SYLLABUS

PHYS/PHIL 329

FOUNDATIONS AND PHILOSOPHY OF QUANTUM MECHANICS

Department of Physics / Department of Philosophy

Schmid College of Science and Technology / Wilkinson College of Arts, Humanities, and Social Sciences

Chapman University, Orange

SPRING 2020

Instructors

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Class Information

Class Times: Tuesdays and Thursdays 2:30pm-3:45pm

Location: 327 Hashinger Science Center (HSC)

Course Website

https://canvas.chapman.edu
Chapman is in the process of switching from Blackboard to Canvas. This course is one of the early adopters for Canvas. Resources explaining how to use Canvas are included in the course website. Feedback on the new system would be greatly appreciated.

Textbook

The foundations of quantum mechanics are a subject of current research and there is no undergraduate-level textbook that covers the entire subject. The course will feature readings from a variety of sources, which should be completed before the corresponding lectures. The readings will be posted on Canvas.

Description

Quantum mechanics is perhaps the most successful theory in all of physics, but the question of what it means has always been controversial. Ideas like multiple universes, signals that travel faster than light, and objects that do not have properties until you look at them, are common in the popular literature, and are taken seriously by some researchers too.

This course is about the foundations of quantum mechanics, which has as its central question, "what must the world be like if quantum mechanics is an (approximately) correct fundamental theory of physics?" Answering this question requires us to draw on the methods of physics, philosophy, and mathematics, but there are no prerequisites in these subjects other than high school mathematics, as we will build the necessary ideas and formalism from scratch.

Topics covered in this course include: quantum superposition, the formalism of quantum mechanics, multiple particles and properties, two path interference, qubits, the no-cloning theorem, quantum entanglement, quantum teleportation, ψ-epistemic modes (models in which the quantum state is a state of knowledge), the Einstein-Podolsky-Rosen (EPR) paradox, the measurement problem, nonlocality, contextuality, decoherence, and interpretations of quantum mechanics (spontaneous collapse theories, de Broglie-Bohm theory, many-worlds, and Copenhagenish interpretations).

Learning Outcomes

Course Learning Outcomes

After completing this course, students will be able to:

1. Recall the fundamental principles of quantum theory and explain how to use them.
2. Explain why the meaning of quantum theory is thought to be unclear.
3. Explain the measurement problem and the most prominent contemporary solutions to it.
4. Debate the merits of existing interpretations of quantum theory.
5. Communicate ideas and results in quantum foundations to a non-specialist audience.
6. Explain the importance of science to philosophy, and philosophy to science.

The Course Learning Outcomes above will be measured by the ability to

1. Answer conceptual questions about quantum mechanics in class and discuss responses with classmates.
2. Review literature and make coherent arguments for positions in written essays and/or the exam.
3. Solve physics and mathematics problems on problem sets and/or the exam.
4. Produce content on the foundations of quantum mechanics for the public in the semester-long assignment.

PHYS Program Learning Outcomes

1. Demonstrate knowledge and understanding of basic mathematics and physical principles used to model natural phenomena.

2. Demonstrate ability to convey physical concepts with mathematical expressions and/or computation, and effectively derive quantitative predictions from a model through

mathematical/computational analysis.

3. Demonstrate competency in using computer tools.

4. Demonstrate the ability to apply advanced knowledge of advanced mechanics, electromagnetism, thermodynamics and quantum physics to the solution of problems in physics.

5. Demonstrate the ability to effectively communicate information, scientific or otherwise, in both written and verbal form

6. Demonstrate the ability to write clear, organized and illustrated technical reports with proper references to previous work in the area.

7. Demonstrate the skills and motivation for continued self-education.

PHIL Program Learning Outcomes

1. Writing Ability to state and support a thesis, apply knowledge of critical reasoning, accurately interpret philosophic sources, and clearly communicate a balanced account in writing.

2. Critical Reasoning Ability to construct and analyze complex arguments, and distinguish good reasoning from bad.

3. Knowledge of Core Philosophical Fields PLO M&E: Metaphysics & Epistemology. Ability to demonstrate knowledge of some of the most important figures and theories in metaphysics and epistemology. 3H: History of Philosophy Ability to demonstrate a deep understanding of central figures, texts, and ideas from the Modern or Ancient and Medieval periods of the history of philosophy.

4. Ethical Reasoning: Ability to reason logically, effectively, and respectfully about ethical matters.

Course Policies

Attendance Policy

You are expected to attend class. However, if you need to miss class for a legitimate reason like illness or bereavement then you do not need to inform the instructors in advance. Students who do not attend any classes within the first two weeks may be dropped from the course.

No Electronic Device Policy

Due to their detrimental effect on learning, laptops, tablets, and similar devices are not permitted during class. You will be given one warning for use of such devices; further offenses may result in the loss of a reading quiz grade. If special circumstances require the use of such devices at some point during the semester, you must clear this with me in advance and provide the relevant documentation.

