The Quantum World

This course presents revolutionary developments in science. These developments have given us transistors , lasers, computers, nuclear power and many more devices have the potential for transforming our lives that is beyond our present imagination. Along with its highly inspiring history to resolve intellectual crisis of the 20^{th} century, and a close look at the lives of many geniuses, it addresses the inherent aesthetics, the simplicity and the weirdness of the laws of nature.

Tentative Outline

In an hour and 15 minute class, I will lecture for first 45 minutes. The next 30 minutes will be devoted to discussing the book " Fundamentals" by Frank Wilczek. Here is a tentative list of topics covered in 14 weeks of the classes.

- Week 1: Classical vs Quantum World:

  As a warm up, we will begin with the planetary model of an atom where electrons encircle the nucleus somewhat analogous to the way planets encircle the sun. This picture where we try to apply classical laws or Newtonian physics to the atoms lead to lots of problems. We will watch Brian Greene's video:

  <https://www.youtube.com/watch?v=YoQYnhHQ95U¿

  describing a "though experiment" with electrons where we discover that the electrons behave neither like particles nor like waves... Welcome to the quantum world.

  Before embarking on a long journey to comprehend the quantum world, we will further warm up by reading and discussing Frank Wilczek's article:

  <http://www.frankwilczek.com/Wilczek_Easy_Pieces/319_World's_Numerical_Recipe.pdf>

  This article provides the essence of what quantum science is. Wilczek says that quantum science began in Pythagorean days (600 B.C) when Pythagorus had the vision that "All Things are Whole Number", that is - the integers. In quantum physics, whole numbers (or

the quantas) are the key to scientific rules. Wilczek also argues that, at its heart, quantum science is a simple theory as everything can be expressed in terms of two or at at most four quantities.

- Week 2 : Continue our discussion of Wilczek's paper.
- Week 3 : Pre-Quantum era: Particles and Waves; and their characterization(mass and charge for particles ; frequency, wave length, amplitude for waves)
- Week 4-7: Quantum Revolution: Historical developments

  (1) How the Radiation coming from a toaster led to the birth of quantum science (Max Planck's Revolutionary Theory of Quanta)

  (2) All Lights (Infrared, ultraviolet etc..) consist of pockets of energy - photons: Einstein's theory of light quanta

  (3) Light *acts* as billiard balls (Compton Effect)

  (4) Some is definitely wrong with classical theory : Atom is unstable.

  Bohr proposes revolutionary model of atom that explains its stability and also the colors of light from sun.

  (5) Wave-Particle Duality : de-Broglie theory unifies wave and particle picture

  (6) Rewriting the laws of Nature: Heisenberg and Schödinger Theory replaces Newtons's Laws of Nature.

  Probabilistic Nature of Laws of Nature ; Heisenberg uncertainity principle

- Week 8-9

  (1) Quantum Spin: Discovery..

  (2) Why Quantum spin is key to our existence: Bosons and Fermions

  (3) Applcations: NMR and Pet Scans and Quantum computers

- Week 10: Discovery of Anti-Matter... Dirac's equation - Piece of Magic- Electron must have a partner- anti-electron (positron);
  What happens when particle-antiparticle collide ?? Richard Feynman's Simple diagrams provide the answer

- Week 11- 12 : Quantum Physics at Macroscopic scale:

  Lasers, Superconductivity and Quantized Resistance

- Week 13-14 Quantum Entanglement, Dark Energy Dark Matter

  Our Future in the Quantum World: Quantum Cryptography, Quantum Computers, Quantum Teleportation and much more...

Grading Policy

(1) Class Participation: 25 percent (includes book discussion)
(2) Quizzes in class: 25 percent
(3) In class presentation on one of the Nobel prize winner in quantum science: 25 percent

(LIST of some of the NOBEL Prize Winners in Quantum Physics Max Planck, Albert Einstein, Louis de Broglie, Neil Bohr, Arther Compton, Werner Heisenberg, Erwin Schrödinger, Wolfgang Pauli, Paul Dirac, ,Richard Feynman)
(4) In class presentation on selected topics of your choice from the book " Fundamentals" : 25 percent
Note that there is NO final exam.
EXTRA CREDIT: You can also earn extra credit, upto 25 percent with " Creative Projects" such as doing a skit on quantum revolution, writing a poetry about quantum world or some painting or drawing such as Mount " Quantmore" that appears on the class web page.

Other Information: Cell phones and other communicative devices are not to be used during class. Engaging in activities not related to the course (e.g., gaming, email, chat, etc.) will result in a significant deduction in your participation grade.

All registered students for this class must have working audio/video on their computer. Students who signed on but do not respond when called during class discussion will be marked absent. If this occurs more than once, your class particilation grade will be F.

We seek to create a learning environment that fosters respect for people across identities. We welcome and value individuals and their differences, including gender expression and identity, race, economic status, sex, sexuality, ethnicity, national origin, first language, religion, age and ability. We encourage all members of the learning environment to engage with the material

personally, but to also be open to exploring and learning from experiences different than their own Disability Services at George Mason University is committed to upholding the letter and spirit of the laws that ensure equal treatment of people with disabilities. Under the administration of University Life, Disability Services implements and coordinates reasonable accommodations and disability-related services that afford equal access to university programs and activities. Students can begin the registration process with Disability Services at any time during their enrollment at George Mason University. If you are seeking accommodations, please visit http://ds.gmu.edu/ for detailed information about the Disability Services registration process. Disability Services is located in Student Union Building I (SUB I), Suite 2500. Email:ods@gmu.edu — Phone: (703) 993-2474