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# **Gauge Theory and the Topology of Four-Manifolds**

**Robert Friedman  
John W. Morgan  
Editors**



**American Mathematical Society  
Institute for Advanced Study**

# Gauge Theory And The Topology Of Four Manifolds

**H. Pedersen, J. Andersen, J.  
Dupont, Andrew Swann**



## **Gauge Theory And The Topology Of Four Manifolds:**

**Gauge Theory and the Topology of Four-Manifolds** Robert Friedman, John W. Morgan, This text is part of the IAS Park City Mathematics series and focuses on gauge theory and the topology of four manifolds Gauge Theory and the Topology of Four-Manifolds Robert Friedman, John W. Morgan, 2024-12-05 The lectures in this volume provide a perspective on how 4 manifold theory was studied before the discovery of modern day Seiberg Witten theory One reason the progress using the Seiberg Witten invariants was so spectacular was that those studying SU 2 gauge theory had more than ten years experience with the subject The tools had been honed the correct questions formulated and the basic strategies well understood The knowledge immediately bore fruit in the technically simpler environment of the Seiberg Witten theory Gauge theory long predates Donaldson s applications of the subject to 4 manifold topology where the central concern was the geometry of the moduli space One reason for the interest in this study is the connection between the gauge theory moduli spaces of a Kähler manifold and the algebro geometric moduli space of stable holomorphic bundles over the manifold The extra geometric richness of the SU 2 moduli spaces may one day be important for purposes beyond the algebraic invariants that have been studied to date It is for this reason that the results presented in this volume will be essential **Gauge Theory and the Topology of Four-Manifolds** Robert Friedman, 1997 The lectures in this volume provide a perspective on how 4 manifold theory was studied before the discovery of modern day Seiberg Witten theory One reason the progress using the Seiberg Witten invariants was so spectacular was that those studying SU 2 gauge theory had more than ten years experience with the subject The tools had been honed the correct questions formulated and the basic strategies well understood The knowledge immediately bore fruit in the technically simpler environment of the Seiberg Witten theory Gauge theory long predates Donaldson s applications of the subject to 4 GAUGE THEORY AND THE TOPOLOGY OF FOUR-MANIFOLDS. ROBERT. FRIEDMAN, 1999 Topological Quantum Field Theory and Four Manifolds Jose Labastida, Marcos Marino, 2007-07-18 The emergence of topological quantum field theory has been one of the most important breakthroughs which have occurred in the context of mathematical physics in the last century a century characterized by independent developments of the main ideas in both disciplines physics and mathematics which has concluded with two decades of strong interaction between them where physics as in previous centuries has acted as a source of new mathematics Topological quantum field theories constitute the core of these phenomena although the main driving force behind it has been the enormous effort made in theoretical particle physics to understand string theory as a theory able to unify the four fundamental interactions observed in nature These theories set up a new realm where both disciplines profit from each other Although the most striking results have appeared on the mathematical side theoretical physics has clearly also benefited since the corresponding developments have helped better to understand aspects of the fundamentals of field and string theory **Seiberg-Witten Gauge Theory** Matilde Marcolli, 2011 Geometry of

Low-dimensional Manifolds: Gauge theory and algebraic surfaces S. K. Donaldson, Charles Benedict Thomas, 1990 This volume is based on lecture courses and seminars given at the LMS Durham Symposium on the geometry of low dimensional manifolds This area has been one of intense research during the 1990s with major breakthroughs that have illuminated the way a number of different subjects interact for example topology differential and algebraic geometry and mathematical physics The workshop brought together a number of distinguished figures to give lecture courses and seminars in these subjects the volume that has resulted is the only expository source for much of the material and will be essential for all research workers in geometry and mathematical physics

