

Supersymmetry And Supergravity Princeton Series In Physics

Supersymmetric models of particle physics predict new superpartner matter states for each particle in the Standard Model. These superpartners will have wide ranging implications, from cosmology to observations at high energy accelerators, such as CERN's LHC. In this 2006 text, the authors develop the basic concepts of supersymmetry and show how it can be incorporated into a theoretical framework for describing unified theories of elementary particles. They develop the technical tools of supersymmetry using four-component spinor notation familiar to high energy experimentalists and phenomenologists. The text takes the reader from an abstract formalism to a straightforward recipe for writing supersymmetric gauge theories of particle physics, and ultimately to the calculations necessary for practical applications at colliders and in cosmology. This is a comprehensive, practical and accessible introduction to supersymmetry for experimental and phenomenological particle physicists and graduate students. Exercises and worked examples that clarify the material are interspersed throughout.

Adopting an elegant geometrical approach, this advanced pedagogical text describes deep and intuitive methods for understanding the subtle logic of supersymmetry while avoiding lengthy computations. The book describes how complex results and formulae obtained using other approaches can be significantly simplified when translated to a geometric setting. Introductory chapters describe geometric structures in field theory in the general case, while detailed later chapters address specific structures such as parallel tensor fields, G-structures, and isometry groups. The relationship between structures in supergravity and periodic maps of algebraic manifolds, Kodaira-Spencer theory, modularity, and the arithmetic properties of supergravity are also addressed. Relevant geometric concepts are introduced and described in detail, providing a self-contained toolkit of useful techniques, formulae and constructions. Covering all the material necessary for the application of supersymmetric field theories to fundamental physical questions, this is an outstanding resource for graduate students and researchers in theoretical physics.

Recent developments in supersymmetric field theory, string theory, and brane theory have been revolutionary. The main focus of the present volume is developments of M-theory and its applications to superstring theory, quantum gravity, and the theory of elementary particles. Topics included are D-branes, boundary states, and world volume solitons. Anti-De-Sitter quantum field theory is explained, emphasising the way it can enforce the holography principle, together with the relation to black hole physics and the way Branes provide the microscopic interpretation for the entropy of black holes. Developments in D-branes within type-I superstring and related theories are described. There are also possible phenomenological implications of superstring theory that would lie within the range of quantum gravity effects in the future generation of accelerators, around 1 TeV.

We read in order to know we are not alone, I once heard, and perhaps it could also be suggested that we write in order not to be alone, to endorse, to promote continuity. The idea for this book took about ten years to materialize, and it is the author's hope that its content will constitute the beginning of further explorations beyond current horizons. More specifically, this book appeals to the reader to engage upon and persevere with a journey, moving through the less well explored territories in the evolution of the very early universe, and pushing towards new landscapes. Perhaps, during or after consulting this book, this attitude and this willingness will be embraced by someone, somewhere, and this person will go on to enrich our quantum cosmological description of the early universe, by means of a clearer supersymmetric perspective. It is to these creative and inquisitive 'young minds' that the book is addressed. The reader will not therefore find in this book all the answers to all the problems regarding a supersymmetric and quantum description of the early universe, and this remark is substantiated in the book by a list of unresolved and challenging problems, itself incomplete.

"Supergravity, together with string theory, is one of the most significant developments in theoretical physics. Although there are many books on string theory, this is the first-ever authoritative and systematic account of supergravity. Written by two of the most respected workers in the field, it provides a solid introduction to the fundamentals of supergravity. It starts by reviewing aspects of relativistic field theory in Minkowski spacetime. After introducing the relevant ingredients of differential geometry and gravity, some basic supergravity theories (D=4 and D=11) and the main gauge theory tools are explained. In the second half of the book, complex geometry and N=1 and N=2 supergravity theories are covered. Classical solutions and a chapter on AdS/CFT complete the book. Numerous exercises and examples make it ideal for Ph.D. students and with applications to model building, cosmology and solutions of supergravity theories, it is also invaluable to researchers"-- This text presents the mathematical concepts of Grassmann variables and the method of supersymmetry to a broad audience of physicists interested in applying these tools to disordered and critical systems, as well as related topics in statistical physics. Based on many courses and seminars held by the author, one of the pioneers in this field, the reader is given a systematic and tutorial introduction to the subject matter. The algebra and analysis of Grassmann variables is presented in part I. The mathematics of these variables is applied to a random matrix model, path integrals for fermions, dimer models and the Ising model in two dimensions. Supermathematics - the use of commuting and anticommuting variables on an equal footing - is the subject of part II. The properties of supervectors and supermatrices, which contain both commuting and Grassmann components, are treated in great detail, including the derivation of integral theorems. In part III, supersymmetric physical models are considered. While supersymmetry was first introduced in elementary particle physics as exact symmetry between bosons and fermions, the formal introduction of anticommuting spacetime components, can be extended to problems of statistical physics, and, since it connects states with equal energies, has also found its way into quantum mechanics. Several models are considered in the applications, after which the representation of the random matrix model by the nonlinear sigma-model, the determination of the density of states and the level correlation are derived. Eventually, the mobility edge behavior is discussed and a short account of the ten symmetry classes of disorder, two-dimensional disordered models, and superbosonization is given.

