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G. Roepstorff

Path Integral Approach to Quantum Physics



Springer

Path Integral Approach To Quantum Physics An Introduction

Franco Strocchi



Path Integral Approach To Quantum Physics An Introduction:

Path Integral Approach to Quantum Physics Gert Roepstorff, 2012-12-06 This book has been written twice After having written and published it in German in 1990 I started all over again and rewrote the whole story for an English speaking audience During the first round I received encouraging words and critical remarks from students and colleagues alike which have helped to sustain me the second time around In the preface the author usually states that his or her book resulted from a course that he or she gave at some university I cannot claim that the present book is any exception to the rule But I expanded and remodelled the original material which circulated as a manuscript so that the printed version would follow a more stringent and coherent architectural plan In doing so I have concentrated on the conceptual problems inherent in the path integral formalism rather than on certain highly specialized techniques used in applications Nevertheless I have also included those methods that are of fundamental interest and have treated specific problems mainly to illustrate them

Path integral approach to quantum physics Gert Roepstorff, 1994 **Introduction to Quantum Mechanics** Harald J W MÅ¼ller-Kirsten, 2006-03-03 After a consideration of basic quantum mechanics this introduction aims at a side by side treatment of fundamental applications of the Schrödinger equation on the one hand and the applications of the path integral on the other Different from traditional texts and using a systematic perturbation method the solution of Schrödinger equations includes also those with anharmonic oscillator potentials periodic potentials screened Coulomb potentials and a typical singular potential as well as the investigation of the large order behavior of the perturbation series On the path integral side after introduction of the basic ideas the expansion around classical configurations in Euclidean time such as instantons is considered and the method is applied in particular to anharmonic oscillator and periodic potentials Numerous other aspects are treated on the way thus providing the reader an instructive overview over diverse quantum mechanical phenomena e g many other potentials Green's functions comparison with WKB calculation of lifetimes and sojourn times derivation of generating functions the Coulomb problem in various coordinates etc All calculations are given in detail so that the reader can follow every step Quantum Field Theory and Functional Integrals Nima Moshayedi, 2023-08-12 Described here is Feynman's path integral approach to quantum mechanics and quantum field theory from a functional integral point of view Therein lies the main focus of Euclidean field theory The notion of Gaussian measure and the construction of the Wiener measure are covered As well the notion of classical mechanics and the Schrödinger picture of quantum mechanics are recalled There the equivalence to the path integral formalism is shown by deriving the quantum mechanical propagator from it Additionally an introduction to elements of constructive quantum field theory is provided for readers **Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets** Hagen Kleinert, 2004 This is the third significantly expanded edition of the comprehensive textbook published in 1990 on the theory and applications of path integrals It is the first book to explicitly solve path integrals of a wide variety of nontrivial quantum mechanical systems in

particular the hydrogen atom The solutions have become possible by two major advances The first is a new euclidean path integral formula which increases the restricted range of applicability of Feynman's famous formula to include singular attractive $1/r$ and $1/r^2$ potentials The second is a simple quantum equivalence principle governing the transformation of euclidean path integrals to spaces with curvature and torsion which leads to time sliced path integrals that are manifestly invariant under coordinate transformations In addition to the time sliced definition the author gives a perturbative definition of path integrals which makes them invariant under coordinate transformations A consistent implementation of this property leads to an extension of the theory of generalized functions by defining uniquely integrals over products of distributions The powerful Feynman Kleinert variational approach is explained and developed systematically into a variational perturbation theory which in contrast to ordinary perturbation theory produces convergent expansions The convergence is uniform from weak to strong couplings opening a way to precise approximate evaluations of analytically unsolvable path integrals Tunneling processes are treated in detail The results are used to determine the lifetime of supercurrents the stability of metastable thermodynamic phases and the large order behavior of perturbation expansions A new variational treatment extends the range of validity of previous tunneling theories from large to small barriers A corresponding extension of large order perturbation theory also applies now to small orders Special attention is devoted to path integrals with topological restrictions These are relevant to the understanding of the statistical properties of elementary particles and the entanglement phenomena in polymer physics and biophysics The Chem Simons theory of particles with fractional statistics anyons is introduced and applied to explain the fractional quantum Hall effect The relevance of path integrals to financial markets is discussed and improvements of the famous Black Scholes formula for option prices are given which account for the fact that large market fluctuations occur much more frequently than in the commonly used Gaussian distributions

