1 Semiclassical Approximation

The semiclassical approximation is a powerful approach to evaluating the propagator under the right conditions. Roughly speaking, we want a smooth potential and short de Broglie wavelengths. In the semiclassical approximation, the propagator takes the following form,

$$K_{sc}(x, x', t) = F \exp(\frac{i}{\hbar} S_c(x, x', t)), \tag{1}$$

where S_c is a strictly classical quantity, the action evaluated along the classical path from x to x'. The pre-factor F is an approximation to the path integral for paths other than the classical path. When the semiclassical approximation is working, most of the important physics is in S_c, not F. The semiclassical approximation is exact, that is not an approximation, for the free particle and the harmonic oscillator, among other examples. It is important to realize that the semiclassical approximation has to do with how close F is to the path integral around the classical path. Any path integral can be written in the form of Eq.(1). The semi-classical approximation then is an approximation to F. The general formula for F in semiclassical approximation is given at the end of these notes.

Classical Paths and Classical Action Consider any path $x(t')$ which starts at x' and ends at x. This means $x(0) = x'$, and $x(t) = x$. Once we have a path, we can calculate the action for that path. This is just

$$S = \int_0^t L(x(t')) dt'.$$

The action certainly depends on the path used to calculate it. Now suppose we go to a nearby path,

$$x(t') \rightarrow x(t') + \delta(t')$$

where $\delta(t')$ is small and vanishes at the endpoints, $\delta(0) = \delta(t) = 0$. In other words, we are considering only paths which start and end at our two points. It is of interest to see how the action varies to $O(\delta)$. Putting $x(t') \rightarrow x(t') + \delta(t')$ into the Lagrangian, we have

$$L \rightarrow \frac{m}{2} \left(\frac{d}{dt}(x + \delta) \right)^2 - V(x + \delta)$$

Expanding, we have

$$L = \frac{m}{2} (\frac{dx}{dt})^2 + m \frac{dx}{dt} \frac{d\delta}{dt} - V(x) - \delta \frac{\partial}{\partial x} V + \dots$$

Putting these terms in the action, we have for δS,

$$\delta S = \int_0^t dt' (\frac{dx}{dt} \frac{d\delta}{dt} - \delta \frac{\partial}{\partial x} V)$$

Semiclassical Approximation In Quantum Mechanics

Harald Friedrich

Semiclassical Approximation In Quantum Mechanics:

    Semi-Classical Approximation in Quantum Mechanics Victor P. Maslov,M.V. Fedoriuk,2001-11-30 This volume is concerned with a detailed description of the canonical operator method one of the asymptotic methods of linear mathematical physics The book is in fact an extension and continuation of the authors works 59 60 65 The basic ideas are summarized in the Introduction The book consists of two parts In the first the theory of the canonical operator is develop ed whereas in the second many applications of the canonical operator method to concrete problems of mathematical physics are presented The authors are pleased to express their deep gratitude to S M Tsidilin for his valuable comments THE AUTHORS IX INTRODUCTION 1 Various problems of mathematical and theoretical physics involve partial differential equations with a small parameter at the highest derivative terms For constructing approximate solutions of these equations asymptotic methods have long been used In recent decades there has been a renaissance period of the asymptotic methods of linear mathematical physics The range of their applicability has expanded the asymptotic methods have been not only continuously used in traditional branches of mathematical physics but also have had an essential impact on the development of the general theory of partial differential equations It appeared recently that there is a unified approach to a number of problems which at first sight looked rather unrelated **V.P. Maslov and M.V. Fedroiuk. Semi-classical approximation in quantum mechanics (Kvaziklassičeskoe približenie dlja uravnenij kvantovoj mechaniki, engl.) Transl. from the Russian by J. Niederle and J. Tolar** V. P. Maslov,Michail Vasil'evič Fedorjuk,1981 Semi-classical Approximation in Quantum Mechanics Viktor Pavlovich Maslov,Mikhail Vasilʹevich Fedori︠u︡k,1981 *Semi-classical Approximation in Quantum Mechanics* D.. Robert,1997 **Quantum Mechanical Irreversibility and Measurement** Paolo Grigolini,1993 The subject of this book emerged from a series of lectures that the author gave at the Department of Physics of the University of North Texas during the 1992 Spring Semester and reflects the vivacious discussions that he has been having with the students and the co workers attending this course The main conclusion of these discussions was that the major tenet of the conservative physicists that classical physics must be recovered from quantum mechanics by adopting the statistical perspective of Gibbs implying by necessity a Gibbs ensemble of Universes as well as a Gibbs ensemble of observers is not satisfactory It is actually as unsatisfactory as the dominant approaches to irreversibility The book examines the current approaches to irreversibility in classical and quantum physics and shows that an objective theory of irreversibility does not exist yet and that all the current theories of irreversibility share with quantum mechanics elements of subjectivity making crucial the role played by the observer In addition to the traditional quantum mechanical paradoxes concerning the quantum theory of measurement the book also discusses the new difficulties that the physics of chaos is causing to the widely accepted correspondence principle and suggests that the Boltzmann dream the dream that the fracture between dynamics and thermodynamics might be healed cannot become true within the framework of the current physics and that the establishment of a new physics is necessary for

