

# PROPAGATOR/GREEN'S FUNCTION IN QUANTUM MECHANICS - SIMPLE DERIVATION OF PROPAGATOR FOR A SIMPLE HARMONIC OSCILLATOR - A TUTORIAL

JAMBUNATHA SETHURAMAN

**Abstract:** The derivation of propagator in quantum mechanics is an interesting problem. The propagator for free particle and simple (one-dimensional) harmonic oscillator (SHO) can be obtained in a closed form from the knowledge of the eigenfunctions of the Hamiltonian of respective systems. The propagator of a SHO is derived in an elegant way making use of the bilinear generating function of Hermite functions [1]. In the limit when force constant tends to zero, the propagator of free particle is recovered.

## Introduction:

Time dependent Schrodinger equation is given by

$$\left( i\hbar \frac{\partial}{\partial t} - H_0 \right) \psi(x; t) = \delta(t), \quad (1)$$

where  $\psi(x; t)$  is the wave function evolving in time and space.  $H_0$  is the time independent Hamiltonian given by  $H_0 = \frac{p^2}{2m} + \frac{k}{2} x^2$ .  $\delta(t)$  is the Dirac delta function. (2)

The time independent Hamiltonian  $H_0$  possesses a discrete set of eigenfunctions  $\{u_n(x)\}$  [1]

$$u_n(x) = \frac{1}{\sqrt{2^n n!}} \left( \frac{n}{\alpha} \right)^{\frac{1}{2}} e^{-\frac{\alpha}{2} x^2} H_n(\sqrt{\alpha} x), \quad (3)$$

where  $\alpha = \frac{m\omega}{\hbar}$ ,  $\hbar$  is the Planck constant,  $\omega = \sqrt{\frac{k}{m}}$ .

$$H_0 u_n(x) = E_n u_n(x), \quad (4)$$

$$E_n = \left( n + \frac{1}{2} \right) \hbar \omega, \quad n = 0, 1, 2, 3, \quad (5)$$

*The set of functions  $\{H_n(\sqrt{\alpha} x)\}$  is the Hermite polynomials of order  $n$ .*

The propagator 
$$G(x, x'; t) = \sum_{n=0}^{\infty} u_n(x) u_n^*(x') e^{-\frac{i}{\hbar} E_n t}. \quad (6)$$

When  $\lim_{t \rightarrow 0} G(x, x'; t) \rightarrow G(x, x'; 0) = \delta(x; x') = \delta(x - x'). \quad (7)$

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*Quantum Statistical Mechanics* Leo P. Kadanoff, Gordon Baym, 1962      **Selected Topics In Statistical Mechanics - 5th International Symposium** Nickolai N Bogolubov Jr, A A Logunov, Vladimir G Kadyshevsky, A S Shumovsky, 1990-07-13 This symposium is dedicated to Prof N N Bogolubov on the occasion of his 80th birthday Besides including a collection of articles by distinguished speakers this volume also contains a review on the life and scientific activities of Prof N N Bogolubov      Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets Hagen Kleinert, 2004-03-05 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 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 Request Inspection Copy      *Statistical Physics II* R. Kubo, M. Toda, N. Hashitsume, 2012-12-06 This

volume of Statistical Physics constitutes the second part of Statistical Physics Springer Series in Solid State Science Vols 30 31 and is devoted to nonequilibrium theories of statistical mechanics We start with an introduction to the stochastic treatment of Brownian motion and then proceed to general problems involved in deriving a physical process from an underlying more basic process Relaxation from nonequilibrium to equilibrium states and the response of a system to an external disturbance form the central problems of nonequilibrium statistical mechanics These problems are treated both phenomenologically and microscopically along the lines of recent developments Emphasis is placed on fundamental concepts and methods rather than on applications which are too numerous to be treated exhaustively within the limited space of this volume For information on the general aim of this book the reader is referred to the Foreword For further reading the reader should consult the bibliographies although these are not meant to be exhaustive

**Development and application of a massively parallel KKR Green function method for large scale systems** Alexander R. Thieß, 2013 **Applied Algorithms**

Subhas C. Nandy, Rajat K. De, Prosenjit Gupta, 2025-04-18 This book LNCS constitutes the refereed proceedings of the Second International Conference on Applied Algorithms ICAA 2025 held in Kolkata India during January 8 10 2025 The 26 full papers and 4 short papers are carefully reviewed and selected from 93 submissions This conference sought original contributions related to the design analysis implementation and experimental evaluation of efficient algorithms and data structures for problems

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presented as a general concept Stochastic processes are introduced as a necessary prerequisite to describe the evolution of a nonequilibrium state Different standard approaches such as master equations kinetic equations and linear response theory are derived after special assumptions This allows for an insight into the problems of nonequilibrium physics a discussion of the limits of the approaches and suggestions for improvements The method of thermodynamic Green's function is outlined that allows for the systematic quantum statistical treatment of many body systems Applications and typical examples are given as well as fully worked problems