Handbook of Feynman Path Integrals Christian Grosche, Frank Steiner, 1998-06-22 The Handbook of Feynman Path Integrals appears just fifty years after Richard Feynman published his pioneering paper in 1948 entitled Space Time Approach to Non Relativistic Quantum Mechanics in which he introduced his new formulation of quantum mechanics in terms of path integrals The book presents for the first time a comprehensive table of Feynman path integrals together with an extensive list of references it will serve the reader as a thorough introduction to the theory of path integrals As a reference book it is unique in its scope and will be essential for many physicists chemists and mathematicians working in different areas of research

Feynman Path Integrals in Quantum Mechanics and Statistical Physics Lukong Cornelius Fai, 2021-04-15 This book provides an ideal introduction to the use of Feynman path integrals in the fields of quantum mechanics and statistical physics It is written for graduate students and researchers in physics mathematical physics applied mathematics as well as chemistry The material is presented in an accessible manner for readers with little knowledge of quantum mechanics and no prior exposure to path integrals It begins with elementary concepts and a review of

quantum mechanics that gradually builds the framework for the Feynman path integrals and how they are applied to problems in quantum mechanics and statistical physics Problem sets throughout the book allow readers to test their understanding and reinforce the explanations of the theory in real situations Features Comprehensive and rigorous yet presents an easy to understand approach Applicable to a wide range of disciplines Accessible to those with little or basic mathematical understanding

Field Theory Ashok Das, 1993 1 Introduction 2 Path integrals and quantum mechanics 3 Harmonic oscillator 4 Generating functional 5 Path integrals for fermions 6 Supersymmetry 7 Semi classical methods 8 Path integral for the double well 9 Path integral for relativistic theories 10 Effective action 11 Invariances and their consequences 12 Systems at finite temperature 13 Ising model

Path Integrals and Quantum Processes Mark S. Swanson, 2014-02-19 Graduate level systematic presentation of path integral approach to calculating transition elements partition functions and source functionals Covers Grassmann variables field and gauge field theory perturbation theory and nonperturbative results 1992 edition

Path Integrals in Physics M Chaichian, A Demichev, 2018-10-03 Path Integrals in Physics Volume I Stochastic Processes and Quantum Mechanics presents the fundamentals of path integrals both the Wiener and Feynman type and their many applications in physics Accessible to a broad community of theoretical physicists the book deals with systems possessing a infinite number of degrees in freedom It discusses the general physical background and concepts of the path integral approach used followed by a detailed presentation of the most typical and important applications as well as problems with either their solutions or hints how to solve them It describes in detail various applications including systems with Grassmann variables Each chapter is self contained and can be considered as an independent textbook The book provides a comprehensive detailed and systematic account of the subject suitable for both students and experienced researchers

Path Integrals In Quantum Mechanics, Statistics, Polymer Physics, And Financial Markets (4th Edition) Hagen Kleinert, 2006-07-19 This is the fourth expanded edition of the comprehensive textbook published in 1990 on the theory and applications of path integrals It is the first book to explicitly solve path integrals of a wide variety of nontrivial quantum mechanical systems in particular the hydrogen atom The solutions have become possible by two major advances The first is a new euclidean path integral formula which increases the restricted range of applicability of Feynman's famous formula to include singular attractive $1/r$ and $1/r^2$ potentials The second is a simple quantum equivalence principle governing the transformation of euclidean path integrals to spaces with curvature and torsion which leads to time sliced path integrals that are manifestly invariant under coordinate transformations In addition to the time sliced definition the author gives a perturbative definition of path integrals which makes them invariant under coordinate transformations A consistent implementation of this property leads to an extension of the theory of generalized functions by defining uniquely integrals over products of distributions The powerful Feynman Kleinert variational approach is explained and developed systematically into a variational perturbation theory which in contrast to ordinary perturbation theory produces convergent expansions The