that ambitious purpose to be achieved *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 r2 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 perturbationexpansions 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 anyohs 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 **Semi-classical Analysis For Nonlinear Schrodinger Equations: Wkb Analysis, Focal Points, Coherent States (Second Edition)** Remi Carles,2020-10-05 The second edition of this book consists of three parts The first one is dedicated to the WKB methods and the semi classical limit before the formation of caustics The second part treats the semi classical limit in the presence of caustics in the special geometric case where the caustic is reduced to a point or to several isolated points The third part is new in this edition and addresses the nonlinear propagation of coherent states The three parts are essentially independent Compared with the first edition the first part is enriched by a new section on multiphase expansions in the case of weakly nonlinear geometric optics and an application related to this study concerning instability results for nonlinear Schr dinger equations in negative order Sobolev spaces The third part is an overview of

results concerning nonlinear effects in the propagation of coherent states in the case of a power nonlinearity and in the richer case of Hartree like nonlinearities It includes explicit formulas of an independent interest such as generalized Mehler s formula generalized lens transform   Quantum Chemistry and Dynamics of Excited States Leticia González,Roland Lindh,2020-11-10 An introduction to the rapidly evolving methodology of electronic excited states For academic researchers postdocs graduate and undergraduate students Quantum Chemistry and Dynamics of Excited States Methods and Applications reports the most updated and accurate theoretical techniques to treat electronic excited states From methods to deal with stationary calculations through time dependent simulations of molecular systems this book serves as a guide for beginners in the field and knowledge seekers alike Taking into account the most recent theory developments and representative applications it also covers the often overlooked gap between theoretical and computational chemistry An excellent reference for both researchers and students Excited States provides essential knowledge on quantum chemistry an in depth overview of the latest developments and theoretical techniques around the properties and nonadiabatic dynamics of chemical systems Readers will learn Essential theoretical techniques to describe the properties and dynamics of chemical systems Electronic Structure methods for stationary calculations Methods for electronic excited states from both a quantum chemical and time dependent point of view A breakdown of the most recent developments in the past 30 years For those searching for a better understanding of excited states as they relate to chemistry biochemistry industrial chemistry and beyond Quantum Chemistry and Dynamics of Excited States provides a solid education in the necessary foundations and important theories of excited states in photochemistry and ultrafast phenomena   **Advances in One-Dimensional Wave Mechanics** Zhuangqi Cao,Cheng Yin,2014-01-16 Advances in One Dimensional Wave Mechanics provides a comprehensive description of the motion of microscopic particles in one dimensional arbitrary shaped potentials based on the analogy between Quantum Mechanics and Electromagnetism Utilizing a deeper understanding of the wave nature of matter this book introduces the concept of the scattered sub waves and a series of new analytical results using the Analytical Transfer Matrix ATM method This work will be useful for graduate students majoring in physics mainly in basic quantum theory as well as for academic researchers exploring electromagnetism particle physics and wave mechanics and for experts in the field of optical waveguide and integrated optics Prof Zhuangqi Cao is a Professor of Physics at Shanghai Jiao Tong University China Dr Cheng Yin is a teacher at Jiangsu Key Laboratory of Power Transmission and Distribution Equipment Technology Hohai University China   Differential Equations and Mathematical Physics Rudi Weikard,Gilbert Weinstein,2000 This volume contains the proceedings of the 1999 International Conference on Differential Equations and Mathematical Physics The contributions selected for this volume represent some of the most important presentations by scholars from around the world on developments in this area of research The papers cover topics in the general area of linear and nonlinear differential equations and their relation to mathematical physics such as multiparticle Schr dinger operators stability of matter relativity

