Quantum Mechanics and Society
Honors 208
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Hours: MWF 11:00-12:00, and by appointment

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Course Description:

We moderns, raised as we are in an age of science, take it for granted that science is the pinnacle of epistemological methodologies. And why not, just look at the technological wonders that have developed from our scientific endeavors: medical devices that can save and prolong life; farming machines that substantially increase the agricultural productive power of humans; labor saving machines (including the PC that this syllabus was constructed on); and a grasp of reality that would make our predecessors blush with envy. Given all of this, have we not a right to be proud of our scientific achievements?

This course will examine the rise of modern science, with particular focus on the social impact that the scientific method has had on not only the West, but humanity itself. We will begin with an historical examination of the development of Western science, including its derivation from ancient Greek philosophic thought, through to the birth of mathematical science, including contemporary issues of methodological demarcation and revolution within science. For these last two points, we will focus on two primary Philosophers of Science who have been influential in the field: Karl Popper, and Thomas Kuhn.

Once we have established the foundations for modern science via history and philosophical methodology, we will turn our attention to a contemporary theory that has not only been the best tested scientific theory we have, but whose impact on society cannot be underestimated: Quantum Mechanics. We will study the historical development of quantum physics, from early work on quantized radiation and explanations for atomic spectra, through experimental confirmation of quantum entanglement and the fundamental probabilistic nature of reality. We will look at the discoveries and personalities, and discuss how this relates to our previous work on the philosophy of science and the nature of the scientific process. We will also grapple with what quantum physics tells us about the nature of the world in which we live, and how it is fundamentally inconsistent with both our intuitive beliefs about reality, and with classical physics (which dominated our understanding of fundamental reality through the 19th century, and which we still use for many practical purposes today).
Course Outcomes:

By the end of this course, students should be able to:

1. Evaluate material critically and develop reasoned positions (research paper, group presentation).
2. Conduct research on a topic, knowing how to evaluate sources (research paper, group presentation).
3. Explain the impact that scientific and philosophical concepts have had on society (essay exams, group presentation).
4. Understand the developmental nature of conceptualizations of reality (essay exams).
5. Explain the historical development of Quantum Mechanics and its impact on society (the entire course).

Required Texts:


Course Expectations:

1. Assignments:

Everyone will be required to keep abreast with the reading material. As much of this material will be new to the student we expect that you set aside time to read the material, and maybe even read it more than once. We are believers in dialogue as the best educational tool, dialogue between student and professor, but this is only possible if everyone keeps abreast with the reading assignments. Your ability to follow and contribute to classroom discussion will be improved if you complete all reading assignments prior to the class in which we are going to discuss them. To facilitate this process everyone will be required to come to class with questions regarding the reading assignment for that class.

There will be short weekly assignments associated with the quantum portion of the course. These will comprise 15% of your course grade.

2. Attendance:

Consistency of attendance is central to the educational process and our experience in the past has shown that students who attend on a regular basis do much better than those who do not. Yet, we look at you as young adults, hence responsible for your own actions, to that end there is no attendance requirement, but know that students who attend on a regular basis tend to do better on the graded assignments.
3. **Exams and paper:**

Grading will be determined through the assignments mentioned above, 3 short papers, a final research paper, and a group presentation. The short papers will be an opportunity for you to comment on the material that was covered in 1/3 of the course, each will involve a specific question, and each will be worth 15% of your final grade.

Your research paper will be between 7-15 typed pages in length, on an issue either dealing with the sciences connected with our authors and that interests you, or a topic within Quantum Mechanics (30% of your final grade). As with any research paper you are to have outside references and it is to be properly formatted and constructed. More will follow on the research paper; its requirements; and its submission.

Academic integrity is an issue that we take very seriously. The papers you will write will rely on other sources for information and substantiation of a position; hence you must be very careful to properly cite your use of information, ideas, or thoughts derived from someone else. For information on plagiarism see the College Catalogue, or a good writing guidebook such as Diana Hacker’s *Rules for Writers*. Also, remember that the Internet has made it both easy to find information, as well as to check for sources. Do not think that because you found information at some obscure web site that there is no need to reference the material. One final point, your papers will be submitted to [turnitin.com](http://turnitin.com), a subscription site that is both a learning tool and a source for checking for plagiarism.

4. **Oral Presentations:**

Students will give oral presentations during the last week of class, in groups of 2–3. In this presentation, you will tell the rest of the class about some impact of quantum mechanics on society today. Your goal is to answer the question: how is society different from what it would otherwise be given the influence of quantum mechanics? Of course, this can be a highly speculative topic that is better in the realm of alternate-historical fiction rather than a class presentation, so it will be incumbent upon you to base your presentation as much in research and documented reality as possible. As one (too big and PhD-thesis-sized) example, you could explore how the solid-state transistor, which relies entirely on the quantum mechanical properties of matter, shapes the way that extended families keep in touch as compared to the bulk of the 20th century, and to an earlier period (when long-distance travel was not as easy as it is today). Given that all microchips ultimately build on the solid-state transistor, and thus all computers and related technology (including those devices we call “phones”), clearly this is a gigantic impact. Your group oral presentation will comprise 10% of your course grade.