**Floer Homology, Gauge Theory, and Low-Dimensional Topology** Clay Mathematics Institute. Summer School, 2006 Mathematical gauge theory studies connections on principal bundles or more precisely the solution spaces of certain partial differential equations for such connections Historically these equations have come from mathematical physics and play an important role in the description of the electro weak and strong nuclear forces The use of gauge theory as a tool for studying topological properties of four manifolds was pioneered by the fundamental work of Simon Donaldson in the early 1980s and was revolutionized by the introduction of the Seiberg Witten equations in the mid 1990s Since the birth of the subject it has retained its close connection with symplectic topology The analogy between these two fields of study was further underscored by Andreas Floer's construction of an infinite dimensional variant of Morse theory that applies in two a priori different contexts either to define symplectic invariants for pairs of Lagrangian submanifolds of a symplectic manifold or to define topological invariants for three manifolds which fit into a framework for calculating invariants for smooth four manifolds Heegaard Floer homology the recently discovered invariant for three and four manifolds comes from an application of Lagrangian Floer homology to spaces associated to Heegaard diagrams Although this theory is conjecturally isomorphic to Seiberg Witten theory it is more topological and combinatorial in flavor and thus easier to work with in certain contexts The interaction between gauge theory low dimensional topology and symplectic geometry has led to a number of striking new developments in these fields The aim of this volume is to introduce graduate students and researchers in other fields to some of these exciting developments with a special emphasis on the very fruitful interplay between disciplines This volume is based on lecture courses and advanced seminars given at the 2004 Clay Mathematics Institute Summer School at the Alfred Renyi Institute of Mathematics in Budapest Hungary Several of the authors have added a considerable amount of additional material to that presented at the school and the resulting volume provides a state of the art introduction to current research covering material from Heegaard Floer homology contact geometry smooth four manifold topology and symplectic four manifolds

**Smooth Four-Manifolds and Complex Surfaces** Robert Friedman, John W. Morgan, 1994-03-10 In 1961 Smale established the generalized Poincare Conjecture in dimensions greater than or equal to 5 129 and proceeded to prove the h cobordism theorem 130 This result inaugurated a major effort to classify all possible smooth and topological structures on manifolds of dimension at least 5 By the mid 1970 s

the main outlines of this theory were complete and explicit answers especially concerning simply connected manifolds as well as general qualitative results had been obtained As an example of such a qualitative result a closed simply connected manifold of dimension  $2 \leq 5$  is determined up to finitely many diffeomorphism possibilities by its homotopy type and its Pontrjagin classes There are similar results for self diffeomorphisms which at least in the simply connected case say that the group of self diffeomorphisms of a closed manifold  $M$  of dimension at least 5 is commensurate with an arithmetic subgroup of the linear algebraic group of all automorphisms of its so called rational minimal model which preserve the Pontrjagin classes 131 Once the high dimensional theory was in good shape attention shifted to the remaining and seemingly exceptional dimensions 3 and 4 The theory behind the results for manifolds of dimension at least 5 does not carryover to manifolds of these low dimensions

Four-Manifold Theory Cameron Gordon, 1984 Covers the proceedings of the Summer Research Conference on 4 manifolds held at Durham New Hampshire July 1982 under the auspices of the American Mathematical Society and National Science Foundation

**The Wild World of 4-Manifolds** Alexandru Scorpan, 2022-01-26 What a wonderful book I strongly recommend this book to anyone especially graduate students interested in getting a sense of 4 manifolds MAA Reviews The book gives an excellent overview of 4 manifolds with many figures and historical notes Graduate students nonexperts and experts alike will enjoy browsing through it Robion C Kirby University of California Berkeley This book offers a panorama of the topology of simply connected smooth manifolds of dimension four Dimension four is unlike any other dimension it is large enough to have room for wild things to happen but small enough so that there is no room to undo the wildness For example only manifolds of dimension four can exhibit infinitely many distinct smooth structures Indeed their topology remains the least understood today To put things in context the book starts with a survey of higher dimensions and of topological 4 manifolds In the second part the main invariant of a 4 manifold the intersection form and its interaction with the topology of the manifold are investigated In the third part as an important source of examples complex surfaces are reviewed In the final fourth part of the book gauge theory is presented this differential geometric method has brought to light how unwieldy smooth 4 manifolds truly are and while bringing new insights has raised more questions than answers The structure of the book is modular organized into a main track of about two hundred pages augmented by extensive notes at the end of each chapter where many extra details proofs and developments are presented To help the reader the text is peppered with over 250 illustrations and has an extensive index

