QUANTUM MECHANICS III

518

Sept. 24 - Dec. 31, 2012

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Course Schedule: (Winter Quarter) MWF 11:00 - 11:50, Disque 919

Review: What We've Done So Far

Broad Historical Sweep
1. The light dialogue: From Newton to Einstein (?) and Beyond?
2. The gravity dialogue: From Newton to Einstein (?) and Beyond?
3. Problems with ∞: Planck $\hbar$; Bohr atom; Renormalization; Casimir.
4. The Phases of Quantum Theory: 1913, 1926, 1964.
5. 1913: Correspondence Principle.
6. 1926: Ehrenfest Theorems.
7. 1935: EPR and Schrödinger's Cat.
8. 1964: Bell's Theorem unlocks the flood.
9. 2000 $\rightarrow$ "At last, we're free from our classical manacles."
10. "The Quantum world is weirder that we could possibly have imagined."

Quantization as an Eigenvalue Problem. I
1. Variational formulation.
2. Standard formulation.
3. Relativistic hydrogen atom: Bound states.
4. Nonrelativistic hydrogen atom: Bound states.

Quantization as an Eigenvalue Problem. II
1. Harmonic oscillator.
2. Rotator with fixed axis (2D).
3. Rigid rotator with free axis (3D).

4. Diatomic molecule.
5. Two-dimensional oscillators.
6. Three-dimensional oscillators.
7. Coupled oscillations.
8. Molecules: 2 atoms/M, 3 atoms/M, 4 atoms/M
9. 1D lattices: 1, 2, 3 atoms/unit cell, phonons
10. Coherent states. (After the first of his 2 intermediate papers.)

Quantization as an Eigenvalue Problem. III

1. Time independent perturbation theory to 3rd order.
2. Stark effect.
3. Finite nuclear size effect.
4. Line strengths.

Quantization as an Eigenvalue Problem. IV

1. Time-dependent wave equation.
2. Perturbation theory (time-dependent).
3. Fermi Golden Rule, Wigner-Weisskopf theory for Lorentz line shape.
4. Resonance phenomena: $SU(2)$ & Rabi; $SU(3)$ & neutrinos.

Ehrenfest Theorems:

1. Expectation values and density matrices/operators.
2. Newton's Equations.
3. Harmonic motion.
4. Orbital angular momentum and torque.
5. Angular momentum and precession.
6. Lorentz force.
7. Hamilton's Equations.

Matrix Mechanics

1. Born, Heisenberg, and Jordan.
2. Schrödinger's demonstration of equivalence.
3. Then and Now: the Swing of the Pendulum.
4. Matrix computations.
5. Gaussian & FEM

Feynman's Path Integrals

1. A particle goes along all possible paths.
2. The Action Integral.
3. Equivalence with Schrödinger's Equation (time-dependent).
4. 2-Slit interference pattern (Young diffration pattern).

Gauge Theories

1. Measuring the gravitational field.
2. Measuring the phase of an electric field.
3. Global gauge transformations: $U(1)$.
4. Local gauge transformations: $U(1)$.
5. Yang-Mills, Nuclear Forces and Mesons: $SU(2)$.
6. Utiyama.
7. Groups and gauge theories: gauge bosons.

8. Renormalizable gauge theories.

Density Operators

Quantization of the Electromagnetic Field (Dirac)

Spin Statistics Relations

1. Fermions and antisymmetry
2. Electron filling order and Mendeleev's Periodic Table
3. Nucleon filling order and Maria Goeppert Mayer's filling order

Dirac Equation

1. Foldy-Wouthuysen transformation
2. Insanities of interpretation
3. Itoh - Structure of many electron Hamiltonians
4. Pragmatic approaches to ground state multiplets
5. Atomic spectroscopy: Hunds Rules, Zeeman Effect, Landé g factor

Preview: What We Haven't Done So Far

Higgs Boson

Angular Momentum

1. Schwinger construction of angular momentum matrices
2. Wigner rotation matrices
3. Coupling coefficients, Clebsch-gordan coefficients
4. Selection Rules
5. Wigner-Eckart theorem

Ligand / Crystal Field Theory

1. Symmetry groups / character tables
2. Fourier analysis on groups

Casimir Effect

1. Surprises of the vacuum
2. Measurements
3. BEC measurements

Elementary Quantum Mechanics in One Dimension

1. Transfer matrices
2. T matrices and S matrices
3. Boundary conditions
4. Scattering states
5. Bound states
6. Resonances
7. Analytic continuation
8. Periodic Potentials
9. Transfer matrices for interferometers

Superconductivity

Bose-Einstein Effects
Quantum Optics
1. Intensity interferometer
2. Lasers
3. Glauber's formulation
4. Interferometers
5. Photon bunching
6. Probabilities: Wigner distribution, P and Q distributions

The Measurement Problem
1. The work of Wineland and his group.

Brute Strength Computation
1. Gaussian
2. FEM

Complex Scaling
Uncertainty Relations: Then and Now
Modern Applications
Third Wave of Quantum Mechanics
1. Bell and his theorem
2. Measurements and sequels
3. GHZ states
4. New entanglement effects
5. "The Great Smokey Dragon"
6. The work of Zeilinger and Gisin
7. The speed of information transport
8. Entanglement, computation, teleportation.
9. What will the future be like?