convergence is uniform from weak to strong couplings opening a way to precise approximate evaluations of analytically unsolvable path integrals Tunneling processes are treated in detail The results are used to determine the lifetime of supercurrents the stability of metastable thermodynamic phases and the large order behavior of perturbation expansions A new variational treatment extends the range of validity of previous tunneling theories from large to small barriers A corresponding extension of large order perturbation theory also applies now to small orders Special attention is devoted to path integrals with topological restrictions These are relevant to the understanding of the statistical properties of elementary particles and the entanglement phenomena in polymer physics and biophysics The Chern Simons theory of particles with fractional statistics anyons is introduced and applied to explain the fractional quantum Hall effect The relevance of path integrals to financial markets is discussed and improvements of the famous Black Scholes formula for option prices are given which account for the fact that large market fluctuations occur much more frequently than in the commonly used Gaussian distributions The author's other book on Critical Properties of 4 Theories gives a thorough introduction to the field of critical phenomena and develops new powerful resummation techniques for the extraction of physical results from the divergent perturbation expansions

Introduction To The Mathematical Structure Of Quantum Mechanics, An: A Short Course For Mathematicians Franco Strocchi, 2005-11-17 This book arises out of the need for Quantum Mechanics QM to be part of the common education of mathematics students Rather than starting from the Dirac Von Neumann axioms the book offers a short presentation of the mathematical structure of QM using the C algebraic structure of the observable based on the operational definition of measurements and the duality between states and observables The description of states and observables as Hilbert space vectors and operators is then derived from the GNS and Gelfand Naimark Theorems For finite degrees of freedom the Weyl algebra codifies the experimental limitations on the measurements of position and momentum Heisenberg uncertainty relations and Schroedinger QM follows from the von Neumann uniqueness theorem The existence problem of the dynamics is related to the self adjointness of the differential operator describing the Hamiltonian and solved by the Rellich Kato theorems Examples are discussed which include the explanation of the discreteness of the atomic spectra Because of the increasing interest in the relation between QM and stochastic processes a final chapter is devoted to the functional integral approach Feynman Kac formula the formulation in terms of ground state correlations Wightman functions and their analytic continuation to imaginary time Euclidean QM The quantum particle on a circle as an example of the interplay between topology and functional integral is also discussed in detail

Path Integrals In Quantum Mechanics, Statistics, Polymer Physics, And Financial Markets (5th Edition) Hagen Kleinert, 2009-05-18 This is the fifth expanded edition of the comprehensive textbook published in 1990 on the theory and applications of path integrals It is the first book to explicitly solve path integrals of a wide variety of nontrivial quantum mechanical systems in particular the hydrogen atom The solutions have been made possible by two major advances The first is a new euclidean path integral formula which

increases the restricted range of applicability of Feynman's time sliced formula to include singular attractive $1/r$ and $1/r^2$ potentials. The second is a new nonholonomic mapping principle carrying physical laws in flat spacetime to spacetimes with curvature and torsion which leads to time sliced path integrals that are manifestly invariant under coordinate transformations. In addition to the time sliced definition the author gives a perturbative coordinate independent definition of path integrals which makes them invariant under coordinate transformations. A consistent implementation of this property leads to an extension of the theory of generalized functions by defining uniquely products of distributions. The powerful Feynman-Kleinert variational approach is explained and developed systematically into a variational perturbation theory which in contrast to ordinary perturbation theory produces convergent results. The convergence is uniform from weak to strong couplings opening a way to precise evaluations of analytically unsolvable path integrals in the strong coupling regime where they describe critical phenomena. Tunneling processes are treated in detail with applications to the lifetimes of supercurrents, the stability of metastable thermodynamic phases and the large order behavior of perturbation expansions. A variational treatment extends the range of validity to small barriers. A corresponding extension of the large order perturbation theory now also applies to small orders. Special attention is devoted to path integrals with topological restrictions needed to understand the statistical properties of elementary particles and the entanglement phenomena in polymer physics and biophysics. The Chern-Simons theory of particles with fractional statistics anyons is introduced and applied to explain the fractional quantum Hall effect. The relevance of path integrals to financial markets is discussed and improvements of the famous Black-Scholes formula for option prices are developed which account for the fact recently experienced in the world markets that large fluctuations occur much more frequently than in Gaussian distributions.