**Quantum Field Theory and Manifold Invariants** Daniel S. Freed, Sergei Gukov, Ciprian Manolescu, Constantin Teleman, Ulrike Tillmann, 2021-12-02 This volume contains lectures from the Graduate Summer School Quantum Field Theory and Manifold Invariants held at Park City Mathematics Institute 2019 The lectures span topics in topology global analysis and physics and they range from introductory to cutting edge Topics treated include mathematical gauge theory anti self dual equations Seiberg Witten

equations Higgs bundles classical and categorified knot invariants Khovanov homology Heegaard Floer homology instanton Floer homology invertible topological field theory BPS states and spectral networks This collection presents a rich blend of geometry and topology with some theoretical physics thrown in as well and so provides a snapshot of a vibrant and fast moving field Graduate students with basic preparation in topology and geometry can use this volume to learn advanced background material before being brought to the frontiers of current developments Seasoned researchers will also benefit from the systematic presentation of exciting new advances by leaders in their fields

*Geometric And Topological Methods For Quantum Field Theory - Proceedings Of The Summer School* Alexander Cardona, Hernan Ocampo, Sylvie

Paycha, 2003-03-21 This volume offers an introduction to recent developments in several active topics of research at the interface between geometry topology and quantum field theory These include Hopf algebras underlying renormalization schemes in quantum field theory noncommutative geometry with applications to index theory on one hand and the study of aperiodic solids on the other geometry and topology of low dimensional manifolds with applications to topological field theory Chern Simons supergravity and the anti de Sitter conformal field theory correspondence It comprises seven lectures organized around three main topics noncommutative geometry topological field theory followed by supergravity and string theory complemented by some short communications by young participants of the school

**Topology, Geometry And Field Theory - Proceedings Of The 31st International Taniguchi Symposium And Proceedings Of The Conference**

Kenji Fukaya, Dieter Kotschick, M Furuta, Toshitake Kohno, 1994-08-31 Nobel Symposium 129 on Neutrino Physics was held at Haga Slott in Enk ping Sweden during August 19 24 2004 Invited to the symposium were around 40 globally leading researchers in the field of neutrino physics both experimental and theoretical The dominant theme of the lectures was neutrino oscillations which after several years were recently verified by results from the Super Kamiokande detector in Kamioka Japan and the SNO detector in Sudbury Canada Discussion focused especially on effects of neutrino oscillations derived from the presence of matter and the fact that three different neutrinos exist Since neutrino oscillations imply that neutrinos have mass this is the first experimental observation that fundamentally deviates from the standard model of particle physics This is a challenge to both theoretical and experimental physics The various oscillation parameters will be determined with increased precision in new specially designed experiments Theoretical physics is working intensively to insert the knowledge that neutrinos have mass into the theoretical models that describe particle physics The lectures provided a very good description of the intensive situation in the field right now The topics discussed also included mass models for neutrinos neutrinos in extra dimensions as well as the seesaw mechanism which provides a good description of why neutrino masses are so small This book is A4 size and in full color

**Quantum Field Theory and Topology** Albert S. Schwarz, 2013-04-09 In recent years topology has firmly established itself as an important part of the physicist's mathematical arsenal It has many applications first of all in quantum field theory but increasingly also in other areas of

physics The main focus of this book is on the results of quantum field theory that are obtained by topological methods Some aspects of the theory of condensed matter are also discussed Part I is an introduction to quantum field theory it discusses the basic Lagrangians used in the theory of elementary particles Part II is devoted to the applications of topology to quantum field theory Part III covers the necessary mathematical background in summary form The book is aimed at physicists interested in applications of topology to physics and at mathematicians wishing to familiarize themselves with quantum field theory and the mathematical methods used in this field It is accessible to graduate students in physics and mathematics

