Philosophy 426, Philosophy of Physics: Quantum Mechanics
Spring 2026; Thursday 10 : 20am - 1 : 20pm
Rutgers Academic Building West, room 2150
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There is no question that quantum mechanics is empirically successful. What the theory says about the nature of the world, however, remains controversial. In this course, we will look at several different theories of quantum mechanics and examine a range of philosophical issues that arise for them, in a way that does not presuppose a background in quantum physics. In the first third to half of the course we will review the mathematics and physics of the standard theory. In the rest of the course we will survey alternative theories, comparing and contrasting the motivations for and difficulties faced by each. Special attention will be paid to the different pictures of reality according to each theory, realistically construed. Topics include the measurement problem; nonlocality; fundamental and nonfundamental physical ontology; the ontological status of the wavefunction; the nature of probability; scientific realism.

Readings

Required book: D. Albert, *Quantum Mechanics and Experience*
Optional book: J. Barrett, *The Conceptual Foundations of Quantum Mechanics*
Other readings are available on Canvas or online as noted below.

Prerequisites

It is strongly recommended that you have had some exposure to physics, at least at the high school level, and that you have had one previous philosophy course. However, this is not absolutely required; please discuss with me.

Requirements and grading

Reading for each class period: Assigned readings will not be very long, but they can be difficult. It is recommended that you read each assignment through once before class and then again after it is discussed.

Participation and attendance: 10% of your final grade. Attendance is mandatory; since quiz and exam questions will be based on what we cover in class, poor attendance is bound to lower your grade. If you are naturally quiet in class, you may send your thoughts and questions to me by email.

Note that if you miss a class, it is *your responsibility* to get notes and announcements from a classmate.

Weekly in-class quizzes: 50% of your final grade. Quizzes are short-answer comprehension checks. They will be held during the first 15 minutes of each class period, and will cover the material discussed during the previous class period. The lowest quiz grade will be dropped. *Quizzes cannot be made up.*

In-class final exam: 40% of your final grade. The exam will be cumulative, covering all the material from the semester.

Optional paper: If you wish to write a paper, you may choose to do so for credit in addition to the other assignments. You must discuss your topic with me in advance, and you must meet with me in person to discuss and defend your paper after you turn it in. If you choose to write the optional paper, your final grade will be as follows: 10% attendance and participation; 40% in-class quizzes; 25% final exam; 25% final paper.

Office hours

Thursdays 1:30-2:30pm or by appointment, 106 Somerset St. room 530.

Academic integrity

Each student in this course is expected to abide by the Rutgers University Principles of Academic Integrity. Rutgers' Academic Integrity Policy (10.2.13) states that students must ensure "that all work submitted in a course, academic research, or other activity is the student's own and created without the aid of impermissible technologies, materials, or collaborations." Any work submitted by a student in this course for academic credit will be the student's own work. More information on Rutgers' Principles of Academic Integrity is here:
`http://academicintegrity.rutgers.edu`

Course materials posted on the course website or handed out in hard copy are intellectual property belonging to the author. Students are not permitted to buy or sell any course materials without the express permission of the instructor. Such unauthorized behavior constitutes academic misconduct.

No use of generative AI tools is permitted and their use for any part of your work for this class will be treated as plagiarism.

Schedule

Readings are listed by the date they will be discussed. Details are subject to change during the semester. Please regularly check the syllabus on Canvas: it will be updated as needed. Note there is a no-device policy for this class. All electronic devices must be silenced and stowed away during class time. Exceptions will be made for needed accommodations: please discuss with me.

Jan. 22: Introduction to quantum mechanics

Overview of quantum mechanics and the departure from classical mechanics. Photoelectric effect and two-slit experiments; wave-like and particle-like behavior; interference phenomena. Spin; experiments with spin boxes; two-path experiments; superposition. Realist theories of quantum mechanics.

Reading: Albert ch. 1; Barrett, "Classical Mechanics" (ch. 1 of *The Conceptual Foundations of Quantum Mechanics*)

Optional: Barrett ch. 2; Maudlin, "Eight Experiments"; Feynman, "Quantum Behavior" secs. 1–5, available at

`https://www.feynmanlectures.caltech.edu/I_37.html`

Jan. 29: NO CLASS

Feb. 5: Mathematical formalism: preliminaries

Vectors and vector spaces; vector components and bases; operations on vectors; complex numbers and complex vector spaces; Dirac notation. Linear operators and matrices; eigenvectors and eigenvalues; the eigenvalue equation.

Reading: begin Albert ch. 2

Optional: Barrett ch. 3; Ismael, "Quantum Mechanics," available at

`https://plato.stanford.edu/entries/qm/`

Feb. 12: The standard formulation of quantum mechanics

The standard postulates and standard way of thinking about them. Representing physical states and observables. Illustrating with the formalism for spin. The standard way of thinking about superposition.