Introduction To The Mathematical Structure Of Quantum Mechanics, An: A Short Course For Mathematicians (2nd Edition) Franco Strocchi, 2008-10-30. The second printing contains a critical discussion of Dirac's derivation of canonical quantization which is instead deduced from general geometric structures. This book arises out of the need for Quantum Mechanics (QM) to be part of the common education of mathematics students. The mathematical structure of QM is formulated in terms of the C^* -algebra of observables which is argued on the basis of the operational definition of measurements and the duality between states and observables for a general physical system. The Dirac-von Neumann axioms are then derived. The description of states and observables as Hilbert space vectors and operators follows from the GNS and Gelfand-Naimark Theorems. The experimental existence of complementary observables for atomic systems is shown to imply the noncommutativity of the observable algebra, the distinctive feature of QM for finite degrees of freedom. The Weyl algebra codifies the experimental complementarity of position and momentum. Heisenberg commutation relations and Schrödinger QM follow from the von Neumann uniqueness theorem. The existence problem of the dynamics is related to the self-adjointness of the Hamiltonian and solved by the Kato-Rellich conditions on the potential which also guarantee quantum

stability for classically unbounded below Hamiltonians Examples are discussed which include the explanation of the discreteness of the atomic spectra Because of the increasing interest in the relation between QM and stochastic processes a final chapter is devoted to the functional integral approach Feynman Kac formula to the formulation in terms of ground state correlations the quantum mechanical analog of the Wightman functions and their analytic continuation to imaginary time Euclidean QM The quantum particle on a circle is discussed in detail as an example of the interplay between topology and functional integral leading to the emergence of superselection rules and sectors

Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets Hagen Kleinert, 2009 This is the fifth expanded edition of the comprehensive textbook published in 1990 on the theory and applications of path integrals It is the first book to explicitly solve path integrals of a wide variety of nontrivial quantum mechanical systems in particular the hydrogen atom The solutions have been made possible by two major advances The first is a new euclidean path integral formula which increases the restricted range of applicability of Feynman's time sliced formula to include singular attractive $1/r$ and $1/r^2$ potentials The second is a new nonholonomic mapping principle carrying physical laws in flat spacetime to spacetimes with curvature and torsion which leads to time sliced path integrals that are manifestly invariant under coordinate transformations In addition to the time sliced definition the author gives a perturbative coordinate independent definition of path integrals which makes them invariant under coordinate transformations A consistent implementation of this property leads to an extension of the theory of generalized functions by defining uniquely products of distributions The powerful Feynman-Kleinert variational approach is explained and developed systematically into a variational perturbation theory which in contrast to ordinary perturbation theory produces convergent results The convergence is uniform from weak to strong couplings opening a way to precise evaluations of analytically unsolvable path integrals in the strong coupling regime where they describe critical phenomena Tunneling processes are treated in detail with applications to the lifetimes of supercurrents the stability of metastable thermodynamic phases and the large order behavior of perturbation expansions A variational treatment extends the range of validity to small barriers A corresponding extension of the large order perturbation theory now also applies to small orders Special attention is devoted to path integrals with topological restrictions needed to understand the statistical properties of elementary particles and the entanglement phenomena in polymer physics and biophysics The Chern-Simons theory of particles with fractional statistics anyons is introduced and applied to explain the fractional quantum Hall effect The relevance of path integrals to financial markets is discussed and improvements of the famous Black-Scholes formula for option prices are developed which account for the fact recently experienced in the world markets that large fluctuations occur much more frequently than in Gaussian distributions

Introductory Quantum Mechanics Paul R. Berman, 2017-12-26 This book presents a basic introduction to quantum mechanics Depending on the choice of topics it can be used for a one semester or two semester course An attempt has been made to anticipate the

conceptual problems students encounter when they first study quantum mechanics. Wherever possible examples are given to illustrate the underlying physics associated with the mathematical equations of quantum mechanics. To this end connections are made with corresponding phenomena in classical mechanics and electromagnetism. The problems at the end of each chapter are intended to help students master the course material and to explore more advanced topics. Many calculations exploit the extraordinary capabilities of computer programs such as Mathematica, MatLab and Maple. Students are urged to use these programs just as they had been urged to use calculators in the past. The treatment of various topics is rather complete in that most steps in derivations are included. Several of the chapters go beyond what is traditionally covered in an introductory course. The goal of the presentation is to provide the students with a solid background in quantum mechanics.

