Syllabus
Quantum Mechanics II
Physics 701
Spring 2013

Dr. James Franson
Physics 314
Ext. 58115
jfranson@umbc.edu

Location: Public Policy 367
Time: Tuesday and Thursday 10:00 – 11:15
Office hours: Any afternoon between 2:00 and 4:30 (except as noted)

Course description:

This course is intended to be a follow-on course to Quantum Mechanics I, which covered most of the basic topics in quantum mechanics, including perturbation theory, operator techniques, and the addition of angular momentum. These techniques will be applied to investigate a variety of more advanced subjects, including mixed states, the quantization of the electromagnetic field, the interaction of light with matter, entanglement, second quantization formalism, the Dirac theory, and anti-particles.

In addition to covering these more advanced topics, the course will also review some of the topics covered in Quantum Mechanics I.

Goals and objectives:

The primary goal of this course is to develop an understanding of some of the more advanced topics and techniques used in quantum mechanics. Most of this material will be essential for graduate research in many areas of physics, such as quantum optics, astrophysics, and atmospheric physics. This course will provide the necessary knowledge and skills to apply advanced techniques in quantum mechanics throughout the students' careers.

A secondary goal is to further develop the students' problem solving ability, which will be essential not only on qualifying exams but in the students' future research. As in Quantum Mechanics I, the use of Mathematica to solve problems will be encouraged.

Textbooks:

The text for the course will be *Lectures on Quantum Mechanics* by Gordon Baym.

Additional material will be taken from a number of other textbooks, which are available in the library:

Photons and Atoms: An Introduction to Quantum Electrodynamics, by C. Cohen-Tannoudji, J. Dupont-Roc, and G. Grynberg.

*Quantum Physic*s by Stephen Gasiorowicz.

Quantum Mechanics by L. Schiff.

Classical Electrodynamics by J.D. Jackson.

Class structure:

Students are strongly encouraged to read the corresponding textbook chapters before each lecture. This allows the students to have some familiarity with the material before the lecture so that any questions can be discussed in class.

Based on the student questionnaires from Quantum Mechanics I, there appears to be a preference for traditional blackboard lectures rather than computerized PowerPoint slides. In response, the lectures in Quantum Mechanics II will be given at the blackboard. Handwritten lecture notes will be posted on the Blackboard website. Homework solutions will also be posted on the Blackboard website.

There will be an in-class midterm exam and an in-class final exam. This will combined with the scores from the homework to determine the course grade, as described below.

Grading procedure:

The grade will be determined as follows:

Homework	15%
Midterm	40%
Final exam	45%
Pop quizzes	0%

The homework will be graded on the scale of 0, 1 or 2. This coarse grading reflects the fact that the homework only determines 15% of the grade.

Course requirements:

The students are expected to make their best effort at solving the homework problems on their own without working in groups, since this provides the best learning opportunity. If the students cannot solve a problem on their own, they may discuss the question with other students or the instructor, but they should still try to solve the problem themselves.

The exams will be open book. Any quantum-mechanics or math textbooks may be used as desired, except for books that are primarily intended to contain solutions to sample problems. A computer and the Mathematica software are also allowed.

Academic integrity:

Academic integrity is an important part of scientific research. The UMBC academic integrity statement is as follows:

> *"By enrolling in this course, each student assumes the responsibilities of an active participant in UMBC's scholarly community in which everyone's academic work and behavior are held to the highest standards of honesty. Cheating, fabrication, plagiarism, and helping others to commit these acts are all forms of academic dishonesty, and they are wrong. Academic misconduct could result in disciplinary action that may include, but is not limited to, suspension or dismissal. To read the full Student Academic Conduct Policy, consult the UMBC Student Handbook, the Faculty Handbook, or the UMBC Policies section of the UMBC Directory [or for graduate courses, the Graduate School website]."*

Class schedule:

The topics to be covered are listed below. The approximate number of lectures to be spent on each topic is shown in parentheses. The schedule will be adjusted as necessary to ensure that enough time is spent on each topic. As a result, some of the more advanced topics may not be covered in detail.

Density matrix formalism (2)
- Mixed states
- Definition of the density matrix
- Expectation value of operators
- Time evolution of the density matrix
- Trace over separate systems

Quantization of the electromagnetic field (4)
- Review of classical electromagnetism
- Classical normal variables
- Quantization of the normal variables
- Classical limit – Maxwell’s equation for field operators
- Quantization in the Lorentz gauge

Interaction of light with matter (4)
- Interaction Hamiltonian
- Review of perturbation theory
- Spontaneous emission
- Electric dipole approximation
- Review of selection rules
- Absorption and scattering of light
- Atomic cascades
- Two-photon absorption

Entanglement (2)
- Generation of entangled states
- Forms of entanglement
- Bell's inequality and experiments

Second quantization formalism (2)
- Creation and annihilation operators
- Pair correlation functions
- Hanbury-Brown and Twiss experiment
- Hamiltonian in second-quantized notation

Review of special relativity (2)
- Postulates of special relativity
- Four vectors and covariance
- Lorentz transformation
- Transformation properties of the EM field

Relativistic Spin Zero particles (3)
- Klein-Gordon equation
- Negative energy states and antiparticles
- Free particle wave packets
- Klein's paradox
- Nonrelativistic limit

Relativistic spin-1/2 particles (4)
- Lorentz transformation of spin
- Dirac equation
- Negative energy states - positrons
- Free particle solutions
- Nonrelativistic limit
- Second quantized Dirac theory

Interaction of light and relativistic particles (3)
- Hamiltonian for the coupled Dirac and Maxwell fields
- Heisenberg equations of motion for the fields
- Classical limit