The Hierarchy Problem is arguably the most important guiding principle concerning the extension to high-energy scales of the Standard Model (SM) of Fundamental Interactions. Every scenario for addressing this issue unavoidably predicts new physics in the TeV energy range, which is currently being probed directly by the LHC experimental program. Among the possible solutions to the Hierarchy Problem, the scenario of a composite Higgs boson is a very simple idea and a rather plausible picture has emerged over the years by combining the following ingredients: First, the Higgs must be a (pseudo-) Nambu-Goldstone boson, rather than a generic hadron of the new strong sector. Second, through the so-called 'partial compositeness', SM particles mix with strong sector resonances with suitable quantum numbers, so that they become a linear combination of elementary and composite degrees of freedom. Recently, general descriptions of the Composite Higgs Scenario were developed which successfully capture the relevant features of this theoretical framework in a largely model-independent way. The present book provides a concise and illustrative introduction to the subject for a broad audience of graduate students and non-specialist researchers in the fields of particle, nuclear and gravitational physics.

This widely acclaimed introduction to N = 1 supersymmetry and supergravity is aimed at readers familiar with relativistic quantum field theory who wish to learn about the supersymmetry algebra. In this new volume Supersymmetry and Supergravity has been greatly expanded to include a detailed derivation of the most general coupling of super-symmetric gauge theory to supergravity. The final result is the starting point for phenomenological studies of supersymmetric theories. The book is distinguished by its pedagogical approach to supersymmetry. It develops several topics in advanced field theory as the need arises. It emphasizes the logical coherence of the subject and should appeal to physicists whose interests range from the mathematical to the phenomenological. In praise of the first edition: "A beautiful exposition of the original ideas of Wess and Zumino in formulating N = 1 supersymmetry and supergravity theories, couched in the language of superfields

introduced by Strathdee and the reviewer.... [All] serious students of particle physics would do well to acquire a copy."--Abdus Salam, Nature
"An excellent introduction to this exciting area of theoretical physics."--C. J. Isham, Physics Bulletin

This book is about supergravity, which combines the principles of general relativity and local gauge invariance with the idea of supersymmetries between bosonic and fermionic degrees of freedom. The authors give a thorough and pedagogical introduction to the subject suitable for beginning graduate or advanced undergraduate students in theoretical high energy physics or mathematical physics. Interested researchers working in these or related areas are also addressed. The level of the presentation assumes a working knowledge of general relativity and basic notions of differential geometry as well as some familiarity with global supersymmetry in relativistic field theories. Bypassing curved superspace and other more technical approaches, the book starts from the simple idea of supersymmetry as a local gauge symmetry and derives the mathematical and physical properties of supergravity in a direct and "minimalistic" way, using a combination of explicit computations and geometrical reasoning. Key topics include spinors in curved spacetime, pure supergravity with and without a cosmological constant, matter couplings in global and local supersymmetry, phenomenological and cosmological implications, extended supergravity, gauged supergravity and supergravity in higher spacetime dimensions.

The contributions to this volume of the famous summer school in Les Houches cover the recent developments in supersymmetric string theory, the gauge theory/string theory correspondence and string duality. The book is a comprehensive introduction to the recent developments in string/M-theory and quantum gravity.