Reading: continue Albert ch. 2

Optional: Barrett ch. 4

Feb. 19: More on the postulates and formalism

Hilbert space; Hermitian operators; incompatible observables; uncertainty principle. Probability and the Born rule; linearity and the dynamics; the collapse postulate; the nature of measurement. Position and momentum; the wavefunction.

Reading: continue Albert ch. 2

Feb. 26: Describing the experiments

Systems with more than one degree of freedom; product states; nonseparable states; entanglement; the singlet state. Describing spin-box and two-path experiments with the standard theory and formalism. The standard way of thinking about these experiments.

Reading: finish Albert ch. 2

Optional: Barrett ch. 5

Mar. 5: Nonlocality

EPR argument; completeness and reality; nonlocality. Bell's argument and the lessons of Bell's theorem. Quantum mechanics and relativity.

Reading: Albert ch. 3

Optional: Barrett ch. 6; Einstein, Podolsky, and Rosen, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?"; Aspect, "Bell's Inequality Test: More Ideal than Ever"; Maudlin, "What Bell Did"; Mermin, "Bringing Home the Atomic World: Quantum Mysteries for Anybody"

Mar. 12: The measurement problem and collapse theories

Linearity of the dynamics; measurement and collapse. The measurement problem and the orthodox theory as failing to answer it. Collapse theories in general, GRW in particular. GRW's answer to the measurement problem.

Reading: Albert ch. 4; begin Albert ch. 5

Optional: Barrett ch. 7; Bell, "Against 'Measurement' "

Mar. 26: Collapse theories, continued

Position eigenstates and energy conservation; revising GRW. The tails problem; the wavefunction and particles in collapse theories. Positionless measurements; microscopic measurements.

Reading: Albert ch. 5

Optional: Albert and Loewer, "Tails of Schrödinger's Cat"; Barrett 8.1-8.3

Apr. 2: The bare theory; many minds

Quantum mechanics without collapse. The dynamics with nothing added; the bare theory. Single minds and many minds. Making sense of probability; empirical adequacy and empirical coherence.

Reading: Albert ch. 6

Optional: Barrett ch. 9, 10.5

Apr. 9: Many worlds
Everettian or many-worlds theories of quantum mechanics. Making sense of probability in many-worlds; the preferred basis problem; the role of decoherence. Fundamental and emergent ontology; functionalism about ordinary objects.

Reading: Albert ch. 6 through p. 115; Lewis, "Uncertainty and Probability for Branching Selves" secs. 1–3; Wallace, "The Emergence of Multiplicity"

Optional: Barrett ch. 10; Greaves, "Probability in the Everett Interpretation"

Apr. 16: Bohm's theory
Bohmian mechanics. Hidden variables; the guiding equation; configuration space; effective collapse and effective wavefunction; particles and the wavefunction. The nature of probability in deterministic theories in general and Bohm's theory in particular. Bohm's account of spin-box and two-path experiments; contextual properties.

Reading: Albert ch. 7

Optional: Barrett ch. 11; Goldstein, "Bohmian Mechanics," available at `https://plato.stanford.edu/entries/qm-bohm/`

Apr. 23: Wavefunction realism
Considerations for and against wavefunction realism. The ontological status of the wavefunction; configuration space and ordinary space; the macro-object problem. The wavefunction, particles, and macroscopic objects in different theories of quantum mechanics. The idea of a separable and local fundamental metaphysics. Primitive ontology; the wavefunction as nomological.

Reading: Albert, "Elementary Quantum Metaphysics" and "Wavefunction Realism"; Allori, "Primitive Ontology and the Structure of Fundamental Physical Theories"

Optional: Barrett ch. 8.4-8.5; Emery, "Against Radical Quantum Ontologies"; Ismael, "What Entanglement Might Be Telling Us: Space, Quantum Mechanics, and Bohm's Fish Tank"; Maudlin, "Completeness, Supervenience, and Ontology" pp. 3151 through the top of p. 3162 and "Can the World be Only Wavefunction?" esp. pp. 121–125; Ney, "The Virtues of Separability and Locality" and "Finding the Macroworld"

Apr. 30 Quantum mechanics and scientific realism
Does quantum mechanics create particular trouble for scientific realism? Traditional arguments for and against scientific realism. Interpreting a physical theory; partially interpreted theories; underdetermination of interpretation by theory; fundamental vs. effective theories; ambiguity as a theoretical virtue. Theoretical equivalence and deep metaphysics.

Reading: Jones, "Realism About What?" secs. 1, 2, and 4; Ruetsche, "Getting Real about Quantum Mechanics"

Optional: Barrett ch. 12; Ruetsche, "Exegesis Saves: Interpreting Physical Theories"; Saatsi, "Scientific Realism Meets Metaphysics of Quantum Mechanics"

Final exam: TBA. The exam will be cumulative, comprising short-essay questions on all the material covered during the semester.