QUANTUM MECHANICS I - III

PHYS 516 - 518

Jan 1 - Dec. 31, 2009

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Course Schedule: MWF 11:00 - 11:50, 12-919

Objective: To provide the foundations for modern physical theory.

Two texts and one supplement will be used for this course. The first two will be used throughout. The third is recommended for those students whose background in this subject is suspicious.

L. E. Ballentine
Quantum Mechanics
Englewood Cliffs, NJ: Prentice Hall, 1990 ISBN 0-13-747932-8

R. Gilmore
Elementary Quantum Mechanics in One Dimension
Baltimore, Johns Hopkins University Press, 2004 ISBN 0-8018-8015-7

R. H. Dicke and J. P. Wittke
Introduction to Quantum Mechanics
Reading, MA: Addison-Wesley, 1960 ISBN 0-?

The following texts are solid. They all contain more or less the same material. Some presentations are better than others.

S. Gasiorowicz
Quantum Physics
NY: Wiley, 1974 ISBN 0-471-29280-X

A. Messiah
Quantum Mechanics, Vol. 1
Amsterdam, North Holland, 1961

E. Merzbacher
Quantum Mechanics, 3^{rd} Ed.
NY: Wiley, 1998 ISBN 0-471-59671-1

J. J. Sakurai
Modern Quantum Mechanics
NY: Benjamin, 1985 ISBN 0-8053-7501-5

David Griffiths
Introduction to Elementary Particles
NY: Wiley, 1987 ISBN 0-471-60386-4

H. A. Bethe and E. Salpeter
Quantum Mechanics of One- and Two-Electron Atoms
NY: Plenum, 1977

D. Bohm
Quantum Theory
NY: Dover, 1989

R. P. Feynman and A. R. Hibbs
Quantum Mechanics and Path Integrals
NY: McGraw Hill, 1965

W. Greiner
Quantum Mechanics: An Introduction, 3rd Ed.
NY: Springer-Verlag, 1994

W. Greiner and B. Müller
Quantum Mechanics: Symmetries, 2nd ed.
NY: Springer-Verlag, 1994

W. Heitler
The Quantum Theory of Radiation
NY: Dover, 1984

L. D. Landau and E. M. Lifschitz
Quantum Mechanics (Non-Relativistic Theory), 3rd ed.
Oxford: Pergamon Press, 1977

L. Pauling and E. B. Wilson, Jr.
Introduction to Quantum Mechanics, with Applications to Chemistry
NY: Dover, 1985

L. I. Schiff
Quantum Mechanics, 3rd ed.
NY: McGraw Hill, 1968

Course Topics

- Schrödinger's Papers
    1. Quantization as an Eigenvalue Problem: Part I
    2. Quantization as an Eigenvalue Problem: Part II
    3. Quantization as an Eigenvalue Problem: Part III
    4. Quantization as an Eigenvalue Problem: Part IV
- Forms of Quantum Theory: Matrix Mechanics, Wave Mechanics, Path Integrals
- Separation of Variables:
    1. Klein-Gordan Equation
    2. Schrödinger Equation
- Frobenius's Method
- Eigenvalues and Eigenvectors
- Brief Remarks: Spherical Harmonics
- Time-Independent Perturbation Theory
- Applictions:
    1. Finite nuclear size
    2. Zeeman Effect
    3. Stark Effect
    4. Crossed Fields
- Harmonic Oscillator
    1. Analytic solution: Frobenius' Method
    2. Operator solution
    3. Discretization and Matrix Diagonalization
    4. Ginzburg-Landau Quartic Potential
- Coupled Oscillators
    1. Linear Molecules and Normal Modes
    2. One-Dimensional Solids

   (a) One atom/unit cell
   (b) Two atoms/unit cell
   (c) Three atoms/unit cell
3. Two-dimensional solids
4. Three-dimensional solids

- Electromagnetic Field
  1. Maxwell's Equations
  2. Vector and Scalar Potentials
  3. Normal Modes
  4. Independent Oscillators
  5. Quantization
- Time Dependence
- Time-dependent perturbation theory
- Representations:
  1. Schrödinger
  2. Interaction
  3. Heisenberg
- Applictions:
  1. Perturbed harmonic oscillator
  2. Fermi golden Rule
  3. Lorentzians
- Angular Momentum
  1. Analytic representation, angular variables: L
  2. Algebraic representation, $|l, m_l\rangle$
  3. $J \simeq a^\dagger a$
  4. Spin angular momentum: S
  5. Total angular momentum: J
  6. Spherical harmonics
  7. Clebsch-Gordan coefficients
- Angular Momentum Applications
  1. Shielder Coulomb Potential $\rightarrow$ Mendelyeev

2. Harmonic + Square Well + Spin Orbit = Nuclear Shell Model
3. Hydrogen → Positronium → Charmonium → Bottomonium

- Phase Shifts

1. "Gauge Transformation of First Kind"
2. "Gauge Transformation of Second Kind"
3. Principle of Minimal Electromagnetic Coupling
4. Yang Mills guage theory
5. Gauge theory and renormalizability

Course Topics:

- Forms of Quantum Theory: Matrix Mechanics, Wave Mechanics, Path Integrals
- Schrödinger's Equations
- Klein-Gordan equation for the hydrogen atom
- Schrödinger's Equation for the hydrogen atom
- Other early Schrödinger solutions
- Schrödinger's Equation in one dimension
- Piecewise constant potentials
- Boundary conditions
- Probabilities and amplitudes
- Diagonalization
- Perturbation theory
- Angular Momentum
- Zeeman Effect, Stark Effect
- Matrix Mechanics
- Relation between Matrix and Wave Mechanics: Quantum mechanics
- Path Integrals
- Pauli Principle
- Periodic Table of the Chemical Elements
- Shell Models of the Nucleus
- Table of Nuclear Isotopes
- Solid state Physics
- Standard Particle Theory
- Gauge Theory
- Aharonov-Bohm Effect
- Quantization of the Electromagnetic Field

- Casimir Effect
- Bell Inequalities
- Interpretations of Quantum Mechanics
  - Copenhagen
  - Path Integral
  - Consistent Histories
  - deBroglie-Bohm
  - Dirac-Gilmore