Physics 88S: God Does Not Play Dice: Why Einstein Hated Quantum Mechanics

Spring 2019

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SEMINAR 1:
Location: PAB 2434
Time: Tuesday 4-4:50 pm
Course Website: https://ccle.ucla.edu/course/view/19S-PHYSICS88SA-1

SEMINAR 2:
Location: PAB 6107
Time: Wednesday 3:30-4:20 pm
Course Website: https://ccle.ucla.edu/course/view/19S-PHYSICS88SA-2

Course Description

"I don't like it, and I'm sorry I ever had anything to do with it." -Erwin Schrödinger, one of the founders of quantum mechanics

Quantum mechanics has revolutionized our understanding of the world and helped us build the modern technological era. However, the theory's fundamental principles and their justifications are seldom taught outside of the physics curriculum and are often hidden under dense vocabulary and high level mathematics. In this seminar, we will look at the foundational principles of quantum mechanics from the scientific perspective. We will also analyze the theory's philosophical implications.

The first part of the course will cover the basic fundamental principles of quantum mechanics. We begin by investigating the experiments that brought classical physics into question: the double slit experiments, the diffraction of matter, and Compton's scattering experiment. These experiments uncovered the wave-particle duality and spurred the development of quantum mechanics. In particular, we shall examine the formulation quantum mechanics centered about the Schrödinger Equation and the wave function. Understanding these ideas requires some knowledge of the mathematics of waves, which we shall also cover in a conceptual manner.

The rest of the course is then divided into two sections: mysterious aspects of quantum mechanics and not so mysterious aspects of quantum mechanics. Not so mysterious aspects of quantum mechanics include the Heisenberg Uncertainty Principle and superposition of the wave function. The main goal of the course is to discuss and analyze the mysterious aspects of quantum mechanics including the relationship between determinism and locality, quantum entanglement, interpretations of quantum mechanical reality, and free will. It was these topics that puzzled (and continue to puzzle) many of the world's best physicists and the founders of quantum mechanics themselves. Albert Einstein even attempted to prove that the theory was incomplete, claiming that "the wave function does not provide a complete description of the physical reality."

Background Knowledge

The course is open to students of all majors. You will not have to do any calculations and will not be evaluated on your mathematical capabilities. We will focus on understanding what the results of calculations mean and their philosophical implications about nature.

Learning Outcomes

Throughout the quarter, students will develop and demonstrate (see Assessments section) the ability to do the following:

- Discuss, explain, and summarize the aspects of quantum mechanics that are not mysterious
- Examine the aspects of quantum mechanics that are mysterious
- Compare, contrast, and analyze different interpretations of quantum mechanics

Assessments

Participation: Students are expected to engage with the material in class by interacting (actively listening and/or engaging in dialectic) with their classmates and me.

In Class Write-Ups: Each class will start with a brief ($\sim$2-4 sentences or bullet points) hand written response to a question that will guide that day's class. These will be collected and graded on effort.

Final Paper: There are three options for the final paper:

- Answer the following question: Which interpretation of quantum mechanics describes reality?
- Present your own interpretation of quantum mechanics. How is it different from previous interpretations?
- Elaborate on any of the questions from the write-ups.

This should be about 2-3 pages (you're welcome to write more, but 2-3 pages is enough for full credit). Formatting parameters: double spaced, times new roman 12 point font, 1 inch margins all sides, name in top right corner of every page.

Grading Policy

The course is graded pass/no pass. The weights of the items to be considered are below. A passing grade requires a minimum of of **70%**.

- **35%** Participation
- **25%** In Class Write-Ups
- **40%** Final Paper

Readings

The readings (include page length) are included in the schedule section. No formal textbook is required. All references or readings will be available for free online. For some weeks, the readings will be in the form of lecture notes posted on CCLE. Here are some additional resources that will not be used in the course but are useful to learn about the topic:

- Philosophical Interpretation: *Speakable and Unspeakable in Quantum Mechanics*, John S. Bell
- Historical Perspective: *The Age of Entanglement*, Louisa Gilder
- Technical Introduction: *Introduction to Quantum Mechanics*, David J. Griffiths

Office Hours

There will be no formal office hours, but I'm more than happy to discuss anything about quantum mechanics with students outside of class. Please email me to set up a meeting.

Electronics Policy

To foster an active and engaging learning environment, I request that all students refrain from using laptops and phones during class time. In the case of an emergency circumstance, please do not hesitate to do what you must do on your devices.

Academic Honesty

All students are expect to adhere to the UCLA standards of academic conduct (UCLA Student Code of Conduct). Any cases of plagiarism will be referred to the Dean of Students.

Resources

UCLA Center for Accessible Education (CAE) facilitates academic accommodations for students with disabilities. The CAE website outlines how to request these services at https://www.cae.ucla.edu/.

UCLA Counseling and Psychological Services (CAPS) provide mental health resources and provide 24/7 support at (310) 825-0768. CAPS is located on the west side of the John Wooden Center. More information is available at: https://www.counseling.ucla.edu/.

UCLA Campus Assault Resources and Education (CARE) provides free confidential support and advocacy to students who are victims of sexual assault, dating violence, domestic violence, and stalking. CARE can be reached at 310-206-2465 by phone and advocate@careprogram.ucla.edu by email. Their website is https://www.careprogram.ucla.edu/.

Schedule

This is a tentative outline of what the course will cover. Based on student interest and how our interactions go, topics could be added or omitted. Weekly readings are also included.

Week	Topic	Reading/Viewing
1	Wave-Particle Duality	Read: The Feynman Lectures Vol. 3: 1.1-1.5, R. P. Feynman, R. B. Leighton, M. Sands (5 Pages)
2	The Wave Function and Schrödinger's Equation	None
3	Waves	Read: Notes on CCLE (5 Pages)
4	Heisenberg's Uncertainty Principle	None
5	Collapse of the Wave Function	Read: Speakable and Unspeakable in Quantum Mechanics Ch. 18, J.S. Bell (4 Pages)
6	Copenhagen Interpretation	Read: The Copenhagen Interpretation of Quantum Theory, W. Heisenberg (12 Pages)
7	Entanglement: EPR Paradox	Read: Excerpts of communications between Albert Einstein and Niels Bohr (5 Pages)
8	Bell's Theorem	Watch: Bell's Theorem: The Quantum Venn Diagram Paradox, H. Reich (18 Minutes)
9	Many Worlds, Bohmian Mechanics	Read: Six Possible Worlds of Quantum Mechanics, J.S. Bell (15 Pages)
10	Quantum Mechanics and Free Will	Read: Is the Universe Deterministic?, V. Vedral (4 Pages)

***FINAL PAPER DUE ON FRIDAY, JUNE 7 AT 11:59 PM**