Physics 3411 – Quantum Physics II

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Course Description

PH3411 is the second course in a year-long sequence devoted to the study of elementary quantum mechanics. The course begins with quantum mechanics in three dimensions. The general central force problem is investigated along with the quantization of angular momentum, and this is followed by Schrödinger's treatment of the hydrogen atom. A refinement of the description of the hydrogen atom is made through the introduction of spin angular momentum. Approximation methods, including the variational principle and time-independent and time-dependent perturbation theory, are explored, and these methods are applied to the fine structure of hydrogen as well as to the behavior of the hydrogen atom in external electric and magnetic fields. Systems of identical particles are investigated, and The Pauli Exclusion Principle is applied to determine the electronic configuration of multi-electron atoms. Relativistic quantum mechanics and scattering theory will be examined, time permitting. Along the way, some mathematics and formalism (Dirac delta function, matrix representation of linear operators) will be introduced to augment that encountered during the first semester.

Course Objectives

The principal course objectives are for you to build a solid base in quantum mechanics by learning the fundamental concepts of the subject and developing the problem-solving skills needed to apply those fundamentals. The objectives are not properly served by a mere survey of factual information; the course will have sufficient depth to explicate the basic concepts. A worthy secondary objective of the course is to strengthen your analytical abilities with exposure to new mathematics.

Topics (subject to refinement and change as the semester progresses)

- The Three-Dimensional Time-Independent Schrödinger Equation
  - Solution in Rectangular Coordinates
  - Central Potentials and the Orbital Angular Momentum
    - Central Potentials
    - The Schrödinger Equation in Spherical Coordinates
    - Separation of Variables
    - Angular Momentum Quantum Numbers
    - Observables in Spherical Coordinates
    - Angular Momentum Commutation Relations
    - Angular Momentum Raising and Lowering Operators
  - One-Electron Atoms
    - The Radial Differential Equation
    - Solutions of the Radial Equation
    - Degeneracy
    - Probability Distributions

Math Interlude: Matrices and the Dirac Delta Function
- The Matrix Representation of Linear Operators
- Functions of an Operator
- The Dirac Delta Function

Spin Angular Momentum
- The Stern-Gerlach Experiment
- Spin Operators
- Adding Angular Momenta
- The Matrix Representation of Spin
- The Time Evolution Operator
- Spin Precession

Methods of Approximation
- The Variational Method
  - Theory
  - Applications
- Time-Independent Perturbation Theory
  - Derivation of Time-Independent Perturbation Theory
  - Perturbation of Atomic Energy Levels
    - Fine Structure
    - Lamb Shift
  - The Atom in External Electric of Magnetic Fields
    - Stark Effect
    - Zeeman Effect
- Time- Dependent Perturbation Theory
  - Derivation of Time-Dependent Perturbation Theory
  - Selection Rules for Electromagnetic Radiation

The Multiparticle Schrödinger Equation
- Wave Function for Identical Particles
- Multielectron Atoms
- Spin Systems with Two Particles
  - Noninteracting Spins
  - Interacting Spins

Scattering Theory
- Definition of the Cross Section
- The Born Approximation
- Partial Waves

Relativistic Quantum Mechanics
- The Klein-Gordon Equation
- The Dirac Equation

Texts

<u>Required</u> Robert Scherrer, *Quantum Mechanics: An Accessible Introduction*

<u>References</u> Serway, Moses and Moyer, *Modern Physics*, 3rd edition
David J. Griffiths, *Introduction to Quantum Mechanics*, 2nd edition
Bransden and Joachain, *Quantum Mechanics*, 2nd edition
R. Shankar, *Principles of Quantum Mechanics*, 2nd edition

Mathematical Tools	Spiegel, *Schaum's Outline Series - Mathematical Handbook of Formulas and Tables* Dwight, *Tables of Integrals and Other Mathematical Data* Jahnke and Emde, *Tables of Functions* Abramowitz and Stegun, *Handbook of Mathematical Functions* www.integrals.com
History	Gamow, *Thirty Years That Shook Physics* Pais, *Inward Bound*

Grading Policy

Your grade for the course will be based on your performance on graded homework, two midterm exams and the final exam. The weight attributed to each component of the course is as follows:

Homework	45%
Midterm Exam I	15%
Midterm Exam II	15%
Final Exam	25%

For each of the four components of the course you will earn a numerical score from 0 to 100. The guidelines for interpreting these scores are as follows:

A	85-100	*C*	60-64
AB	80-84	*CD*	55-59
B	70-79	*D*	50-54
BC	65-69	*F*	0-49

The *Michigan Tech Undergraduate Catalog* defines the *C* grade to be average. I prefer to use the following grade descriptions, used at MIT, to guide my assignment of grades:

A: Exceptionally good performance demonstrating a superior understanding of the subject matter, a foundation of extensive knowledge, and a skillful use of concepts and/or materials.

B: Good performance demonstrating capacity to use the appropriate concepts, a good understanding of the subject matter, and an ability to handle the problems and materials encountered in the subject.

C: Adequate performance demonstrating an adequate understanding of the subject matter, an ability to handle relatively simple problems, and adequate preparation for moving on to more advanced work in the field.

D: Minimally acceptable performance demonstrating at least partial familiarity with the subject matter and some capacity to deal with relatively simple problems, but also demonstrating deficiencies serious enough to make it inadvisable to proceed further in the field without additional work.

An additional consideration used in assigning letter grades is that most physics graduate programs require applicants to have an undergraduate grade point average of at least 3.00. Students earning *A* and *B* grades in my courses have, in my opinion, the ability to succeed in a physics graduate program. Students earning grades of *C* or lower in my courses who aspire to attend graduate school need, in my opinion, to reassess their goals and commitment to the study of physics.

Homework

A homework assignment will be issued approximately once every two to three weeks. The homework must be turned in at the beginning of the class period on the day it is due. All assigned homework problems will be graded and no late homework will be accepted. Your homework must conform with the following basic format:

1. Print your name and date at the top of the first page.
2. Use either lined paper or lightly lined graph paper. Many students find engineering paper to be especially well suited to the task. Write only on one side of the paper. Use alternate lines to keep the work from becoming too difficult to read, and honor the margins at the top, bottom and sides to allow for comments.
3. Your work must be neat and well organized.
4. Begin each problem on a new page with the problem number identified at the upper left.
5. Number each page at the upper right.
6. Your work must be stapled together prior to submission and not be dog-eared, taped, paper-clipped, or held together with a clothespin.

Working in groups is a valuable way to learn physics, but the work you submit for grading must be your own.

Exams

The midterm exams will be given during the evening so that time will not be a factor. The exams will be closed book and closed notes, and calculators will not be permitted. The final exam will be a comprehensive final examination with the time of this exam restricted to two hours, and the exam will be closed book and closed notes with no calculators permitted.

Miscellaneous

You should anticipate that at some time in the future you will ask various instructors to write letters of recommendation for employment and/or graduate school. In addition to commenting on academic performance, instructors are typically asked to address issues including maturity, motivation, communication skills, and integrity. You can assure positive remarks in these areas with regular attendance in class, punctuality, attentiveness, and timely submission of well organized and neat homework solutions.

MTU ADA Statement

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