The lectures featured in this book treat fundamental concepts necessary for understanding the physics behind these mathematical applications. Freed approaches the topic with the assumption that the basic notions of supersymmetric field theory are unfamiliar to most mathematicians. He presents the material intending to impart a firm grounding in the elementary ideas.

The essential introduction to modern string theory—now fully expanded and revised String Theory in a Nutshell is the definitive introduction to modern string theory. Written by one of the world's leading authorities on the subject, this concise and accessible book starts with basic definitions and guides readers from classic topics to the most exciting frontiers of research today. It covers perturbative string theory, the unity of string interactions, black holes and their microscopic entropy, the AdS/CFT correspondence and its applications, matrix model tools for string theory, and more. It also includes 600 exercises and serves as a self-contained guide to the literature. This fully updated edition features an entirely new chapter on flux compactifications in string theory, and the chapter on AdS/CFT has been substantially expanded by adding many applications to diverse topics. In addition, the discussion of conformal field theory has been extensively revised to make it more student-friendly. The essential one-volume reference for students and researchers in theoretical high-energy physics Now fully expanded and revised Provides expanded coverage of AdS/CFT and its applications, namely the holographic renormalization group, holographic theories for Yang-Mills and QCD, nonequilibrium thermal physics, finite density physics, and entanglement entropy Ideal for mathematicians and physicists specializing in theoretical cosmology, QCD, and novel approaches to condensed matter systems An online illustration package is available to professors

In this volume, topics such as the AdS/CFT correspondence, non-BPS states, noncommutative gauge theories and the Randall-Sundrum scenario are discussed. For the AdS/CFT correspondence, some of its generalizations, including examples of non-AdS/nonconformal backgrounds, are described. Myer's effect in this context and otherwise is also treated. Recent results in the context of non-BPS states are reviewed, in particular the use of open string field theory in understanding the related problem of tachyon condensation. Instantons and solitons in noncommutative gauge theories are described, as are various issues in the framework of the Randall-Sundrum scenario.

Perhaps quantum mechanics is viewed as the most remarkable development in 20th century physics. Each successful theory is exclusively concerned about "results of measurement". Quantum mechanics point of view is completely different from classical physics in measurement, because in microscopic world of quantum mechanics, a direct measurement as classical form is impossible. Therefore, over the years of developments of quantum mechanics, always challenging part of quantum mechanics lies in measurements. This book has been written by an international invited group of authors and it is created to clarify different interpretation about measurement in quantum mechanics.

This book provides a self-contained presentation of supergravity theories from its fundamentals to its most recent union with string and superstring theories, which are also reviewed in a self-contained manner. The subject is presented consistently in a unified geometric formalism, relying on the calculus of exterior forms and the mathematics needed to develop the theory is explained in appropriate chapters.

Noncommutative differential geometry is a new approach to classical geometry. It was originally used by Fields Medalist A. Connes in the theory of foliations, where it led to striking extensions of Atiyah-Singer index theory. It also may be applicable to hitherto unsolved geometric phenomena and physical experiments. However, noncommutative differential geometry was not well understood even among mathematicians. Therefore, an international symposium on commutative differential geometry and its applications to physics was held in Japan, in July 1999. Topics covered included: deformation problems, Poisson groupoids, operad theory, quantization problems, and D-branes. The meeting was attended by both mathematicians and physicists, which resulted in interesting discussions. This volume contains the refereed proceedings of this symposium. Providing a state of the art overview of research in these topics, this book is suitable as a source book for a seminar in noncommutative geometry and physics.

An expansive and conceptually unifying textbook of fundamental and theoretical physics, describing elementary particles and their interactions.

These proceedings cover the possible manifestations of electron-phonon interactions in understanding high T_c superconductivity. The results of measurements of different experimental methods have been analysed, and the role played by electrons in superconductivity, taking into account the van Hove singularity, has also been discussed. The pairing of electrons by other bosonic excitations, as well as the effects of strong local electron-lattice interactions are reviewed. Another important point is the ab initio calculations discussed by several authors that remark the importance of electron-phonon effects for high T_c superconductivity.