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*Statistical Condensed Matter Physics* Carlo Di Castro, Roberto Raimondi, 2015-08-27 An innovative and modular textbook combining established classical topics in statistical mechanics with the latest developments in condensed matter physics

[Progress in Nonequilibrium Green's Functions](#) Michael Bonitz, Renate Nareyka, Dirk Semkat, 2000 Equilibrium and nonequilibrium properties of correlated many body systems are of growing interest in many fields of physics including condensed matter dense plasmas nuclear matter and particles The most powerful and general method which applies equally to all these areas is given by quantum field theory Written by the leading experts and understandable to non specialists this book provides an overview on the basic ideas and concepts of the method of nonequilibrium Green's functions It is complemented by modern applications of the method to a variety of topics such as optics and transport in dense plasmas and semiconductors correlations bound states and coherence strong field effects and short pulse lasers nuclear matter and QCD Authors include Gordon Bayan Pawel Danielewicz Don DuBois Hartmut Haug Klaus Henneberger Antti Pekka Jauho Jörn Kuoll Dietrich Kremp Pavel Lipavsky and Paul C Martin

**Advances in Chemical Physics, Volume 22** Ilya Prigogine, Stuart A. Rice, 2009-09-08 The Advances in Chemical Physics series provides the chemical physics and physical chemistry fields with a forum for critical authoritative evaluations of advances in every area of the discipline Filled with cutting edge research reported in a cohesive manner not found elsewhere in the literature each volume of the Advances in Chemical Physics series serves as the perfect supplement to any advanced graduate class devoted to the study of chemical physics

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Physics And Mathematical Tools: Methods And Examples Angel Alastuey, Marc Magro, Pierre Pujol, Maxime Clusel, 2015-12-30 This book presents mathematical methods and tools which are useful for physicists and engineers response functions Kramers Kronig relations Green s functions saddle point approximation The derivations emphasize the underlying physical arguments and interpretations without any loss of rigor General introductions describe the main features of the methods while connections and analogies between a priori different problems are discussed They are completed by detailed applications in many topics including electromagnetism hydrodynamics statistical physics quantum mechanics etc Exercises are also proposed and their solutions are sketched A self contained reading of the book is favored by avoiding too technical derivations and by providing a short presentation of important tools in the appendices It is addressed to undergraduate and graduate students in physics but it can also be used by teachers researchers and engineers

Physics of Hot Electron Transport in Semiconductors Chin Sen Ting, 1992 This review volume is based primarily on the balance equation approach developed since 1984 It provides a simple and analytical description about hot electron transport particularly in semiconductors with higher carrier density where the carrier carrier collision is much stronger than the single particle scattering The steady state and time dependent hot electron transport thermal noise hot phonon effect the memory effect and other related subjects of charge carriers under strong electric fields are reviewed The application of Zubarev s nonequilibrium statistical operator to hot electron transport and its equivalence to the balance equation method are also presented For semiconductors with very low carrier density the problem can be regarded as a single carrier transport which will be treated non perturbatively by the nonequilibrium Green s function technique and the path integral theory The last part of this book consists of a chapter on the dynamic conductivity and the shot noise suppression of a double carrier resonant tunneling system

**Energy Research Abstracts**, 1989 Semiannual with semiannual and annual indexes References to all scientific and technical literature coming from DOE its laboratories

energy centers and contractors Includes all works deriving from DOE other related government sponsored information and foreign nonnuclear information Arranged under 39 categories e g Biomedical sciences basic studies Biomedical sciences applied studies Health and safety and Fusion energy Entry gives bibliographical information and abstract Corporate author subject report number indexes      **New Technical Books** ,1926      **Perspectives on Organisms** Giuseppe Longo, Maël Montévil, 2013-12-13 This authored monograph introduces a genuinely theoretical approach to biology Starting point is the investigation of empirical biological scaling including their variability which is found in the literature e g allometric relationships fractals etc The book then analyzes two different aspects of biological time first a supplementary temporal dimension to accommodate proper biological rhythms secondly the concepts of protension and retention as a means of local organization of time in living organisms Moreover the book investigates the role of symmetry in biology in view of its ubiquitous importance in physics In relation with the notion of extended critical transitions the book proposes that organisms and their evolution can be characterized by continued symmetry changes which accounts for the irreducibility of their historicity and variability The authors also introduce the concept of anti entropy as a measure for the potential of variability being equally understood as alterations in symmetry By this the book provides a mathematical account of Gould s analysis of phenotypic complexity with respect to biological evolution The target audience primarily comprises researchers interested in new theoretical approaches to biology from physical biological or philosophical backgrounds but the book may also be beneficial for graduate students who want to enter this field

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