Quantum Mechanics: Uncertainty, Measurement and Entanglement

Arts & Sciences 1138.xx, Freshman Seminar

1 Semester-hour Credit

Day/Time: Monday, 1:50 PM Room: Smith Laboratory 1094

Professor: Bill Putikka
2180 Physics Research Building
putikka.1@osu.edu
Office Hours: By appointment

Course Description: Quantum mechanics is the *lingua franca* of modern physics. Students taking an introductory physics course, however, typically only experience a limited introduction to quantum ideas at the end of the year. This one credit seminar will provide an introduction to the ideas of quantum mechanics at a mathematical level suitable for first year students without requiring calculus. Conventional intuition about measurement does not apply to quantum systems, as captured in the Heisenberg Uncertainty Principle. This course explores this issue through the electron's magnetic moment. Furthermore, entanglement describes what happens when mutiple quantum particles interact, leading to profound changes in our thinking about objective reality. This point bothered Einstein and led to his belief that quantum mechanics is incomplete. We will consider the issues that bothered Einstein through interacting magnetic moments. Our approach permits us to do the quantum mechanical calculation and compare it to a common sense analysis favored by Einstein and show that the two disagree. Recent experiments agree with quantum mechanics, not Einstein.

Course Objectives:

1. To learn the nature of quantum states and observables.
2. To study the limits on measurement in quantum mechanics.
3. To investigate the challenges to common sense concepts of reality posed by entanglement.
4. To apply quantum mechanics to physical systems and determine their properties.

Required Text: Jordan, T. (2005), *Quantum Mechanics in Simple Matrix Form*, Mineola, NY, Dover, ISBN 0-486-44530-5.

Course Policies: Students are expected to attend class and participate in the course discussions. Each student should bring to class two written questions or comments based on the reading and problems for that class. Physics is a full-contact sport - active engagement with working the problems is crucial to learn the material. Students need to work out the assigned homework problems in the text for each class. Discussion of the homework problems with other students in the class is strongly encouraged, though each student should turn in their own work.

Grading: Satisfactory/Unsatisfactory (S/U)

A satisfactory grade requires an overall score of 70%

Class Participation: 40%

Homework: 60%

Academic Misconduct: It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term academic misconduct includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct (http://studentlife.osu.edu/pdfs/csc_12-31-07.pdf).

Students with Disabilities: Students with disabilities that have been certified by the Office for Disability Services will be appropriately accommodated and should inform the instructor as soon as possible of their needs. The Office for Disability Services is located in 150 Pomerene Hall, 1760 Neil Avenue; telephone 292-3307, TDD 292-0901; http://www.ods.ohio-state.edu/.

Biographical Statement:I am currently a professor in the Department of Physics. I have taught introductory physics courses for 20 years on the Mansfield Campus of Ohio State. My research interests are in the area of theoretical condensed matter physics and I have wrestled with the short shrift quantum mechanics receives in a standard introductory physics course for many years. I earned my doctoral degree from the University of Wisconsin Department of Physics. Prior to joining OSU I was a NATO postdoctoral research fellow at the ETH in Zürich, Switzerland and a postdoctoral research associate in the Department of Physics at the University of Florida and at the National High Magnetic Field Laboratory at Florida State University. I have been twice named a Kavli Institue for Theoretical Physics Scholar at the University of California Santa Barbara. In my research I do numerical calculations for models of strongly correlated electrons motivated by high temperature superconductors. I also do phenomenological calculations for the relaxation of electron magnetic moments in semiconductors, a topic of importance to spintronics.

Course Schedule

Aug 29	pp. 1 - 18	Imaginary Numbers Homework: Chap. 2 Prob. 1 - 7
Sept 5		LABOR DAY - NO CLASS
12	pp. 19 - 36	Matrices, Pauli Matrices Homework: Chap. 3 Prob. 1 - 7, Chap. 4 Prob. 1 - 6
19	pp. 37 - 59	Vectors, Probability, Basic Rules Homework: Chap. 5 Prob. 1, Chap. 6 Prob. 1 - 6, Chap. 7 Prob. 1
26	pp. 60 - 81	Spin and Magnetic Moment, First View, All Quantities Made From Spin Homework: Chap. 8 Prob. 1, Chap. 10 Prob. 1 - 5
Oct 3	pp. 82 - 96	Non-negative Quantities, What Can Be Measured Homework: Chap. 11 Prob. 1 - 2, Chap. 12 Prob. 1 - 4
10	pp. 97 - 116	General Rules, Two Spins Homework: Chap. 14 Prob. 1 - 9
17	pp. 117 - 128	Einstein's Instincts, Bell's Inequalities Homework: None

24	pp. 129 - 151	Heisenberg's Uncertainty Relation, Quantized Oscillator Energy Homework: Chap. 17 Prob. 1 - 6, Chap. 18 Prob. 1 - 4
31	pp. 152 - 171	Bohr's Model, Angular Momentum Homework: Chap. 19 Prob. 1 - 3, Chap. 20 Prob. 1 - 7
Nov 7	pp. 172 - 186	Rotational Energy, Hydrogen Atom Homework: Chap. 22 Prob. 1 - 2
14	pp. 187 - 198	Spin Rotations Homework: Chap. 23 Prob. 1 - 8
21	pp. 199 - 215	Small Rotations Homework: Chap. 24 Prob. 1 - 7
28	pp. 216 - 233	Changes in Space Location, Changes in Time Homework: Chap. 25 Prob. 1 - 2, Chap. 26 Prob. 1
Dec 5	pp. 234 - 256	Changes in Velocity, Invariance Homework: Chap. 27 Prob. 1 - 7, Chap. 28 Prob. 1 - 6