Statistical Mechanics of Lattice Systems David Lavis, George M. Bell, 1999-03-08. Most of the interesting and difficult problems in statistical mechanics arise when the constituent particles of the system interact with each other with pair or multiparticle energies. The types of behaviour which occur in systems because of these interactions are referred to as cooperative phenomena giving rise in many cases to phase transitions. This book and its companion volume Lavis and Bell 1999 referred to in the text simply as Volume 1 are principally concerned with phase transitions in lattice systems. Due mainly to the insights gained from scaling theory and renormalization group methods this subject has developed very rapidly over the last thirty years. In our choice of topics we have tried to present a good range of fundamental theory and of applications some of which reflect our own interests. A broad division of material can be made between exact results and approximation methods. We have found it appropriate to include some of our discussion of exact results in this volume and some in Volume 1. Apart from this much of the discussion in Volume 1 is concerned with mean field theory. Although this is known not to give reliable results close to a critical region it often provides a good qualitative picture for phase diagrams as a whole. For complicated systems some kind of mean field method is often the only tractable method available. In this volume our main concern is with scaling theory, algebraic methods and the renormalization group.

Path Integrals George J. Papadopoulos, J. T. Devreese, 2013-11-11. The Advanced Study Institute on Path Integrals and Their Applications in Quantum Statistical and Solid State Physics was held at the University of Antwerpen R U C A July 17-30 1977. The Institute was sponsored by NATO. Co-sponsors were A C E C Belgium, Agfa Gevaert Belgium, Alair Liuide Belge Belgium, Belgonucleaire Belgium, Bell Telephone Mfg Co Belgium, Boelwerf Belgium, Generale Bankmaatschappij Belgium, I B M Belgium, Kredietbank Belgium, National Science Foundation U S A, Siemens Belgium. A total of 100 lecturers and participants attended the Institute. The development of path or functional integrals in relation to problems of stochastic nature dates back to the early 20s. At that time Wiener succeeded in obtaining the fundamental solution of the diffusion equation using Einstein's joint probability of finding a Brownian particle in a succession of space intervals during a corresponding succession of time intervals. Dirac in the early 30s sowed the seeds of the path integral formulation of quantum mechanics. However the major and decisive step in this

direction was taken with Feynman's works in quantum and statistical physics and quantum electrodynamics. The applications now extend to areas such as continuous mechanics and recently functional integration methods have been employed by Edwards for the study of polymerized matter.

A Brief Introduction to Topology and Differential Geometry in Condensed Matter Physics Antonio Sergio Teixeira Pires, 2019-03-21 In the last years there have been great advances in the applications of topology and differential geometry to problems in condensed matter physics. Concepts drawn from topology and geometry have become essential to the understanding of several phenomena in the area. Physicists have been creative in producing models for actual physical phenomena which realize mathematically exotic concepts and new phases have been discovered in condensed matter in which topology plays a leading role. An important classification paradigm is the concept of topological order where the state characterizing a system does not break any symmetry but it defines a topological phase in the sense that certain fundamental properties change only when the system passes through a quantum phase transition. The main purpose of this book is to provide a brief self-contained introduction to some mathematical ideas and methods from differential geometry and topology and to show a few applications in condensed matter. It conveys to physicists the basis for many mathematical concepts avoiding the detailed formality of most textbooks.

Hamiltonian Mechanics of Gauge Systems Lev V. Prokhorov, Sergei V. Shabanov, 2011-09-22 The principles of gauge symmetry and quantization are fundamental to modern understanding of the laws of electromagnetism, weak and strong subatomic forces and the theory of general relativity. Ideal for graduate students and researchers in theoretical and mathematical physics, this unique book provides a systematic introduction to Hamiltonian mechanics of systems with gauge symmetry. The book reveals how gauge symmetry may lead to a non-trivial geometry of the physical phase space and studies its effect on quantum dynamics by path integral methods. It also covers aspects of Hamiltonian path integral formalism in detail along with a number of related topics such as the theory of canonical transformations on phase space supermanifolds, non-commutativity of canonical quantization and elimination of non-physical variables. The discussion is accompanied by numerous detailed examples of dynamical models with gauge symmetries clearly illustrating the key concepts.

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