4. **Classroom expectations:**

First, it is desirable that a certain demeanor be maintained in the classroom. Please refrain from holding side conversations during the class with other members of the course. This is disturbing for both your fellow students and professors, and distracts from the academic environment. If
you have a question about the material ask us, not your classmate, as chances are that others also have the same issue.

Use of cell-phones and other electronic devices in class will not be tolerated. Both instructors have, over time, become increasingly curmudgeonly in regards to this as they tend to be a disturbance and distraction not only to the user, but to all in the classroom; any potential pedagogical value they may have as an information gathering tool is overwhelmed by their drawback as a distraction. As such, all cell-phones and tablets must be turned off during class, no exceptions.

**Course Chronology**

The chronology below outlines what we will be doing on Monday and Wednesday of each week. This chronology will be subject to change as we make our way through the course; we will not stick to it slavishly. Every Friday, we will be working on learning some of the basics of quantum theory, with the goal of understanding what it means when quantum mechanics talks about entangled particles, and how physicists make predictions in simple quantum systems. **No calculus is required for this part of the course!** Your instructor has taught this same material to general students (i.e. not physics majors, not people who have taken calculus, and not honors students) in the past, and it worked! You will only need a background in high-school algebra; you will learn the (not very complicated) additional math you need during this course. In the end, you will be able to have some insight into the actual quantitative quantum theory.

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<th>week</th>
<th>topic</th>
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<tbody>
<tr>
<td>1.</td>
<td>A methodological distinction: <em>mythos</em> versus <em>logos</em>, two methodologies for answering the “big questions” and how the reasoned approach to reality became the foundation of Western thought.</td>
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<td>2.</td>
<td>The birth of modern science: Francis Bacon and the drive towards experimentation as the means obtain the secrets from nature, secrets that nature keeps hidden. A transitional phase from the influence of the Church to scientific discovery.</td>
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<td>4.</td>
<td>A patent clerk rides a trolley, the revolution that Albert Einstein started with the papers from his “golden year”. A revolution in the way things move, and our measurement of time. <strong>First Short Paper</strong></td>
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<td>5.</td>
<td>Logical Positivism, the <em>Vienna Circle</em> and the impact that it had on science.</td>
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With the impact of Einstein on modern physics, Karl Popper poses a question: What is it that demarcates science from pseudo-science? What differentiates Freudian psychology from Einstein’s relativity.

Popper and the problem of inductive reasoning and its significance to empirical experimentation, a reexamination of the problem that Hume first proposed.

Kuhn, what is it that precipitates revolution in science? Why would one give up a position, and especially one that seems to work?

Further examination of Kuhn’s understanding of revolution and the process that leads to paradigmatic foundations in a science, especially an understanding of the educational realities that follow once a paradigm is established.  *Second Short Paper.*

The cracks in classical physics: We'll look at the earliest experiments that pointed towards the need for a quantum theory, and the experiments and observations that were difficult or impossible to reconcile with classical physics. This will lead to the first theory of the atom, proposed by Bohr who postulated quantized energy levels for electrons in atoms. Bohr was able to explain the observed spectrum of Hydrogen, as well as the general structure of the Periodic Table of chemistry. (Gribbin Chapters 1-4)

Wave-particle duality, and early attempts to formulate a quantum theory. The notion of photons (rather than waves of light) and of things like electrons as waves (rather than particles) was considered absurd by many at the time, even as experimental evidence mounted that both had to be taken seriously. This would lead to the development of quantum theory using formulations that physicists still use today.  (Gribbin Chapter 5-7)

Uncertainty, Interference, and Entanglement: quantum physics produces some surprising statements about reality. Some physical quantities are fundamentally uncertain; it's not just that there is imprecision in our measurements, but that the physical quantity *does not have* a precise value. An electron moving through a system can apparently move through multiple paths at the same
time, and somehow interfere with itself. Physical quantities only seem to take on definite values when we measure them… suggesting that we are perhaps somehow "creating reality" by observing it. (Gribbin Chapter 8-9; EPR paper; Mermin "Moon" article) Third Short Paper

13. Collapsing Waves and Multiple Worlds: to this day, the "measurement problem" and its disturbing suggestions about the nature of reality remain a conundrum. This has led some physicists to honestly believe that, in a sense, our Universe is constantly splitting into multiple parallel universes, each containing the different result of probabilistic quantum processes. (Gribbin Chapter 9-10)

14. Quantum Computers and Quantum Cryptography: quantum physics allows us to predict the results of huge numbers of experiments, has allowed us to create the basis of today's technology (for instance, transistors and lasers), and points to a fundamental nature of reality that is intrinsically weird. But what has it done for us lately? Beyond the pure intellectual pursuit of trying to understand the nature of our world, people are trying to build useful devices that are fundamentally quantum in nature, which would not be possible (even inefficiently) under classical physics. (Reading TBD) Research Paper

15. Oral presentations