Physics 352: Quantum Mechanics — *Spring 2005*

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	Room	Time
Lecture	Eaton 105	11:15-12:10 MWF

Texts

- David J. Griffiths, *Introduction to Quantum Mechanics*, 2nd Edition (Prentice-Hall, 2004).
- N. N. Lebedev, *Special Functions & Their Applications* (Dover).

Recommended Texts

- Murray R. Spiegel, *Mathematical Handbook* (Addison-Wesley) in the Schaum's Outlines Series.
- Yoav Peleg, Reuven Pnini, and Elyahu Zaarur, *Quantum Mechanics* (Addison-Wesley) in the Schaum's Outlines Series.
- Albert Messiah, *Quantum Mechanics* (Dover).

Office Hours

Initially office hours will be Monday and Wednesday 9:00 am and Friday 1:20 pm and by appointment. If these hours are inconvenient for you, please tell me and I'll try to find some more convenient times. In addition, you may stop by any time to see if I am free to discuss physics, life, the universe, or anything else.

Course Structure

The course will consist of meetings three times a week. Although I expect to lecture at most meetings, I hope that you will have questions and that we can have good, spontaneous discussions on this difficult but fascinating subject. Please read the text carefully outside of class and bring to class your questions and confusions from the reading.

Course Requirements

Regular Homework Problems
2 Exams
Final Exam

Grading

Grades in this class will be based on the following elements.

- **Participation** I expect each student to do the assigned readings and problems and to bring questions and comments to class and to participate in class discussions. Implicit in this is the expectation that all students will attend all classes. Some of the lecture material will not be in the text, so it is important that students attend lecture. The grade for participation will be assigned at my discretion at the end of the semester.

- **Homework** Homework will be assigned on a regular basis and collected. I reserve the right not to give credit for late homework assignments, based on the belief that keeping up is an essential ingredient for success in the course. You may work together on the homework. Indeed, I encourage you to work together to understand the problems. However, you must each separately write up solutions in your own words (and equations) and may not turn in something that you do not understand. (That is, you may not simply paraphrase someone else's solution as your own.) Paraphrasing without understanding, or outright copying, will be considered plagiarism.

- **Exams** There will be two mid-term exams and a final exam. The final will be comprehensive. In the past I have had take-home exams exclusively, and I anticipate continuing this policy.
- **Quizzes** There may be quizzes in class, mostly for your own diagnostic use. Any quizzes will be announced in advance and will count towards your participation grade.

The relative weights of each element of the grade for the course is as follows.

Element	Weight
participation	10%
homework	30%
hour exams	30%
final exam	30%

Tentative Course Outline

This outline is fairly ambitious, but I hope we can cover most of it.

I. Wave Phenomena & Quantum Mechanics
- *A.* Background & History
  - *1.* Planck's Hypothesis & The Ultraviolet Catastrophe
  - *2.* Einstein & the Photoelectric Effect
  - *3.* de Broglie waves
  - *4.* Interference & double-slit experiment
  - *5.* What is mechanics: Classical *vs.* Quantum
- *B.* Wave equations and Wave Phenomena
  - *1.* Wave equation
  - *2.* Sinusoidal waves
  - *3.* Standing waves
  - *4.* Junctions of different materials: Transmission & Reflection
- *C.* The Schrödinger Equation
  - *1.* $E^2 = (pc)^2$ and light
  - *2.* $E = p^2/2m + V(x)$ and Schrödinger's Equation

3. Necessity of complex wave functions

II. PROBABILITY FORMULATION OF QUANTUM MECHANICS

A. Interpretation of the Wave Function

1. Analogy of ψ to electric field: Double-slit experiment

2. Intensity $\propto |\psi|^2$

3. Probability density

4. Normalization of ψ

5. Probability Current

6. Constancy of Normalization

B. Précis of Probability Theory

1. *A priori* probability

2. Expected values

3. Variance & standard deviation

C. Operators & Expectation values

1. Position & Momentum Operators

2. Expectation values of $\hat{x}^n$, $\hat{p}^n$

3. Classical connection: Ehrenfest's Theorem

III. TIME-INDEPENDENT SCHRÖDINGER EQUATION

A. Separation of Variables

1. States of definite energy (Stationary states)

2. Energy Eigenvalues

B. Infinite Square Well

1. Boundary conditions determine energies

2. Particle on a ring

3. Orthogonality of states of differing energy

C. Finite Well

1. Bound states

2. Scattering: Transmission and Reflection

3. Probability current

4. Tunneling

D. Harmonic Oscillator

1. Importance of problem

2. Algebraic solution by raising operators

3. Eigenstates & series solution

E. Landau Problem

1. Charged particles in a background B field

2. Degenerate ground state

IV. FORMAL STRUCTURE OF QUANTUM MECHANICS

A. Linear Algebra

1. Vector spaces

2. Linear transformations & matrices

3. Eigenvalues & eigenvectors

- *B.* Inner products & Norms
  - *1.* Real Spaces
  - *2.* Complex Spaces
- *C.* Norm-preserving Linear Transformations
  - *1.* Adjoints
  - *2.* Orthogonal Transformations
  - *3.* Unitary Transformations
  - *4.* Self-adjoint Transformations
- *D.* Function Spaces & Dirac Notation
- *E.* Generalized Statistical Interpretation
- *F.* Uncertainty Principle
- *G.* Measurement Theory

V. QUANTUM MECHANICS IN 3 DIMENSIONS

- *A.* Central Forces
  - *1.* Spherical Coordinates, Laplacian
  - *2.* Separation of Variables
- *B.* Hydrogen Atom
  - *1.* Radial Equation
  - *2.* Exact solution
    - *a.* Operator Method
    - *b.* Series method
  - *3.* Quantum Numbers
- *C.* Angular Momentum and Spherical Symmetry
  - *1.* L_x, L_y, and L_z operators
  - *2.* Commutation relations
  - *3.* Eigenvalues
  - *4.* Spherical Harmonics

VI. SPIN & STATISTICS

- *A.* Spin Angular Momentum
- *B.* Pauli Matrices
- *C.* Addition of Angular Momentum
- *D.* Identical Particles

VII. APPROXIMATE METHODS & APPLICATIONS

- *A.* Non-degenerate Perturbation Theory
- *B.* Degenerate Perturbation Theory
- *C.* Applications of Perturbation Theory
  - *1.* Fine Structure of Hydrogen
    - *a.* Relativistic Correction
    - *b.* Spin-Orbit Coupling
  - *2.* Zeeman Effect
  - *3.* Hyperfine Structure of Hydrogen
- *D.* Variational Principle
  - *1.* Helium Atom

- *E.* Adiabatic & Sudden Approximations
- *F.* Time-dependent Perturbation Theory
  - *1.* Two Level Systems
  - *2.* Sinusoidal Perturbations
    - *a.* Transition Rates: Fermi's Golden Rule
- *G.* Applications of Time-dependent Perturbation Theory
  - *1.* Emission & Absorption of radiation
  - *2.* Spontaneous Emission of Radiation
  - *3.* Stimulated Emission of Radiation: Lasers
  - *4.* Selection Rules
- *H.* Semi-Classical Methods (WKB Approximation)

VIII. FURTHER TOPICS

- *A.* Bell's Inequality & EPR Paradox
- *B.* Relativistic Quantum Theory: Dirac Equation
- *C.* Aharonov-Bohm Effect
- *D.* Berry's Phase
- *E.* Scattering