theory fluid dynamics spectral and scattering theory including inverse problems Titles in this series are co published with International Press Cambridge MA **The Physics of Energy** Robert L. Jaffe,Washington Taylor,2018-01-25 A comprehensive and unified introduction to the science of energy sources uses and systems for students scientists engineers and professionals Variational Principles in Physics Jean-Louis Basdevant,2007-03-12 Optimization under constraints is an essential part of everyday life Indeed we routinely solve problems by striking a balance between contradictory interests individual desires and material contingencies This notion of equilibrium was dear to thinkers of the enlightenment as illustrated by Montesquieu s famous formulation In all magistracies the greatness of the power must be compensated by the brevity of the duration Astonishingly natural laws are guided by a similar principle Variational principles have proven to be surprisingly fertile For example Fermat used variational methods to demonstrate that light follows the fastest route from one point to another an idea which came to be known as Fermat s principle a cornerstone of geometrical optics Variational Principles in Physics explains variational principles and charts their use throughout modern physics The heart of the book is devoted to the analytical mechanics of Lagrange and Hamilton the basic tools of any physicist Prof Basdevant also offers simple but rich first impressions of Einstein s General Relativity Feynman s Quantum Mechanics and more revealing and amazing interconnections between various fields of physics Theoretical Atomic Physics Harald Friedrich,2017-05-10 This expanded and updated well established textbook contains an advanced presentationof quantum mechanics adapted to the requirements of modern atomic physics Itincludes topics of current interest such as semiclassical theory chaos atom optics andBose Einstein condensation in atomic gases In order to facilitate the consolidationof the material covered various problems are included together with completesolutions The emphasis on theory enables the reader to appreciate the fundamentalassumptions underlying standard theoretical constructs and to embark on independentresearch projects The fourth edition of Theoretical Atomic Physics contains anupdated treatment of the sections involving scattering theory and near thresholdphenomena manifest in the behaviour of cold atoms and molecules Special attentionis given to the quantization of weakly bound states just below the continuum thresholdand to low energy scattering and quantum reflection just above Particular emphasisis laid on the fundamental differences between long ranged Coulombic potentialsand shorter ranged potentials falling off faster than $1/r^2$ at large distances r The newsections on tunable near threshold Feshbach resonances and on scattering in two spatialdimensions also address problems relevant for current and future research in the fieldof cold and ultra cold atoms Graduate students and researchers will find this book avaluable resource and comprehensive reference alike Quantum Theory Charis Anastopoulos,2023-08-31 The ideal text for a two semester graduate course on quantum mechanics Fresh comprehensive and clear it strikes the optimal balance between covering traditional material and exploring contemporary topics Focusing on the probabilistic structure of quantum mechanics and the central role of symmetries to unify principles this textbook guides readers through the logical development of the theory

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29 research and survey papers contributed by conference participants The conference provided researchers a forum to present and discuss their recent results in a broad range of areas encompassing the theory of differential equations and their applications in mathematical physics Papers in this volume represent some of the most interesting results and the major areas of research that were covered including spectral theory with applications to non relativistic and relativistic quantum mechanics including time dependent and random potential resonances many body systems pseudodifferential operators and quantum dynamics inverse spectral and scattering problems the theory of linear and nonlinear partial differential equations with applications in fluid dynamics conservation laws and numerical simulations as well as equilibrium and nonequilibrium statistical mechanics The volume is intended for graduate students and researchers interested in mathematical physics

Structural Stability in Physics G. Güttinger,H. Eikemeier,2012-12-06 This volume is the record and product of two International Symposia on the Appli cation of Catastrophe Theory and Topological Concepts in Physics held in May and December 1978 at the Institute for Information Sciences University of TUbingen The May Symposium centered around the conferral of an honorary doctorate upon Professor Rene Thom Paris by the Faculty of Physics of the University of TUbingen in recognition of his discovery of universal structure principles and the new di mension he has added to scientific knowledge by his pioneering work on structural stability and morphogenesis Owing to the broad scope and rapid development of the field the May Sympos ium was followed in December by a second one on the same sub jects The symposia attended by more than 50 scientists brought together mathe maticians physicists chemists and biologists to exchange ideas about the recent faSCinating impact of topological concepts on the physical sciences and also to introduce young scientists to the field The contributions covering a wide spectrum are summarized in the subsequent Introduction The primary support of the Symposia was provided by the Vereinigung der Freunde der Univertat TUbingen Association of the Benefactors of the University We are particularly indebted to Dr H Doerner for his personal engagement and efficient help with the projects both in his capacity as Secretary of the Association and as Administrative Director of the University

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