' This book presents, for the first time, a systematic formulation of the geometric theory of noncommutative PDE's which is suitable enough to be used for a mathematical description of quantum dynamics and quantum field theory. A geometric theory of supersymmetric quantum PDE's is also considered, in order to describe quantum supergravity. Covariant and canonical quantizations of (super) PDE's are shown to be founded on the geometric theory of PDE's and to produce quantum (super) PDE's by means of functors from the category of commutative (super) PDE's to the category of quantum (super) PDE's. Global properties of solutions to (super) (commutative) PDE's are obtained by

means of their integral bordism groups. Contents: Quantized PDE's I: Noncommutative Manifolds Quantized PDE's II: Noncommutative PDE's Quantized PDE's III: Quantizations of Commutative PDE's Addendum I: Bordism Groups and the (NS)-Problem Addendum II: Bordism Groups and Variational PDE's Readership: Researchers and graduate students in the fields of partial differential equations, mathematical physics and theoretical physics. Keywords: Noncommutative Manifolds; Noncommutative PDE's; (Co)Bordism Groups in (Noncommutative) PDE's; (Quantum) Navier-Stokes Equations; (Quantum) Super Yang-Mills Equations; Quantum Supergravity; Global Existence Solutions of (Quantum) PDE's'

This book provides a thorough introduction to the phenomenology of heavy flavour physics, those working on the B-factories, LHCb, BTeV, HERA and the Tevatron. It explains how heavy quark theory could be implemented on the lattice, and discusses the status of CP-violation in the neutral kaon system.

A presentation of outstanding achievements and ideas, of both eastern and western scientists, both mathematicians and physicists. Their presentations of recent work on quantum field theory, supergravity, M-theory, black holes and quantum gravity, together with research into noncommutative geometry, Hopf algebras, representation theory, categories and quantum groups, take the reader to the forefront of the latest developments. Other topics covered include supergravity and branes, supersymmetric quantum mechanics and superparticles, (super) black holes, superalgebra representations, and SUSY GUT phenomenology. Essential reading for workers in the modern methods of theoretical and mathematical physics.

This book offers a detailed guide on the journey towards the minimal supersymmetric standard model down the orbifold road. It takes the viewpoint that the chirality of matter fermions is an essential aspect that orbifold compactification allows to derive from higher-dimensional string theories in a straightforward manner. Halfway between textbook and tutorial review, the book is intended for the graduate student and particle phenomenologist wishing to get acquainted with this field.

This widely acclaimed introduction to $N = 1$ supersymmetry and supergravity is aimed at readers familiar with relativistic quantum field theory who wish to learn about the supersymmetry algebra. In this new volume Supersymmetry and Supergravity has been greatly expanded to include a detailed derivation of the most general coupling of supersymmetric gauge theory to supergravity. The final result is the starting point for phenomenological studies of supersymmetric theories. The book is distinguished by its pedagogical approach to supersymmetry. It develops several topics in advanced field theory as the need arises. It emphasizes the logical coherence of the subject and should appeal to physicists whose interests range from the mathematical to the phenomenological. In praise of the first edition: "A beautiful exposition of the original ideas of Wess and Zumino in formulating $N = 1$ supersymmetry and supergravity theories, couched in the language of superfields introduced by Strathdee and the reviewer.... [All] serious students of particle physics would do well to acquire a copy".--Abdus Salam, Nature "An excellent introduction to this exciting area of theoretical physics".--C. J. Isham, Physics Bulletin

Twenty-five years of Schladming Winter School 1. The Start Twenty-five years ago P. Urban had the idea of organizing a winter school in the Austrian mountains. The very concept of a school was not new: to bring physicists together in an environment which differs totally from the daily world of institutes and laboratories, to contrast hard classroom work in lectures by distinguished speakers with a relaxed atmosphere, to provide opportunities for entering newly developing fields and exchanging ideas, all this had already resulted in a few summer schools in southern Europe and the US. The idea of combining physics with skiing rather than swimming was, however, new. After some sampling by a few younger members of Urban's group, Schladming was selected as an appropriate place. At that time skiing was not very much developed here; there were few lifts, but a road to Hochwurzen and a regular bus service opened at least one longer track. The first meeting took place in a classroom of the local school, where some 40 participants were squeezed into benches designed for children. In the next year we moved into the dining hall of a small inn, which does not exist any more (an attempt to serve beer during the lectures was stopped by the organizing committee). Only in later years did we find a permanent home here in the Stadtsaal.