Make Up Policy

All assignments must be submitted by the due date. Extensions will only be permitted in exceptional circumstances, e.g. illness or bereavement, by arrangement with the instructors. Bear in mind that you are only required to submit 5 out of 10 assignments in this course, so instead of granting an extension we may recommend that you submit a different assignment.

The final exam must be submitted by all students by the due date. Since the due date is the end of

finals week, extensions are not possible for the final exam.

Policy on Working Together

Students may discuss essay assignments and problem sets with each other, but after doing so, are expected to complete the assignments on their own. Students must complete the final exam on their own, without discussion with other students. Copying work, either from a classmate or the internet, is plagiarism, which is a serious academic offense. Plagiarism or cheating in examinations will result in a final grade of F, or a more severe punishment.

Course Structure

Announcements

All announcements for this course will be posted on Canvas. Canvas has a sophisticated system of notifications whereby you can be informed of changes to the course via email or text/SMS. Please take the time to set your notification settings on Canvas during the first week of the semester. We strongly recommend that you set things up to receive notifications for important changes to the course, such as the addition of a new assignment or a change in due date. Due dates are always shown on the Modules page, your Canvas calendar, and the Syllabus page.

Reading and Reading Quizzes

Reading materials will be posted on Canvas before lectures. Students are required to complete the reading as well as a short reading quiz on Canvas before lectures. The reading quizzes are not intended to be difficult, but to asses your understanding of the material and give you an opportunity to raise any questions or confusions with the instructors before class. Although most lectures will have a reading, there may be a few that do not. This will be indicated on Canvas.

Reading quizzes are worth 10% of your grade, but your lowest three reading quiz scores will be dropped. This is mainly to allow for students who miss classes due to illness, bereavement, or other legitimate reasons. If you fail to complete more than three quizzes, and think you have a legitimate reason, you must discuss this with one of the instructors in order to avoid it affecting your grade.

Slides and Lecture Notes

During class, the instructor will display slides and use the whiteboard. Lecture slides and notes will be posted on Canvas after each lecture, so you do not need to take notes in class unless you want to. You should still bring a pen or pencil and paper to class, as some class activities will require them.

Essay Assignments and Problem Sets

As the students taking this course have a wide variety of backgrounds, the course is designed so that you may take a more mathematical or a more philosophical route through the material. During the semester, 5 problem sets, and 5 essay assignments will be issued, but only your top 5 scores on these will be counted towards your grade. We require that every student submit at least one problem set and one essay during the semester, and we strongly recommend that everyone attempt the first problem set in order to gain familiarity with the mathematics used in the course. Problem sets and essays are worth 60% of your final grade.

All assignments should be submitted on Canvas. If you choose to write your assignments by hand then please either use a document scanner (as included in many photocopiers or printers) or an app on your smartphone that is specifically designed to handle documents (an example is Microsoft Office Lens,

which is free to Chapman students). Please check your scans for legibility before submission. Sending raw photographs from your phone will likely lead to illegible images or file sizes that are too large to be reliably uploaded.

There will be no credit for assignments that are handed in late, but extensions may be granted by the instructor for legitimate reasons (e.g. illness or bereavement).

Final Exam

There will be a take-home, open-book, final exam worth 30% of your final grade. Half of the exam will consist of mathematical problems and the other half will be essay questions. You only have to complete half of the exam. If you complete more than that, then only your top scoring answers than make up half of the exam will be counted.

You are expected to work on your exam on your own, but you may discuss the exam with the instructors before submitting it. The due date will be strictly enforced unless there are serious extenuating circumstances, e.g. bereavement or illness. The exam is due at 11:59pm on the Friday of finals week (May 22).

The exam should be submitted on Canvas. If you choose to write it by hand, then it should be scanned following the same directions as for the other assignments.

Getting Help Outside Class

If you are struggling with the course assignments it is important to ASK EARLY and ASK OFTEN. Both instructors will have two hours of scheduled office hours each week. Prof. McQueen's scheduled office hours are 4-5pm on Tuesdays and Thursdays. Prof. Leifer's scheduled office hours will be decided via a Doodle poll during the first week of class. If you cannot attend Prof. Leifer's scheduled office hours you can schedule an appointment with him at another time by going to https://calendly.com/leifer This takes account of his availability and ensures that he will be in his office when you come.

Course Grade

There are three components to the course grade as follows:

- Reading Quizzes 10%
- Problem Sets and Essay Assignments: 60%
- Final Exam: 30%

Extra credit assignments may be given at the discretion of the instructors.

The grade boundaries will be:

A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
90-100	85-90	80-85	75-80	70-75	65-70	60-65	55-60	50-55	45-50	40-45	0-40

Grade boundaries may be adjusted downwards to avoid students missing a boundary by a very small amount.

