Advanced Quantum Mechanics

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Quantum Mechanics: One of the **major theory** in Physics

- QM is one hundred years old and has never been found at fault.
- Nowadays, one can perform very delicate and accurate experiments ("thought experiments") at large scale $\Rightarrow$ non-locality
- Success of QM :
  - **Fundamental**: Understanding of matter (atomic, molecular, nuclear, elementary particles, and condensed matter physics, optics, chemistry)
  - **Technological applications**: transistor, NMR, LASER, spintronic, cryptography, teleportation, quantum computing...
- Challenge for theoretical Physics: Put together QM and general relativity?
- QM has undergone great advances in mathematics: $M \cap \Phi$ mathematical physics
- But...

"I think I can safely say that nobody understands quantum mechanics"

R.P. Feynman

Organization and required background

- Semester 1 = 13 weeks
- **Lectures**: 32H = 10 + 22 **Problem sessions**: 8H = 2 + 6
  1. A. Perez: 12 hours / 3 weeks (will start on Thursday September 7)
  2. S. Lazzarini: 28 hours / 10 weeks (will start on Thursday September 28)
- Final written exam (4 hours $\simeq$ 1 + 3)

Background:

- Basics on quantum mechanics (Schrödinger eq, gauge theory, rotations in quantum mechanics, spin, perturbation theory)
- Some aquaintance with functional analysis and Lie groups, representation theory would help.

Part I: Path integral approach (A. Perez - 12 hours)

- Path integral in quantum mechanics (propagator and derivation of the formula using Trotter's formula, rough derivation of the least action principle)
- Harmonic oscillator (either using the discretization or direct continuum calculation using determinants)
- Particle in a magnetic field (Calculation for a constant field and Aharonov-Bohm)
- Tunneling via path integrals
- Brownian motion (discretization and interpretation of the continuum limit as a sum over paths)

Part II: Selected topics in quantum physics (S.Lazzarini - 28 hours)

Using a few books depending on the choice of the topics

- M. Le Bellac, *Quantum Physics* (2006) Cambridge Univ. Press.
- S. Weinberg, *Lectures on Quantum Mechanics* (2013) Cambridge Univ. Press.
- S. Weinberg, *The Quantum Theory of Fields*, vol-I (1995) Cambridge Univ. Press.
- Any other material...

Main subjects in relation with fundamental physics:

- Symmetries and covariance:
  - Review on projective representations, emphasis on rotations: $O(3)$, $SU(2)$ / spin 1/2
  - The most general expression for the Hamiltonian (Galilean and Lorentzian convariances)
  - Non-relativistic version of the spin-statistics theorem
- Relativistic QM (useful also for Relativisitic QFT):
  - Klein-Gordon equation: Energy spectrum.
  - Rotations: Spinorial representation ($SL(2,\mathbb{C})$, $SU(2) \times SU(2)$). Spinors.
  - Dirac equation: properties, spin and helicity. Hyperfine structure of the H atom. Non relativistic limit. Foldy-Wouthuysen transformation. Klein paradox.
  - Majorana spinors: neutrinos - dark matter candidate.

Advanced Quantum Mechanics. P.J. Mulders Nikhef and Department of Physics and Astronomy, Faculty of Sciences, Vrije Universiteit Amsterdam De Boelelaan 1081, 1081 HV Amsterdam, the Netherlands.Â 2. Preface. The lectures Advanced Quantum Mechanics in the fall semester 2015 will be taught by Piet Mulders with assistance from Tom van Daal (tom.van.daal@nikhef.nl). We will be using a few books, depending on the choice of topics. Wiki Targeted (Entertainment). Do you like this video? Play Sound. Advanced Quantum Mechanics was a book of advanced quantum (TV: The Day of the Doctor) and temporal theory (PROSE: The Day of the Doctor) that the Eleventh Doctor was reading when Clara Oswald entered the TARDIS on her motorbike after her day teaching at Coal Hill School. The dust jacket of the book had images of the TARDIS in its police box shape on both the front and back covers. (TV: The Day of the Doctor). Advanced Quantum Mechanics Peter S. Riseborough February 19, 2015 Contents 1 Introduction 5 2 Quantum Mechanics of a Single Photon 6 2.1 Rotations and Intrinsic Spin . . . 7 2.2 Massless Particles with Spin Zero . . . 11 2.3 Massless Particles with Spin One . . . Presents advanced quantum mechanics clearly enough to make it accessible to graduate students in physics, chemistry and engineering. Provides appendices with essential material on analytical mechanics, special relativity and covariant electrodynamics. see more benefits. Buy this book.Â This textbook, now in an expanded third edition, emphasizes the importance of advanced quantum mechanics for materials science and all experimental techniques which employ photon absorption, emission, or scattering. 3 Relativistic quantum mechanics. 73. 3.1 Synopsis of special relativity . . .Â Although unphysical, the advanced states play a formal role in the construction of elements of scattering theory. 12 chapter 1. scattering theory. i.e. are eigenstates at some denite energy E. The Fourier convolution theorem (or a short explicit check) then leads equation.