Non-Locality and Relativity*. *Feb. 13* Puzzle 2: Contextuality **Problem Set 2 due.** Required reading: – Handout.
Week 6	*Feb. 18* Puzzle 3: Incoherence? (Wigner's Friend) Required reading: – Wigner, Eugene P. 1964. "Remarks on the Mind-Body Question." In *Philosophical Reflections and Syntheses*, 171–84. – Castelvecchi, Davide. 2018. "Reimagining of Schrödinger's cat breaks quantum mechanics—and stumps physicists." In *Nature*. https://go.nature.com/2Omndyh *Feb. 20* Puzzle 4: Measurement Required reading: – Wallace, David. 2007. "The Quantum Measurement Problem: State of Play." In Dean Rickles (ed.), *The Ashgate Companion to Contemporary Philosophy of Physics*. Sections 1 and 2.

	Block 3: What Does QM say is Real?
Week 7	*Feb. 25* Non-Realists (Copenhagen/Pragmatism/QBism) Required reading: – Healey, Richard. 2012. "Quantum Theory: A Pragmatist Approach." *The British Journal for the Philosophy of Science* 63 (4): 729–71. *Feb. 27* Hidden Variables (Bohmian Mechanics and Modal Views) Required reading: – Goldstein, Sheldon. 2017. "Bohmian Mechanics." In *Stanford Encyclopedia of Philosophy*. https://plato.stanford.edu/entries/qm-bohm/ – Lombardi, Olimpia and Dennis Dieks. 2017. "Modal Interpretations of Quantum Mechanics." In *Stanford Encyclopedia of Philosophy*. Sections 1–4. https://plato.stanford.edu/entries/qm-modal/
Week 8	*March 4* Collapse theories Required reading: – Ghirardi, Giancarlo. 2016. "Collapse Theories." In *Stanford Encyclopedia of Philosophy*. Sections 5–6. https://plato.stanford.edu/entries/qm-collapse/ – Wolchover, Natalie. 2018. "Famous Experiment Dooms Alternative to Quantum Weirdness." In *Quanta Magazine*. https://bit.ly/2ybwU8M *March 6* Wave Function Realism Required reading: – Ney, Alyssa. 2015. "Fundamental Physical Ontologies and the Constraint of Empirical Coherence: A Defense of Wave Function Realism." *Synthese* 192 (10): 3105–24. – Emery, Nina. 2017. "Against Radical Quantum Ontologies." *Philosophy and Phenomenological Research* 95 (3): 564–91.
Week 9	**Spring Break**
Week 10	*March 18* A Deep ψ (Many-worlds & Consistent Histories) **Essay 1 due.** Required reading: – Wallace, David. 2012. *The Emergent Multiverse: Quantum Theory According to the Everett Interpretation*. Oxford University Press. Chapter 3. *March 20* **Debate.** Does QM tell us about the world? (Realists vs. Non-realists)

	Block 4: Does QM Push Us to Revise Logic?
Week 11	*March 25* Realist Quantum Logic Required reading: – Putnam, Hilary. 1975. "The Logic of Quantum Mechanics." In *Mathematics, Matter and Method*, 174–97. – Finkelstein, David. 1963. "The Logic of Quantum Physics." *Transactions of the New York Academy of Sciences* 25 (6): 621–37. *March 27* The Meaning of the Connectives Required reading: – Dummett, Michael. 1978. "Is Logic Empirical?" In *Truth and Other Enigmas*, 269–89. Cambridge: Harvard University Press.
Week 12	*April 1* Is Logic Empirical? Required reading: – Bacciagaluppi, Guido. 2009. "Is Logic Empirical?" In *Handbook of Quantum Logic and Quantum Structures: Quantum Logic*, Amsterdam: Elsevier. *April 3* One True Logic? Required reading: – Beall, Jeffrey C., and Greg Restall. 2000. "Logical Pluralism." *Australasian Journal of Philosophy* 78 (4): 475–93. – Franks, Curtis. 2015. "Logical Nihilism." In *Logic Without Borders*, Berlin: De Gruyter. – Novaes, Catarina Dutilh. 2012. "Towards a Practice-Based Philosophy of Logic: Formal Languages as a Case Study." *Philosophia Scientiæ* 16 (1): 71–102.
Week 13	*April 8* **Debate.** Does QM have something to say about 'true logic'? (Non-monists vs. Monists)

	Block 5: What Are the Probabilities in QM?
Week 13	*April 10* Interpretations of Probability: A Crash Course Required reading: – Galavotti, Maria Carla. 2008. "Probability." In *The Routledge Companion to Philosophy of Science*. – Cartwright, Nancy. 1974. "A Dilemma for the Traditional Interpretation of Quantum Mixtures." In *PSA 1972*, edited by K. F. Schaffner, and R. S. Cohen, 251–58. Dordrecht: Reidel. Optional reading: – Feynman, Richard P. 1963. *The Feynman Lectures on Physics*, vol. 1. Chapter 6: Probability.
Week 14	*April 15* A Chance of Collapse (Propensities and GRW) Required reading: – Suárez, Mauricio. 2007. "Quantum Propensities." *Studies in History and Philosophy of Modern Physics* 38 418–38. – Frigg, Roman, and Carl Hoefer. 2007. "Probability in GRW Theory." *Studies in History and Philosophy of Modern Physics* 38 (2): 371–89. *April 17* No Chance (QBism) **Essay 2 Due.** Required reading: – Caves, Carlton M., Christopher A. Fuchs, and Rüdiger Schack. 2007. "Subjective Probability and Quantum Certainty." *Studies in History and Philosophy of Modern Physics* 38 255–74.

Week 15	*April 22* Many-worlds is 'no worse off'? (Wallace-Deutsch) Required reading: – Wallace, David. 2012. *The Emergent Multiverse: Quantum Theory According to the Everett Interpretation.* Oxford University Press. Chapter 4. – Adlam, Emily. 2014. "The Problem of Confirmation in the Everett Interpretation." Sections 4, 5.1, and 5.2. *Studies in History and Philosophy of Modern Physics* 47 21–32. *April 24* Chances on the Modal View Required reading: – Dieks, Dennis. 2007. "Probability in Modal Interpretations of Quantum Mechanics." *Studies in History and Philosophy of Modern Physics* 38 (2): 292–310. Optional reading: – Ruetsche, Laura, and John Earman. 2011. "Interpreting Probabilities in Quantum Field Theory and Quantum Statistical Mechanics." In *Probabilities in Physics.*
Week 16	*April 29* **Debate.** Are there objective probabilities in QM? (Objectivists vs. Personalists) *May 1* **Final essays due.**