University Policies
Chapman University's Academic Integrity Policy
Chapman University is a community of scholars that emphasizes the mutual responsibility of all members to seek knowledge honestly and in good faith. Students are responsible for doing their own work and academic dishonesty of any kind will be subject to sanction by the instructor/administrator and referral to the university Academic Integrity Committee, which may impose additional sanctions including expulsion. Please see the full description of Chapman University's policy on Academic Integrity at www.chapman.edu/academics/academicintegrity/index.aspx.

Chapman University's Students with Disabilities Policy

In compliance with ADA guidelines, students who have any condition, either permanent or temporary, that might affect their ability to perform in this class are encouraged to contact the Office of Disability Services http://www.chapman.edu/students/health-and-safety/disability-services/index.aspx. If you will need to utilize your approved accommodations in this class, please follow the proper notification procedure for informing your professor(s). This notification process must occur more than a week before any accommodation can be utilized. Please contact Disability Services at (714) 516-4520 if you have questions regarding this procedure, or for information and to make an appointment to discuss and/or request potential accommodations based on documentation of your disability. Once formal approval of your need for an accommodation has been granted, you are encouraged to talk with your professor(s) about your accommodation options. The granting of any accommodation will not be retroactive and cannot jeopardize the academic standards or integrity of the course.

Equity and Diversity Policy

Chapman University is committed to ensuring equality and valuing diversity. Students and professors are reminded to show respect at all times as outlined in Chapman's Harassment and Discrimination Policy http://www.chapman.edu/diversity/_files/harassment-and-discrimination-policy.pdf. Any violations of this policy should be discussed with the professor, the Dean of Students http://www.chapman.edu/students/dean-of-students/index.aspx and/or otherwise reported in accordance with this policy.

Student Support at Chapman University

Over the course of the semester, you may experience a range of challenges that interfere with your learning, such as problems with friend, family, and or significant other relationships; substance use; concerns about personal adequacy; feeling overwhelmed; or feeling sad or anxious without knowing why. These mental health concerns or stressful events may diminish your academic performance and/or reduce your ability to participate in daily activities. You can learn more about the resources available through Chapman University's Student Psychological Counseling Services here: https://www.chapman.edu/students/health-and-safety/psychological-counseling/
Fostering a community of care that supports the success of students is essential to the values of Chapman University. Occasionally, you may come across a student whose personal behavior concerns or worries you, either for the student's well-being or yours. In these instances, you are encouraged to contact the Chapman University Student Concern Intervention Team who can respond to these concerns and offer assistance: https://www.chapman.edu/students/health-and-safety/student-concern/index.aspx
While it is preferred that you include your contact information so this team can follow up with you, you can submit a report anonymously. 24-hour emergency help is also available through Public Safety at 714-997-6763.

Class Schedule

Final Exam due: Friday May 22, 11:59pm

Week	Tuesday	Thursday
1: Feb. 3-7	Introduction (Leifer & McQueen)	Superposition (McQueen)
2: Feb. 10-14	A Simple Mathematical Formalism (Leifer)	Quantum Mechanics (McQueen)
3: Feb 17-21	Multiple Particles, Multiple Properties (McQueen)	The Two Path Experiment (McQueen) Problem Set 1 Issued
4: Feb 24-28	How Much Information is in a Quantum System? (Leifer)	No Cloning and Teleportation (Leifer) Essay 1 Issued
5: March 2-6	The EPR argument and the Measurement Problem (McQueen) Problem Set 1 due	ψ-epistemic models (Leifer) Problem Set 2 Issued
6: March 9-13	ψ-epistemic models (Leifer) Essay 1 due	Nonlocality (Leifer) Essay 2 Issued
7: March 16-20	Hardy's Theorem and PBR (Leifer) Problem Set 2 due	Contextuality (Leifer) Problem Set 3 Issued
8: March 23-27	SPRING BREAK	SPRING BREAK
9: March 30 – April 3	Interpretation 1: Collapse Theories (McQueen) Essay 2 due	Interpretations 1: Collapse Theories (McQueen) Essay 3 Issued
10: April 6-10	Interpretation 1: Collapse Theories (McQueen) Problem Set 3 due	Interpretation 1: Collapse Theories (McQueen) Essay 4 Issued
11: April 13-17	Special Surprise Topic (Leifer) Essay 3 due	Decoherence and the Classical World (Leifer) Problem Set 4 Issued
12: April 20-24	Interpretation 2: de Broglie-Bohm Theory (Leifer) Essay 4 due	Interpretation 2: de Broglie-Bohm Theory (Leifer) Problem Set 5 Issued
13: April 27-May 1	Interpretation 3: Many-Worlds (McQueen) Problem Set 4 due	Interpretation 3: Many-Worlds (McQueen) Essay 5 Issued Final Exam Issued
14: May 4-8	Interpretation 3: Many-Worlds (McQueen) Problem Set 5 due	Interpretation 3: Many-Worlds (McQueen)
15: May 11-15	Interpretation 4: Copenhagenish Interpretations (Leifer) Essay 5 due	Interpretation 4: Copenhagenish Interpretations (Leifer)