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This volume contains the proceedings of the conference String-Math 2015, which was held from December 31, 2015–January 4, 2016, at Tsinghua Sanya International Mathematics Forum in Sanya, China. Two of the main themes of this volume are frontier research on Calabi-Yau manifolds and mirror symmetry and the development of non-perturbative methods in supersymmetric gauge theories. The articles present state-of-the-art developments in these topics. String theory is a broad subject, which has profound connections with broad branches of modern mathematics. In the last decades, the prosperous interaction built upon the joint efforts from both mathematicians and physicists has given rise to marvelous deep results in supersymmetric gauge theory, topological string, M-theory and duality on the physics side, as well as in algebraic geometry, differential geometry, algebraic topology, representation theory and number theory on the mathematics side.

This book offers a comprehensive discussion of developments at the interface of particle physics, supergravity, and cosmology, for graduates and researchers.

We read in order to know we are not alone, I once heard, and perhaps it could also be suggested that we write in order not to be alone, to endorse, to promote continuity. The idea for this book took about 10 years to materialize, and it is the author's hope that its content will constitute the beginning of further explorations beyond current horizons. More specifically, this book appeals to the reader to engage upon and persevere with a journey, moving through the less well explored territories in the evolution of the very early universe, and pushing towards new landscapes. Perhaps, during or after consulting this book, this attitude and this willingness will be embraced by someone, somewhere, and this person will go on to enrich our quantum cosmological description of the early universe, by means of a clearer supersymmetric perspective. It is to these creative and inquisitive 'young minds' that the book is addressed. The reader will not therefore find in this book all the answers to all the problems regarding a supersymmetric and quantum description of the early universe, and this remark is substantiated in the book by a list of unresolved and challenging problems, itself incomplete.

Designed as a sequel to the authors' Introduction to Gauge Field Theory, Supersymmetric Gauge Field Theory and String Theory introduces first-year graduate students to supersymmetric theories, including supergravity and superstring theories. Starting with the necessary background in quantum field theory, the book covers the three key topics of high-energy physics. The emphasis is on practical calculations rather than abstract generalities or phenomenological results. Where possible, the authors show how to calculate, connecting the theoretical with the phenomenological. While the field continues to advance and grow, this book addresses the basic theory at the core and will likely remain relevant even if more advanced ideas change.

This is a set of lecture notes given by the author at the Universities of Göttingen and Wrocław. The text presents the axiomatic approach to field theory and studies in depth the concepts of symmetry and supersymmetry and their associated generators, currents and charges. It is intended as a one-semester course for graduate students in the field of mathematical physics and high energy physics.

This book presents the superfield description of various supersymmetric field theory models in three- and four-dimensional space-times. A mapping between superfield and component formulations of supersymmetric field theories is discussed. The author also describes the methodology for calculating quantum corrections in these theories employing supergraph formalism and functional methods, and illustrates these approaches with many detailed examples of how such calculations are performed for various superfield models.

This selection of outstanding articles – an outgrowth of the QMath9 meeting for young scientists – covers new techniques and recent results on spectral theory, statistical mechanics, Bose-Einstein condensation, random operators, magnetic Schrödinger operators and more. The book's pedagogical style makes it a useful introduction to the research literature for postgraduate students. For more expert researchers it

will serve as a concise source of modern reference.

The 2002 Pan-American Advanced Studies Institute School on Quantum Gravity was held at the Centro de Estudios Científicos (CECS), Valdivia, Chile, January 4-14, 2002. The school featured lectures by ten speakers, and was attended by nearly 70 students from over 14 countries. A primary goal was to foster interaction and communication between participants from different cultures, both in the layman's sense of the term and in terms of approaches to quantum gravity. We hope that the links formed by students and the school will persist throughout their professional lives, continuing to promote interaction and the essential exchange of ideas that drives research forward. This volume contains improved and updated versions of the lectures given at the School. It has been prepared both as a reminder for the participants, and so that these pedagogical introductions can be made available to others who were unable to attend. We expect them to serve students of all ages well.