**Geometric and Topological Methods for Quantum Field Theory** Hernan Ocampo, Eddy Pariguan, Sylvie

Paycha, 2010-04-29 Aimed at graduate students in physics and mathematics this book provides an introduction to recent developments in several active topics at the interface between algebra geometry topology and quantum field theory The first part of the book begins with an account of important results in geometric topology It investigates the differential equation aspects of quantum cohomology before moving on to noncommutative geometry This is followed by a further exploration of quantum field theory and gauge theory describing AdS CFT correspondence and the functional renormalization group approach to quantum gravity The second part covers a wide spectrum of topics on the borderline of mathematics and physics ranging from orbifolds to quantum indistinguishability and involving a manifold of mathematical tools borrowed from geometry algebra and analysis Each chapter presents introductory material before moving on to more advanced results The chapters are self contained and can be read independently of the rest *Proceedings of the Summer School Geometric and Topological Methods for Quantum Field Theory* Alexander Cardona, Hernan Ocampo, Sylvie Paycha, 2003 This volume offers an introduction to recent developments in several active topics of research at the interface between geometry topology and quantum field theory These include Hopf algebras underlying renormalization schemes in quantum field theory noncommutative geometry with applications to index theory on one hand and the study of aperiodic solids on the other geometry and topology of low dimensional manifolds with applications to topological field theory Chern Simons supergravity and the anti de Sitter conformal field theory correspondence It comprises seven lectures organized around three main topics noncommutative geometry topological field theory followed by supergravity and string theory complemented by some short communications by young participants of the school *Mathematical Aspects of Classical Field Theory* Mark J. Gotay, Jerrold E. Marsden, Vincent Moncrief, 1992 Classical field theory has undergone a renaissance in recent years Symplectic techniques have yielded deep insights into its foundations as has an improved understanding of the variational calculus Further impetus for the study of classical fields has come from other areas such as integrable systems Poisson geometry global analysis and quantum theory This book contains the proceedings of the AMS IMS SIAM Joint Summer Research Conference on Mathematical Aspects of Classical Field Theory held in July 1991 at the University of Washington at Seattle The conference brought together researchers in many of the main areas of classical field theory to present the latest ideas and results The

volume contains thirty refereed papers both survey and research articles and is designed to reflect the state of the art as well as chart the future course of the subject The topics fall into four major categories global analysis and relativity cosmic censorship initial value problem quantum gravity geometric methods symplectic and Poisson structures momentum mappings Dirac constraint theory BRST theory and the calculus of variations the variational bicomplex higher order theories Also included are related topics with a classical basis such as geometric quantization integrable systems symmetries deformation theory and geometric mechanics

*Symplectic 4-Manifolds and Algebraic Surfaces* Denis Auroux, Fabrizio Catanese, Marco Manetti, Gang Tian, Paul Seidel, Bernd Siebert, Ivan Smith, 2008-04-17 Modern approaches to the study of symplectic 4 manifolds and algebraic surfaces combine a wide range of techniques and sources of inspiration Gauge theory symplectic geometry pseudoholomorphic curves singularity theory moduli spaces braid groups monodromy in addition to classical topology and algebraic geometry combine to make this one of the most vibrant and active areas of research in mathematics It is our hope that the five lectures of the present volume given at the C I M E Summer School held in Cetraro Italy September 2 10 2003 will be useful to people working in related areas of mathematics and will become standard references on these topics The volume is a coherent exposition of an active field of current research focusing on the introduction of new methods for the study of moduli spaces of complex structures on algebraic surfaces and for the investigation of symplectic topology in dimension 4 and higher

Geometry and Physics H. Pedersen, J. Andersen, J. Dupont, Andrew Swann, 1996-10-11 Based on the proceedings of the Special Session on Geometry and Physics held over a six month period at the University of Aarhus Denmark and on articles from the Summer school held at Odense University Denmark Offers new contributions on a host of topics that involve physics geometry and topology Written by more than 50 leading international experts



## **Gauge Theory And The Topology Of Four Manifolds** Book Review: Unveiling the Power of Words

In a global driven by information and connectivity, the power of words has become more evident than ever. They have the capability to inspire, provoke, and ignite change. Such may be the essence of the book **Gauge Theory And The Topology Of Four Manifolds**, a literary masterpiece that delves deep to the significance of words and their effect on our lives. Written by a renowned author, this captivating work takes readers on a transformative journey, unraveling the secrets and potential behind every word. In this review, we shall explore the book's key themes, examine its writing style, and analyze its overall effect on readers.

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