Research in string theory over the last several decades has yielded a rich interaction with algebraic geometry. In 1985, the introduction of Calabi-Yau manifolds into physics as a way to compactify ten-dimensional space-time has led to exciting cross-fertilization between physics and mathematics, especially with the discovery of mirror symmetry in 1989. A new string revolution in the mid-1990s brought the notion of branes to the forefront. As foreseen by Kontsevich, these turned out to have mathematical counterparts in the derived category of coherent sheaves on an algebraic variety and the Fukaya category of a symplectic manifold. This has led to exciting new work, including the Strominger-Yau-Zaslow conjecture, which used the theory of branes to propose a geometric basis for mirror symmetry, the theory of stability conditions on triangulated categories, and a physical basis for the McKay correspondence. These developments have led to a great deal of new mathematical work. One difficulty in understanding all aspects of this work is that it requires being able to speak two different languages, the language of string theory and the language of algebraic geometry. The 2002 Clay School on Geometry and String Theory set out to bridge this gap, and this monograph builds on the expository lectures given there to provide an up-to-date discussion including subsequent developments. A natural sequel to the first Clay monograph on Mirror Symmetry, it presents the new ideas coming out of the interactions of string theory and algebraic geometry in a coherent logical context. We hope it will allow students and researchers who are familiar with the language of one of the two fields to gain acquaintance with the language of the other. The book first introduces the notion of Dirichlet brane in the context of topological quantum field theories, and then reviews the basics of string theory. After showing how notions of branes arose in string theory, it turns to an introduction to the algebraic geometry, sheaf theory, and homological algebra needed to define and work with derived categories. The physical existence conditions for branes are then discussed and compared in the context of mirror symmetry, culminating in Bridgeland's definition of stability structures, and its applications to the McKay correspondence and quantum geometry. The book continues with detailed treatments of the Strominger-Yau-Zaslow conjecture, Calabi-Yau metrics and homological mirror symmetry, and discusses more recent physical developments. This book is suitable for graduate students and researchers with either a physics or mathematics background, who are interested in the interface between string theory and algebraic geometry. During the last three decades supersymmetry has grown into one of the busiest theoretical avenues of particle physics. Supersymmetric ideas dominate the scenario of "beyond the standard model phenomenology", in spite of the thirty-year-old experimental opacity, a situation that could change within the following decade. One additional important reason for the good health of supersymmetry must be found in the most speculative areas of particle physics. Much of its success comes from superstring theory. The Advanced School on Supersymmetry in the Theories of Fields, Strings and Branes attempted to provide an up-to-date perspective of the role played by supersymmetry in these subjects. The lectures dealt with most of the main theoretical developments of the nineties, from the exact solutions of the Seiberg-Witten type to the physics of D-branes and their impact on the physics of black holes and string phenomenology. Many of these results are contrasted with the recent results on the holographic duality between string theories in anti-de Sitter spaces and certain large N conformal gauge theories, the so-called "Maldacena conjecture", or "AdS/CFT correspondence". The lecture notes contained in this volume are the result of the effort made by the lecturers to introduce the reader to these topics, assuming a basic knowledge of supersymmetry, quantum field theory and string theory.

The first portion of the text is devoted to a review of those aspects of Lie groups necessary for the application of group theory to the physics of particles and fields. The second describes the way in which compact Lie groups are used to construct gauge theories.

Proceedings of the NATO Advanced Study Institute on Particle Physics: Ideas and Recent Developments, Cargèse, France, July 26-August 7, 1999

The orbit method influenced the development of several areas of mathematics in the second half of the 20th century and remains a useful and powerful tool in such areas as Lie theory, representation theory, integrable systems, complex geometry, and mathematical physics. Among the distinguished names associated with the orbit method is that of A.A. Kirillov, whose pioneering paper on nilpotent orbits (1962), places him as the founder of orbit theory. The original research papers in this volume are written by prominent mathematicians and reflect recent achievements in orbit theory and other closely related areas such as harmonic analysis, classical representation theory, Lie superalgebras, Poisson geometry, and quantization. Contributors: A. Alekseev, J. Alev, V. Baranovskiy, R. Brylinski, J. Dixmier, S. Evens, D.R. Farkas, V. Ginzburg, V. Gorbounov, P. Grozman, E. Gutkin, A. Joseph, D. Kazhdan, A.A. Kirillov, B. Kostant, D. Leites, F. Malikov, A. Melnikov, P.W. Michor, Y.A. Neretin, A. Okounkov, G. Olshanski, F. Petrov, A. Polishchuk, W. Rossmann, A. Sergeev, V. Schechtman, I. Shchepochkina. The work will be an invaluable reference for researchers in the above mentioned fields, as well as a useful text for graduate seminars and courses.

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